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: 2019**

Instructions

1. This paper consists of section A, B and C with total of nine questions.
2. Answer five questions, choosing at least one question from each section.
3. Each question carries twenty marks.

1.(a)(i)Give the meaning of the terms velocity gradient, tangential stress, and coefficient of viscosity as used in fluid dynamics.

Velocity gradient is the rate at which velocity changes per unit distance in the direction perpendicular to the flow of the fluid. It is given by du/dy.

Tangential stress is the force per unit area exerted by a fluid in motion due to internal friction between adjacent layers moving at different velocities. It is given by $\tau = \eta$ (du/dy).

Coefficient of viscosity (η) is a measure of a fluid's resistance to deformation due to internal friction between its layers. It is defined as the ratio of tangential stress to velocity gradient.

(ii)Write Stokes' equation defining clearly the meaning of all symbols used.

Stokes' equation for the drag force (F) experienced by a sphere moving through a viscous fluid is:
$F = 6\pi\eta rv$

where:
F = viscous drag force (N)
η = coefficient of viscosity (Ns/m^2)
r = radius of the sphere (m)
v = velocity of the sphere (m/s)

(iii)State two assumptions used to develop the equation in 1(a)(ii).

1. The flow of the fluid is laminar.
2. The sphere is moving at a constant velocity.

(b)Calculate the terminal velocity of the raindrops falling in air assuming that the flow is laminar, the raindrops are spheres of diameter 1 mm and the coefficient of viscosity, $\eta = 1.8 \times 10^{-5}$ Ns/m^2.

Given:
Diameter, d = 1 mm = 1×10^{-3} m
Radius, r = d/2 = 0.5×10^{-3} m
Coefficient of viscosity, $\eta = 1.8 \times 10^{-5}$ Ns/m^2
Density of water, $\rho = 1000$ kg/m^3
Density of air, $\rho_a = 1.2$ kg/m^3
Acceleration due to gravity, g = 9.81 m/s^2

Using Stokes' terminal velocity formula:
$v_t = (2r^2 g (\rho - \rho_a)) / (9\eta)$

Substituting values:

$v_t = (2 \times (0.5 \times 10^{-3})^2 \times 9.81 \times (1000 - 1.2)) / (9 \times 1.8 \times 10^{-5})$
$v_t = (2 \times 0.25 \times 10^{-6} \times 9.81 \times 998.8) / (1.62 \times 10^{-4})$
$v_t = (4.902 \times 10^{-3}) / (1.62 \times 10^{-4})$
$v_t \approx 0.03$ m/s

(c)Water flows past a horizontal plate of area 1.2 m^2. If its velocity gradient and coefficient of viscosity adjacent to the plate are 10 s^{-1} and 1.3×10^{-3} Nsm^{-2} respectively, calculate the force acting on the plate.

Given:
Area, A = 1.2 m^2
Velocity gradient, du/dy = 10 s^{-1}
Coefficient of viscosity, $\eta = 1.3 \times 10^{-3}$ Nsm^{-2}

Using shear stress formula:
$\tau = \eta\,(du/dy)$

$\tau = (1.3 \times 10^{-3}) \times (10)$
$\tau = 1.3 \times 10^{-2}$ N/m^2

Force acting on the plate:
$F = \tau A$
$F = (1.3 \times 10^{-2}) \times (1.2)$
$F = 1.56 \times 10^{-2}$ N

(d)A horizontal pipe of cross-sectional area 10 cm^2 has one section of cross-sectional area 5 cm^2. If water flows through the pipe, and the pressure difference between the two sections is 300 Pa, how many cubic meters of water will flow out of the pipe in 1 minute?

Given:
$A_1 = 10\ cm^2 = 10 \times 10^{-4}\ m^2$
$A_2 = 5\ cm^2 = 5 \times 10^{-4}\ m^2$
Pressure difference, $\Delta P = 300$ Pa
Density of water, $\rho = 1000$ kg/m^3
Time, t = 1 min = 60 s

Using Bernoulli's equation and the continuity equation:
$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

Rearranging for v_2:
$v_2 = \sqrt{2\Delta P / \rho + v_1^2}$

Using the continuity equation:
$A_1 v_1 = A_2 v_2$

$v_1 = (A_2 / A_1) v_2$

Substituting values and solving gives:
Flow rate, $Q = A_2v_2 = 0.0005 \times 1.14$
$Q \approx 5.7 \times 10^{-4}$ m³/s

Total volume in 1 minute:
$V = Q \times t$
$V = (5.7 \times 10^{-4}) \times 60$
$V \approx 0.034$ m³

2.(a)(i)Provide one evidence which proves that sound is a wave.

One evidence that sound is a wave is its ability to undergo interference, diffraction, and reflection. For example, the phenomenon of echo, where sound waves reflect off surfaces, proves that sound propagates as a wave.

(ii)Why is thunder of lightning heard some moments after seeing the flash?

Thunder is heard after the flash because light travels much faster than sound. The speed of light in air is approximately 3×10^8 m/s, while the speed of sound is about 340 m/s. This difference in speed causes the delay in hearing thunder.

(b)(i)What is Doppler effect?

The Doppler effect is the change in frequency of a wave observed when the source and observer are in relative motion. If they move towards each other, the frequency increases, and if they move apart, the frequency decreases.

(ii)The cyclist moving at 10 m/s and the railway train at 20 m/s are approaching each other. If the engine driver sounds a warning siren at a frequency of 480 Hz, calculate the frequency of the note heard by the cyclist before and after the train has passed away.

Given:
Speed of sound in air, $v = 340$ m/s
Speed of source (train), $v_s = 20$ m/s
Speed of observer (cyclist), $v_o = 10$ m/s
Frequency of source, $f_s = 480$ Hz

When the train is approaching the cyclist:
$f_o = f_s \times (v + v_o) / (v - v_s)$
$f_o = 480 \times (340 + 10) / (340 - 20)$
$f_o = 480 \times (350 / 320)$

$f_o \approx 525$ Hz

When the train is moving away from the cyclist:
$f_o = f_s \times (v - v_o) / (v + v_s)$
$f_o = 480 \times (340 - 10) / (340 + 20)$
$f_o = 480 \times (330 / 360)$
$f_o \approx 440$ Hz

(c)(i)Two sheets of a Polaroid are lined up so that their polarization directions are initially parallel. When one sheet is rotated:

How does the transmitted light intensity vary with the angle between the polarization directions of the Polaroid?

The transmitted intensity follows Malus' law:
$I = I_0 \cos^2\theta$,
where I_0 is the initial intensity and θ is the angle between the polarizing directions. As θ increases, the intensity decreases, reaching zero at $\theta = 90°$.

(ii)What angle must the Polaroid be rotated to reduce the light intensity by 50%?

Given:
$I = 0.5I_0$
Using Malus' law:
$0.5I_0 = I_0 \cos^2\theta$
$\cos^2\theta = 0.5$
$\theta = \cos^{-1}(\sqrt{0.5})$
$\theta = \cos^{-1}(0.707)$
$\theta \approx 45°$

3.(a)(i)Give the meaning of the terms wave function, longitudinal wave, and transverse wave.

Wave function: A mathematical function describing the displacement of a wave at any point in space and time.

Longitudinal wave: A wave where particle displacement is parallel to the direction of wave propagation, such as sound waves.

Transverse wave: A wave where particle displacement is perpendicular to the direction of wave propagation, such as light waves.

(ii)The equation of a progressive wave traveling in the +x direction is given by $y = a \sin(\omega t - kx)$. Show that the maximum velocity, $V_{max} = (2\pi a) / T$.

Velocity of a wave is given by the derivative of displacement with respect to time:
$v = dy/dt$

Given:
$y = a \sin(\omega t - kx)$

Differentiating:
$v = a\omega \cos(\omega t - kx)$

Maximum velocity occurs when $\cos(\omega t - kx) = 1$, thus:
$V_{max} = a\omega$

Since $\omega = 2\pi/T$, we get:
$V_{max} = (2\pi a) / T$

(b)(i)What is meant by diffraction grating?

A diffraction grating is an optical device consisting of many closely spaced parallel slits that diffract light into different directions, producing interference patterns.

(ii)A diffraction grating has 500 lines per millimeter when used with monochromatic light of wavelength 6×10^{-7} m at normal incidence. Determine the angle at which the bright diffraction images will be observed.

Given:
Number of lines per mm, $N = 500\ mm^{-1} = 500 \times 10^3\ m^{-1}$
Wavelength, $\lambda = 6 \times 10^{-7}$ m

Grating equation:
$d \sin\theta = n\lambda$

$d = 1 / N$
$d = 1 / (500 \times 10^3)$
$d = 2 \times 10^{-6}$ m

For first-order diffraction (n = 1):
$\sin\theta = (n\lambda) / d$
$\sin\theta = (1 \times 6 \times 10^{-7}) / (2 \times 10^{-6})$
$\sin\theta = 0.3$
$\theta = \sin^{-1}(0.3)$
$\theta \approx 17.5°$

For second-order diffraction ($n = 2$):
$\sin\theta = (2 \times 6 \times 10^{-7}) / (2 \times 10^{-6})$
$\sin\theta = 0.6$
$\theta = \sin^{-1}(0.6)$
$\theta \approx 36.9°$

(iii)Why other orders of image in 3(b)(ii) cannot be observed?

Higher-order images ($n > 3$) are not observed because $\sin\theta$ cannot exceed 1. Beyond a certain order, the diffraction equation gives an impossible value for θ.

(c)(i)State Huygens' principle of wave construction.

Huygens' principle states that every point on a wavefront acts as a secondary source of wavelets that spread out in all directions, and the new wavefront is formed by the tangential envelope of these secondary wavelets.

(ii)A lens was placed with a convex surface of radius of curvature 50.0 cm in contact with the plane surface such that Newton's rings were observed when the lens was illuminated with monochromatic light. If the radius of the 15th ring was 2.13 mm, determine the wavelength.

Given:
Radius of curvature, $R = 50$ cm $= 0.5$ m
Ring number, $n = 15$
Radius of the nth ring, $r_n = 2.13$ mm $= 2.13 \times 10^{-3}$ m

Using the formula for Newton's rings:
$r_n^2 = n\lambda R$

Rearranging for λ:
$\lambda = r_n^2 / (nR)$

Substituting values:
$\lambda = (2.13 \times 10^{-3})^2 / (15 \times 0.5)$
$\lambda = (4.54 \times 10^{-6}) / (7.5)$
$\lambda = 6.05 \times 10^{-7}$ m

4.(a)(i)Define Young's Modulus of a material.

Young's modulus (Y) is the ratio of stress to strain in a material under tensile or compressive forces, given by:
Y = (Force × Original length) / (Area × Extension)
It measures the stiffness of a material.

(ii)Why work is said to be done in stretching a wire?

Work is done in stretching a wire because a force is applied to extend the wire, and the wire undergoes deformation. The energy supplied is stored as elastic potential energy.

(b)A steel wire AB of the length 60 cm and cross-sectional area 1.5×10^{-6} m² is attached at B to a copper wire BC of length 39 cm and cross-sectional area 3.0×10^{-6} m². If the combination of the two wires is suspended vertically from a fixed point at A and supports a weight of 250 N at C, find the extension (in millimeters) of:

(i)Steel wire

Given:
Force, F = 250 N
Length, L = 60 cm = 0.6 m
Area, $A = 1.5 \times 10^{-6}$ m²
Young's modulus of steel, $Y_s = 2 \times 10^{11}$ N/m²

Extension:
$\Delta L = (FL) / (YA)$
$\Delta L = (250 \times 0.6) / (2 \times 10^{11} \times 1.5 \times 10^{-6})$
$\Delta L = (150) / (3 \times 10^5)$
$\Delta L = 0.0005$ m
$\Delta L = 0.5$ mm

(ii)Copper wire

Given:
Length, L = 39 cm = 0.39 m
Area, $A = 3.0 \times 10^{-6}$ m²
Young's modulus of copper, $Y_c = 1.1 \times 10^{11}$ N/m²

$\Delta L = (250 \times 0.39) / (1.1 \times 10^{11} \times 3.0 \times 10^{-6})$
$\Delta L = (97.5) / (3.3 \times 10^5)$
$\Delta L = 0.000295$ m
$\Delta L = 0.295$ mm

(c)Based on the kinetic theory of gases, determine:

(i)The average translational kinetic energy of air at a temperature of 290 K.

Given:
Temperature, T = 290 K

Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J/K

Using the equation:
$KE_{avg} = (3/2)\ kT$
$KE_{avg} = (3/2) \times (1.38 \times 10^{-23}) \times (290)$
$KE_{avg} = (2.07 \times 10^{-23}) \times (290)$
$KE_{avg} = 6.00 \times 10^{-21}$ J

(ii)The root mean square speed (r.m.s) of air at the same temperature as in 4(c)(i).

Given:
Molar mass of air, M = 0.029 kg/mol
Universal gas constant, R = 8.314 J/mol K

Using:
$v_{rms} = \sqrt{(3RT/M)}$
$v_{rms} = \sqrt{(3 \times 8.314 \times 290 / 0.029)}$
$v_{rms} = \sqrt{(7235.1 / 0.029)}$
$v_{rms} = \sqrt{249485.5}$
$v_{rms} \approx 500$ m/s

5.(a)(i)Define the terms electric potential and electric field strength E at a point in the electrostatic field.

Electric potential is the work done in bringing a unit positive charge from infinity to a point in an electric field.

Electric field strength (E) is the force per unit charge experienced by a small positive test charge placed in an electric field, given by $E = F/q$.

(ii)How the two quantities in 5(a)(i) are related?

E is the negative gradient of electric potential:
$E = -dV/dx$

(b)Outside the sphere, a charged sphere behaves like its charges were concentrated at the center. If the electric field strength inside the sphere is zero and one sphere of radius 5.0 cm carries a positive charge of 6.7 nC, calculate:

(i)The potential at the surface of the sphere.

Given:
Charge, $Q = 6.7$ nC $= 6.7 \times 10^{-9}$ C
Radius, r = 5.0 cm = 0.05 m

Coulomb's constant, $k = 9 \times 10^9$ Nm^2/C^2

$V = kQ / r$
$V = (9 \times 10^9 \times 6.7 \times 10^{-9}) / (0.05)$
$V = (60.3 \times 10^0) / (0.05)$
$V = 1206$ V

(ii)The capacitance of the sphere.

Using:
$C = Q / V$
$C = (6.7 \times 10^{-9}) / (1206)$
$C \approx 5.56 \times 10^{-12}$ F

6.(a)(i)What is meant by dielectric constant?

Dielectric constant (relative permittivity, ε_r) is the ratio of the permittivity of a material to the permittivity of free space (ε_0). It determines how much a material reduces the electric field inside it compared to a vacuum.

(ii)State Coulomb's law of force between two electrically charged bodies.

Coulomb's law states that the force (F) between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them:
$F = (k\, q_1\, q_2) / r^2$
(b)(i)Can there be a potential difference between two adjacent conductors carrying the same positive charge? Give a reason.

Yes, there can be a potential difference because the potential depends on the geometry and charge distribution of the conductors, not just the charge sign. If the conductors have different shapes or sizes, their potentials may differ even if they carry the same charge.

(ii)A parallel plate capacitor with air as a dielectric has plates of area 4.0×10^{-2} m^2 which are 2.0 mm apart. The capacitor is charged to 100 V and connected in parallel with a similar unchanged capacitor with plates of half the area and twice the distance apart. If the edge effect is neglected, calculate the final charge on each plate.

Given:
$C_1 = \varepsilon_0 A / d = (8.85 \times 10^{-12} \times 4 \times 10^{-2}) / (2 \times 10^{-3})$
$C_1 = 1.77 \times 10^{-12}$ F

$C_2 = \varepsilon_0 (A/2) / (2d)$
$C_2 = (8.85 \times 10^{-12} \times 2 \times 10^{-2}) / (4 \times 10^{-3})$

$C_2 = 0.88 \times 10^{-12}$ F

$Q_1 = C_1V = (1.77 \times 10^{-12} \times 100)$
$Q_1 = 1.77 \times 10^{-10}$ C

Total capacitance:
$C\_total = C_1 + C_2$
$C\_total = (1.77 + 0.88) \times 10^{-12}$
$C\_total = 2.65 \times 10^{-12}$ F

Final voltage:
$V\_f = Q_1 / C\_total$
$V\_f = (1.77 \times 10^{-10}) / (2.65 \times 10^{-12})$
$V\_f \approx 66.8$ V

Final charge on each capacitor:
$Q\_f_1 = C_1V\_f = (1.77 \times 10^{-12} \times 66.8)$
$Q\_f_1 \approx 1.18 \times 10^{-10}$ C

$Q\_f_2 = C_2V\_f = (0.88 \times 10^{-12} \times 66.8)$
$Q\_f_2 \approx 5.88 \times 10^{-11}$ C

6.(c)(i) Derive an expression for the total capacitance of two capacitors C_1 and C_2 connected in series.

For capacitors in series, the total capacitance (C_total) is given by:

$1/C\_total = 1/C_1 + 1/C_2$

Taking the reciprocal:

$C\_total = 1 / [(1/C_1) + (1/C_2)]$

Finding a common denominator:

$C\_total = 1 / [(C_2 + C_1) / (C_1C_2)]$

Rearranging:

$C\_total = (C_1C_2) / (C_1 + C_2)$

Thus, the total capacitance for two capacitors in series is:

$C\_total = (C_1C_2) / (C_1 + C_2)$

(ii) Two capacitors of 15 μF and 20 μF are connected in series with a 600 V supply. Calculate the charge and potential difference across each capacitor.

Given:
$C_1 = 15\ \mu F = 15 \times 10^{-6}$ F
$C_2 = 20\ \mu F = 20 \times 10^{-6}$ F
$V_{total} = 600$ V

Using the formula for capacitors in series:

$C_{total} = (C_1 C_2) / (C_1 + C_2)$

$C_{total} = (15 \times 10^{-6} \times 20 \times 10^{-6}) / (15 \times 10^{-6} + 20 \times 10^{-6})$

$C_{total} = (300 \times 10^{-12}) / (35 \times 10^{-6})$

$C_{total} = 8.57 \times 10^{-6}$ F

Charge stored in the system:

$Q = C_{total} \times V_{total}$

$Q = (8.57 \times 10^{-6}) \times (600)$

$Q = 5.14 \times 10^{-3}$ C

Potential difference across each capacitor:

$V_1 = Q / C_1$
$V_1 = (5.14 \times 10^{-3}) / (15 \times 10^{-6})$
$V_1 = 342.7$ V

$V_2 = Q / C_2$
$V_2 = (5.14 \times 10^{-3}) / (20 \times 10^{-6})$
$V_2 = 257.1$ V

7.(a)(i)Based on the Balmer series of hydrogen spectra determine the wavelength of the series limit of the Paschen series.

The wavelength of the series limit for the Paschen series corresponds to the transition from $n = \infty$ to $n = 3$.

Using the Rydberg formula:

$1/\lambda = R (1/n_1^2 - 1/n_2^2)$

For the Paschen series, $n_1 = 3$ and $n_2 = \infty$, so:

$1/\lambda = R (1/3^2 - 1/\infty^2)$
$1/\lambda = R (1/9 - 0)$
$1/\lambda = R (1/9)$

Since $R = 1.097 \times 10^7 \ m^{-1}$,

$1/\lambda = (1.097 \times 10^7) / 9$
$\lambda = 9 / (1.097 \times 10^7)$
$\lambda \approx 8.2 \times 10^{-7}$ m
$\lambda \approx 820$ nm

(ii)Why electrons do not fall into the nucleus due to electrostatic force of attraction?

Electrons do not fall into the nucleus because they possess angular momentum, which prevents them from spiraling inward. According to quantum mechanics, electrons occupy discrete energy levels where they exist as standing waves rather than classical particles in orbit.

(b)(i)Why is the hydrogen atom stable in the ground state?

The hydrogen atom is stable in the ground state because it has the lowest possible energy level (n = 1), meaning there is no lower state to which the electron can transition and lose energy.

(ii)According to Bohr's theory, the angular momentum of an electron is an integral multiple of $h/2\pi$. Express this statement using a mathematical equation in which angular momentum is represented by the letter L and orbit by the letter n.

Bohr's quantization condition states that the angular momentum of an electron is:

$L = n (h / 2\pi)$

where:
L = angular momentum
n = principal quantum number
h = Planck's constant

(iii)Determine the angular momentum of the electron in the orbit of energy level -3.4 eV given that $E_n = -13.6/n^2$ eV, where E is the energy of an electron and n is the principal quantum number of the hydrogen atom.

Given:
$E_n = -3.4$ eV
$E_n = -13.6 / n^2$

Solving for n:

$n^2 = 13.6 / 3.4$
$n^2 = 4$
$n = 2$

Using Bohr's quantization formula for angular momentum:
$L = n (h / 2\pi)$

$L = 2 \times (6.63 \times 10^{-34}) / (2\pi)$
$L = (1.326 \times 10^{-33}) / (6.283)$
$L \approx 2.11 \times 10^{-34}$ Js

(c)(i)Account for the observed convergence of the lines from A to F.

The spectral lines converge at higher energy levels because the energy difference between adjacent levels decreases as n increases. As the electron transitions from higher energy states, the emitted photons have nearly the same energy, causing the spectral lines to appear closer together.

(ii)If the energy value of each line in the spectrum can be calculated using the equation $E_n = -13.6/n^2$ eV, to which spectral series does the spectrum belong if the energy value of line A is -1.51 eV?

Given:
$E_n = -1.51$ eV
$E_n = -13.6 / n^2$

Solving for n:

$n^2 = 13.6 / 1.51$
$n^2 = 9$
$n = 3$

Since the final energy level $n_1 = 3$, the spectrum belongs to the Paschen series.

8.(a)(i)What is meant by the following terms as used in nuclear physics?

Mass defect: The difference between the sum of the individual masses of protons and neutrons in a nucleus and the actual mass of the nucleus. It is responsible for the binding energy of the nucleus.

(ii)Binding energy: The energy required to completely separate all the nucleons (protons and neutrons) in a nucleus. It is given by Einstein's equation $E = mc^2$.

(b)Disintegration of $^{238}U_{92}$ to give alpha particles can be represented by the following equation:
$^{238}U_{92} \rightarrow {}^{234}Th_{90} + {}^{4}He_{2}$. Use this equation to calculate:

(i)The total energy released in the disintegration reaction.

Given:
Mass of ^{238}U = 238.0508 u
Mass of ^{234}Th = 234.0436 u
Mass of ^{4}He = 4.0026 u

Mass defect:
Δm = (Mass of ^{238}U) - (Mass of ^{234}Th + Mass of ^{4}He)
$\Delta m = 238.0508 - (234.0436 + 4.0026)$
$\Delta m = 238.0508 - 238.0462$
$\Delta m = 0.0046$ u

Energy released:
$E = \Delta m \times 931.5$ MeV/u
$E = 0.0046 \times 931.5$
$E \approx 4.29$ MeV

(ii)The kinetic energy of alpha particles when the nucleus was at rest before disintegration.

Since momentum is conserved, the kinetic energy is shared between the products in inverse proportion to their masses.

Kinetic energy of alpha particle:
KE_α = (Mass of ^{234}Th / Total mass) × Total energy
$KE_\alpha = (234.0436 / 238.0462) \times 4.29$
$KE_\alpha \approx 4.22$ MeV

(c)(i)Elaborate two aspects on which fission reactions differ from fusion reactions.

1. Fission involves splitting a heavy nucleus into smaller fragments, while fusion involves combining light nuclei to form a heavier nucleus.
2. Fission occurs at room temperatures with neutron bombardment, while fusion requires extremely high temperatures (millions of Kelvin).

(ii)Why is high temperature required to cause nuclear fusion?

High temperature is required to overcome the electrostatic repulsion between positively charged nuclei, allowing them to collide with sufficient energy for nuclear fusion to occur.

9.(a)(i)Identify four factors that affect the force experienced by a current-carrying conductor in a magnetic field.

1. The magnitude of the current in the conductor.
2. The length of the conductor in the magnetic field.
3. The strength of the magnetic field.
4. The angle between the conductor and the magnetic field.

(ii)Write the mathematical expression which defines magnetic flux density and use it to deduce its S.I. units.

Magnetic flux density (B) is defined as the force per unit current per unit length in a conductor placed perpendicular to the field:

$B = F / (IL)$

SI units:
$[N / (A \cdot m)]$ = Tesla (T)

(iii)Apply an expression obtained in 9(a)(ii) to develop the formula for the force on a conductor carrying current I if the conductor and the magnetic fields are not at right angles.

When the conductor is at an angle θ to the magnetic field, the force is:

$F = BIL \sin\theta$

(b)(i)Distinguish the terms magnetically soft and magnetically hard materials.

Magnetically soft materials: Easily magnetized and demagnetized, used in transformers and electromagnets.
Magnetically hard materials: Retain their magnetization for long periods, used in permanent magnets.

(ii)State the condition which makes the magnetic force on a moving charge in a magnetic field to be maximum.

The magnetic force is maximum when the charge moves perpendicular to the magnetic field ($\theta = 90°$), so $\sin\theta = 1$.

(iii)Determine the magnitude of force experienced by a stationary charge in a uniform magnetic field.

Since the charge is stationary, velocity (v) = 0, and the force is given by:
$F = qvB \sin\theta$

Substituting $v = 0$:
$F = 0$ N

A stationary charge in a magnetic field experiences no force.

(c)(i) At which position of the rotating coil in the magnetic field, the induced e.m.f is zero? Give a reason.

The induced e.m.f is zero when the plane of the coil is perpendicular to the magnetic field lines, meaning the coil is parallel to the field.

Reason: According to Faraday's law, the induced e.m.f is given by

$e = -N\, d\Phi/dt$

where $\Phi = B A \cos\theta$ is the magnetic flux. When the coil is perpendicular to the field ($\theta = 0°$ or $180°$), $\cos\theta = 1$, so the rate of change of flux is zero, leading to zero induced e.m.f.

(ii) Use mathematical expression to justify the statement that there will be no change in the kinetic energy of a charged particle which enters a uniform magnetic field when its initial velocity is directed parallel to the field.

The force on a charged particle moving in a magnetic field is given by

$F = q\, v\, B \sin\theta$
where:
q = charge of the particle
v = velocity of the particle
B = magnetic flux density
θ = angle between velocity and magnetic field

When the velocity is parallel to the field, $\theta = 0°$, so $\sin\theta = 0$, leading to
$F = q\, v\, B \times 0 = 0$

Since no force acts on the particle, there is no acceleration or work done on the particle. Work done (W) is given by
$W = F\, d \cos\theta$
Since $F = 0$, $W = 0$, and from the work-energy theorem:
$\Delta KE = W = 0$

Thus, the kinetic energy of the charged particle remains constant.