NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL AND WATER ENGINEERING

ECW 1105 -MATERIALS SCIENCE

2024 – 2025 EXAM SESSION

This Examination Paper consists of 5 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: None

Internal Examiner: T Shumba

External Examiner:

INSTRUCTIONS

1. Answer all questions
2. Calculators are permissible
3. Ensure that your work is neat and legible to avoid unnecessary loss of marks

SPECIAL REQUIREMENTS

1. Periodic Table

MARK ALLOCATION

QUESTION	MARKS
1.	25
2.	25
3.	25
4.	25

QUESTION ONE

a) Cite two important quantum-mechanical concepts associated with the Bohr model of the atom [4]

b) Cite two important additional refinements that resulted from the wave-mechanical atomic model [4]

c) Describe a composite material and outline the design goals of composites [3]

d) Indium has two naturally occurring isotopes: 113In, with an atomic weight of 112.904 amu; and 115In, with an atomic weight of 114.904 amu. If the average atomic weight for In is 114.818 amu, calculate the fraction-of-occurrences of these two isotopes. [3]

e) Zinc has five naturally occurring isotopes: 48.63% of 64Zn, with an atomic weight of 63.929 amu; 27.90% of 66Zn, with an atomic weight of 65.926 ; 4.10% of 67Zn, with an atomic weight of 66.927 amu; 18.75% of 68Zn, with an atomic weight of 67.925 amu; and 0.62% of 70Zn, with an atomic weight of 69.925 amu. Calculate the average atomic weight of Zn. [4]

f) The atomic radii of Mg^{2+} and F^- ions are 0.072 and 0.133 nm, respectively.

i. Calculate the force of attraction between these two ions at their equilibrium interionic separation [4]

ii. What is the force of repulsion at this same separation distance? (i.e., when the ions just touch one another). [3]

[25 MARKS]

QUESTION TWO

a) The Figure below shows the Body-centered cubic crystal structure

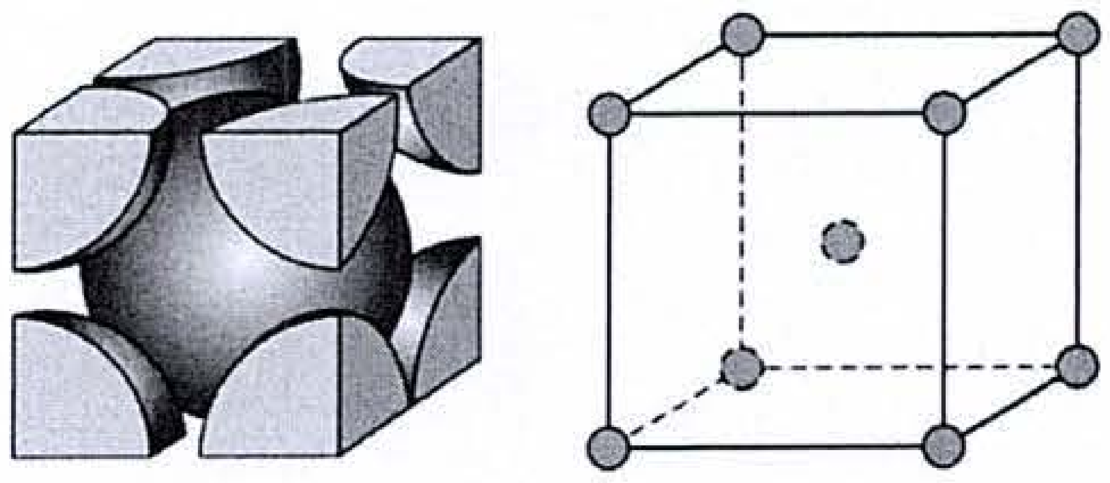

Figure 1:Body Centred Crystal Structure

i. With the aid of diagrams, show that the unit cell length (a) and the atomic radius (r)are related through the equation

$$a = \frac{4R}{\sqrt{3}}$$ [5]

ii. Show that the atomic packing factor for BCC is 0.68 [5]

b) Given that lead has an FCC crystal structure and an atomic radius of 0.175 nm, calculate the volume of its unit cell in cubic meters [3]

c) Molybdenum (Mo) has a BCC crystal structure, an atomic radius of 0.1363 nm, and an atomic weight of 95.94 g/mol. Calculate its theoretical density [4]

d) Calculate the radius of a palladium (Pd) atom, given that Pd has an FCC crystal structure, a density of 12.0 g/cm3, and an atomic weight of 106.4 g/mol. [3]

e) Rhodium has an atomic radius of 0.1345 nm and a density of 12.41 g/cm3. Determine whether it has an FCC or BCC crystal structure. [5]

[25 MARKS]

QUESTION THREE

a) With the aid of diagrams, describe the five stages in a cup-and-cone fracture [15]

b) What is the magnitude of the maximum stress that exists at the tip of an internal crack having a radius of curvature of 1.9×10^{-4} mm and a crack length of 3.8×10^{-2} mm when a tensile stress of 140 MPa is applied? [5]

c) Estimate the theoretical fracture strength of a brittle material if it is known that fracture occurs by the propagation of an elliptically shaped surface crack of length 0.5 mm and a tip radius of curvature of 5×10^{-3} mm, when a stress of 1035 MPa is applied. [5]

[25 MARKS]

QUESTION FOUR

a) A specimen of copper having a rectangular cross section 15.2 mm × 19.1 mm is pulled in tension with 44,500 N force, producing only elastic deformation. Calculate the resulting strain. [3]

b) A cylindrical specimen of a nickel alloy having an elastic modulus of 207 GPa , an original diameter of 10.2 mm experiences only elastic deformation when a tensile load of 8900 N is applied. Compute the maximum length of the specimen before deformation if the maximum allowable elongation is 0.25 mm. [5]

c) An aluminum bar 125 mm long and having a square cross section 16.5 mm on an edge is pulled in tension with a load of 66,700 N and experiences an elongation of 0.43 mm. Assuming that the deformation is entirely elastic, calculate the modulus of elasticity of the aluminum [5]

d) Consider a cylindrical nickel wire 2.0 mm in diameter and 3×10^4 mm long. Calculate its elongation when a load of 300 N is applied. Assume that the deformation is totally elastic (E for Nickel = 270GPa) [5]

e) For a brass alloy, the stress at which plastic deformation begins is 345 MPa, and the modulus of elasticity is 103 GPa.

i. What is the maximum load that can be applied to a specimen with a cross-sectional area of 130 mm^2 without plastic deformation? [3]

ii. If the original specimen length is 76 mm , what is the maximum length to which it can be stretched without causing plastic deformation? [3]

[25 MARKS]

[END OF EXAMINATION]

Equations and Constants

$$F_A = \frac{1}{4\pi\epsilon_0 r^2}(|Z_1|e)(|Z_2|e)$$

$$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2}$$

Permittivity of a vacuum = 8.85 x 10^{-12} F/m

N_A = 6.02x10^{23} atoms/mol

k = 8.62 x 10^{-5} eV/K

Boltzmann's Constant = 1.38 x 10^{-23} J/atom

$$\sigma_T = K\varepsilon_T{}^n$$

$$\varepsilon_T = ln\,(\frac{l_t}{l_0})$$