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: 2022**

Instructions

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

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1. (a) (i) Give three importance of coefficient of viscosities of liquids in daily life activities.

1. It helps in determining the efficiency of lubricants used in machinery to reduce friction and wear.
2. It is essential in medical applications such as blood flow analysis to diagnose cardiovascular diseases.
3. It is crucial in industrial processes like the design of pipelines for transporting fluids, ensuring smooth and efficient flow.

(ii) Identify two assumptions made in deriving the Poiseuille's equation for the flow of a liquid through a narrow tube.

- The fluid is incompressible and has a constant viscosity throughout the flow.
- The flow is laminar, meaning there is no turbulence and the velocity of the fluid layers remains parallel.

(b) (i) If the radius of a pipe carrying liquid gets decreased by 8%, how much would the pressure difference between the ends of the constricted pipe increase to maintain a constant flow rate?

Given:
Initial radius, r
New radius, $r' = 0.92r$

Using Poiseuille's equation:

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

Since the flow rate Q remains constant,

$\Delta P' / \Delta P = (r / r')^4$

Substituting $r' = 0.92r$:

$\Delta P' / \Delta P = (1 / 0.92)^4$

$\Delta P' / \Delta P \approx 1.41$

Thus, the pressure difference must increase by 41%.

(ii) Describe the mode of action of a Pitot-static tube and apply Bernoulli's equation to obtain the formulae used to measure the velocity of a flowing liquid.

A Pitot-static tube measures the velocity of a fluid by comparing the stagnation pressure and the static pressure. The total pressure (stagnation pressure) is obtained from a tube facing the flow, while the static pressure is obtained from a side hole.

Using Bernoulli's equation:

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

Since $V_2 = 0$ at the stagnation point:

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

Solving for velocity:

$V = \text{sqrt}(2(P_2 - P_1) / \rho)$

This equation is used to determine the velocity of a fluid using a Pitot-static tube.

(c) (i) Under what circumstance does Torricelli's theorem apply?

Torricelli's theorem applies when a liquid is flowing out of an orifice under the influence of gravity, assuming no viscosity and negligible air resistance. The theorem is valid when the liquid is incompressible, and the exit velocity depends only on the height of the fluid column above the orifice.

(ii) Water is maintained at a height of 10 m in a tank. Calculate the diameter of the circular hole needed at the base of the tank to discharge water at the rate of 26.4 m^3/minute.

Given:
Height, $h = 10$ m
Flow rate, $Q = 26.4\ m^3/min = 26.4 / 60\ m^3/s = 0.44\ m^3/s$
Acceleration due to gravity, $g = 9.81\ m/s^2$

Using Torricelli's theorem:

$V = \text{sqrt}(2gh)$

$V = \text{sqrt}(2 \times 9.81 \times 10)$

$V = \text{sqrt}(196.2)$

$V \approx 14$ m/s

The area of the hole:

$A = Q / V$

$A = 0.44 / 14$

$A \approx 0.0314\ m^2$

Diameter:

$d = \sqrt{4A / \pi}$

$d = \sqrt{4 \times 0.0314 / 3.1416}$

$d \approx 0.20\ m$

2. (a) (i) Give a concrete reason behind a straight-line propagation of light irrespective of its wave nature.

Light propagates in a straight line because its wavelength is much smaller than the objects it encounters, making diffraction effects negligible in everyday situations. This straight-line behavior is evident in ray optics, where light travels in straight paths unless it encounters obstacles or changes medium.

(ii) In a Young's double slit experiment, the green light of mercury of wavelength 0.54 μm was used with a pair of parallel slits of separation 0.6 mm. If the fringes were observed at a distance of 40 cm from the slit, calculate the distance of separation between the fringes.

Given:
Wavelength, $\lambda = 0.54\ \mu m = 0.54 \times 10^{-6}\ m$
Slit separation, $d = 0.6\ mm = 0.6 \times 10^{-3}\ m$
Screen distance, $L = 40\ cm = 0.4\ m$

Fringe width formula:

$\Delta y = (\lambda L) / d$

$\Delta y = (0.54 \times 10^{-6} \times 0.4) / (0.6 \times 10^{-3})$

$\Delta y = (2.16 \times 10^{-7}) / (6 \times 10^{-4})$

$\Delta y = 3.6 \times 10^{-4}\ m$

$\Delta y = 0.36\ mm$

(b) (i) Identify two cases in which there is no Doppler effect in sound.

1. When both the source and observer are at rest relative to the medium.
2. When both the source and observer move with the same velocity in the same direction.

(ii) A car is sounding a horn which produces a note of frequency 500 Hz. If it approaches and then passes a stationary observer Q at a steady speed of 20 m/s, calculate the change in pitch of the note as heard by Q.

Given:
Source frequency, $f = 500$ Hz
Speed of sound, $v = 340$ m/s
Speed of car, $v_s = 20$ m/s

Approaching frequency:

$$f' = f \left(\frac{v}{v - v_s}\right)$$

$$f' = 500 \left(\frac{340}{340 - 20}\right)$$

$$f' = 500 \left(\frac{340}{320}\right)$$

$$f' \approx 531.25 \text{ Hz}$$

Receding frequency:

$$f'' = f \left(\frac{v}{v + v_s}\right)$$

$$f'' = 500 \left(\frac{340}{340 + 20}\right)$$

$$f'' = 500 \left(\frac{340}{360}\right)$$

$$f'' \approx 472.22 \text{ Hz}$$

Change in pitch:

$$\Delta f = f' - f''$$

$$\Delta f = 531.25 - 472.22$$

$$\Delta f \approx 59 \text{ Hz}$$

(c) (i) What properties of a medium are responsible for the propagation of a wave through it? Give two points.

- The elasticity of the medium, which allows the medium to return to its original shape after deformation.
- The density of the medium, which affects the speed at which waves travel.

(ii) A horizontal stretched elastic string of length and mass of 3.0 m and 12 kg respectively is subjected to a tension of 1.6 N. If a transverse wave of frequency 40 Hz is propagated down the string, determine the distance between successive crests of this wave motion.

Given:
Length, L = 3.0 m
Mass, m = 12 kg
Tension, T = 1.6 N
Frequency, f = 40 Hz

Linear mass density:

$\mu = m / L$

$\mu = 12 / 3$

$\mu = 4$ kg/m

Wave speed:

$v = \text{sqrt}(T / \mu)$

$v = \text{sqrt}(1.6 / 4)$

$v = \text{sqrt}(0.4)$

$v \approx 0.63$ m/s

Wavelength:

$\lambda = v / f$

$\lambda = 0.63 / 40$

$\lambda \approx 0.0158$ m
3. (a) (i) What is meant by the angle of contact between the liquid and a solid as used in properties of matter?

The angle of contact is the angle formed between the tangent to the liquid surface at the point of contact with a solid and the solid surface inside the liquid. It determines the wetting properties of the liquid on the solid surface.

(ii) Outline four factors on which the value of angle of contact depends.

- The nature of the liquid and the solid surface.
- The presence of impurities on the solid surface or in the liquid.
- The temperature of the liquid and solid.
- The presence of surface-active agents such as detergents, which alter surface tension.

(b) (i) Give a qualitative distinction between surface tension and surface energy of a liquid.

1. Surface tension is the force per unit length acting on the surface of a liquid that causes it to contract, whereas surface energy is the energy required to increase the surface area of a liquid by one unit.
2. Surface tension has units of N/m, while surface energy is measured in J/m^2.

(ii) A small air bubble of radius 0.1 mm is situated just below the water surface. If the atmospheric pressure is 1.013×10^5 N/m^2, determine the pressure inside the air bubble.

Given:
Radius, $r = 0.1$ mm $= 1 \times 10^{-4}$ m
Surface tension of water, $T = 0.0728$ N/m
Atmospheric pressure, $P_0 = 1.013 \times 10^5$ N/m^2

For a gas bubble inside a liquid, the excess pressure is given by:

$\Delta P = 2T / r$

$\Delta P = (2 \times 0.0728) / (1 \times 10^{-4})$

$\Delta P = 1.456 \times 10^3$ N/m^2

Total pressure inside the bubble:

$P = P_0 + \Delta P$

$P = (1.013 \times 10^5) + (1.456 \times 10^3)$

$P = 1.02756 \times 10^5$ N/m^2

$P \approx 1.03 \times 10^5$ N/m^2

(c) (i) Stipulate four practical applications of capillarity in daily life activities.

- The rise of water in the roots and stems of plants through xylem vessels.
- The absorption of ink by blotting paper.
- The movement of oil in a lamp wick.
- The capillary action of porous materials such as sponges and towels to soak up liquids.

(ii) Water rises in a capillary tube to a height of 2.0 cm. Compute the height at which water will rise in another capillary tube whose radius is one-third of the first tube.

Given:
$h_1 = 2.0$ cm
$r_1 = r$
$r_2 = r/3$

The height of capillary rise is inversely proportional to the radius:

$h_2 / h_1 = r_1 / r_2$

$h_2 = h_1 \times (r_1 / r_2)$

$h_2 = 2.0 \times (r / (r/3))$

$h_2 = 2.0 \times 3$

$h_2 = 6.0$ cm

4. (a) (i) State Coulomb's law.

Coulomb's law states that the force between two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them. Mathematically,

$F = (k\, q_1\, q_2) / r^2$

where k is Coulomb's constant, q_1 and q_2 are the magnitudes of the charges, and r is the distance between them.

(ii) A proton of mass 1.673×10^{-27} kg falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N/C. If air resistance and acceleration due to gravity are neglected, calculate its time of fall.

Given:
Mass, $m = 1.673 \times 10^{-27}$ kg
Distance, $d = 1.5$ cm $= 1.5 \times 10^{-2}$ m
Electric field, $E = 2.0 \times 10^4$ N/C
Charge of proton, $q = 1.6 \times 10^{-19}$ C

Force on proton:

$F = qE$

$F = (1.6 \times 10^{-19}) \times (2.0 \times 10^{4})$

$F = 3.2 \times 10^{-15}$ N

Acceleration:

$a = F / m$

$a = (3.2 \times 10^{-15}) / (1.673 \times 10^{-27})$

$a = 1.91 \times 10^{12}$ m/s²

Using equation of motion:

$d = ½ a t^2$

Solving for t:

$t = \text{sqrt}(2d / a)$

$t = \text{sqrt}((2 \times 1.5 \times 10^{-2}) / (1.91 \times 10^{12}))$

$t = \text{sqrt}((3 \times 10^{-2}) / (1.91 \times 10^{12}))$

$t = \text{sqrt}(1.57 \times 10^{-14})$

$t \approx 1.25 \times 10^{-7}$ s

(b) A 100 V battery terminals are connected to two large and parallel plates which are 2 cm apart. If the field in the region between the plates is nearly uniform, determine the force on an electron in this field.

Given:
Voltage, V = 100 V
Plate separation, d = 2 cm = 0.02 m
Charge of electron, $e = 1.6 \times 10^{-19}$ C

Electric field between plates:

$E = V / d$
$E = 100 / 0.02$
$E = 5000$ V/m

Force on electron:

$F = eE$
$F = (1.6 \times 10^{-19}) \times (5000)$
$F = 8.0 \times 10^{-16}$ N

(c) If an electron is released from rest from the upper plate inside the field in 4(b), determine:

(i) The velocity with which it will hit the lower plate.
Using energy conservation:

Kinetic energy gained = Electric potential energy lost

$\frac{1}{2} m v^2 = eV$

Solving for v:

v = sqrt((2eV) / m)

Given:
$m = 9.11 \times 10^{-31}$ kg
$e = 1.6 \times 10^{-19}$ C
V = 100 V

$v = \text{sqrt}((2 \times 1.6 \times 10^{-19} \times 100) / (9.11 \times 10^{-31}))$

$v = \text{sqrt}((3.2 \times 10^{-17}) / (9.11 \times 10^{-31}))$

$v = \text{sqrt}(3.51 \times 10^{13})$

$v \approx 5.92 \times 10^{6}$ m/s

(ii) Its kinetic energy and the time it will take for the whole journey.

Kinetic energy:

$KE = \frac{1}{2} m v^2$

$KE = \frac{1}{2} \times (9.11 \times 10^{-31}) \times (5.92 \times 10^{6})^2$

$KE = \frac{1}{2} \times (9.11 \times 10^{-31}) \times (3.5 \times 10^{13})$

$KE = (9.11 \times 10^{-31} \times 3.5 \times 10^{13}) / 2$

$KE = 1.59 \times 10^{-17}$ J

Time of travel:

Using kinematic equation:

$d = \frac{1}{2} a t^2$

$t = \text{sqrt}(2d / a)$

Acceleration:

$a = eE / m$

$a = (1.6 \times 10^{-19} \times 5000) / (9.11 \times 10^{-31})$

$a = (8 \times 10^{-16}) / (9.11 \times 10^{-31})$

$a = 8.78 \times 10^{14}$ m/s²

$t = \text{sqrt}((2 \times 0.02) / (8.78 \times 10^{14}))$

$t = \text{sqrt}(4.56 \times 10^{-17})$

$t \approx 6.75 \times 10^{-9}$ s

5.(a)(i)Why do magnetic lines of force always form a closed loop?

Magnetic field lines always form closed loops because there are no isolated magnetic monopoles; the field lines emerge from the north pole and always return to the south pole, ensuring continuity in the field.

(ii)A force of 0.025 N was experienced by a test wire of length 0.05 m placed in a magnetic field of strength 0.2 T carrying a current of 2.5 A. Calculate the angle between the wire and the field lines.

Given:
Force, $F = 0.025$ N
Length of wire, $L = 0.05$ m
Magnetic field strength, $B = 0.2$ T
Current, $I = 2.5$ A

Using the formula for magnetic force:
$F = BIL \sin \theta$

Solving for sin θ:
$\sin\theta = F / (BIL)$

$\sin\theta = (0.025) / (0.2 \times 2.5 \times 0.05)$
$\sin\theta = (0.025) / (0.025)$
$\sin\theta = 1$
$\theta = 90°$

(b)(i)Identify two classes of magnetic materials which are weakly affected by the magnetic field.

1. Diamagnetic materials
2. Paramagnetic materials

(ii)A toroid with an air core, carrying a current of 0.15 A has a mean circumference of 50 cm and 500 number of turns. Determine its magnetizing force and magnetic flux density.

Given:
Current, $I = 0.15$ A
Number of turns, $N = 500$
Mean circumference, $l = 50$ cm $= 0.50$ m
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ H/m

Magnetizing force:
$H = NI / l$

$H = (500 \times 0.15) / 0.50$
$H = 75$ A/m

Magnetic flux density:
$B = \mu_0 H$

$B = (4\pi \times 10^{-7}) \times (75)$
$B = 9.42 \times 10^{-5}$ T

(c)(i)Briefly explain the cause of earth's magnetic field.
Earth's magnetic field is generated by the movement of molten iron and other conducting materials in the outer core. This motion, driven by convection currents and Earth's rotation, creates electric currents, which in turn generate a magnetic field through the dynamo effect.

(ii)An aircraft is flying horizontally at 860 km/hr in a region where the vertical component of the earth's magnetic field is 6.0×10^{-5} T. If its wingspan is of 54 m, determine the potential difference induced between one wing tip and the other.

Given:
Velocity, $v = 860$ km/hr $= (860 \times 1000) / 3600 = 238.89$ m/s
Magnetic field, $B = 6.0 \times 10^{-5}$ T
Wingspan, $L = 54$ m

Induced emf:
$\varepsilon = BLv$

$\varepsilon = (6.0 \times 10^{-5}) \times (54) \times (238.89)$
$\varepsilon = 0.773$ V
6.(a)(i)What is meant by energy level?

An energy level is a quantized state of energy that an electron in an atom can occupy, corresponding to discrete energy values.

(ii)How does ionization energy differ from excitation energy?

1. Ionization energy is the energy required to completely remove an electron from an atom, while excitation energy is the energy needed to move an electron from a lower to a higher energy level without removing it.
2. Ionization energy results in ion formation, whereas excitation energy leads to a temporary excited state of the atom.

(b)(i)Why did the Thompson's model fail?

1. It could not explain the existence of a nucleus and why electrons do not spiral into the center.
2. It did not account for the discrete spectral lines observed in atomic emission spectra.

(ii)Identify four applications of Cathode ray oscilloscope.

1. Measurement of voltage, frequency, and phase difference in electrical signals.
2. Displaying waveforms in electronics and communication engineering.
3. Monitoring heart signals in electrocardiography (ECG).
4. Analyzing audio signals in sound engineering.

(iii)Calculate the wavelength of the most energetic x-rays produced by a tube operating at 1.5×10^5 V.

Given:
Voltage, $V = 1.5 \times 10^5$ V
Planck's constant, $h = 6.63 \times 10^{-34}$ Js
Speed of light, $c = 3 \times 10^8$ m/s
Charge of electron, $e = 1.6 \times 10^{-19}$ C

Using the equation:

$\lambda = hc / eV$

$\lambda = (6.63 \times 10^{-34} \times 3 \times 10^{8}) / (1.6 \times 10^{-19} \times 1.5 \times 10^{5})$
$\lambda = (1.989 \times 10^{-25}) / (2.4 \times 10^{-14})$
$\lambda = 8.29 \times 10^{-12}$ m

(c)Study the following Figure of the energy level diagram for hydrogen atom and then answer the questions that follow.

(i)Calculate the frequency and the wavelength of the radiation emitted as a result of an electron transition from n = 3 to n = 2.

Energy difference:
$\Delta E = E_3 - E_2$
$\Delta E = (-1.51 \text{ eV}) - (-3.39 \text{ eV})$
$\Delta E = 1.88$ eV

Converting to joules:
$\Delta E = 1.88 \times (1.6 \times 10^{-19})$
$\Delta E = 3.008 \times 10^{-19}$ J

Frequency:
$f = \Delta E / h$

$f = (3.008 \times 10^{-19}) / (6.63 \times 10^{-34})$
$f = 4.54 \times 10^{14}$ Hz

Wavelength:
$\lambda = c / f$

$\lambda = (3 \times 10^{8}) / (4.54 \times 10^{14})$
$\lambda = 6.61 \times 10^{-7}$ m or 661 nm

(ii)What is the energy at the level where n = 5?

From the diagram,
$E_5 = -0.85$ eV