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: JANUARY 2020	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

SUPPLEMENTARY/SECOND 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 5 PAGES (Including front page and formula sheet)

Question 1 **[20]**

1.1 When making hardness measurements, what will be the effect of making an indentation very close to pre-existing indentation? Why? (5)

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

(a) What is the maximum load that may be applied to a specimen with a cross-sectional area of 130 mm^2 without plastic deformation? (5)

(b) If the original specimen length is 76 mm, what is the maximum length to which it may be stretched without causing plastic deformation? (5)

1.3 (a) What is tensile testing? (3)

(b) Why is tensile testing important? (2)

Question 2 **[20]**

2.1 Explain why, on a cold day, the metal door handle of an automobile feels colder to the touch than a plastic steering wheel, even though both are at the same temperature. (5)

2.2 Railroad tracks made of 1025 steel are to be laid during the time of year when the temperature averages 4^0C. If a joint space of 5.4 mm is allowed between the standard 11.9 m long rails, what is the highest possible temperature that can be tolerated without the introduction of thermal stresses? (5)

For these railroad tracks, each end can expand one-half of the joint space distance, or the track may expand a total of this distance (4.6 mm). The value of α for the 1025 steel is 12.0×10^{-6} $(^0C)^{-1}$.

2.3 (a) Define thermal stress. (3)

(b) Explain how thermal stress resulting from restrained thermal expansion and contraction varies. (7)

Question 3 **[20]**

3.1 Which of the following oxide materials when added to fused silica (SiO_2) will increase its index of refraction: Al_2O_3, TiO_2, NiO, MgO? Why? (5)

3.2 The fraction of non-reflected light that is transmitted through a 200-mm thickness of glass is 0.98. Calculate the absorption coefficient of this material. (5)

3.3 (a) Define photoconductivity. (3)

(b) State two applications of photoconductivity (2)

(c) Explain, giving reasons, whether the semiconductor Zinc Selenide (ZnSe), which has a band gap of 2.58 eV, is, or is not, photoconductive when exposed to visible light radiation. (5)

Question 4 **[20]**

4.1 Explain the following:

(a) dielectric loss (2)
(b) dielectric break down (2)
(c) local electric field (3)
(d) polarizability (3)

4.2 10^{23} m^{-3} arsenic atoms are added to high-purity silicon.
(a) Is the resulting material *n*-type or *p*-type? Explain your answer. (2)

(b) Given that the charge of electron = -1.6×10^{-19} C, and that electron mobility = 0.07 $m^2/V/s$; calculate the room-temperature electrical conductivity of this material. (3)

4.3 Briefly explain why the ferroelectric behaviour of $BaTiO_3$ ceases above its ferroelectric Curie temperature. (5)

Question 5 **[20]**

5.1 Given that the saturation magnetization for Fe_2O_3 is 5.0×10^5 A/m, and that the unit cell edge length of ferrite is 0.839 nm, design a cubic mixed-ferrite magnetic material that has a saturation magnetization of 5.25×10^5A/m. (5)

5.2 Schematically sketch on a single plot the B-versus-H behaviour for a ferromagnetic material
(a) at 0 K, (2)
(b) at a temperature just below its Curie temperature, and (2)
(c) at a temperature just above its Curie temperature. (2)
(d) Briefly explain why these curves have different shapes. (4)

5.3 State the differences between soft magnetic materials from hard magnetic materials. (5)

Question 6 **[20]**

6.1 In the table below are listed four hypothetical aligned fibre-reinforced composites (labelled A, B, D, and D), along with their characteristics. On the basis of these data, rank the four composites from highest to lowest strength in the longitudinal direction, and then justify your ranking. (5)

Composite	Fibre type	Vol. Fraction fibre	Fibre Strength (MPa)	Ave. Fibre length (mm)	Critical length (mm)
A	Glass	0.20	3.5×10^3	8	0.70
B	Glass	0.35	3.5×10^3	12	0.75
C	Carbon	0.40	5.5×10^3	8	0.40
D	Carbon	0.30	5.5×10^3	8	0.50

6.2 Differentiate between polymorphism and isomerism. (5)

6.3 Sketch the repeat structure for each of the following alternating copolymers:

(a) poly (ethylene-propylene) (3)

(b) poly(butadienestyrene) (3)

(c) poly(isobutylene-isoprene). (4)

END

Formula Sheet: Materials Physics

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

shear stress τ=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: $\lambda_{\max} = \frac{2897{,}8\ \mu\text{m K}}{T}$

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. $t_s=r_s+1$, $n_2t_p=n_1(r_p+1)$, 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: ν=(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: $S = \frac{v_{A-Material}}{v_{A-Mask}}$ $\quad S = \frac{v_{111}}{v_{100}}$