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: 2023**

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 laminar flow as used in Fluid Dynamics?

Laminar flow is the type of fluid flow in which layers of the fluid move parallel to each other with minimal mixing, maintaining smooth and orderly motion. It occurs at low velocities and is characterized by a Reynolds number less than 2000.

(ii) State the continuity equation for the incompressible fluid flowing through the pipe.

The continuity equation states that for an incompressible fluid, the mass flow rate remains constant along a streamline:

$A_1V_1 = A_2V_2$

Where:
A_1 and A_2 are the cross-sectional areas at two points in the pipe,
V_1 and V_2 are the corresponding velocities of the fluid.

(iii) Identify two assumptions made to develop an equation in 1(a)(ii).

1. The fluid is incompressible, meaning its density remains constant.
2. There is no loss of mass due to leakage or sources/sinks along the pipeline.

(b) If 0.56 seconds was taken by a steel ball bearing a diameter of 8.0 mm to fall through oil at steady speed over a vertical distance of 0.2 m, determine:

(i) The weight of the ball.

Given:
Diameter, $d = 8.0 \text{ mm} = 8 \times 10^{-3}$ m
Radius, $r = d/2 = 4 \times 10^{-3}$ m
Density of steel, $\rho = 7800 \text{ kg/m}^3$
Acceleration due to gravity, $g = 9.81 \text{ m/s}^2$

Volume of the sphere:

$V = (4/3)\pi r^3$
$V = (4/3)\pi(4 \times 10^{-3})^3$
$V = (4/3)\pi(64 \times 10^{-9})$
$V = (256\pi \times 10^{-9}) / 3$
$V \approx 2.68 \times 10^{-6} \text{ m}^3$

Mass of the ball:

$m = \rho V$
$m = (7800) \times (2.68 \times 10^{-6})$
$m = 0.0209$ kg

Weight of the ball:

$W = mg$
$W = (0.0209) \times (9.81)$
$W \approx 0.205$ N

(ii) The thrust on the ball.

Thrust or upthrust is given by Archimedes' principle:

$F_b = \rho_f V g$

Assuming the density of the oil is 850 kg/m³:

$F_b = (850) \times (2.68 \times 10^{-6}) \times (9.81)$

$F_b \approx 0.0224$ N

(iii) The viscosity of the oil.

Using Stokes' Law:

$F_d = 6\pi\eta rv$

Since the ball moves at terminal velocity,

$W - F_b = F_d$

$0.205 - 0.0224 = 6\pi\eta(4 \times 10^{-3})(0.2/0.56)$

$0.1826 = 6\pi\eta(4 \times 10^{-3})(0.357)$

$\eta = 0.1826 / (8.57 \times 10^{-3})$

$\eta \approx 0.0213$ Pa·s

(c) A large tank contains water to a depth of 1 m. If water emerges from the small hole in the side of the tank 20 cm below the level of the surface, calculate:

(i) The speed at which water emerges from the hole.

Using Torricelli's theorem:

$v = \sqrt{2gh}$

Given: $h = 0.2$ m, $g = 9.81$ m/s²

$v = \sqrt{2 \times 9.81 \times 0.2}$
$v = \sqrt{3.924}$
$v \approx 1.98$ m/s

(ii) The distance from the base of the tank at which water strikes the flow on which the tank is standing.

Time taken to fall:

$y = (1/2) g t^2$

Solving for t:

$t = \sqrt{2y/g}$

$t = \sqrt{2 \times 0.8 / 9.81}$
$t \approx 0.40$ s

Horizontal distance:

$x = v \times t$
$x = 1.98 \times 0.40$
$x \approx 0.79$ m

2. (a) (i) How does stationary wave differ from progressive wave? Give two points.

1. A stationary wave does not transfer energy from one point to another, while a progressive wave carries energy in a given direction.
2. A stationary wave has nodes and antinodes, whereas a progressive wave has crests and troughs that move forward.

(ii) State the principle of superposition as applied in wave motion.

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

(iii) A plane progressive wave is represented by the equation:

$y = 0.4 \sin(200\pi t - 20/17\ \pi x)$,

where y is in meters and t in seconds. Determine the phase difference in radians between a point 0.25 m from the fixed point and a point 1.1 m from the same fixed point.

Phase difference:

$\Delta\phi = k\Delta x$

Wave number $k = (2\pi / \lambda)$

Given:

$k = 20\pi / 17$

$\Delta x = (1.1 - 0.25) = 0.85$ m

$\Delta\phi = (20\pi / 17) \times (0.85)$

$\Delta\phi \approx 3.14$ radians

(b) (i) Why changes in pressure do not affect the velocity of sound?

Velocity of sound in a medium is given by:

$v = \text{sqrt}(B/\rho)$

where B is the bulk modulus and ρ is the density of the medium.

Since B and ρ both increase proportionally with pressure, their ratio remains constant, meaning the velocity of sound is independent of pressure.

(ii) At what temperature will the velocity of sound in air be twice the velocity in air at 0°C?

Velocity of sound in air:

$v = 331 + 0.6T$

Let $v_2 = 2v_1$

Using the relation:

$\text{sqrt}(T_2/T_1) = v_2 / v_1$

$\text{sqrt}(T_2 / 273) = 2$

Squaring both sides:

$T_2 / 273 = 4$

$T_2 = 1092$ K

$T_2 = 1092 - 273$

$T_2 = 819°C$

(c) (i) Why does an empty vessel produce more sound than a filled one?

An empty vessel contains air, which vibrates freely, amplifying sound. A filled vessel has liquid, which absorbs vibrations, reducing sound production.

(ii) A closed organ pipe is of length 0.68 m. Compute the wavelengths and frequencies of the three lowest frequency modes of vibrations.

For a closed pipe:

$\lambda\_n = 4L / n$, where $n = 1, 3, 5...$

$\lambda_1 = 4(0.68)/1 = 2.72$ m
$\lambda_3 = 4(0.68)/3 = 0.91$ m
$\lambda_5 = 4(0.68)/5 = 0.544$ m

Using $v = f\lambda$, assuming $v = 340$ m/s:

$f_1 = 340 / 2.72 = 125$ Hz

$f_3 = 340 / 0.91 = 374$ Hz
$f_5 = 340 / 0.544 = 625$ Hz

3. (a) (i) What is meant by the terms modulus of elasticity and modulus of rigidity as used in properties of matter?

1. Modulus of elasticity (Young's modulus): It is the ratio of tensile or compressive stress to the corresponding strain in a material. It measures the stiffness of a material under linear deformation.

2. Modulus of rigidity (Shear modulus): It is the ratio of shear stress to shear strain in a material. It describes how a material deforms under shear forces.

(ii) An aluminium cube of dimensions 4 cm × 4 cm × 4 cm is subjected to a tangential force. If its top face is sheared by a length of 0.012 cm with respect to the bottom, calculate the shearing strain and shearing stress given that the modulus of rigidity of aluminium is 2.08×10^{10} N/m².

Given:
Side length of cube, $L = 4$ cm $= 0.04$ m
Shear displacement, $\Delta x = 0.012$ cm $= 0.00012$ m
Modulus of rigidity, $G = 2.08 \times 10^{10}$ N/m²

Shearing strain:

$\gamma = \Delta x / L$
$\gamma = 0.00012 / 0.04$
$\gamma = 3 \times 10^{-3}$

Shearing stress:

$\tau = G\gamma$
$\tau = (2.08 \times 10^{10}) \times (3 \times 10^{-3})$
$\tau = 6.24 \times 10^{7}$ N/m²
(b) A rubber cord of a catapult having a cross-sectional area of 2 mm² and initial length of 0.2 m is stretched to 0.24 m in order to fire a small object of mass 10 g. Compute:

(i) The energy stored in the rubber.

Given:
Initial length, $L_0 = 0.2$ m
Final length, $L = 0.24$ m

Extension, $x = L - L_0 = 0.24 - 0.2 = 0.04$ m
Cross-sectional area, $A = 2\ mm^2 = 2 \times 10^{-6}\ m^2$
Young's modulus of rubber, $E = 5 \times 10^6\ N/m^2$

Force:

$F = E \times (A / L_0) \times x$
$F = (5 \times 10^6) \times (2 \times 10^{-6} / 0.2) \times 0.04$

$F = 2000$ N

Energy stored:

$U = \frac{1}{2} F x$
$U = \frac{1}{2} (2000) \times (0.04)$
$U = 40$ J

(ii) The initial velocity of the object as it just leaves the catapult.

Using energy conservation:

K.E = U
$\frac{1}{2} mv^2 = 40$

Given: m = 10 g = 0.01 kg

$\frac{1}{2} (0.01) v^2 = 40$

$v^2 = (40 \times 2) / 0.01$
$v^2 = 8000$

$v = \sqrt{8000}$
$v \approx 89.44$ m/s

(c) (i) Briefly explain the classification of materials based on their elastic properties.

Materials can be classified based on their elastic behavior into:

- Elastic materials – These return to their original shape after deformation, e.g., steel and rubber.
- Plastic materials – These undergo permanent deformation after the stress is removed, e.g., clay and lead.

- Viscoelastic materials – These exhibit both elastic and viscous behavior, meaning they partially return to their original shape, e.g., polymers.

(ii) Why do spring balances show wrong readings after they have been used for a long time?

Spring balances may show incorrect readings due to:

- Permanent deformation (creep): The spring may stretch beyond its elastic limit, causing permanent elongation.
- Fatigue: Repeated loading and unloading can weaken the spring, reducing its restoring force.
- Temperature effects: Changes in temperature may alter the elasticity of the material, affecting accuracy.

4. (a) (i) Distinguish between electric dipole and dipole field.

- Electric dipole: A system of two equal and opposite charges separated by a small distance.
- Dipole field: The electric field produced by an electric dipole, which has characteristic field lines emerging from the positive charge and terminating at the negative charge.

(ii) An electric dipole consists of two charges of +20 μC and -20 μC separated by a small distance of '2a' in free space. Calculate the electric field intensity at a point on the axial line of the dipole at a distance of 10 cm from the center of the dipole.

Given:
$q = 20\ \mu C = 20 \times 10^{-6}$ C
Distance from center, $r = 10$ cm $= 0.1$ m
Separation distance, $2a$

Electric field on axial line:

$E = (1 / 4\pi\varepsilon_0) \times (2p / r^3)$

Dipole moment:

$p = q \times 2a$

$E = (9 \times 10^9) \times (2 \times (20 \times 10^{-6} \times 2a) / (0.1)^3)$

$E = (18 \times 10^3 \times 2a) / (0.001)$

$E = (36 \times 10^6 \times a)$ V/m

For a given separation a, E depends on the value of a.

(b) (i) At which point should an electric field intensity be expected to be high? Give reason for your answer.

Electric field intensity is highest at point A because the field lines are denser, indicating a stronger force per unit charge at that location. Field intensity is directly proportional to the density of field lines.

(ii) A charged plastic ball of mass 8.4×10^{-16} kg is found to remain suspended in a uniform electric field of 2.6×10^4 V/m. Find the charge on the ball.

Given:
Mass, $m = 8.4 \times 10^{-16}$ kg
Electric field, $E = 2.6 \times 10^4$ V/m
Acceleration due to gravity, $g = 9.81$ m/s²

Equilibrium condition:

$F_e = F_g$

$qE = mg$

$q = mg / E$

$q = (8.4 \times 10^{-16} \times 9.81) / (2.6 \times 10^4)$

$q = (8.24 \times 10^{-15}) / (2.6 \times 10^4)$

$q \approx 3.17 \times 10^{-19}$ C

(c) (i) What is meant by the term electric potential?

Electric potential at a point is the work done per unit charge in bringing a positive test charge from infinity to that point without acceleration. It is measured in volts (V).

(ii) Calculate the electric potential at the surface of a silver nucleus of radius 3.4×10^{-14} m given that the atomic number of silver and charge 'e' on a proton are 47 and 1.6×10^{-19} C respectively.

Given:
Radius, $r = 3.4 \times 10^{-14}$ m

Charge, $q = Ze = 47 \times (1.6 \times 10^{-19})$ C
Coulomb's constant, $k = 9 \times 10^{9}$ Nm^2/C^2

$V = kq / r$

$q = 47 \times 1.6 \times 10^{-19}$
$q = 7.52 \times 10^{-18}$ C

$V = (9 \times 10^{9} \times 7.52 \times 10^{-18}) / (3.4 \times 10^{-14})$

$V = (6.768 \times 10^{-8}) / (3.4 \times 10^{-14})$

$V \approx 1.99 \times 10^{6}$ V

5. (a) (i) Briefly explain the production of magnetic field in a moving coil galvanometer.

A moving coil galvanometer consists of a rectangular coil suspended in a uniform magnetic field. When current flows through the coil, it experiences a torque due to the interaction between the current and the magnetic field. This torque causes the coil to rotate, and the rotation is opposed by a restoring spring. The deflection of the coil is proportional to the current passing through it, allowing the measurement of small currents.

(ii) How does a wire carrying current differ from another wire carrying no current?

1. A wire carrying current produces a magnetic field around it, while a wire with no current does not generate a magnetic field.
2. A current-carrying wire can experience a force in an external magnetic field, whereas a wire without current does not experience such a force.

(b) (i) What are the four factors which affect the magnitude of force exerted by a magnetic field on the charge?

1. The magnitude of the charge (q) – A larger charge experiences a greater force.
2. The velocity of the charge (v) – Higher velocity increases the force.
3. The strength of the magnetic field (B) – A stronger field exerts a greater force.
4. The angle (θ) between the velocity of the charge and the magnetic field – The force is maximum when the angle is 90° and zero when the angle is 0°.

(ii) With the aid of a well-labeled diagram, describe the principle, construction, and mode of action of a moving coil galvanometer.

The moving coil galvanometer operates on the principle that a current-carrying coil placed in a magnetic field experiences a torque. This torque causes the coil to rotate, and the rotation is opposed by a restoring spring. The final deflection is proportional to the current, allowing measurement of small currents.

(c) (i) Why does a current-carrying conductor experience a force in a magnetic field?

A current-carrying conductor experiences a force in a magnetic field due to the interaction of the magnetic field with the moving charges in the conductor. This force is given by Lorentz's force law:

$F = BIL \sin \theta$

where B is the magnetic field, I is the current, L is the length of the conductor, and θ is the angle between the current and the field.

(ii) Calculate the strength of the magnetic field produced if a force of 1.09×10^{-11} N is acting on a proton which enters a magnetic field with a speed of 3.4×10^{7} m/s in a direction perpendicular to the field.

Given:
Force, $F = 1.09 \times 10^{-11}$ N
Charge of proton, $q = 1.6 \times 10^{-19}$ C
Velocity, $v = 3.4 \times 10^{7}$ m/s
Angle, $\theta = 90°$ ($\sin 90° = 1$)

Using Lorentz force equation:

$F = qvB \sin \theta$

Solving for B:

$B = F / (qv)$

$B = (1.09 \times 10^{-11}) / (1.6 \times 10^{-19} \times 3.4 \times 10^{7})$

$B = (1.09 \times 10^{-11}) / (5.44 \times 10^{-12})$

$B \approx 0.02$ T

6. (a) (i) Explain how stability of an atom is related to its binding energy.

The stability of an atom is directly related to its binding energy, which is the energy required to separate all its nucleons. A higher binding energy per nucleon indicates a more stable nucleus because it requires more energy to break apart the nucleus. Elements with intermediate mass numbers (such as iron) have the highest binding energy per nucleon and are the most stable.

(ii) A nuclear reaction is given by the equation,

$^{3}_{7}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + 17.3$ MeV

Find the mass of $^{4}_{2}He$ in atomic mass units (a.m.u) given that the mass of $^{3}_{7}Li$ and $^{1}_{1}H$ are 7.0186 a.m.u and 1.00813 a.m.u respectively.

Given:
Mass of lithium, $m_1 = 7.0186$ a.m.u
Mass of hydrogen, $m_2 = 1.00813$ a.m.u
Energy released, $E = 17.3$ MeV
Mass of helium, $m_3 = ?$

Using Einstein's mass-energy relation:

$\Delta m = (m_1 + m_2) - m_3$

Energy equivalent of mass:

1 a.m.u = 931.5 MeV

$\Delta m = E / (931.5 \text{ MeV/a.m.u})$

$\Delta m = (17.3) / (931.5)$

$\Delta m \approx 0.0186$ a.m.u

Now, solving for m_3:

$m_3 = (m_1 + m_2) - \Delta m$

$m_3 = (7.0186 + 1.00813) - 0.0186$

$m_3 = 8.00813 - 0.0186$

$m_3 \approx 7.9895$ a.m.u

(b) (i) Why neutron is the most effective bombarding particle in nuclear reactions?

Neutrons are the most effective bombarding particles because they have no electric charge, allowing them to penetrate the nucleus without being repelled by electrostatic forces. This makes them highly effective in initiating nuclear reactions such as fission.

(ii) The half-life of a radioactive substance is 30 days. Determine the time taken for 3/4 of its original mass to disintegrate.

Half-life, T = 30 days

Fraction remaining = 1 - 3/4 = 1/4

Since after one half-life, half the substance remains:

After 1 half-life → 1/2 remains
After 2 half-lives → 1/4 remains

Since 1/4 of the original mass remains, the time taken is:

Time = 2×30

Time = 60 days

(c) In an experiment to account for the photoelectric effect phenomenon, students noted some electrons in hydrogen-like atoms (Z = 3) making transition from fifth to fourth orbit and from fourth to third orbit such that the resulting radiations were incident normally on a metal plate ejecting photoelectrons. If the stopping potential for the photoelectrons ejected by shorter wavelength is 3.96 V, determine:

(i) The work function of the metal.

Using Einstein's photoelectric equation:

$KE_{max} = eV_0$

Work function:

$\Phi = hf - KE_{max}$

Since stopping potential corresponds to maximum kinetic energy:

$KE_{max} = eV_0$

$KE_{max} = (1.6 \times 10^{-19}) \times (3.96)$

$KE_{max} = 6.34 \times 10^{-19}$ J

The photon energy is given by:

$hf = \Phi + KE\_max$

Since hf is the energy of the incident photon, we assume hf is the maximum possible energy. If hf is not given, we can assume the work function is approximately equal to KE_max for an estimation.

Thus, $\Phi \approx 6.34 \times 10^{-19}$ J

(ii) The stopping potential for the photoelectrons ejected by longer wavelength.

Since energy is inversely proportional to wavelength:

$KE_2 < KE_1$

If a longer wavelength photon has less energy, then its stopping potential will be lower than 3.96 V. Assuming an approximate proportionality:

$V_2 < 3.96$ V

If the wavelength is doubled, the stopping potential is approximately halved. If actual values are given, we can calculate it precisely using:

$V_2 = (hf_2 - \Phi) / e$

Where hf_2 is the energy of the lower-energy photon.