THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Duration: 3 Hours **ANSWERS** **Year: 2025**

Instructions

1. This paper consists of **six (6)** questions
2. Answer **five (5)** questions.
3. Each question carries **twenty (20)** marks.
4. Mathematics tables and non-programmable calculators may be used.
5. All writing must be in **black** or **blue** ink except for drawings which must be in pencil
6. Communication devices and any unauthorised materials are **not** allowed in the examination room.
7. Write your **Examination Number** on every page of your answer booklet(s).
8. The following information may be useful:
   a) Acceleration due to gravity, $g = 9.8\ m/s^2$
   b) Pie, $\pi = 3.14$
   c) Speed of light, $c = 3 \times 10^8\ m\ s^{-1}$
   d) The coefficient of viscosity of water, $\eta = 10^{-3}\ N\ s\ m^{-2}$
   e) Speed of sound in still air = $340\ ms^{-1}$
   f) Charge of an electron, e, = 1.6×10^{-19} C
   g) Mass of an electron, $m_e = 9.0 \times 10^{-31}$ kg
   h) Plank's constant, h, = 6.63×10^{-34} Js
   i) Permeability of free space, $\mu_o = 4\pi \times 10^{-7}\ Hm^{-1}$
   j) Reydberg constant, $R_H = 1.097 \times 10^7\ m^{-1}$

1.(a)(i) Account for a suction effect phenomenon based on Bernoulli's Theorem.

According to Bernoulli's theorem, the sum of pressure energy, kinetic energy, and potential energy per unit volume of a moving fluid remains constant along a streamline. When the velocity of a fluid increases, the pressure decreases. The suction effect occurs due to this inverse relationship between pressure and velocity. For example, when air moves faster over the mouth of a tube, the pressure above the liquid in the tube decreases, causing the liquid to rise due to higher pressure inside the container pushing it upward. This phenomenon is observed in atomizers, sprays, and carburetors.

(ii) A raindrop of radius 2 mm falls from a height of 500 m above the ground with decreasing acceleration to half its original height. If it attains its maximum terminal speed and moves with uniform speed thereafter, determine the work done by the gravitational force on the drop in the first and second of its journey.

The mass of the raindrop is given by $m = (4/3)\pi r^3\rho$, where $\rho = 1000$ kg/m³ and $r = 2 \times 10^{-3}$ m.

$m = (4/3) \times 3.142 \times (2 \times 10^{-3})^3 \times 1000$

$m = 3.35 \times 10^{-5}$ kg

Work done by gravity = mgh.

For the first half of the fall (250 m):

$W_1 = 3.35 \times 10^{-5} \times 9.8 \times 250 = 0.082$ J

For the second half (250 m):

$W_2 = 3.35 \times 10^{-5} \times 9.8 \times 250 = 0.082$ J

Hence, the work done by gravity in each half of the fall is the same, 0.082 J.

(b)(i) Distinguish between static pressure and dynamic pressure as applied in laminar fluid flow.

Static pressure is the pressure exerted by a fluid at rest or in motion but measured when the fluid velocity component is zero. It represents the potential energy per unit volume of the fluid.

Dynamic pressure is the pressure associated with the motion of the fluid, representing its kinetic energy per unit volume. It is given by $\frac{1}{2}\rho v^2$, where ρ is the fluid density and v is the velocity.

(ii) Water is flowing steadily through a horizontal pipe of uniform cross-sectional area. If the velocity and pressure at a point where cross-section area is 0.02 m^2 are 2 m/s and 4×10^4 N/m^2 respectively, calculate the pressure at a point where the cross-sectional area is reduced to 0.01 m^2.

Using continuity equation, $A_1V_1 = A_2V_2$

$0.02 \times 2 = 0.01 \times V_2$

$V_2 = 4$ m/s

By Bernoulli's equation:

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

Substitute $\rho = 1000$ kg/m^3:

$4 \times 10^4 + \frac{1}{2}(1000)(2^2) = P_2 + \frac{1}{2}(1000)(4^2)$

$40000 + 2000 = P_2 + 8000$

$P_2 = 42000 - 8000 = 34000$ N/m^2

Hence, pressure at the narrow end is 3.4×10^4 N/m^2.

(c) Determine the rate of flow of glycerine of density 1.25×10^3 kg/m³ through the cross section of a pipe if the radii at its ends and the pressure drop across its length are 0.1 m, 0.04 m and 10 N/m², respectively.

By Poiseuille's equation:

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

Since the viscosity (η) and length (l) are not given, the problem can only express the relationship symbolically:

The rate of flow (Q) depends directly on the pressure difference (ΔP) and the fourth power of the radius (r^4), and inversely on viscosity and length. Therefore, the flow rate increases rapidly with an increase in radius and pressure difference but decreases with higher viscosity or longer tube length.

2.(a)(i) Determine the number of beats per second heard by the observer (assuming there was no wind), when a whistle gave a sound of frequency of 500 Hz moving away with the velocity of 1.5 m/s from a stationary observer in a direction towards and perpendicular to a flat wall.

When the sound source moves away from a stationary observer, the apparent frequency decreases, and when it reflects from a wall, the reflected sound behaves as if it comes from a source moving towards the observer.

Apparent frequency from the direct sound:

$f_1 = f(v / (v + v_s))$

Apparent frequency from the reflected sound:

$f_2 = f(v / (v - v_s))$

Where f = 500 Hz, v = 340 m/s, and v_s = 1.5 m/s.

Substituting:

$f_1 = 500(340 / (340 + 1.5)) = 500(340 / 341.5) = 497.8$ Hz

$f_2 = 500(340 / (340 - 1.5)) = 500(340 / 338.5) = 502.2$ Hz

Number of beats per second = $f_2 - f_1 = 502.2 - 497.8 = 4.4 \approx 4$ beats per second.

Therefore, the observer hears 4 beats per second.

(ii) Determine the width of the central maximum on a screen placed at a distance of 1 m from the slit, if the given slit width was 0.1 mm, and the slit was illuminated with a monochromatic light of wavelength of 5000 Å.

The width of the central maximum in single slit diffraction is given by

$W = 2\lambda D / a$

Where $\lambda = 5000$ Å $= 5 \times 10^{-7}$ m, D = 1 m, a = 0.1 mm $= 1 \times 10^{-4}$ m.

Substitute:

$W = 2 \times (5 \times 10^{-7} \times 1) / (1 \times 10^{-4})$

$W = 1 \times 10^{-2}$ m = 1 cm

Hence, the width of the central maximum is 1 cm.

(b)(i) Calculate the frequency of the note when a wire of length 140 cm and mass was stretched by means of a load of 16 kg.

The frequency of vibration of a stretched string is given by

$f = (1 / 2L) \sqrt{(T / \mu)}$

Where $T = mg = 16 \times 9.8 = 156.8$ N, $L = 1.4$ m, and $\mu = m / L$.
Since the mass per unit length is not given, we assume a uniform string where μ must be known to calculate frequency. If $\mu = 0.01$ kg/m (for instance), then:

$f = (1 / 2 \times 1.4) \times \sqrt{(156.8 / 0.01)}$
$f = 0.357 \times \sqrt{15680}$
$f = 0.357 \times 125.2 = 44.7$ Hz

Therefore, the frequency is approximately 45 Hz for $\mu = 0.01$ kg/m.

(ii) Estimate the positions where two bridges were to be placed to divide the wire into three segments whose fundamental frequencies were in the ratio of 1:2:3.

The frequency ratio is inversely proportional to the length of the wire ($f \propto 1/L$).

Let the total length = 140 cm, and segments be L_1, L_2, and L_3.
Then $L_1 : L_2 : L_3 = 1/1 : 1/2 : 1/3 = 6 : 3 : 2$ (by taking common multiple).

Total = 6 + 3 + 2 = 11 parts.
Therefore, each part = 140 / 11 = 12.7 cm.

$L_1 = 6 \times 12.7 = 76.2$ cm
$L_2 = 3 \times 12.7 = 38.1$ cm
$L_3 = 2 \times 12.7 = 25.4$ cm

Hence, the bridges should be placed at 76.2 cm and 114.3 cm from one end.

(c)(i) Identify the necessary conditions for interference of light to occur.

The sources must be coherent, meaning they maintain a constant phase difference.
The sources must emit light of the same wavelength and frequency.

The sources should have comparable intensities for clear interference fringes.
The waves must overlap and travel in the same region of space.
The interference should take place in a medium of uniform refractive index.

(ii) Explain briefly when Fraunhofer's diffraction takes place.

Fraunhofer's diffraction occurs when both the source of light and the screen are at infinite distance from the slit, or parallel light rays are used. This can be achieved using a convex lens to make the light rays parallel. The pattern formed on the screen consists of a central bright maximum and alternate dark and bright fringes due to the interference of diffracted light rays.

3.(a)(i) Explain why reducing the volume of a gas at constant temperature leads to an increase in pressure.

When the volume of a gas decreases at constant temperature, the gas molecules become confined to a smaller space. As a result, they collide more frequently with the walls of the container. Each collision exerts a force on the wall, and since the number of collisions per second increases, the total force per unit area (pressure) also increases. According to Boyle's law, pressure is inversely proportional to volume at constant temperature (PV = constant).

(ii) Deduce Avogadro's law in terms of the kinetic theory of gases.

According to the kinetic theory, pressure P is given by $P = 1/3\ (Nm/V)\ c^2$, where N is the number of molecules, m is the mass of one molecule, V is the volume, and c^2 is the mean square speed. At constant temperature and pressure, the mean square speed c^2 remains constant. Therefore,
$P \propto N/V$, or $N \propto V$.
This shows that at constant temperature and pressure, the number of molecules (and

therefore moles) of gas is directly proportional to its volume, which is Avogadro's law.

(b)(i) Explain the terms root mean square speed and mean speed of gas molecules.

The root mean square (r.m.s) speed is the square root of the average of the squares of the molecular speeds of gas particles. It gives a measure of the effective speed that relates to the kinetic energy of the gas molecules.

The mean speed is the arithmetic average of all molecular speeds in a given gas sample, found by dividing the sum of all speeds by the total number of molecules.

(ii) Determine the root mean square speed of a hydrogen molecule at a given temperature of 27°C, using the Boltzmann constant $K = 1.38 \times 10^{-23}$ J/K.

$T = 27°C = 27 + 273 = 300$ K
$m = 2 \times 10^{-3} / 6.02 \times 10^{23} = 3.32 \times 10^{-27}$ kg

Using $c_{rms} = \sqrt{(3kT/m)}$,
$c_{rms} = \sqrt{(3 \times 1.38 \times 10^{-23} \times 300 / 3.32 \times 10^{-27})}$
$c_{rms} = \sqrt{(3.726 \times 10^{6})} = 1930$ m/s

Hence, the root mean square speed of a hydrogen molecule at 27°C is 1930 m/s.

(c) State six assumptions that form the basic postulates of the kinetic theory of gases.

Gas molecules are in constant random motion.
The volume of individual gas molecules is negligible compared to the volume of the container.
Collisions between gas molecules and the container walls are perfectly elastic.
There are no intermolecular attractive or repulsive forces between molecules.

The duration of a collision is negligible compared to the time between collisions.
The average kinetic energy of gas molecules is directly proportional to the absolute temperature.

4.(a)(i) How is the direction of the field strength specified?

The direction of an electric field strength at a point is specified as the direction of the force experienced by a small positive test charge placed at that point. It shows the line of action along which the charge would move if free to do so.

(ii) Two point charges +2q and -4q respectively are situated 90 mm apart. Where should a point charge of -2q be placed so that it experiences no resultant electrostatic force?

Let the +2q charge be at point A, and -4q be at point B, separated by 90 mm. The -2q charge must be placed between them for equilibrium.

Let the distance from +2q to -2q be x, and from -4q to -2q be (90 − x).

For equilibrium, the magnitudes of the forces must be equal:
$k(2q \times 2q)/x^2 = k(4q \times 2q)/(90 - x)^2$

Simplify:
$4/x^2 = 8/(90 - x)^2$
$(90 - x)^2 = 2x^2$
$90 - x = \sqrt{2}x$
$90 = x(\sqrt{2} + 1)$
$x = 90 / (\sqrt{2} + 1) = 90 / 2.414 = 37.3$ mm

Hence, the -2q charge must be placed 37.3 mm from +2q and 52.7 mm from -4q.

(b)(i) What are the common properties of electric field lines?

Electric field lines start from positive charges and end on negative charges.
They never intersect each other.
The density of the field lines indicates the strength of the field.
They are perpendicular to the surface of a conductor.
Field lines are continuous and do not form closed loops in an electrostatic field.

(ii) In demonstrating the motion of a charged particle, students considered an electron projected with an initial velocity of 10^7 m/s into a uniform electric field between two parallel plates of length 2 cm being at a distance of 1 cm apart. If the direction of the field was vertically downwards when the electron just missed the upper plate as it emerges from the field, evaluate the magnitude of electric field.

Time taken to cross the plates horizontally:
$t = L / v = 0.02 / 10^7 = 2 \times 10^{-9}$ s

Vertical displacement y = 0.01 m.
Using equation of motion, $y = \frac{1}{2} a t^2$, and $a = eE / m$.

Substitute:
$0.01 = \frac{1}{2} \times (1.6 \times 10^{-19} \times E / 9.11 \times 10^{-31}) \times (2 \times 10^{-9})^2$
$0.01 = 0.5 \times (1.756 \times 10^{11} E) \times 4 \times 10^{-18}$
$0.01 = 3.512 \times 10^{-7} E$
$E = 0.01 / 3.512 \times 10^{-7} = 2.85 \times 10^4$ N/C

Hence, the electric field strength is 2.85×10^4 N/C.

(c) If a spherical conductor of radius 12 cm has a charge of 1.6×10^{-7} C distributed uniformly on its surface; calculate the electric field:

(i) Inside the sphere.
(ii) At a point from the sphere 18 cm away.

(i) Inside the sphere, the electric field is zero because the charge resides on the surface of the conductor.

(ii) Outside the sphere, electric field is given by $E = kQ / r^2$.

$$E = (9 \times 10^9 \times 1.6 \times 10^{-7}) / (0.18)^2$$
$$E = (1.44 \times 10^3) / 0.0324 = 4.44 \times 10^4 \text{ N/C}$$

Hence, the electric field at 18 cm from the center is 4.44×10^4 N/C.

5.(a)(i) Permanent magnets are made of steel while the core of a transformer is made of soft iron.

Permanent magnets are made of steel because steel has high retentivity and high coercivity, meaning once magnetized it retains magnetism for a long time. Soft iron, on the other hand, has low coercivity and low retentivity, making it easy to magnetize and demagnetize. This property makes soft iron suitable for transformer cores, where the magnetic field direction changes frequently.

(ii) Like poles of nearby magnets repel each other while unlike poles attract.

This occurs due to the nature of the magnetic field lines. Field lines of like poles move in opposite directions and therefore push away from each other, causing repulsion. Field lines between unlike poles move in the same direction and merge together, pulling the poles closer and creating attraction.

(iii) Above Curie temperature, ferromagnetic material becomes paramagnetic.

At temperatures above the Curie point, the thermal agitation of atoms becomes strong enough to disrupt the alignment of magnetic dipoles. The material loses its strong magnetic order and behaves as a weakly magnetic (paramagnetic) substance, meaning its magnetic properties diminish with increasing temperature.

(b)(i) Distinguish between diamagnetic materials and ferromagnetic materials with one example in each case.

Diamagnetic materials are weakly repelled by a magnetic field because they induce a magnetic moment opposite to the applied field. They have relative permeability less than one. Examples include bismuth and copper.

Ferromagnetic materials are strongly attracted by a magnetic field because their atomic dipoles align parallel to the field, producing strong magnetization. They have high permeability and exhibit hysteresis. Examples include iron, cobalt, and nickel.

(ii) Describe the hysteresis loop for soft and hard steel with the aid of labelled sketches.

In soft steel, the hysteresis loop is narrow and small, indicating low energy loss per cycle of magnetization. This makes it ideal for devices like transformers and electromagnets that require repeated magnetization and demagnetization.

In hard steel, the hysteresis loop is wide and large, showing high energy loss and strong retention of magnetism. This makes it suitable for making permanent magnets.

(c)(i) Calculate the force on the conductor carrying current of 5 A passing through it, when a vertical straight conductor of length 0.6 m is situated in a horizontal uniform magnetic field of 0.1 tesla.

The force on a current-carrying conductor is given by $F = BIL \sin\theta$.
For maximum force, $\theta = 90°$, $\sin\theta = 1$.

$F = 0.1 \times 5 \times 0.6 = 0.3$ N

Hence, the force on the conductor is 0.3 N.

(ii) Determine the angle through which the conductor must be substituted in the vertical plane so that the force on the conductor is halved.

For $F = \frac{1}{2} \times 0.3 = 0.15$ N,
$F = BIL \sin\theta$

$0.15 = 0.1 \times 5 \times 0.6 \times \sin\theta$
$0.15 = 0.3 \times \sin\theta$
$\sin\theta = 0.5$
$\theta = 30°$

Hence, the conductor must be inclined at 30° to the field direction for the force to be halved.

6.(a)(i) Explain a line spectrum based on the transition of electrons between energy levels.

A line spectrum is produced when electrons in an excited atom fall back from higher energy levels to lower energy levels. As the electrons make these transitions, they emit photons of specific energies corresponding to the difference between the energy levels. Since the energy levels are discrete, the emitted photons have specific wavelengths, producing a line spectrum with distinct lines instead of a continuous range of colors.

(ii) Calculate the ionisation energy of an element, when the energy of the convergence limit line of that element is -1.6 eV and that of the first energy level is -10.4 eV.

Ionization energy is the energy required to remove an electron from the ground state to infinity.

Ionization energy = $E_\infty - E_1 = (-1.6) - (-10.4) = 8.8$ eV

Hence, the ionization energy of the element is 8.8 eV.

(b)(i) Evaluate the kinetic energy gained by electrons in the X-ray tube, when the potential difference across its ends is 40 kV.

Kinetic energy, KE = eV = $1.6 \times 10^{-19} \times 40 \times 10^3 = 6.4 \times 10^{-15}$ J.

Hence, each electron gains kinetic energy of 6.4×10^{-15} joules.

(ii) Determine the electric current flowing in the tube, when 0.5% of the energy obtained in 6(b)(i) is transformed into X-rays and 600 W was produced.

Power of X-rays, $P = 600 \text{ W} = 0.005 \times I \times V$

$600 = 0.005 \times I \times 40000$

$600 = 200I$

$I = 600 / 200 = 3$ A

Hence, the current in the tube is 3 amperes.

(c)(i) A beam of alpha-particles is directed normally at a thin metal foil in an alpha-scattering experiment. Briefly explain why most alpha-particles pass straight through the foil.

Most alpha particles pass straight through the foil because the atoms of the metal consist mostly of empty space, and only a small portion of the alpha particles encounter the dense nucleus.

(ii) Some alpha-particles are deflected through angles of more than 90°.

A few alpha particles are deflected through large angles because they come very close to the positively charged nucleus. The strong electrostatic repulsion between the positively charged alpha particle and the nucleus causes large-angle deflections.

(iii) Multiple scattering of an individual alpha-particle is unlikely.

Multiple scattering is unlikely because the nucleus occupies a very small volume of the atom. The probability that a single alpha particle will encounter more than one nucleus during its passage through the foil is extremely low.