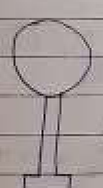
IFEANYI-OBI ADAEZE CLARE
19/MHB01/193

1(a) PRODUCTION OF A NEGATIVELY CHARGED SPHERE BY METHOD OF INDUCTION.

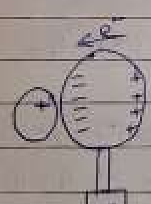
When we charge a metal sphere negatively by bringing a positively charged rod near its left surface, the electrons get attracted towards the left side and positive charges on the right side. Now, when the sphere is earthed the electrons from earth flow to the sphere to neutralise the positive charge collected on the right side. Now, when the positively charged rod is removed the negative charges get distributed over the metal surface and the sphere gets negatively charged.

Diagram i)



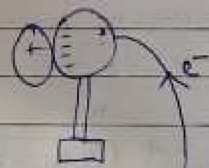
a neutral spher

Diagram ii)



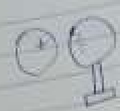
electrons are attracted to the positive rod/balloon.

Diagram iii)



Electrons enter sphere from the ground, attracted to the + charge in the sphere.

Diagram iv)



The sphere has an excess of e^- having entered from the ground

Diagram v)

Electrons redistribute uniformly.

1b) Using: $F = \frac{KQ_1Q_2}{r^2}$

Given: $F = 1N$, $r = 2m$, $Q_1 = ?$, $Q_2 = ?$

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

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

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

$1 = \frac{(5 \times 10^{-5} - Q_2) \times 9 \times 10^9 Q_2}{4}$

$4 = 9 \times 10^9 Q_2 [(5 \times 10^{-5}) - Q_2]$

$4 = 450000 Q_2 - 9 \times 10^9 Q_2^2$

$9000000000 Q_2^2 - 450000 Q_2 + 4 = 0$

Using the quadratic formula.

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$Q_2 = \frac{-(-45000) \pm \sqrt{(450000)^2 - 4 \times 9 \times 10^9 \times 4}}{2 \times 9 \times 10^9}$$

$$Q_2 = \frac{450000 \pm 241867.7324}{1.8 \times 10^{10}}$$

$Q_2 = 3.84 \times 10^{-5} C$

If $Q_2 = 3.84 \times 10^{-5} C$

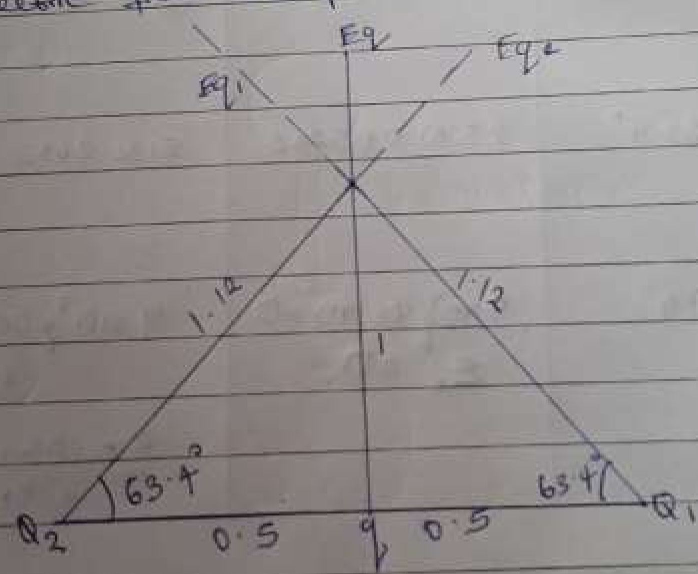
Then $Q_1 = 5 \times 10^{-5} - 3.84 \times 10^{-5}$

$\therefore Q_1 = 1.16 \times 10^{-5} C$ //

1c) $Q_1 = Q_2 = 8\mu C$

$d = 0.5m$

If electric field at a point P is zero.



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

$\sqrt{x} = \sqrt{.25}$

$x = 1.12$

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

$\tan\theta = \frac{1}{0.5}$

$\tan\theta = 2$

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

$\theta = 63.4$

$E_{q_1} = \frac{Kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2}$

$E_{q_1} = E_{q_2} = 57397.959..$

$E_q = \frac{Kq}{r^2} = \frac{9\times10^9\times q}{1}$

$= 9\times10^9 q$

Vector	Angle	X - component	Y - component
E_{q_1} 57397.95918	63.4°	2570.046785	5132.26287
E_{q_2} 57397.95918	63.4°	2570.045785	5132.2683
E_q $9\times10^9 q$	90°	$9\times10^9 q \cos 90° = 0$ $E_x = 0$	$9\times10^9 q \sin 90° = 9\times10^9 q$ $E_y = 1.026\times10^5 NC^{-1} + 9\times10^9 q$

$E_q = \sqrt{E_x^2 + E_y^2}$

$= \sqrt{(0)^2 + [(1.026\times10^5)^2 + (9\times10^9 q)^2]}$

$= \sqrt{1.053\times10^{10} + (9\times10^9 q)^2}$

But $E_q = 0$

$\therefore 0 = \sqrt{1.053\times10^{10} + (9\times10^9 q)^2}$

$0 = 1.053\times10^{10} + (9.0\times10^9 q)^2$

1c) $(9 \times 10^9 q)^2 = 1.053 \times 10^{10}$

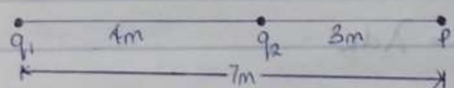
$$\therefore q^2 = \frac{1.053 \times 10^{10}}{9 \times 10^9} = 1.299 \times 10^{-10}$$

$$\therefore q = \sqrt{1.2996 \times 10^{-10}} = 1.14 \times 10^{-5} C$$

$$\therefore q = 11.4 \mu C.$$

2a Electric field is the region of space in which an electric charge will experience an electric force while electric field intensity also known as electric field strength is defined as the force per unit charge; it is the magnitude of electric field.

bi $q_1 = 8nC \quad q_2 = 12nC$



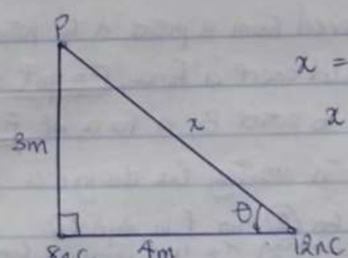
$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-9}C}{7^2} = 1.469NC^{-1}$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 Nm^2C^{-2} \times 12\times10^{-9}C}{3^2} = 12NC^{-1}$

$E_{net} = E_1 + E_2 = 1.469NC^{-1} + 12NC^{-1} = 13.469NC^{-1}$

$\therefore E_{net} \simeq 13.5NC^{-1}$

bii



$x = \sqrt{3^2 + 4^2}$

$x = \sqrt{9+16} = \sqrt{25}\,m$

$\therefore x = 5m$

$\theta = \sin^{-1}(3/5) = 36.9°$

$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-9}C}{3^2} = 8NC^{-1}$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 Nm^2C^{-2} \times 12\times10^{-9}C}{5^2} = 4.32NC^{-1}$

Vector	Angle	X- Component	Y component
$8NC^{-1}$	90°	$8NC^{-1}\cos 90 = 0NC^{-1}$	$8\sin 90° = 8NC^{-1}$
$4.32NC^{-1}$	36.9°	$4.32\cos 36.9 = 3.45NC^{-1}$	$4.32\sin 36.9 = 2.60NC^{-1}$
		$\Sigma x = 3.45NC^{-1}$	$\Sigma y = 10.60NC^{-1}$

$\Sigma_{net} = \sqrt{\Sigma Fx^2 + \Sigma Fy^2}$

$\Sigma_{net} = \sqrt{3.45^2 + 10.60^2} = \sqrt{124.2625}$

$\Sigma_{net} = 11.147\,NC^{-1} \simeq 11.5\,NC^{-1}$

a) Magnetic Flux refers to the number of magnetic lines of force passing through a given closed surface which is the magnetic ~~surface~~ field. It is what generates the field around a magnetic material. Its S.I unit is Weber (Wb)

b) $m = 9.11 \times 10^{-31}$ kg, $r = 1.4 \times 10^{-7}$ m, $\theta = 90°$, $B = 3.5 \times 10^{-1}$ T, $V = 3 \times 10^{8}$ ms^{-1}

$$F = qVB\sin\theta = \frac{mv^2}{r}$$

$$q = \frac{mv^2}{vBr\sin\theta} = \frac{9.11\times10^{-31}kg \times 3\times10^{8}ms^{-1} \times 3\times10^{8}ms^{-1}}{3\times10^{8}ms^{-1} \times 3.5\times10^{-1}T \times 1.4\times10^{-7}m \times \sin 90}$$

$$q = \frac{2.733\times10^{-22}kgms^{-1}}{4.9\times10^{-8}} = 5.578\times10^{-15}\ C$$

$$\omega = \frac{qB}{m_e} = \frac{5.578\times10^{-15}C \times 3.5\times10^{-4}T}{9.11\times10^{-31}kg} = 2.14\times10^{15} rad/s$$

$$\therefore \omega = 2.14\times10^{15} rad/s$$

c) Electrons exhibit uniform circular motion. The acceleration, thus, is centripetal

d) acceleration v^2/r [$F_B = qVB = mv^2/r$]. The angular speed is $\omega = v/r$. Substituting adequately, the angular speed (also cyclotron frequency) is 2.14×10^{15} rad/s. The electron circulates at this angular speed in the type of accelerator called a cyclotron.

5) a) Biot - Savart Law

The Biot - Savart law states that at any point P, the magnetic field $\vec{dB}$ due to an element $\vec{dl}$ of a current-carrying wire is given by

$$\vec{dB} = \frac{\mu_0}{4\pi} \int \frac{I\vec{dl} \times \hat{r}}{r^2}$$

The constant μ_0 is known as the permeability of free space and is exactly

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

8.1.2 **Magnetic Field of a Straight Current Carrying Conductor**

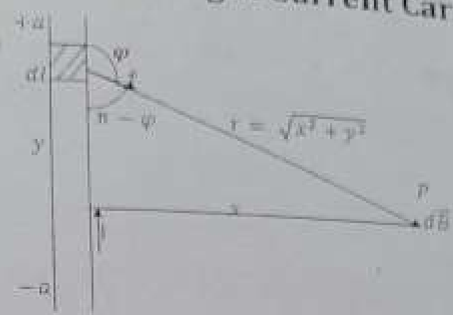


Fig 1: A section of a Straight Current Carrying Conductor

Applying the Biot-Savart law, we find the magnitude of the field $d\vec{B}$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dl\sin\varphi}{r^2}$$

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

$$\therefore B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dlsin(\pi - \varphi)}{r^2}$$

From diagram, $r^2 = x^2 + y^2$ $(Pythagoras\ theorem)$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dl\sin(\pi-\varphi)}{x^2 + y^2} \quad \cdots \quad (*)$$

$$But \ \sin(\pi-\varphi) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}} \quad \cdots \quad (**)$$

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

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)(x^2 + y^2)^{1/2}}$$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)^{3/2}}$$

Recall $dl = dy$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{x}{(x^2 + y^2)^{3/2}} dy$$

$$B = \frac{\mu_o I x}{4\pi}\int_{-a}^{a}\frac{1}{(x^2 + y^2)^{3/2}} dy \quad \cdots \quad (***)$$

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

$$B = \frac{\mu_o I x}{4\pi}\left[\frac{y}{x^2(x^2 + y^2)^{1/2}}\right]_{-a}^{a}$$

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

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

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 largerthan x.

$$(x^2 + a^2)^{1/2} \cong a, as \ a \to \infty$$

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

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

$$B = \frac{\mu_o I}{2\pi r} \qquad \dots \qquad (ii)$$

IFEANYI-OBI ADAEZE CLARE
19/MHS01/193
MBBS