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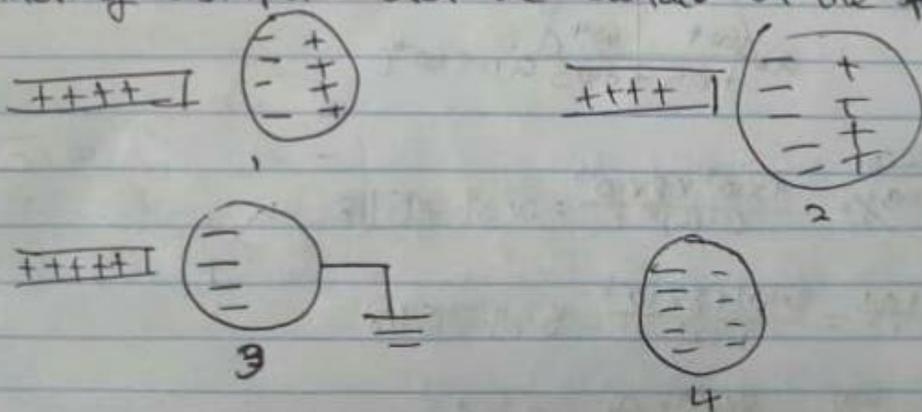
Assignment

Matrix no: 19/MHS01/313

Department: M.B.B.S

Course Code: PHY 102

1a Put a negatively charged rubber rod near a neutral insulated conducting sphere, insulated to ensure there is no conducting path to the ground. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some electrons move to the side of the sphere farthest away from the rod. The part of the sphere nearest to the rod has an excess of positive charge because of the migration of electrons away from this location. Connecting a grounded conducting wire to the sphere, some of the electrons leave the sphere and travel to the earth. If the wire is removed the sphere is left with an excess of induced positive charge. When the rubber rod is removed from the vicinity of the sphere the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.



1b $k = 9 \times 10^9$
 $Q_1 + Q_2 = 5 \times 10^{-5} \text{ C}$
 $F = 1 \text{ N}$
 $d = 2 \text{ m}$

Calculate the charge on each
 Sphere?

$k = 9 \times 10^9$
 $F = \frac{k Q_1 Q_2}{r^2}$

$1 = \frac{9 \times 10^9 \times (Q_1 Q_2 5 \times 10^{-5})}{2^2}$

$4 = 9 \times 10^9 \times 5 \times 10^{-5} Q_1 + 9 \times 10^9 Q_2$

$4 = 4.5 \times 10^5 Q_1 + 9 \times 10^9 Q_2$

$9 \times 10^9 Q_2 - 4.5 \times 10^5 Q_1 + 4 = 0$

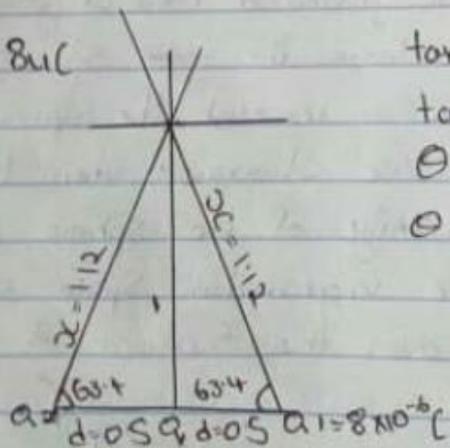
$Q_1 = 0.000011 \text{ C}$

$Q_2 = 0.000038 \text{ C}$

$\approx Q_1 = 1.1 \times 10^{-5} \text{ C}$

$\approx Q_2 = 3.8 \times 10^{-5} \text{ C}$

1c $Q_1 = Q_2 = 8 \mu\text{C}$
 $d = 0.5 \text{ m}$



$\tan \theta = \frac{\text{opp}}{\text{adj}}$

$\tan \theta = \frac{0.5}{x} = e$

$\theta = \tan^{-1}(2)$

$\theta = 63.4$

$x^2 = 1^2 + 0.5^2$

$\sqrt{x} = \sqrt{1.25}$

$x = \sqrt{1.25}$

$x = 1.12$

$E = k \frac{Q_1}{r^2}$

$E_1 = \frac{k Q_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.795918$

$E_2 = \frac{k Q_2}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.12^2} = 5739.795918$

$E_Q = \frac{k Q}{r^2} = \frac{9 \times 10^9 \times Q}{1} = 9 \times 10^9 Q$

Vector	angle	x-comp	y-comp
$E_1 = 5739.795918$	634°	$E_1 \cos 634^\circ$	5132.262839
$E_2 = 5739.795918$	634°	2576.045785	5132.262839
$E_{av} = 9 \times 10^9 v$	90°	$E_{av} \cos 90^\circ = 0$ $\sum x = 0$	$9 \times 10^9 v$ $\sum y = 10264.52568$

magnitude = $\sqrt{(\sum x)^2 + (\sum y)^2}$

$E_{av} = \sqrt{(0)^2 + (10264.52568)^2}$

Since $E = 0$

$0 = 9 \times 10^9 v + 10264.52568$

$v = \frac{-10264.52568}{9 \times 10^9}$

$v = 1.140502853 \times 10^{-6}$

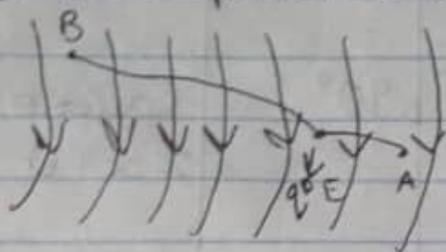
$\underline{v} = 11.4 \mu C$

3a) Volume Charge density, $\rho = \frac{dQ}{dV} \cdot dV = \rho dV$

ii) Surface charge density, $\sigma = \frac{dQ}{dA} \cdot dA = \sigma dA$

iii) Linear Charge density, $\lambda = \frac{dQ}{dL} \cdot dL = \lambda dL$

3b) The electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to the other. It is measured in Volt (V) or Joules per Coulomb (J/C). Electric potential difference is a scalar quantity.



Consider the diagram above. Suppose a test charge q_0 is moved from point A to point B along an arbitrary path inside an electric field E . The electric field E exerts a force $F = q_0 E$ on the charge as shown in Fig 3.1. To move the test charge ~~for~~ from A to B at constant velocity, an external force of $F = -q_0 E$ must act on the charge. Therefore, the elemental work done dW is given as:

$$dW = F \cdot dL \quad \dots (1)$$

but $F = -q_0 E \quad \dots (2)$

Substituting equation (2) in (1) yields

$$dW = -q_0 E dL \quad \dots (3)$$

Then total work done in moving the test charge from A to B is:

$$W(A \rightarrow B)_{A_0} = -q_0 \int_A^B E dL \quad \dots (4)$$

From the definition of electric potential difference. It follows that

$$V_B - V_A = \frac{W(A \rightarrow B)_{A_0}}{q_0}$$

Putting equation (4) in (5) yields

$$V_B - V_A = - \int_A^B E dL \quad \dots (6)$$

$$3c.) Q_1 = 10 \times 10^{-6} \text{ C}$$

$$Q_2 = -2 \times 10^{-6} \text{ C}$$

$$\frac{1}{2} \times 20 \times 10^{-6} = \left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right)$$

$$0 \Rightarrow 9 \times 10^9 \left(\frac{10 \times 10^{-6}}{4+x} + \frac{-2 \times 10^{-6}}{x} \right) = 0$$

$$0 \Rightarrow 9 \times 10^9 \left(\frac{10 \times 10^{-6}}{4+x} - \frac{2 \times 10^{-6}}{x} \right) = 0$$

$$0 = \frac{90000}{4+x} - \frac{18000}{x}$$

multiply through by $(4+x)x$

$$(4+x)x \cdot 0 \Rightarrow \frac{90000}{4+x} - \frac{18000}{x}$$

$$0 = 90000x - 18000(4+x)$$

$$72000 = 90000x - 18000x$$

$$72000 = 72000x$$

if $x=1$ m

$$4+x = 4+1 = 5 \text{ m}$$

to find the distance between the charges (1) multiply the charge by the distance of the charges (2) multiply the charge by the distance of the charges

3c
 4a magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol Φ . mathematically given as $\Phi = B \cdot dA$

4b $m = 9 \times 10^{-31} \text{ kg}$
 $r = 1.4 \times 10^{-7} \text{ m}$
 $B = 3.5 \times 10^{-1} \text{ weber/meter}^2$

Cyclotron Frequency = angular Speed

$$\omega = \frac{v}{r} = \frac{qB}{m}$$

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$$\omega = 6.2222222222 \cdot 22222 \text{ T}^{-1}$$

4c. we were given

i mass of the electron = $9.11 \times 10^{-31} \text{ kg}$

ii A radius of $1.4 \times 10^{-7} \text{ m}$

iii magnetic field of $3.5 \times 10^{-1} \text{ weber/meter Square}$

and asked to find the cyclotron frequency which is equal to angular speed. It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron

Recall that angular speed is given as $\omega = \frac{v}{r} = \frac{qB}{m}$

$$\text{Substitute } \omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$\frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = 6.2222222222 \cdot 22222 \text{ T}^{-1}$$

So since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $= 6.2222222222 \cdot 22222 \text{ T}^{-1}$, having a unit as $1/\text{T}$ which is equal to the unit of frequency dimensionally.

5a Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ_0), the current (i), the charge or length, the radius and inversely proportional to square of radius (r^2). It can be represented mathematically by
$$dB = \frac{\mu_0 i dl \times r}{4\pi r^2}$$

where μ_0 is a constant called permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$$

The unit of B is weber/metre square

5b Magnetic field of a straight current carrying conductor

Applying the Biot-Savart law, we find the magnitude of the field dB

$$B = \frac{\mu_0 i}{4\pi} \int_a^a \frac{db \sin \theta}{r^2}$$

$$\sin(\pi - \theta) = \sin \theta$$

$$\therefore B = \frac{\mu_0 i}{4\pi} \int_a^a \frac{db \sin(\pi - \theta)}{r^2}$$

$r = \sqrt{x^2 + y^2}$ (Pythagoras theorem)

$$B = \frac{\mu_0 i}{4\pi} \int_a^a \frac{dl \sin(\pi - \theta)}{x^2 + y^2} \quad \text{but } \sin(\pi - \theta) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}}$$

Substituting $(*)$ into $(**)$, we have

$$B = \frac{\mu_0 i}{4\pi} \int_a^a dl \frac{x}{(x^2 + y^2)^{3/2}}$$

$$= B = \frac{\mu_0 i}{4\pi} \int_a^a dl \frac{x}{(x^2 + y^2)^{3/2}}$$

Recall $dl = dy$,
$$B = \frac{\mu_0 i}{4\pi} \int_a^a \frac{x}{(x^2 + y^2)^{3/2}} dy$$

$$B = \frac{\mu_0 i x}{4\pi} \int_a^a \frac{1}{(x^2 + y^2)^{3/2}} dy \dots (***)$$

Using Special integrals:

$$\int \frac{dy}{(x^2 + y^2)^{3/2}} = \frac{1}{x^2} \frac{y}{(x^2 + y^2)^{1/2}}$$

Equation (**) therefore becomes

$$B = \frac{\mu_0 I x}{4\pi} \left[\frac{2a}{x^2 + a^2} \right]^{1/2}$$

$$B = \frac{\mu_0 I x}{4\pi} \left(\frac{2a}{x^2 + a^2} \right)^{1/2}$$

$$B = \frac{\mu_0 I}{4\pi x} \left(\frac{2a}{x^2 + a^2} \right)^{1/2}$$

when the length $2a$ of the conductor is very great in comparison to its distance x from point P, we consider it infinitely long. That is, when a is much longer than x ,

$$(x^2 + a^2)^{1/2} \approx a, \text{ as } a \rightarrow \infty$$

$$\therefore B = \frac{\mu_0 I}{2\pi x}$$

In a physical situation, we have axial symmetry about the y -axis. Thus at all points in a circle of radius r , around the conductor, the magnitude of B is

$$B = \frac{\mu_0 I}{2\pi r} \quad (\#)$$

Equation (#) defines the magnitude of the magnetic field of flux density B near a long, straight current carrying conductor