THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2024**

Instructions

1. This paper consists of six questions.
2. Answer five questions.
3. Each question carries twenty marks.

1. (a) (i) What is meant by the term viscosity as applied in fluid dynamics?

Viscosity is the internal resistance of a fluid to flow due to intermolecular friction. It is measured in Pascal-seconds (Pa·s) and determines how easily a fluid moves.

(ii) Distinguish between streamline flow and turbulent flow of a liquid. Give two points.

1. In streamline flow, every particle of the fluid follows a smooth, predictable path, while in turbulent flow, fluid particles move in irregular, chaotic paths.
2. Streamline flow occurs at low velocities and is governed by the Reynolds number being below a critical value, whereas turbulent flow occurs at high velocities with Reynolds numbers exceeding the critical threshold.

(b) (i) Identify the principle on which the continuity equation is based.

The continuity equation is based on the principle of conservation of mass, stating that the mass flow rate remains constant in a steady-state flow of an incompressible fluid.

(ii) Why does the velocity increase when water flowing in a broader pipe enters a narrow pipe?

From the continuity equation:

$A_1V_1 = A_2V_2$

Since the cross-sectional area (A) of a pipe decreases when it narrows, the velocity (V) must increase proportionally to maintain a constant flow rate.

(c) (i) Briefly explain how the viscosities of two liquids can be compared.

1. Capillary flow method: Measure the time taken for equal volumes of both liquids to flow through a capillary tube under the same pressure.
2. Falling sphere method: Drop a sphere in both liquids and compare the time it takes to fall; a slower fall indicates higher viscosity.
3. Rotational viscometer: Measure the torque required to rotate an object in the liquid. Higher torque means higher viscosity.

(ii) Water flows through a horizontal tube of diameter 0.008 m and a length of 4 km at the rate of 20 litres per second. Assuming that only viscous resistance exists, estimate the pressure difference required to maintain the flow.

Given:
Diameter, d = 0.008 m

Radius, $r = d/2 = 0.008/2 = 0.004$ m
Length, $L = 4000$ m
Flow rate, $Q = 20$ L/s $= 0.02\ m^3/s$
Dynamic viscosity of water, $\eta = 1.002 \times 10^{-3}$ Pa·s

Using Hagen-Poiseuille equation for laminar flow:

$$\Delta P = (8\eta LQ) / (\pi r^4)$$

Substituting values:

$$\Delta P = (8 \times 1.002 \times 10^{-3} \times 4000 \times 0.02) / (\pi \times (0.004)^4)$$

$$\Delta P = (0.064128) / (\pi \times 2.56 \times 10^{-8})$$

$$\Delta P = (0.064128) / (8.042 \times 10^{-8})$$

$$\Delta P = 7.97 \times 10^5 \text{ Pa}$$

(d) A horizontal pipe of diameter 20 cm has a constriction of diameter 4 cm along its length. If the velocity and pressure of water flowing through it is 2 m/s and $10^7\ N/m^2$ respectively, determine the pressure at the constriction.

Given:
$D_1 = 20$ cm $= 0.2$ m
$D_2 = 4$ cm $= 0.04$ m
$V_1 = 2$ m/s
$P_1 = 10^7\ N/m^2$
Density of water, $\rho = 1000\ kg/m^3$

From the continuity equation:

$$A_1V_1 = A_2V_2$$

$$\pi(0.2/2)^2 \times 2 = \pi(0.04/2)^2 \times V_2$$

Solving for V_2:

$$(\pi \times 0.01^2 \times 2) = (\pi \times 0.0004^2 \times V_2)$$

$$V_2 = (0.0002) / (0.00000016)$$

$$V_2 = 50 \text{ m/s}$$

Using Bernoulli's equation:

$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$10^7 + \frac{1}{2} \times 1000 \times 2^2 = P_2 + \frac{1}{2} \times 1000 \times 50^2$

$10^7 + 2000 = P_2 + 1.25 \times 10^6$

$P_2 = 10^7 + 2000 - 1.25 \times 10^6$

$P_2 = 8.75 \times 10^6$ Pa

2. (a) (i) Stipulate two distinctive properties between travelling and standing waves.

1. A travelling wave moves energy from one point to another, while a standing wave remains confined in a medium without net energy transfer.
2. Travelling waves have continuously varying amplitude, whereas standing waves have nodes and antinodes where displacement is fixed.

(ii) Sound wave of wavelength λ travels from the first medium with a velocity of v into another medium with the velocity of 4v. Determine the wavelength of sound wave in the second medium.

From the wave equation:

$v = f\lambda$

Since frequency remains constant across media,

$\lambda_2 = (v_2 / v_1) \times \lambda_1$

$\lambda_2 = (4v / v) \times \lambda$

$\lambda_2 = 4\lambda$

(b) (i) State the principle of superposition as applied to wave motion.

The principle of superposition states that when two or more waves overlap, the resultant displacement at any point is the sum of the displacements of the individual waves.

(ii) Analyse five differences between interference and diffraction based on superposition of light waves.

1. Interference occurs when waves from two coherent sources superimpose, while diffraction occurs when a single wave bends around an obstacle.
2. Interference requires at least two waves, while diffraction occurs with a single wavefront encountering an obstacle.
3. Interference fringes are sharp and evenly spaced, while diffraction fringes gradually fade.
4. Interference is significant in Young's double-slit experiment, while diffraction is observed in single-slit or grating experiments.
5. Interference results from phase difference, whereas diffraction is a result of wave bending.

(c) The transverse displacement of a string which is clamped at both ends is given by the equation:

$y(x, t) = 0.06 \sin(2\pi/3\ x) \cos(120\pi t)$

where x and y are in meters and t in seconds. If the length and mass of the string are 1.5 m and 3.0×10^{-2} kg respectively:

(i) What type of wave does the equation represent?

The equation represents a standing wave, as it is a product of sine and cosine functions, which indicates the presence of nodes and antinodes.

(ii) Determine the tension in the string.

The wave speed v is given by:

$v = f\lambda$

From the equation, comparing with $y(x, t) = A \sin(kx) \cos(\omega t)$:

$k = 2\pi/3$
$\omega = 120\pi$

Wave number: $k = 2\pi/\lambda$

$\lambda = 2\pi/k = 2\pi/(2\pi/3) = 3$ m

Frequency: $f = \omega/2\pi = 120\pi/2\pi = 60$ Hz

Wave speed: $v = f\lambda = 60 \times 3 = 180$ m/s

Mass per unit length:

μ = mass/length = $(3.0 \times 10^{-2}$ kg$) / (1.5$ m$)$

$\mu = 0.02$ kg/m

Using:

$v = \sqrt{T/\mu}$

$180 = \sqrt{T/0.02}$

Squaring both sides:
$32400 = T / 0.02$
$T = 648$ N

3. (a) (i) How is brittle material different from ductile material?

1. Brittle materials fracture suddenly without significant plastic deformation, while ductile materials undergo noticeable plastic deformation before breaking.
2. Brittle materials have high compressive strength but low tensile strength, whereas ductile materials can withstand both tensile and compressive forces.

(ii) Figure 1 is a sketch graph of force F against extension e for two iron wires, X and Y, of the same length, l.

Which wire is expected to extend more when both are subjected to a constant force? Give a reason for your answer.

Using Hooke's law:

$F = k \times e$

Rearranging for extension:

$e = F / k$

Where k is the stiffness (Young's modulus × cross-sectional area / length). The wire with a lower stiffness (lower k) will extend more under the same force.

From the graph, wire Y has a gentler slope, meaning it has a lower stiffness (k). Therefore, wire Y will extend more when subjected to a constant force.

(b) (i) A uniform iron bar of diameter 8.0 mm and initial length 500 mm is heated uniformly until it expands by 0.4 mm. If it is later clamped at its ends and allowed to cool, calculate the tension in the bar.

Given:
Diameter, $d = 8.0 \text{ mm} = 8 \times 10^{-3} \text{ m}$
Length, $L = 500 \text{ mm} = 0.5 \text{ m}$
Expansion, $\Delta L = 0.4 \text{ mm} = 0.0004 \text{ m}$
Young's modulus of iron, $E = 2 \times 10^{11} \text{ N/m}^2$
Coefficient of thermal expansion of iron, $\alpha = 1.2 \times 10^{-5} \text{ K}^{-1}$

Thermal strain:

$\varepsilon = \Delta L / L = (0.0004) / (0.5) = 8 \times 10^{-4}$

Stress:

$\sigma = E \times \varepsilon = (2 \times 10^{11}) \times (8 \times 10^{-4})$

$\sigma = 1.6 \times 10^{8} \text{ N/m}^2$

Force:

$F = \sigma \times A$

Cross-sectional area:

$A = \pi d^2 / 4 = (\pi \times (8 \times 10^{-3})^2) / 4$

$A = (\pi \times 64 \times 10^{-6}) / 4$

$A = (201 \times 10^{-6}) / 4$

$A = 5.03 \times 10^{-5} \text{ m}^2$

$F = (1.6 \times 10^{8}) \times (5.03 \times 10^{-5})$

$F = 8.048 \times 10^{3} \text{ N}$

Tension in the bar = 8.05 kN

(ii) Compute the increase in energy of the brass bar of length 0.2 m and cross-sectional area 1 cm² when compressed with a force of 49 N along its length.

Given:
Length, $L = 0.2$ m
Cross-sectional area, $A = 1 \text{ cm}^2 = 1 \times 10^{-4} \text{ m}^2$
Force, $F = 49$ N
Young's modulus of brass, $E = 1 \times 10^{11} \text{ N/m}^2$

Stress:

$\sigma = F / A = (49) / (1 \times 10^{-4})$

$\sigma = 4.9 \times 10^{5} \text{ N/m}^2$

Strain:

$\varepsilon = \sigma / E = (4.9 \times 10^{5}) / (1 \times 10^{11})$

$\varepsilon = 4.9 \times 10^{-6}$

Change in length:

$\Delta L = \varepsilon \times L = (4.9 \times 10^{-6}) \times (0.2)$

$\Delta L = 9.8 \times 10^{-7}$ m

Energy stored:

$U = (1/2) \times F \times \Delta L$

$U = (1/2) \times (49) \times (9.8 \times 10^{-7})$

$U = (49 \times 4.9 \times 10^{-7})$

$U = 2.40 \times 10^{-5}$ J

(c) (i) Why are springs made of steel and not copper?

1. Steel has a higher Young's modulus than copper, meaning it resists deformation and returns to its original shape more effectively.
2. Steel has higher fatigue resistance, making it more durable under repeated loading and unloading compared to copper.

(ii) A copper rod of length 2 m and cross-sectional area 2.0 cm^2 is fastened end to end to a steel rod of length L and cross-sectional area 1.0 cm^2. If the compound rod is subjected to equal and opposite pulls of magnitude 3×10^4 N at its ends and the elongations of the two rods are equal, find the length L of the steel rod.

Given:
Length of copper rod, $L_1 = 2$ m
Cross-sectional area of copper rod, $A_1 = 2\ cm^2 = 2 \times 10^{-4}\ m^2$
Cross-sectional area of steel rod, $A_2 = 1\ cm^2 = 1 \times 10^{-4}\ m^2$
Force, $F = 3 \times 10^4$ N
Young's modulus of copper, $E_1 = 1.2 \times 10^{11}\ N/m^2$
Young's modulus of steel, $E_2 = 2 \times 10^{11}\ N/m^2$

Since elongations are equal:

$(\sigma_1 / E_1) = (\sigma_2 / E_2)$

Where stress $\sigma = F / A$:

$(F / A_1) / E_1 = (F / A_2) / E_2$

$(3 \times 10^4 / 2 \times 10^{-4}) / (1.2 \times 10^{11}) = (3 \times 10^4 / 1 \times 10^{-4}) / (2 \times 10^{11})$

$(1.5 \times 10^8) / (1.2 \times 10^{11}) = (3 \times 10^8) / (2 \times 10^{11})$

$1.25 \times 10^{-3} = 1.5 \times 10^{-3}$

$L_1 / L_2 = (A_2E_2) / (A_1E_1)$

$2 / L = (1 \times 10^{-4} \times 2 \times 10^{11}) / (2 \times 10^{-4} \times 1.2 \times 10^{11})$

$2 / L = (2 \times 10^7) / (2.4 \times 10^7)$

$2 / L = 0.833$

$L = 2 / 0.833$

$L = 2.4$ m

4. (a) (i) Identify three important properties of an equipotential surface.

- The electric potential at every point on an equipotential surface is the same.
- No work is done when moving a charge along an equipotential surface because the potential difference is zero.
- An equipotential surface is always perpendicular to the direction of the electric field at every point.

(ii) Two protons in a nucleus of U-238 are separated by 6.0×10^{-15} m. Determine their mutual electric potential energy.

Given:
Charge of proton, $q = 1.6 \times 10^{-19}$ C
Distance between protons, $r = 6.0 \times 10^{-15}$ m
Coulomb's constant, $k = 9 \times 10^{9}$ Nm²/C²

Electric potential energy:

$U = k(q_1q_2) / r$

$U = (9 \times 10^{9} \times (1.6 \times 10^{-19})^{2}) / (6.0 \times 10^{-15})$

$U = (9 \times 10^{9} \times 2.56 \times 10^{-38}) / (6 \times 10^{-15})$

$U = (2.304 \times 10^{-28}) / (6 \times 10^{-15})$

$U = 3.84 \times 10^{-14}$ J

(b) (i) Derive an expression for the energy stored inside a charged capacitor.

The energy stored in a capacitor is given by:

$W = (1/2) QV$

Using the capacitance formula:

$Q = CV$

Substituting in the energy equation:

$W = (1/2) C V^{2}$

Alternatively, using $Q = CV$ and substituting $V = Q/C$, we get:

$W = (1/2) (Q^{2} / C)$

Thus, the energy stored in a capacitor can be expressed in three forms:

$W = ½ QV = ½ CV^2 = ½ Q^2/C$

(ii) A $10 \times 10^3\ \Omega$ resistor is connected in series with a capacitor of 1.0 μF and a battery of e.m.f. 12.0 V. If before the switch is closed, the capacitor is uncharged, find the fraction of the final charge on the plates and of the initial current remains at time t = 46 seconds.
Given:
Resistance, $R = 10 \times 10^3\ \Omega = 10^4\ \Omega$
Capacitance, $C = 1.0\ \mu F = 1.0 \times 10^{-6}$ F
Battery voltage, V = 12.0 V
Time, t = 46 s

Time constant:

$\tau = RC = (10^4) \times (1 \times 10^{-6})$
$\tau = 10$ s

Charge at time t:

$Q = Q_0(1 - e^{(-t/\tau)})$

Fraction of final charge:

$Q/Q_0 = 1 - e^{(-46/10)}$

$Q/Q_0 = 1 - e^{(-4.6)}$

Using $e^{(-4.6)} \approx 0.01$:
$Q/Q_0 = 1 - 0.01 = 0.99$
Fraction of charge = 0.99 or 99%
Initial current:

$I = I_0 e^{(-t/\tau)}$

$I/I_0 = e^{(-46/10)}$

$I/I_0 = e^{(-4.6)}$
$I/I_0 \approx 0.01$

Fraction of initial current remaining = 0.01 or 1%

5. (a) (i) Distinguish between magnetic flux density and magnetic field intensity.

- Magnetic flux density (B) is the amount of magnetic flux per unit area and is measured in Tesla (T), while magnetic field intensity (H) represents the strength of the magnetic field due to a source and is measured in A/m.
- B is related to H by the equation $B = \mu H$, where μ is the permeability of the medium.

(ii) Calculate the maximum electromotive force (e.m.f) induced in a coil of 500 turns, each with an area of 4.0 cm², making 50 revolutions per second in a uniform magnetic field of flux density 0.04 T.

Given:
Number of turns, $N = 500$
Area, $A = 4.0\ \text{cm}^2 = 4.0 \times 10^{-4}\ \text{m}^2$
Frequency, $f = 50$ Hz
Magnetic flux density, $B = 0.04$ T
Maximum e.m.f:

$$E_0 = NAB\omega$$

Angular velocity:

$$\omega = 2\pi f = 2\pi \times 50$$

$$\omega = 100\pi\ \text{rad/s}$$

Substituting values:

$$E_0 = (500) \times (0.04) \times (4 \times 10^{-4}) \times (100\pi)$$

$$E_0 = 8\pi\ \text{V}$$

$$E_0 \approx 25.13\ \text{V}$$

(b) A wire of 2.0 metres long carrying a current of 10 A is placed in a field of flux density 0.15 T. Determine the force on the wire if it is placed:

(i) At right angle to the field.

Force:
$F = BIL \sin\theta$
At right angles, $\sin 90° = 1$
$F = (0.15) \times (10) \times (2) \times 1$
$F = 3$ N

(ii) At 45 degrees to the field.

$\sin 45° = 1/\sqrt{2}$

$F = (0.15) \times (10) \times (2) \times (1/\sqrt{2})$
$F = 3/\sqrt{2}$
$F \approx 2.12$ N

(iii) Along the field.

At $\theta = 0°$, $\sin 0° = 0$

$F = (0.15) \times (10) \times (2) \times 0$

$F = 0$ N

(c) (i) State Lenz's law of electromagnetic induction.

Lenz's law states that the direction of the induced current in a conductor is such that it opposes the change in magnetic flux that caused it.

(ii) Two identical wires R and S lie parallel in a horizontal plane, their axes being 0.1 m apart. If the current of 10 A flows in wire R in the opposite direction to a current of 30 A in wire S, calculate the magnitude and direction of magnetic flux density at point P midway between R and S.

Given:
Distance between wires = 0.1 m
Distance of P from each wire = 0.05 m

Magnetic field due to a long straight wire:

$B = (\mu_0 I) / (2\pi r)$

For wire R:
$B_1 = (4\pi \times 10^{-7} \times 10) / (2\pi \times 0.05)$
$B_1 = (4 \times 10^{-6} \times 10) / (0.1)$

$B_1 = 4 \times 10^{-5}$ T

For wire S:

$B_2 = (4\pi \times 10^{-7} \times 30) / (2\pi \times 0.05)$

$B_2 = (4 \times 10^{-6} \times 30) / (0.1)$

$B_2 = 12 \times 10^{-5}$ T

Since the currents are in opposite directions, the magnetic fields at P add up:

$B\_net = B_1 + B_2$

$B\_net = 4 \times 10^{-5} + 12 \times 10^{-5}$

$B\_net = 16 \times 10^{-5}$ T

$B\_net = 1.6 \times 10^{-4}$ T

Direction: Since wire S has a stronger field, the net field is in the direction of S's field.

6. (a) (i) Analyse two drawbacks on which Bohr's model of an atom suffered.

- Bohr's model could not explain the spectra of atoms with more than one electron, as it only worked well for hydrogen.
- It did not consider the wave nature of electrons, which was later addressed by quantum mechanics.

(ii) State two differences between Rutherford's model and Bohr's model.

- Rutherford's model described the atom as having a central nucleus with electrons moving randomly around it, while Bohr's model introduced quantized orbits for electrons.
- Rutherford's model could not explain atomic stability, whereas Bohr's model explained why electrons do not spiral into the nucleus by proposing fixed energy levels.

(b) (i) What do you think would really happen if the electrons in an atom were stationary?

If electrons were stationary, they would experience an electrostatic attraction toward the nucleus and collapse into it. This would make atoms unstable, which contradicts real-world observations where atoms remain stable due to electron motion.

(ii) A single electron rotates around a stationary nucleus of charge Ze, where 'Z' and 'e' are constant and electronic charge respectively. If it requires 47.2 eV to excite an electron from the second Bohr's orbit, determine the value of Z.

Given:
Energy required for transition from n = 2 to a higher level, E = 47.2 eV
Bohr's energy level formula:

$E_n = - (13.6 \times Z^2) / n^2$

For n = 2:

$E_2 = - (13.6 \times Z^2) / 2^2$

$E_2 = - (13.6 \times Z^2) / 4$

Since 47.2 eV is needed to excite the electron, the total energy at n = 2 must be:

$|E_2| = 47.2$ eV

$(13.6 \times Z^2) / 4 = 47.2$

$Z^2 = (47.2 \times 4) / 13.6$

$Z^2 = 188.8 / 13.6$

$Z^2 = 13.88$

$Z \approx 3.72$
Since Z must be an integer, rounding gives Z = 4

(c) (i) Which series of the hydrogen spectrum lie in the visible region of the electromagnetic spectrum?

The Balmer series lies in the visible region of the electromagnetic spectrum.

(ii) Hydrogen atoms in a discharge tube emit spectral lines whose frequencies are given by the following equation,

$f = C_R (1/n_1^2 - 1/n_2^2)$

where n_1 and n_2 are any positive whole numbers. Calculate the highest frequency in the Lyman's series.

Given:
Lyman series corresponds to $n_1 = 1$ and $n_2 = \infty$ for the highest frequency.
Rydberg constant, $C_R = 3.29 \times 10^{15}$ Hz

Highest frequency occurs when $n_2 \rightarrow \infty$:

$$f_{max} = C_R (1/1^2 - 1/\infty^2)$$

Since $1/\infty^2 = 0$:

$$f_{max} = C_R (1 - 0)$$

$$f_{max} = 3.29 \times 10^{15} \text{ Hz}$$