ELECTRICITY, MAGNETISM AND MODERN PHYSICS

PHY 102

GIWA ESTHER TITILAYO

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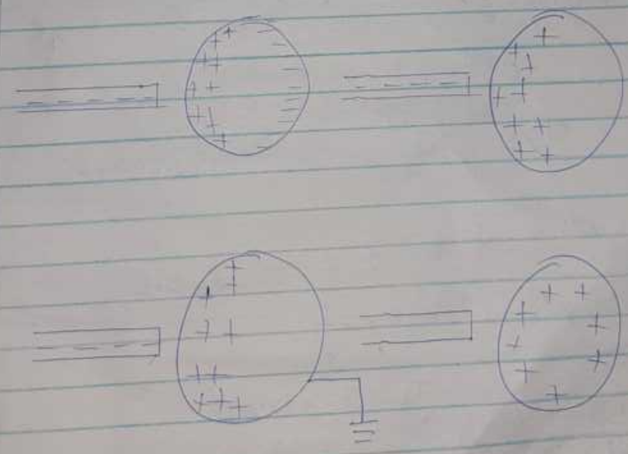
1a) A negatively charged rubber rod brought near a neutral conducting sphere that is insulated so that there is no conducting path to ground. The repulsive force between the electrons in the rod and sphere causes a redistribution of charges on the sphere so that some of electrons move to d side of the sphere farthest away from the rod. The region of the sphere nearest the negatively charged rod has an excess of positive charge. Connect a grounded conducting wire to the sphere, some of the electrons leave the sphere & travel to the earth. Removed the wire in ground, then the conducting sphere is left with an excess of induced positive charge. When the rubber rod is removed the induced positive charge remains on the sphere and becomes uniformly distributed over the surface of the sphere.



2.025×10

b) $q_1 + q_2 = 5\times10^{-5}C$, $q_1 = 5\times10^{-5} - q_2$

$F = \frac{kq_1q_2}{r^2} = 1.0 = \frac{9\times10^9 q_1q_2}{2^2}$

$4 = 9\times10^9(5\times10^{-5} - q_2)q_2$

$4 = 4.5\times10^5 q_2 - 9\times10^9 q_2^2$

$-9\times10^9 q_2^2 + 4.5\times10^5 q_2 - 4 = 0$

Using the quadratic formula, $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$\cancel{= 4.5\times10^5 \pm}$

$= \frac{-4.5\times10^5 \pm \sqrt{(4.5\times10^{-5})^2 - 4(-9\times10^9)(-4)}}{2(-9\times10^9)}$

$= \frac{+4.5\times10^5 \pm \sqrt{5.8\times10^{10}}}{-18\times10^9}$

$q_2 = \frac{-4.5\times10^5 \pm 241867.7}{-18\times10^9}$

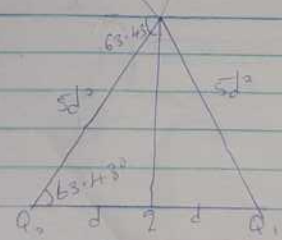
$q_2 = 1.156\times10^{-5}$ or $3.84\times10^{-5}C$

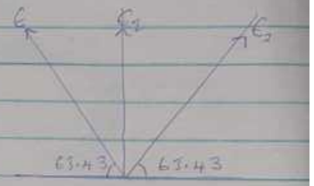
$\cancel{q_1 = 1.156\times10^{-5}C}$

$q_1 = 5\times10^{-5} - q_2$

$q_1 = 5\times10^{-5} - 3.84\times10^{-5}$

$= 1.156\times10^{-5}C$





$d = 0.5$

$\sqrt{2d^2 + d^2} = d\sqrt{5}$ $\quad \tan\theta = 2\frac{d}{d}$

$\tan^{-1}(2) = 63.43°$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9\times(8\times10^{-6})}{(d\sqrt{5})^2} = 57600N/C$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9\times(8\times10^{-6})}{(d\sqrt{5})^2} = 57600N/C$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{(0.1)^2} = \frac{9\times10^9 q}{r^2} = 9\times10^{9} q \, N/C$ 2

$E_{net} = \sqrt{E_{ex}^2 + E_{exy}^2}$, $\because$ but E_{net} at point $P = 0$

$0 = \sqrt{0^2 + (103033.6 + 9\times10^9 q)^2} = 103033.6 + 9\times10^9 q$

$q = -\frac{103033.6}{9\times10^9}$

$= -11.4\times10^{-6}$

$\therefore q = -11.4 \, \mu C$

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8) 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, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$

b) The electric potential difference between 2 points in an electric field

3 can be defined as work done per unit charge against electrical forces when a charge is transported from one point to the other. Measured in volt (V) or J/C.

Work done $dW = F \cdot dL$

But $F = -q_0 E$

$\therefore dW = -q_0 E dL$

Total work done moving from A to B is

$$W(A \rightarrow B)_{Aq} = -q_0 \int_A^B E dL$$

$\therefore$ Electric potential difference is

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

$$\therefore V_B - V_A = \frac{-q_0 \int_A^B E dL}{q_0}$$

$$\therefore V_B - V_A = -\int_A^B E dL$$

b

4

4a) Magnetic flux is the strength of magnetic field represented by lines of force. It is usually represented by the symbol ϕ.

b) $M_e = 9.11 \times 10^{-31} kg$, $r = 1.4 \times 10^{-1} m$ $\theta = 90^\circ$

Magnetic field $= 3.5 \times 10^{-1}$ weber/meter square

$$w = \frac{qB}{m}$$

$$w = \frac{1.6 \times 10^{-19} \times (3.5 \times 10^{-1})}{9.11 \times 10^{-31}}$$

$w = 6.115 \times 10^{10}$ rad/s

8) An electron of mass $9.11 \times 10^{-31} kg$ and charge $1.6 \times 10^{-19} C$ in motion in a magnetic field of 3.5×10^{-1} Tesla perpendicular with the field will have an angular frequency ~~by~~ of 6.15×10^{10} rad/s.

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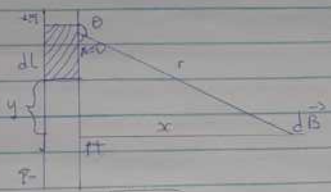
The vector $d\vec{B}$ is perpendicular both to $d\vec{l}$ (which points in the direction of the current) and to the unit vector $\hat{r}$ directed from $d\vec{l}$ toward P.

The magnitude of $d\vec{B}$ is inversely proportional to r^2, where r is the distance from $d\vec{l}$ to P.

The magnitude of $d\vec{B}$ is proportional to the current I and to the magnitude of the length element $d\vec{l}$.

The magnitude of $d\vec{B}$ is proportional to $\sin\theta$ where θ is the angle between $\hat{r}$ and dl.

These observations are summarized in the mathematical expression known as Biot-Savart Law.



$$r = \sqrt{y^2 + x^2}$$

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

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

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

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

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

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

$$(x^2+a^2)^{1/2} \simeq a$$
$$a \gg x$$

$$B = \frac{\mu_0 I}{2\pi x} \cdot \frac{a}{(a^2)^{1/2}}$$

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

$$B = \frac{\mu_0 I}{2\pi r}$$