NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF HEALTH AND APPLIED SCIENCES

DEPARTMENT OF NATURAL AND APPLIED SCIENCES

QUALIFICATION : BACHELOR OF SCIENCE HONOURS	
QUALIFICATION CODE: 08BOSH	**LEVEL:** 8
COURSE NAME: MATERIALS PHYSICS	**COURSE CODE:** MAP821S
SESSION: NOVEMBER 2019	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

FIRST OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER(S)	**Prof Dipti R. Sahu**
MODERATOR:	**Dr Zivayi Chiguvare**

INSTRUCTIONS
1. Answer any **5** of the 6 questions given. 2. Write clearly and neatly. 3. Number the answers clearly.

PERMISSIBLE MATERIALS

Non-programmable calculator

THIS QUESTION PAPER CONSISTS OF 4 PAGES (Including front page and formula sheet)

Question 1 **[20]**

1.1 State the primary differences between elastic, anelastic, viscoelastic, and plastic deformation behaviours. (5)

1.2 The Young's modulus of a rubber is measured and found to be E = 3.5 MPa for a temperature of T = 300° K. (5)

(a) Determine its molar crosslink density, and

(b) What is its molecular weight per segment?

1.3 (a) Draw a schematic plot showing the tensile engineering stress - strain behaviour for a typical metal alloy to the point of fracture. (3)

(b) On this plot, superimpose a schematic compressive engineering stress – strain curve for the same alloy. (3)

(c) Explain any differences between the two curves. (4)

Question 2 **[20]**

2.1 The thermal conductivity of a single-crystal ceramic specimen is slightly greater than a polycrystalline one of the same materials. Why is this so? (5)

2.2 A copper wire 15 m long is cooled from 40 to -9 °C. How much change in length will it experience? For cupper $\alpha_l = 16.5 \times 10^{-6}\ (^{\circ}C)^{-1}$ (5)

2.3 (a) Explain thermal shock resistance? (7)

(b) What factors control thermal shock resistance of a material? (3)

Question 3 **[20]**

3.1 Briefly explain why glass-ceramics are generally not transparent. (5)

3.2 Determine the penetration depth of the primary electrons in ZnS for an incident beam of energy 10 keV, given that $K = 1.2 \times 10^{-4}$ and $b = 0.0175$. (5)

3.3 (a) What is Photoluminescence? (4)

(b) State the difference between photoluminescence and fluorescence (4)

(c) Mention two uses of photoluminescence. (2)

Question 4 **[20]**

4.1 For intrinsic gallium arsenide, the room-temperature electrical conductivity is 3×10^{-7} $(\Omega.m)^{-1}$. The electron and hole mobilities are, respectively, 0.80 and 0.04 m^2/Vs. Calculate the intrinsic carrier concentration, n_i, at room temperature. Charge of electron $= 1.6 \times 10^{-19}$ C. (5)

4.2 Consider a parallel-plate capacitor of area of 6.45×10^{-4} m^2 and a plate separation of 2×10^{-3} m across which a potential of 10 V is applied. If a material having a dielectric constant of 6.0 is positioned within the region between the plates, compute the following:

(a) The capacitance (3)

(b) The magnitude of the charge stored on each plate (2)

(c) The dielectric displacement D (2)

(d) The polarization (3)

4.3 What are the properties of an ideal electrical insulating material? (5)

Question 5 **[20]**

5.1 Calculate the saturation magnetization for Fe_3O_4, given that each cubic unit cell contains 8 Fe^{2+} and 16 Fe^{3+} ions; the unit cell edge length is 0.839 nm; and that Bohr magneton $= 9.27 \times 10^{-24}$ $A.m^2$. (5)

5.2 State two major similarities and differences between ferromagnetic and ferrimagnetic materials. (5)

5.3 Explain, with the aid of a diagram, the most important properties of permanent magnetic materials. (10)

Question 6 **[20]**

6.1 State the general difference in strengthening mechanism between large-particle and dispersion strengthened particle-reinforced composites. (5)

6.2 What is the difference between configuration and conformation in relation to polymer chains? (5)

6.3 What are the different types of point defects? (5)
How are they caused? (5)

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Formula Sheet: Materials Physics

Mechanical properties: stress $\sigma = F/A$, strain $\varepsilon = (l - l_0)/l_0 = \Delta l/l_0$, stress-strain curve $\sigma = f(\varepsilon) = E\varepsilon$

shear stress $\tau = F/A$, shear strain $\Delta b/h = \tan\gamma$, $\tau = G \tan\gamma$, compressibility $\Delta V/V_0 = -\kappa p = -p/K$

$K = E/(3(1-2\nu))$ $\quad$ $G = E/(2(1+\nu))$ $\quad$ $E/G = 9/(3+(G/K))$

Elastic energy $W_{def} = E = \int_0^S F(s)ds = \int_0^S Dsds = \frac{1}{2}DS^2$ or $E = \frac{1}{2}\frac{\sigma 2}{E} = \frac{1}{2}E\varepsilon^2$

Thermal properties: Heat capacity $C = \Delta Q/\Delta T$, specific heat capacity $c = \Delta Q/(m\Delta T)$

Thermal expansion $l_1 - l_0 = \alpha(T_1 - T_0)$, $\Delta V = \gamma \Delta T$

Heat conductivity and heat transition: $\frac{\Delta Q}{\Delta t} = \dot{Q} = -\lambda\frac{A}{d}|grad(T)| = \lambda\frac{A}{d}\Delta T = \lambda\frac{A}{d}(T1 - T2)$

H. transfer: $\frac{\Delta Q}{\Delta t} = \dot{Q} = \alpha A \Delta T = \alpha A(T1 - T2)$, h. transition: $\frac{\Delta Q}{\Delta t} = \dot{Q} = kA\Delta T = kA(T1 - T2)$

Stefan-Boltzmann law: $= \sigma A T^4$, Wien's displacement law: $\lambda_{\max} = \frac{2897{,}8\ \mu\mathrm{m\,K}}{T}$

Optical properties: Snell's law: $n_1\sin(\alpha) = n_2\sin(\beta)$,

Some of Fresnel's laws: reflection coeff. $r_p = \frac{\tan(\alpha-\beta)}{\tan(\alpha+\beta)}$ $\quad$ $r_s = \frac{\sin(\alpha-\beta)}{\sin(\alpha+\beta)}$,

transmission coeff. $t_s = r_s + 1$, $n_2 t_p = n_1(r_p + 1)$, reflectivity $\rho = r^2$, transmittivity $\tau = (n_2\cos\beta)/(n_1\cos\alpha)t^2$,

Brewster angle: $\tan\alpha_B = n_2/n_1$. critical angle: $\sin\alpha_G = n_2/n_1$, spectr. reflectivity $R(\lambda) = \frac{I_{ref}(\lambda)}{I_0(\lambda)}$

Lambert-Beer law: $I_t(x,\lambda) = I_0(\lambda)\exp[-\alpha(\lambda)x]$ $\quad$ $I_t(x,\lambda) = I_0(\lambda)10^{-OD}$ $\quad$ $-\lg(I/I_0) = ODBel$

Abbe number: $\nu = (n(green)-1)/(n(blue)-n(red))$

Electrical properties: resistance $R = \rho L/A$, electrical conductivity $\sigma = 1/\rho$, $\rho(T) = \rho(T_0)[1 + \beta(T - T_0)]$

Current density $j = I/A = Q/\tau A = neAL/A\tau = nev$, electron mobility $v = \mu_e E$, Lorentz force:

$\vec{F} = q(\vec{v} \times \vec{B})$, capacity of a plate capacitor $C_0 = \varepsilon_0\frac{A}{d}$, $C = \varepsilon_r\varepsilon_0\frac{A}{d}$ flux density $D = \varepsilon_r\varepsilon_0 E$

Susceptibility $\chi_e = \varepsilon_r - 1$, $P = \varepsilon_0 c_e E$,

Magnetic properties: MF of a straight wire: $\vec{H}(r) = \mu_0\frac{I}{r}\overrightarrow{e_\varphi}$, coil: $H = \frac{NI}{L}$ magn. flux density:

$\overrightarrow{B_o} = \mu_0\vec{H}$, $\vec{B} = \mu_0\mu_r\vec{H}$, $\vec{B} = \mu_0\vec{H} + \mu_0\vec{M} = \mu_0(\vec{H} + \vec{M}) = \mu_0(\vec{H} + \chi_m\vec{H}) = \mu_0\vec{H}(1 + \chi_m)$

Faraday effect: $\beta = VdB$

Metallic materials: Force on charged particle in field E: $\vec{F}_{el} = q\vec{E} = m\dot{\vec{v}}$ drift velocity: $v_D = \frac{e\tau}{m}E$

Conductivity $\sigma = \frac{j}{E} = \frac{ne^2\tau}{m}$ thermo voltage $U_{th} = (S_B - S_A)\ DT$

Magnetic materials: magn. moment: $\vec{m} = I\vec{A}$, $\vec{m} = m_l\mu_B$, $\vec{\mu} = g_e\mu_B\frac{\vec{s}}{\hbar}$

Etching: Anisotropy: $A = 1 - \frac{v_{lateral}}{v_{vertical}}$ $\quad$ $A = 1 - \frac{v_{111}}{v_{100}}$ $\quad$ Selectivity: $S = \frac{v_{A-Material}}{v_{A-Mask}}$ $\quad$ $S = \frac{v_{111}}{v_{100}}$