**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**FACULTY OF INDUSTRIAL TECHNOLOGY**

**DEPARTMENT OF CIVIL AND WATER ENGINEERING**

**BACHELOR OF ENGINEERING (HONOURS) DEGREE**

**PART I SECOND SEMESTER EXAMINATIONS – JUNE 2010**

**MATERIAL SCIENCE – TCW 1202**

**INSTRUCTIONS**

1. Each question carries twenty **(20)** marks and there are six **(6)** questions in total.
2. Attempt the whole of Section A and three **(3)** questions from Section B.
3. Pay attention to the instructions on the cover page of your answer booklet.

Total marks: 100

Time: 3 Hours

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## Section A

**QUESTION 1**

a) Discuss the differences between interstitial and substitutional solid solutions. **[8 marks]**

b) In Table Q1 below, atomic radius, crystal structure, electronegativity, and the most common valence are tabulated, for several elements; for those that are non-metals, only atomic radii are indicated. Which of these elements would be expected to form the following with nickel?

i. A substitutional solid solution having complete solubility **[4 marks]**

ii. A substitutional solid solution of incomplete solubility **[4 marks]**

iii. An interstitial solid solution **[4 marks]**

**Table Q1**

| Element | Atomic Radius (nm) | Crystal Structure | Electronegativity | Valence |
|---|---|---|---|---|
| Nickel | 0.1246 | FCC | 1.8 | +2 |
| Carbon | 0.071 | | | |
| Hydrogen | 0.046 | | | |
| Oxygen | 0.060 | | | |
| Silver | 0.1445 | FCC | 1.9 | +1 |
| Aluminium | 0.1431 | FCC | 1.5 | +3 |
| Cobalt | 0.1253 | HCP | 1.8 | +2 |
| Chromium | 0.1249 | BCC | 1.6 | +3 |
| Iron | 0.1241 | BCC | 1.8 | +2 |
| Platinum | 0.1387 | FCC | 2.2 | +2 |
| Zinc | 0.1332 | HCP | 1.6 | +2 |

## QUESTION 2

a) Distinguish plastic deformation from elastic deformation. **[4 marks]**

b) Explain some of the limitations of concrete as a structural material. **[6 marks]**

c) A cylindrical specimen of steel having an original diameter of 12.8 mm is tensile tested to fracture and found to have an engineering fracture strength of 460 MPa. If its cross-sectional diameter at fracture is 10.7 mm, determine:

i. The ductility in terms of percent reduction in area **[5 marks]**

ii. The true stress at fracture **[5 marks]**

# SECTION B

## QUESTION 3

a) Give definitions for the following material mechanical properties.

i. Resilience **[2 marks]**

ii. Toughness **[2 marks]**

iii. Ductility **[2 marks]**

iv. Tensile strength **[2 marks]**

v. Poisson's ratio **[2 marks]**

b) A tensile stress is to be applied along the long axis of a cylindrical brass rod that has a diameter of 13 mm. Determine the magnitude of the load required to produce a $5.6 \times 10^{-3}$ mm change in diameter if the deformation is entirely elastic. Poisson's ratio for brass is 0.34. **[10 marks]**

## QUESTION 4

a) Given in Table Q4 below are the solidus and liquidus temperatures for the copper (Cu) - gold (Au) system. Construct on graph paper the phase diagram for this system and label each region. **[10 marks]**

b) For the solidification of pure gold, calculate the critical radius and the activation free energy if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are $-1.16 \times 10^9$ J/m$^3$ and 0.132 J/m$^3$, respectively. Use 230 $^o$C as the supercooling value and the melting temperature of gold is 1084$^o$C. **[6 marks]**

c) Now calculate the number of atoms found in a nucleus of critical size. Assume a lattice parameter of 0.413 nm for solid gold at its melting temperature and an FCC structure. **[4 marks]**

**Table Q4**

| Composition Weight % (Au) | Solidus Temperature ($^o$C) | Liquidus Temperature ($^o$C) |
|---|---|---|
| 0 | 1085 | 1085 |
| 20 | 1019 | 1042 |
| 40 | 972 | 996 |
| 60 | 934 | 946 |
| 80 | 911 | 911 |
| 90 | 928 | 942 |
| 95 | 974 | 984 |
| 100 | 1064 | 1064 |

## QUESTION 5

a) What is the difference between thermal fatigue and corrosion fatigue? **[4 marks]**

b) Briefly describe one standard method for testing the impact toughness of metallic materials. **[6 marks]**

c) Draw a graph showing the typical progression of creep failure in metals under constant stress and temperature and explain each stage. **[10 marks]**

**QUESTION 6**

a) Identify and explain briefly the following forms of corrosion:

i. A water pipe develops a hole at a bend. **[3 marks]**

ii. A stainless steel ladder rung submerged in a swimming pool cracks. **[3 marks]**

iii. A garden shed roof that has been covered with dead rotting leaves for years is observed to have wasted away. **[4 marks]**

b) Discuss, using illustrations where appropriate, how underground steel pipes can be protected against corrosion. **[10 marks]**

**END OF EXAMINATION**