THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/1 **PHYSICS 1**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2010**

Instructions

1. This paper consists of sections Section A, B and C with total of fourteen questions.
2. Answer ten questions choosing four questions from section A and three questions from each of section B and C.

1. (a) mention two uses of dimensional analysis.

- checking the consistency of physical equations (ensuring units match on both sides).
- deriving relationships between physical quantities when no other information is available.

1. (b) the critical velocity of a liquid flowing in a certain pipe is 0.5 ms^{-1}. assuming that the critical velocity v depends on the density ρ of the liquid, its viscosity η, and the diameter d of the pipe. use the method of dimensional analysis to derive the equation of the critical velocity.

critical velocity v depends on ρ, η, and d. we assume:

$v = k \rho^a \eta^b d^c$

where k is a dimensionless constant.

dimensions:
$v = [lt^{-1}]$
$\rho = [ml^{-3}]$
$\eta = [ml^{-1}t^{-1}]$ (viscosity, dynamic)
$d = [l]$

equate dimensions:

$[lt^{-1}] = [ml^{-3}]^a [ml^{-1}t^{-1}]^b [l]^c$

$[lt^{-1}] = m^{(a+b)} l^{(-3a-b+c)} t^{(-b)}$

match exponents:

mass (m): $a + b = 0$
length (l): $1 = -3a - b + c$
time (t): $-1 = -b$

from t: $b = 1$

from m: $a + 1 = 0$, so $a = -1$

from l: $1 = -3(-1) - 1 + c$
$1 = 3 - 1 + c$
$1 = 2 + c$
$c = -1$

thus:

$v = k \rho^{(-1)} \eta^{1} d^{(-1)} = k (\eta / \rho d)$

this resembles the reynolds number criterion, so:

$v = (k \eta) / (\rho d)$

given v = 0.5 m/s, this form is consistent.

1. (c)(i) define an error.
- an error is the difference between the measured or calculated value of a quantity and its true or accepted value, often due to limitations in measurement or methodology.

(ii) in an experiment to determine the acceleration due to gravity g, a small ball bearing is timed while falling freely from rest through a vertical height of 2 m. the timing data were obtained:
time taken $t = 0.90 \pm 0.03$ s

calculate the numerical value of g from the experimental data, clearly specify the errors.
use $s = (1/2) g t^2$, where s = 2 m, t = 0.90 s.
rearrange:
$g = (2s) / (t^2)$
$g = (2 \times 2) / (0.90)^2$
$g = 4 / 0.81$
$g \approx 4.938$ m/s²

error in t is ±0.03 s. use error propagation:
$g = (2s) / t^2$,
$\Delta g = g \times 2 (\Delta t / t)$

$\Delta t = 0.03$ s, $t = 0.90$ s
$(\Delta t / t) = (0.03 / 0.90) = 0.0333$
$\Delta g = 4.938 \times 2 \times 0.0333$
$\Delta g \approx 0.329$ m/s²
so, $g = 4.94 \pm 0.33$ m/s².
2. (a)(i) mention two examples of projectile motion.
- a ball thrown horizontally off a cliff.
- a cannonball fired at an angle into the air.

(ii) define the trajectory.
- the trajectory is the path followed by a projectile in motion, typically a parabolic curve under uniform gravity (ignoring air resistance).

2. (b)(i) mention two uses of projectile motion.

- used in sports (e.g., javelin throw, basketball shots) to optimize distance or accuracy.
- used in ballistics to calculate the range and trajectory of projectiles like bullets or rockets.

(ii) find the velocity and angle of projection of a particle which passes in a horizontal direction just over the top of a wall which is 12 m high and 32 m away.

let u be the initial velocity, θ the angle.

horizontal motion:

$x = u \cos\theta \times t$

$32 = u \cos\theta \times t$ (1)

vertical motion:

$y = u \sin\theta \times t - (1/2) g t^2$

$12 = u \sin\theta \times t - (1/2) (9.8) t^2$ (2)

at the wall (12 m high), solve for t and θ. use:

$u_x = u \cos\theta$, $u_y = u \sin\theta$

from (1):

$t = 32 / (u \cos\theta)$

substituting into (2):

$12 = u \sin\theta \times (32 / u \cos\theta) - (1/2) (9.8) (32 / u \cos\theta)^2$

$12 = 32 \tan\theta - (4.9 \times 1024) / (u^2 \cos^2\theta)$

assume θ = 45° (common for max range, check):

$\tan 45° = 1$, $\cos 45° = \text{sqrt}(2) / 2$

$12 = 32 \times 1 - (5017.6) / (u^2 \times 0.5)$

$12 = 32 - (5017.6 / (0.5 u^2))$

$-20 = - (5017.6 / (0.5 u^2))$

$20 = 5017.6 / (0.5 u^2)$

$0.5 u^2 = 5017.6 / 20$

$0.5 u^2 = 250.88$

$u^2 = 501.76$

$u \approx 22.4$ m/s

at θ = 45°:

$u_x = 22.4 \times \text{sqrt}(2) / 2 \approx 15.83$ m/s

$u_y = 15.83$ m/s

magnitude:

$u = \text{sqrt}(15.83^2 + 15.83^2)$

$u = \text{sqrt}(2 \times 15.83^2)$

$u = 15.83 \text{ sqrt}(2)$, $u \approx 22.4$ m/s

angle:
$\theta = 45°$
velocity = 22.4 m/s, angle = 45°.

3. (a)(i) what is the origin of centripetal force.
- the centripetal force is the net force acting toward the center of circular motion, provided by tension, gravity, friction, or other forces depending on the system (e.g., tension in a string for circular motion).

(ii) is a satellite orbiting around the earth, an electron in the hydrogen atom?
- yes, a satellite orbiting earth experiences centripetal force (due to gravity).
- yes, an electron in a hydrogen atom experiences centripetal force (due to electrostatic attraction).

3. (b) a small mass of 0.15 kg is suspended from a fixed point by a thread of a fixed length. the mass is given a push so that it moves along a circular path making 1.82 m in a horizontal plane at a steady speed, taking 1.80 s.

(i) calculate the speed of the mass.
circumference = 1.82 m, time = 1.80 s.
v = distance / time
$v = 1.82 / 1.80$
$v \approx 1.01$ m/s

(ii) calculate the tension in the thread.
centripetal force:
$f_c = (mv^2) / r$

$m = 0.15$ kg
$v = 1.01$ m/s
$r = 1.82 / (2\pi) \approx 0.29$ m

$f_c = (0.15 \times (1.01)^2) / 0.29$
$f_c = (0.15 \times 1.0201) / 0.29$
$f_c \approx (0.153) / 0.29$
$f_c \approx 0.528$ N

tension = centripetal force (assuming horizontal circle, no vertical component mentioned):
$t \approx 0.53$ N

3. (b) (iii) calculate the centripetal acceleration.

centripetal acceleration is given by:
$a_c = v^2 / r$

substituting the values:
$a_c = (1.01)^2 / 0.29$
$a_c = 1.0201 / 0.29$
$a_c \approx 3.52 \text{ m/s}^2$

4. (a) (i) state surface tension in terms of energy.
- surface tension (γ) is the energy per unit area of the surface, with units j/m² or n/m, representing the work required to increase the surface area.

(ii) the surface tension of water at 20°c is 7.2×10^{-2} n/m. The vapour pressure at this temperature is 2.33×10^3 Pa. determine the radius of the smallest spherical water drop which it can form without evaporating.
To determine the radius of the smallest spherical water drop that can form without evaporating, we use the relation between surface tension and excess pressure inside a droplet:

$\Delta P = 2\gamma / r$
where:
ΔP = excess pressure inside the droplet
γ = surface tension of water = 7.2×10^{-2} N/m
r = radius of the droplet
For the smallest drop, the excess pressure is given by the difference between atmospheric pressure and vapor pressure:
$\Delta P = P_{atm} - P_{vapor}$
Assuming atmospheric pressure $P_{atm} = 1.01 \times 10^5$ Pa and given vapor pressure $P_{vapor} = 2.33 \times 10^3$ Pa, we calculate:
$\Delta P = 1.01 \times 10^5 - 2.33 \times 10^3$
$\Delta P = 9.767 \times 10^4$ Pa
Now, solving for r:
$r = 2\gamma / \Delta P$
$r = (2 \times 7.2 \times 10^{-2}) / (9.767 \times 10^4)$
$r = 0.144 / 9.767 \times 10^4$
$r \approx 1.47 \times 10^{-6}$ m

(b) a circular ring of thin wire 3 cm in radius is suspended with its plane horizontal by a thread passing through the 10 cm mark with its plane pivoted at its center and is balanced by an 8 g weight suspended at a fixed point on the ring. when the ring is just balanced in contact with the surface of a liquid, the 8 g weight is removed, and the ring is to be moved to the 90 cm mark to just detach the ring from the liquid. find the surface tension of the liquid.

radius of ring: r = 3 cm = 0.03 m
circumference: $l = 2\pi r = 2 \times 3.1416 \times 0.03$
$l = 0.1885$ m

weight of 8 g:
$w = mg = (0.008 \text{ kg} \times 9.8 \text{ m/s}^2)$
$w = 0.0784$ n
force due to surface tension = $\gamma \times l$

$0.0784 = \gamma \times 0.1885$
solving for γ:
$\gamma = 0.0784 / 0.1885$
$\gamma \approx 0.416$ n/m

5. (a) (i) define thermal convection in a fixed mass of a gas has a volume.
- thermal convection is the transfer of heat through the movement of a fluid (gas or liquid) due to density differences caused by temperature variations, in a fixed mass with constant volume, it occurs if temperature gradients exist.

(ii) in a special type of thermometer 81 cm^3 of the gas at the ice point and volume of 124 cm^3 and pressure of 90 cmhg at steam point. determine the temperature if its volume is 120 cm^3 and pressure 85 cmhg.
using the ideal gas law for constant mass:
$p_1 v_1 / t_1 = p_2 v_2 / t_2$

ice point (0°c = 273 k): $v_1 = 81$ cm^3
steam point (100°c = 373 k): $v_2 = 124$ cm^3, $p_2 = 90$ cmhg
new state: $v_3 = 120$ cm^3, $p_3 = 85$ cmhg

$p_2 v_2 / t_2 = p_3 v_3 / t_3$
$(90 \times 124) / 373 = (85 \times 120) / t_3$

solve for t_3:
$t_3 = (85 \times 120 \times 373) / (90 \times 124)$
$t_3 \approx 341$ k

convert to celsius:
$t_3 = 341 - 273$
$t_3 \approx 68$°c

6. (a) (i) state newton's law of cooling.

- newton’s law of cooling states that the rate of heat loss of a body is proportional to the difference in temperature between the body and its surroundings:

$dT/dt = -k (T - T_s)$
where k is a constant.

(ii) explain the observation that a piece of wire when steadily heated up appears reddish in color before turning bluish.
- as the wire heats, it emits thermal radiation. at lower temperatures, it emits more in the red wavelength (longer, lower energy), appearing reddish. as temperature increases, it emits shorter, higher-energy blue wavelengths, appearing bluish (related to blackbody radiation and wien's displacement law).

(b) (i) a glass disc of radius 5 cm and uniform thickness of 2 mm had one of its sides maintained at 100°c while the other side was found to be at 70°c. the good thermal contact with this side was found to be at 70°c. the copper block weighs 0.75 kg. the cooling curve at 70°c was studied over a range of temperature and the thermal conductivity was found to be 16.8 w/m·k. determine the thermal conductivity of glass.

using fourier's law:
$q = -k a (\Delta t / \Delta x)$
where q is heat flow, k is thermal conductivity, a is area, Δt is temperature difference, Δx is thickness.
radius r = 5 cm = 0.05 m
thickness = 2 mm = 0.002 m
$\Delta t = 100 - 70 = 30°c$

area $a = \pi r^2 = \pi (0.05)^2 \approx 0.00785 \text{ m}^2$
assume steady-state conduction, same heat transfer through glass and copper:
$q = k\_glass \times 0.00785 \times (30 / 0.002)$
assuming similar geometry, $k\_glass \approx 0.8$ w/m·k (estimated, clarify if more data).

(ii) a cylindrical element of 1kw electric fire is 30 cm long and 1 cm in diameter. if the temperature of the surroundings is 20°c, estimate the working temperature of the element.
power p = 1 kw = 1000 w
length = 30 cm = 0.3 m, diameter = 1 cm = 0.01 m, radius = 0.005 m

surface area:
$a = 2\pi r l = 2\pi (0.005) (0.3)$
$a \approx 0.00942 \text{ m}^2$

using stefan's law:
$p = \sigma a (t^4 - t_s^4)$

where $\sigma = 5.67 \times 10^{-8}$ w/m²k⁴, $t_s = 20 + 273 = 293$ k
$1000 = 5.67 \times 10^{-8} \times 0.00942 \times (t^4 - 293^4)$
$t^4 - 293^4 = 1.87 \times 10^{12}$

solving for t:
$t = (1.87 \times 10^{12} + 7.31 \times 10^{12})^{(1/4)}$
$t \approx 477$ k

convert to celsius:
$t = 477 - 273$
$t \approx 204°c$
working temperature ≈ 204°c.

7. (a) Distinguish between stationary waves and progressive waves.
- Stationary waves: These waves do not transfer energy from one point to another. The wave oscillates in place, forming nodes (points of no displacement) and antinodes (points of maximum displacement).
- Progressive waves: These waves transfer energy from one point to another. The wave propagates through the medium, carrying energy with it.

(b) A wave is represented by the equation $y = 10\sin(0.4\pi(60t - x))$, where the distance parameters are measured in meters and the time in seconds.
(i) State whether the wave is stationary or progressive.

- Since the equation is of the form $y = A \sin(kx - \omega t)$, where $k = 0.4\pi$ and $\omega = 60\pi$, this is a progressive wave.

(ii) Determine the wavelength and frequency of the wave.
The general wave equation is:
$y = A \sin(kx - \omega t)$

Where:
k = wave number = $2\pi / \lambda$
ω = angular frequency = $2\pi f$

Comparing with the given equation:
$k = 0.4\pi$ and $\omega = 60\pi$
From $k = 2\pi / \lambda$:

$\lambda = 2\pi / 0.4\pi$
$\lambda = 5$ m

From $\omega = 2\pi f$:
$60\pi = 2\pi f$
$f = 60\pi / 2\pi$
$f = 30$ Hz

Wavelength = 5 m
Frequency = 30 Hz

(iii) What will be the phase difference between two points which are 40 cm apart?

Phase difference is given by:
$\Delta\phi = (2\pi / \lambda) \times \Delta x$

Substituting values:
$\Delta\phi = (2\pi / 5) \times 0.40$
$\Delta\phi = (0.8 \times 2\pi) / 5$
$\Delta\phi = 1.6\pi / 5$
$\Delta\phi = 0.32\pi$ radians

(iv) Calculate the period and amplitude of the wave.
The period T is given by:

$T = 1 / f$
$T = 1 / 30$
$T = 0.0333$ s
From the equation, the amplitude A is the coefficient of the sine function:

$A = 10$ m
Period = 0.0333 s
Amplitude = 10 m

8. (a) (i) Distinguish between magnetic flux density and magnetic induction.

- Magnetic flux density (B): It is the measure of the strength of the magnetic field in a given region, defined as the force experienced per unit current per unit length of a conductor placed in the field. It is measured in Tesla (T).
- Magnetic induction: It refers to the process by which a changing magnetic field induces an electromotive force (emf) or current in a conductor. It is governed by Faraday's Law of Electromagnetic Induction.

(ii) Describe using a sketch graph how magnetic flux density varies with the axis (both inside and at the ends) of a long solenoid carrying current.

- Inside the solenoid, the magnetic flux density (B) is uniform and strong.
- At the ends of the solenoid, the magnetic flux density decreases gradually.
- Beyond the solenoid, the field weakens significantly, behaving like that of a bar magnet with field lines spreading out at the ends.

(b) A solenoid 80m long has a cross-sectional area of 16 cm^2 and a total of 3500 turns closely wound. If the coil is filled with air and carries a current of 3A, calculate:

(i) Magnetic field density B at the middle of the coil.
The magnetic field inside a solenoid is given by:
$B = \mu_0 n I$
where:
μ_0 = permeability of free space = $4\pi \times 10^{-7}$ H/m
n = number of turns per unit length = total turns / length = 3500 / 80
I = current = 3A
n = 3500 / 80 = 43.75 turns/m
Substituting values:

$B = (4\pi \times 10^{-7}) \times (43.75) \times (3)$
$B = (4\pi \times 10^{-7}) \times 131.25$
$B = 1.65 \times 10^{-4}$ T

(ii) Magnetic flux inside the coil.
Magnetic flux (Φ) is given by:
$\Phi = B \times A$
where:
A = cross-sectional area = 16 cm^2 = 16×10^{-4} m^2
$\Phi = (1.65 \times 10^{-4}) \times (16 \times 10^{-4})$
$\Phi = 2.64 \times 10^{-7}$ Wb

(iii) Magnetic force H at the centre of the coil.
Magnetic field intensity H is given by:

$H = n I$
$H = (43.75) \times (3)$
H = 131.25 A/m

(iv) Magnetic induction at the end of the coil.
At the ends of a solenoid, the magnetic field strength is approximately half of that at the center:
$B_{end} \approx B / 2$

$B_{end} = (1.65 \times 10^{-4}) / 2$
$B_{end} = 8.25 \times 10^{-5}$ T

(v) Magnetic field intensity at the middle of the coil.
Since H = nI, we already calculated it in part (iii):
H = 131.25 A/m

9. (a) (i) Define the temperature coefficient of resistance.
- The temperature coefficient of resistance (α) is the fractional change in the resistance of a material per degree change in temperature. It is given by:

$R = R_0(1 + \alpha\Delta T)$

where R is the resistance at temperature T, R_0 is the resistance at reference temperature (usually 0°C), and ΔT is the temperature change.

(ii) Briefly describe an experiment to measure the temperature coefficient of a wire.
- Connect a sample wire in series with an ammeter and a variable power supply.
- Immerse the wire in a beaker of water with a thermometer to monitor the temperature.
- Measure the resistance of the wire at room temperature using a voltmeter and an ammeter.
- Heat the water gradually and record the resistance at different temperatures.
- Plot a graph of resistance (R) against temperature (T).
- The slope of the straight-line graph gives the temperature coefficient of resistance (α).

(b) A heating coil is made of a nichrome wire which will operate on a 12V supply and will have a power of 36W when immersed in water at 373K. The wire available has a cross-sectional area of 0.10 mm². What length of the wire will be required?

Given data:
Voltage, V = 12V
Power, P = 36W
Cross-sectional area, $A = 0.10\ mm^2 = 1.0 \times 10^{-8}\ m^2$
Resistivity of nichrome, $\rho = 1.10 \times 10^{-6}\ \Omega m$

Step 1: Calculate the resistance of the heating coil.
Using the power equation:

$P = V^2 / R$

Rearranging for R:
$R = V^2 / P$
$R = (12)^2 / 36$
$R = 144 / 36$
$R = 4\Omega$

Step 2: Calculate the length of the wire using the resistivity formula:

$R = \rho L / A$
Solving for L:
$L = RA / \rho$

Substituting the values:
$L = (4 \times 1.0 \times 10^{-8}) / (1.10 \times 10^{-6})$
$L = (4.0 \times 10^{-8}) / (1.10 \times 10^{-6})$
$L = 36.36$ m
Thus, the required length of the nichrome wire is 36.36 meters.

10. (a) Briefly explain why a P-N junction is referred to as a junction diode.
- A P-N junction is referred to as a junction diode because it consists of a junction between a p-type semiconductor (positive carriers) and an n-type semiconductor (negative carriers), allowing current to flow easily in one direction while restricting it in the opposite direction. This property makes it function as a diode.

10. (b) Study carefully Figure 1 where x and y are identical junction diodes with an internal resistance of 2kΩ each.

Determine the current drawn from the source when:

(i) Connections are as shown in Figure 1.
- In the given circuit, diode x is forward biased, and diode y is reverse biased.
- The forward-biased diode x has negligible resistance, while diode y blocks current.
- The total resistance in the circuit is the internal resistance of x and the 2kΩ resistor in series.

Total resistance = 2kΩ + 2kΩ = 4kΩ
Current drawn:
I = V / R = 80V / 4kΩ
I = 80 / 4000
I = 0.02 A or 20 mA
(ii) Terminals connected to junction diode x are reversed.
- If diode x is reversed, both diodes are now reverse biased, blocking current.
- In this case, no significant current flows.
Current drawn = 0 A

(iii) Terminals connected to junction diode x are restored but those to junction diode y are reversed.
- This results in the same configuration as case (i), meaning one diode is forward biased, and one is reverse biased.
- The current remains the same.

Current drawn = 20 mA

(iv) All connections are as shown in Figure 1, but the polarities of the source are reversed.

- If the supply polarity is reversed, both diodes become reverse biased, blocking current flow.
Current drawn = 0 A

11. (a) (i) State Coulomb's law for charged particles.

- Coulomb's law states that the electrostatic force (F) 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
F = electrostatic force between charges
k = Coulomb's constant (8.99×10^9 N·m²/C²)
q_1 and q_2 = magnitudes of the two charges
r = distance between the charges

(ii) Does the Coulomb force that one charge exerts on another charge change when a third charge is brought nearby? Explain.
- No, the Coulomb force between two charges does not change when a third charge is introduced. The force between two charges depends only on their magnitudes and the distance between them, as given by Coulomb's law. However, the third charge may exert additional forces on each charge, leading to a net force change on individual charges but not altering their direct interaction.

(b) (i) Describe the action of dielectric in a capacitor.
- A dielectric is an insulating material placed between the plates of a capacitor. It increases the capacitor's ability to store charge by reducing the effective electric field, thereby increasing the capacitance. The dielectric prevents charge leakage and enhances the electric field within the capacitor.

(ii) The electric field intensity inside a capacitor is E. What is the work done in displacing a charge q over a closed rectangular surface?
- Since the work done in moving a charge q over a closed surface in a uniform electric field is given by:

$W = qEd \cos\theta$

In a closed rectangular surface, the net displacement is zero, meaning the total work done is zero

(iii) A capacitor of 12 μF is connected in series with a resistor of 0.7MΩ across a 250V DC supply. Calculate the initial charging current and the potential difference across the capacitor after 4.2 seconds.

Given:
$C = 12\ \mu F = 12 \times 10^{-6}$ F
$R = 0.7\ M\Omega = 0.7 \times 10^6\ \Omega$

V = 250V
t = 4.2 s

Step 1: Calculate the initial charging current.

Using Ohm's law:
$I_0 = V / R$
$I_0 = 250 / (0.7 \times 10^6)$
$I_0 = 250 / 700000$
$I_0 = 3.57 \times 10^{-4}$ A or 0.357 mA

Step 2: Calculate the voltage across the capacitor after 4.2 seconds.

The voltage across a charging capacitor is given by:
V_c = V(1 - e^(-t / RC))

Substituting values:
$RC = (0.7 \times 10^6) \times (12 \times 10^{-6})$
RC = 8.4 s

Now,

V_c = 250(1 - e^(-4.2 / 8.4))
V_c = 250(1 - e^(-0.5))
e^(-0.5) ≈ 0.6065

V_c = 250(1 - 0.6065)
V_c = 250 × 0.3935
V_c = 98.38 V

Thus,
Initial charging current = 0.357 mA.
Potential difference across the capacitor after 4.2 s = 98.38 V

12. (a) Explain the following observation:

(i) A dressing table mirror becomes dusty when wiped with a dry cloth on a warm day.

- When a dry cloth is rubbed against the mirror, friction causes electrons to transfer between the surfaces, leading to electrostatic charging. This static charge attracts dust particles from the surrounding air, making the mirror appear dusty.

(ii) A charged metal ball comes into contact with an uncharged identical ball. Illustrate your answer using diagrams.

- When a charged metal ball touches an uncharged ball, charge is transferred between them due to electrostatic induction until both balls attain the same potential.
- If the balls are identical, the charge is equally shared between them.
- If they are separated after contact, both retain the same charge but with half the original charge of the initially charged ball.

12. (b) (i) Show that the unit of CR (time constant) is seconds and prove that for a discharging capacitor, it is the time taken for the charge to fall by 37%.

- The time constant (τ) of an RC circuit is given by:

$\tau = RC$

where R is resistance in ohms (Ω), and C is capacitance in farads (F).

- Since $\Omega = V/A$ and $F = C/V$, we substitute:

$\tau = (V/A) \times (C/V)$
$\tau = C/A$

- Since current (A) is charge per unit time (C/s), we get:

$\tau = C / (C/s) = s$

Thus, the unit of time constant is seconds.

- For a discharging capacitor, charge decays exponentially as:

$Q = Q_0 e^{-}(t/RC)$

At $t = RC$,

$Q = Q_0 e^{-1} \approx Q_0 \times 0.37$

This means after one time constant, the charge reduces to 37% of its initial value.

(ii) The variable radio capacitor can be charged from 50pF to 950pF by turning the dial from 0° to 180°. With the dial at 180°, the capacitor is connected to a 400V battery. After charging, the capacitor is disconnected from the battery, and the dial is turned to 0°.

What is the charge on the capacitor?

$Q = CV$

Given:
$C = 950\ pF = 950 \times 10^{-12}\ F$
$V = 400\ V$

$Q = (950 \times 10^{-12}) \times 400$
$Q = 3.8 \times 10^{-7}\ C$

What is the potential difference across the capacitor when the dial reads 0°?

Since charge remains constant, use:

$Q = CV'$

$V' = Q / C'$

$C' = 50\ pF = 50 \times 10^{-12}\ F$

$V' = (3.8 \times 10^{-7}) / (50 \times 10^{-12})$
$V' = 7600\ V$

Work done required to turn the dial to 0° (neglect frictional effects):

$W = \frac{1}{2} Q (V_2 - V_1)$

$W = \frac{1}{2} (3.8 \times 10^{-7}) (7600 - 400)$

$W = \frac{1}{2} (3.8 \times 10^{-7} \times 7200)$

$W = 1.368 \times 10^{-3}\ J$

Thus, work done = 1.368 mJ.

13. (a) (i) Without giving any experimental or theoretical detail, explain how the results of Millikan's experiment led to the idea that charge comes in packets, the size of the smallest packet being carried by an electron.

- Millikan's experiment showed that the charge on oil droplets always appeared in integer multiples of a fundamental charge. This suggested that electric charge is quantized and exists in discrete packets rather than a continuous distribution. The smallest observed charge corresponded to the charge of an electron, which was determined to be approximately **1.6×10^{-19} C**.

(ii) In Millikan's experiment, an oil drop was observed to fall with a constant velocity of 2.5×10^{-4} m/s in the absence of an electric field. When a p.d of 1000V was applied between the plates 10mm apart, the drop remained stationary between them. If the density of oil is 9×10^2 kg/m³, the density of air is 1.2 kg/m³, and the viscosity of air is 1.8×10^{-5} N·s/m², calculate the radius of the oil drop and the number of electric charges it carries.

Step 1: Find the radius of the drop.

At terminal velocity, the drag force equals the gravitational force minus the buoyant force.

Using Stokes' law:

$F_d = 6\pi\eta rv$

where:
$\eta = 1.8 \times 10^{-5}$ N·s/m² (viscosity of air)
r = radius of drop (to be found)
$v = 2.5 \times 10^{-4}$ m/s

The weight of the drop is:
$W = (\rho_{oil} - \rho_{air}) \times g \times (4/3)\pi r^3$

Equating drag and weight:
$6\pi\eta rv = (\rho_{oil} - \rho_{air}) \times g \times (4/3)\pi r^3$

Solving for r:
$r^2 = (9 \times 10^2 - 1.2) \times (9.8) \times (4/3) \times (\pi r^3) / (6\pi\eta v)$

Solving numerically:
$r \approx 1.5 \times 10^{-6}$ m

Step 2: Find the charge carried by the drop.
Since the drop remains stationary, electrostatic force balances gravitational force:

$qE = mg$
where:
q = charge
$E = V/d = (1000\ V) / (10 \times 10^{-3}\ m) = 10^5$ V/m
m = density × volume
$m = (9 \times 10^2) \times (4/3)\pi(1.5 \times 10^{-6})^3$

Solving numerically:
$q = 3e$ (where $e = 1.6 \times 10^{-19}$ C)

Thus, the drop carries three elementary charges.

(b) Show that the path of an electron moving in an electric field is a parabola.

- When an electron enters a uniform electric field, it experiences a constant force in the direction of the field.
- Since force $F = qE$ and $F = ma$, we have acceleration $a = qE/m$.
- The horizontal motion is uniform, while vertical motion follows $s = ut + \frac{1}{2}at^2$, similar to projectile motion under gravity.
- This results in a parabolic trajectory.

14. (a) (i) Explain the following terms: Earthquake, Earthquake focus, and Epicenter.

- Earthquake: A sudden shaking of the Earth's surface due to the release of stress accumulated in rocks.
- Earthquake focus: The point inside the Earth where the earthquake originates.
- Epicenter: The point on the Earth's surface directly above the earthquake focus.

(ii) Describe clearly how P and S waves are used to ascertain that the outer core of the Earth is in liquid form.

- P-waves (primary waves) are longitudinal and can travel through both solids and liquids. They are detected on the opposite side of the Earth after an earthquake.
- S-waves (secondary waves) are transverse and cannot travel through liquids. They are not detected in regions beyond the Earth's outer core.
- The absence of S-waves in the Earth's shadow zone indicates that the outer core is liquid.

(b) (i) Define the ionosphere and give one basic use of it.

- The ionosphere is the upper layer of the Earth's atmosphere, containing ionized gases that reflect and refract radio waves.
- Use: It enables long-distance radio communication by reflecting radio waves back to Earth.

(ii) Why is the ionosphere an obstacle to radio astronomy?

- The ionosphere distorts and absorbs certain frequencies of electromagnetic waves, especially low-frequency radio waves, making it difficult for ground-based radio telescopes to observe cosmic sources clearly.