UNAM
UNIVERSITY OF NAMIBIA

SCHOOL	ENGINEERING AND THE BUILT ENVIRONMENT
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SUBJECT	MATERIALS ENGINEERING
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MARKS	100

FIRST OPPORTUNITY EXAMINATION

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This question paper consists of six (6) pages excluding this page.

INSTRUCTIONS:

1 Closed book examination.
2 Read the questions carefully.
3 Answer **ALL QUESTIONS** and show your working.
4 Marks for each question are indicated.
5 Start each question on a fresh page.

POLYMERIC MATERIALS

QUESTION 1 [35 MARKS]

(a) Nylon was first reported by Wallace Hume Carothers, of du Pont in about 1934. In 1939, du Pont's Charles Stine reported the discovery of this first synthetic fiber to a group of 3000 women gathered for the New York World's Fair. The first application was nylon stockings that were strong. Today nylon is used in hundreds of applications. Before nylon, Carothers had discovered neoprene (an elastomer).

The linear polymer 6,6-nylon is to be produced by combining 1000 g of hexamethylene diamine (HMDA) with adipic acid. A condensation reaction then produces the polymer. Show how this reaction occurs and determine the byproduct that forms. How many grams of adipic acid are needed, and how much 6,6-nylon is produced, assuming 100% efficiency?

[8]

(b) Design the type of polymeric material you might select for the following applications: a surgeon's glove, a beverage container, and a pulley. **[6]**

(c) A storage tank for liquid hydrogen will be made of metal, but we wish to coat the metal with a 3-mm thickness of a polymer as an intermediate layer between the metal and additional insulation layers. The temperature of the intermediate layer may drop to -80°C. Design a material for this layer. **[6]**

(d) Table Q1(d), lists molecular weight data for a polypropylene material. Compute;

I. The number-average molecular weight, **[2]**

II. The weight-average molecular weight, and **[2]**

III. The degree of polymerization. **[2]**

Table Q1(d): *Molecular weight for Polypropylene material*

Molecular weight Range (g/mol)	x_i	w_i
8,000 – 16,000	0.05	0.02
16,000 – 24,000	0.16	0.10
24,000 – 32,000	0.24	0.20
32,000 – 40,000	0.28	0.30
40,000 – 48,000	0.20	0.27
48,000 – 56,000	0.07	0.11

(e) Namibia Plastics and Packaging Distributors (Pty) Ltd gave you two samples of the same polymer type, extruded in slightly different ways. Polymer one has a density of 1.54 kg/m^3 and is 40% crystalline. Polymer two has a density of 1.31 kg/m^3 and is 28% crystalline. Find the 100% crystalline and amorphous densities. **[6]**

(f) Explain how the tensile strength of a polymer depends on the following factors:

I. Temperature, **[1]**

II. Degree of polymerization, and **[1]**

III. Percent crystallinity. **[1]**

CERAMIC MATERIALS

QUESTION 2 [35 MARKS]

(a) Ceramic tile accounts for about 15% of the floor tile market.

I. State one available alternative. [1]

II. State one advantage and one disadvantage ceramics have over the alternative. [2]

III. State two factors that could influence the total amount of ceramic floor tiles used. [2]

(b) Indicate the following types of defects by Kroger–Vink notation:

I. Vacancy in the Ca^{2+} sublattice of $CaCl_2$, [1]

II. Vacancy in the Cl^- sublattice of $CaCl_2$, [1]

III. Ca^{2+} in the interstitial position of $CaCl_2$, and [1]

IV. Cl^- in the interstitial position of $CaCl_2$, [1]

(c) Write the defect reactions for the following:

I. Dissolution of CaO in Fe_2O_3, [2]

II. Dissolution of K_2O in CoO, and [2]

III. Dissolution of MgO in Al_2O_3, [2]

(d) Show that the minimum cation-to-anion radius ratio for a coordination number of 6 is 0.414. [Hint: Use the NaCl crystal structure, and assume that anions and cations are just touching along cube edges and across face diagonals]. [5]

(e) The compound MX has a density of 2.1 g/cm^3, and a cubic unit cell with a lattice parameter of 0.57 nm. The atomic weights of M and X are 28.5 and 30 g/mol, respectively. Based on this information, which of the following structures is (are) possible: rock salt (NaCl), cesium chloride (CsCl), or zinc blende (ZnS)? Justify your choice(s). [5]

(f) Many shaping methods are used for ceramic products, and these can be grouped into three basic categories, which are not necessarily independent. Briefly explain the following:

I. Powder compaction, **[2]**

II. Casting ceramics, and **[2]**

III. Plastic forming. **[2]**

(g) Describe the toughening mechanism based on ZrO_2. What property of ZrO_2 is it based on, and how does it work? **[4]**

COMPOSITE MATERIALS

QUESTION 3 [30 MARKS]

(a) A cemented carbide cutting tool used for machining contains 75 wt.% WC, 15 wt.% TiC, 5 wt.% TaC, and 5 wt.% Co. The densities of the components of the composite are 15.77 g/cm^3 (WC), 4.94 g/cm^3 (TiC), 14.5 g/cm^3 (TaC), and 8.90 g/cm^3 (Co) respectively. Estimate the density of the composite.

[5]

(b) Derive the equation for Elastic Modulus of a lamellar continuous-fiber-plastic matrix composite for Isostrain conditions.

$$E_C = E_f V_f + E_m V_m$$

[4]

(c) A continuous and aligned fiber-reinforced composite is to be produced consisting of 30 vol% aramid fibers and 70 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are as follows:

Table Q3: *Mechanical properties of two materials*

	Modulus of Elasticity [GPa]	*Tensile Strength [MPa]*
Aramid fiber	131	3600
Polycarbonate	2.4	65

Also, the stress on the polycarbonate matrix when the aramid fibers fail is 45 MPa. For this composite, compute:

I. the longitudinal tensile strength, and **[2]**

II. the longitudinal modulus of elasticity **[3]**

(d) A continuous and aligned glass fiber–reinforced composite consists of 40 vol% of glass fibers having a modulus of elasticity of 69 GPa and 60 vol% of a polyester resin that, when hardened, displays a modulus of 3.4 GPa.

I. Compute the modulus of elasticity of this composite in the longitudinal direction. **[2]**

II. If the cross-sectional area is 250 mm^2 and a stress of 50 MPa is applied in this longitudinal direction, compute the magnitude of the load carried by each of the fiber and matrix phase. **[4]**

III. Determine the strain that is sustained by each phase when the stress in part (II) is applied. **[3]**

(e) For a polymer-matrix fiber-reinforced composite,

I. List three functions of the matrix phase. **[3]**

II. Compare the desired mechanical characteristics of matrix and fiber phases. **[2]**

III. Cite two reasons why there must be a strong bond between fiber and matrix at their interface. **[2]**

.... **THE END** ....

FORMULA SHEET

	M	c	I	σ
Rectangular	$\frac{FL}{4}$	$\frac{d}{2}$	$\frac{bd^3}{12}$	$\frac{3FL}{2bd^2}$
Circular	$\frac{FL}{4}$	R	$\frac{\pi R^4}{4}$	$\frac{FL}{\pi R^3}$

$$E_r(t) = \frac{\sigma(t)}{\epsilon_0}$$

$$TS = TS_\infty - \frac{A}{\overline{M}_n}$$

$$\overline{M}_n = \Sigma x_i M_i$$

$$\overline{M}_w = \Sigma w_i M_i$$

$$DP = \frac{\overline{M}_n}{m}$$

$$E_c(u) = E_m V_m + E_p V_p$$

$$E_c(l) = \frac{E_m E_p}{V_m E_p + V_p E_m}$$

$$l_c = \frac{\sigma_f^* d}{2\tau_c}$$

$$E_{cl} = E_m V_m + E_f V_f$$

$$E_{ct} = \frac{E_m E_f}{V_m E_f + V_f E_m}$$

$$\sigma_{cl}^* = \sigma_m'(1-V_f) + \sigma_f^* V_f$$

$$\sigma_{cd}^* = \sigma_f^* V_f\left(1 - \frac{l_c}{2l}\right) + \sigma_m'(1-V_f)$$

$$\sigma_{cd'}^* = \frac{l\tau_c}{d} V_f + \sigma_m'(1-V_f)$$

$$\rho = \frac{n'(\Sigma A_C + \Sigma A_A)}{V_C N_A}$$

$$\sigma_{fs} = \frac{3F_f L}{2bd^2}$$

$$\sigma_{fs} = \frac{F_f L}{\pi R^3}$$

$$E = E_0(1 - 1.9P + 0.9P^2)$$

$$\sigma_{fs} = \sigma_0 \exp(-nP)$$

$$\overline{m} = \Sigma f_j m_j$$

$$\%\ \text{crystallinity} = \frac{\rho_c(\rho_s - \rho_a)}{\rho_s(\rho_c - \rho_a)} \times 100$$

$$J = P_M \frac{\Delta P}{\Delta x}$$