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19/MHS01/265

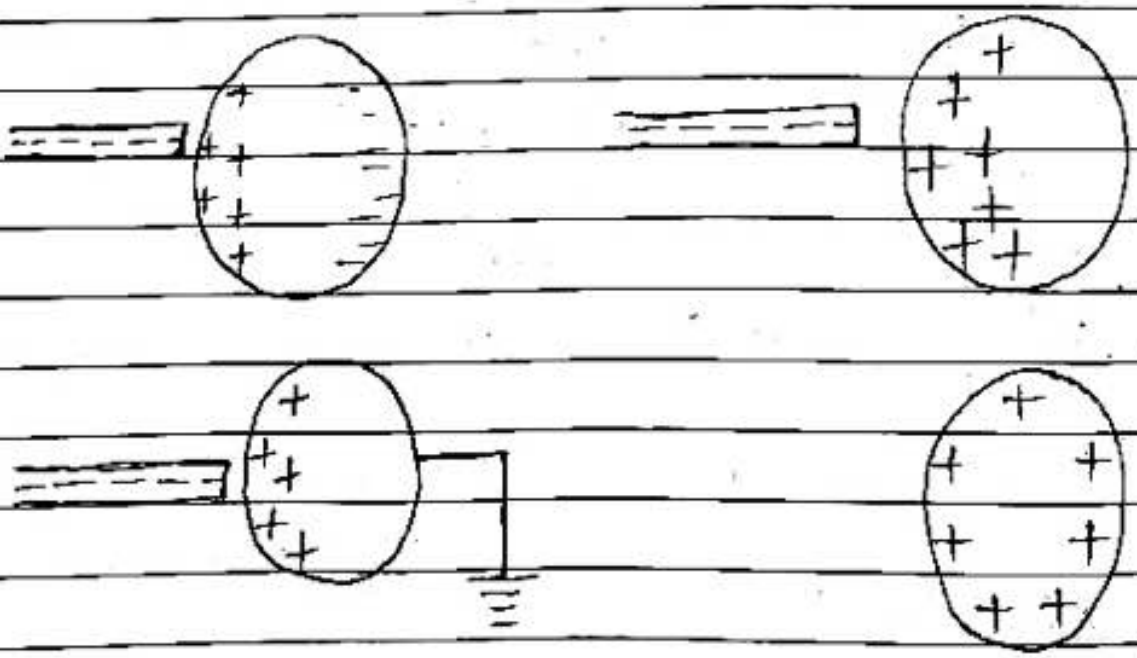
PHY 102

COLLEGE; MEDICINE AND ~~HEALTH~~ HEALTH SCIENCES DEPT: MBBS.

Section A

1a. Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction.

Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that 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 region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from the location. Finally, 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. $k = 9 \times 10^9$

$q_1 + q_2 = 5 \times 10^{-5} C$

$F = 1N$, $d = 2m$

Calc the charge on each sphere

$F = \frac{kq_1 q_2}{r^2}$

$= \frac{9 \times 10^9 \times (q_1 q_2 \, 5 \times 10^{-5})}{2^2}$

$= 9 \times 10^9 \times 5 \times 10^{-5} q_1 + 9 \times 10^9 q_2$

$= 4.5 \times 10^5 q_1 + 9 \times 10^9 q_2$

It is a quadratic equation

$9 \times 10^9 q_2 - 4.5 \times 10^5 q_1 + 4 = 0$

$q_1 = 0.000011C$

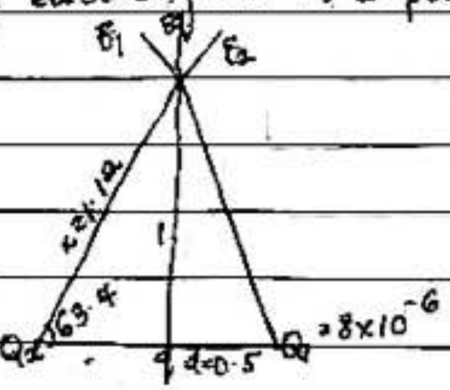
$q_2 = 0.000038C$

$q_1 \simeq 1.11 \times 10^{-5} C \quad q_2 \simeq 3.8 \times 10^{-5} C$

1c. $Q = Q_2 = 8 \mu C$

$d = 0.5m$

Determine if electric field at a point P is zero.



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

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

$x = \sqrt{1.25}$

$x = 1.12$

$\tan \theta = \text{opp}/\text{Adj}$

$\tan \theta = 1/0.5$

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

$\theta = 63.4$

$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.795$

$E_2 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.795$

$E_q = \frac{kq}{r^2} = \frac{9 \times 10^9 \times q}{1} = 9 \times 10^9 q$

Vector	Angle	x-comp	y-comp
$E_1 = 5739.795918$	$63.4°$	-2570.045785	5132.263
$E_2 = 5739.8$	63.4	2570.5	5132.3
$E_q = 9\times10^9 q$	$90°$	0	10264.6

Magnitude; $\sqrt{(\Sigma_x)^2 + (\Sigma_y)^2}$

$E_q = \sqrt{(0)^2 + (10264.6)^2}$

$0 = 9\times10^9 q + 10264.53$

Making q the subject of formulae.

$q = \frac{-10264.53}{9\times10^9}$

$q = -0.0000011405$

$q = 1.1405\times10^{-6}$

$q = 1.14\mu C$

3a. Volume charge density, $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

Linear charge density, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$.

3B Electrical potential difference between 2 points can be defined as work done per unit charge against electrical forces when a charge is transported from one point to another.

$dW = F\,dL$

3c. $q_1 = 10\times10^{-6}C$, $q_2 = -2\times10^{-6}C$, $r = 4m$, $K = 9\times10^9$, $F = \frac{9\times10^9 \times 10\times10^{-6} \times -2\times10^{-6}}{4^2}$

$F = 0.0113N$. $W = F\times d = 0.0113\times4 = -0.045J$.

$V = W/q = -0.045/-2\times10^{-6} = 22$. Workdone at a position of 10m $= 0.0113\times0 = 0$

V at the position of 10m = 0.

$= 10m$.

Section B.

4a. Magnetic flux is defined as the strength of the magnetic field which can be represented by lines of forces it is represented by the symbol ϕ Mathematically, $\phi = B\ \delta A$.

4b $m = 9 \times 10^{-31}$ kg.

$r = 1.4 \times 10^{-7}$ m.

$B = 3.5 \times 10^{-1}$ w/m^2

cyclotron freq = angular speed.

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

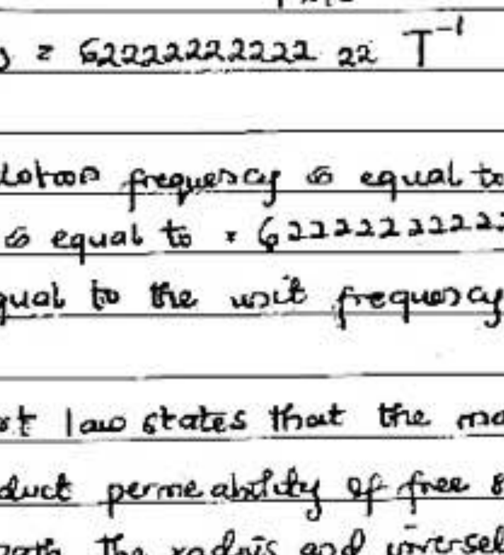
$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$$\omega = 62222222222\ 22\ T^{-1}$$

4c. Since cyclotron frequency is equal to angular speed, the cyclotron frequency is equal to = 62222222222 22 T^{-1}, having a unit 1/T which is equal to the unit frequency dimensionally.

5a. Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to square of radius (r^2)

5b



Applying the Biot-savart law, find the magnitude of the field dB

$$B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin\phi}{r^2}$$

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

$$\therefore B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin(\pi - \phi)}{r^2}$$

From the diagram, $r^2 = x^2 + y^2$ (Pythagorax theorem)

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin(\pi - \phi)}{x^2 + y^2} \quad -(1)$$

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

Substituting (2) in (1);

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2+y^2)(x^2+y^2)^{1/2}}$$

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

Recall $dl = dy$

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{x}{(x^2+y^2)^{3/2}} dy$$

$$B = \frac{\mu_0 I x}{4\pi}\int_{-a}^{a} \frac{1}{(x^2+y^2)^{3/2}} dy \quad -(3)$$

Using special integrals,

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

Eq (3) becomes; $B = \frac{\mu_0 I x}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$

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

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

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

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

In a physical situation, we have axial symmetry about the y axis. Thus, all points in a circle of radius r, around the conductor, the magnitude B is; $B = \frac{\mu_0 I}{2\pi r}$ --- (6); Eq (6) depicts the magnitude of the field of flux density B near a long straight current carrying conductor.