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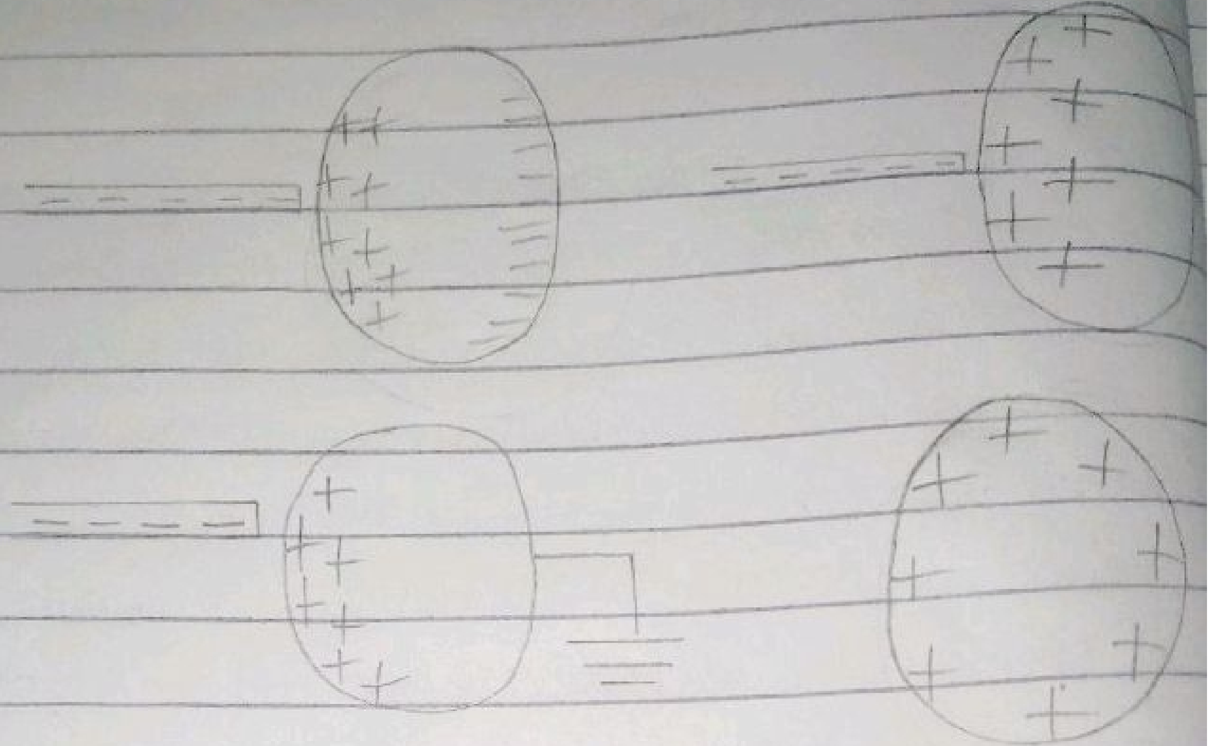
Course Code - PHY 102

(a) Electric charges can be obtained on an object without touching it, by a process called electrostatic induction. Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere which insulated so that there will be no conducting path to ground as shown in the figure below. 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 to the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded conducting wire is connected to the sphere, some of the electrons leave the sphere and travel to the earth and if the wire to the ground is then removed, the conducting 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) $q_1 + q_2 = 5.0 \times 10^{-5} C$

$F = 1.0N \quad K = 9 \times 10^9 Nm^2/C^2$

$d = 2m$

$$F = \frac{Kq_1 q_2}{r^2}$$

$$1 = \frac{9 \times 10^9 \times q_1 q_2 \, 5 \times 10^{-5}}{1 \quad 2^2}$$

$4 = 9 \times 10^9 \times 5 \times 10^{-5} q_1 + 9 \times 10^9 q_2$

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

$\underset{a}{9 \times 10^9 q_2} - \underset{b}{4.5 \times 10^5 q_1} + \underset{c}{4} = 0$

using quadratic formula

$$q_2 = \frac{4.5\times10^5 + \sqrt{[4.5\times10^5]^2 - 4[9\times10^9][4]}}{2[9\times10^9]}$$

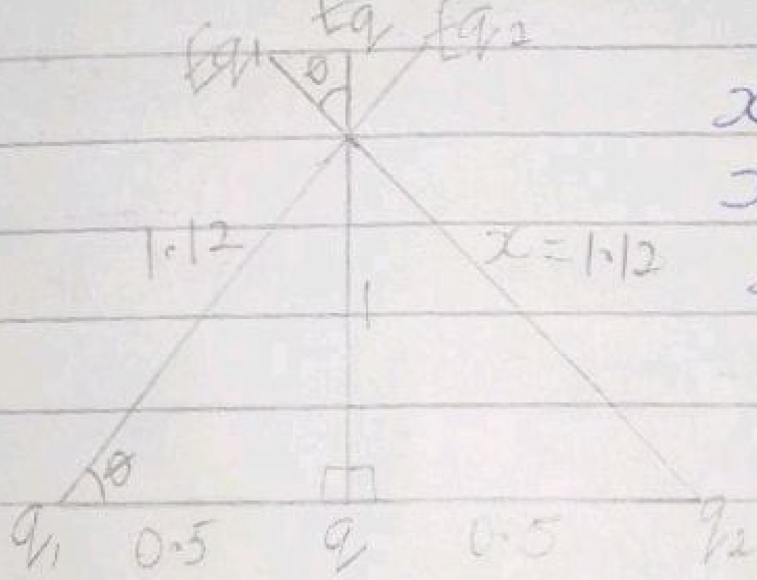
$$q_2 = 3.84\times10^{-5}C$$

$$q_1 = \frac{4.5\times10^5 \cancel{+} - \sqrt{[4.5\times10^5]^2 - 4[9\times10^9][4]}}{2[9\times10^9]}$$

$$q_1 = 1.16\times10^{-5}C$$

c] $Q_1 = Q_2 = 8\mu C$

$d = 0.5m$



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

$x = \sqrt{1.25}$

$x = 1.12$

$\tan\theta = 1/0.5$

$\tan^{-1}[2]$

$\theta = 63.4^\circ$

$$F = \frac{kq}{r^2}$$

$Fq_1 + Fq_2 = 0$

$F = Fq_1 + Fq_2 + Fq$

$$E_{q_1} = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = 57397.96\,N/C$$

$$E_{q_2} = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = 57397.96\,N/C$$

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

Vector	Angle	X-comp	Y-comp
$E_{q_1} = 57397.96$	$63.4°$	$-57397.96\cos 63.4 = -25700$	$57397.96\sin 63.4 = 51322.63$
$E_{q_2} = 57397.96$	63.4	$57397.96\cos 63.4 = 25700$	$57397.96\sin 63.4 = 51322.63$
$E_q = 9\times10^9 q$	$90°$	$9\times10^9 q\cos 90 = 0$	$9\times10^9 q \sin 90 = 9\times10^9 q$
		$\Sigma f_x = 0$	$\Sigma f_y = 102645.26 + 9\times10^9 q$

$$E_p = \sqrt{0^2 + [102645.26 + 9\times10^9 q]^2}$$

$$E_p = \sqrt{[102645.26 + 9\times10^9 q]^2}$$

$$E_p = 102645.26 + 9\times10^9 q$$

$$102645.26 + 9\times10^9 q = 0$$

$$9\times10^9 q = -102645.26$$

$$q = \frac{-102645.26}{9\times10^9}$$

$$q = -1.141\times10^{13}$$

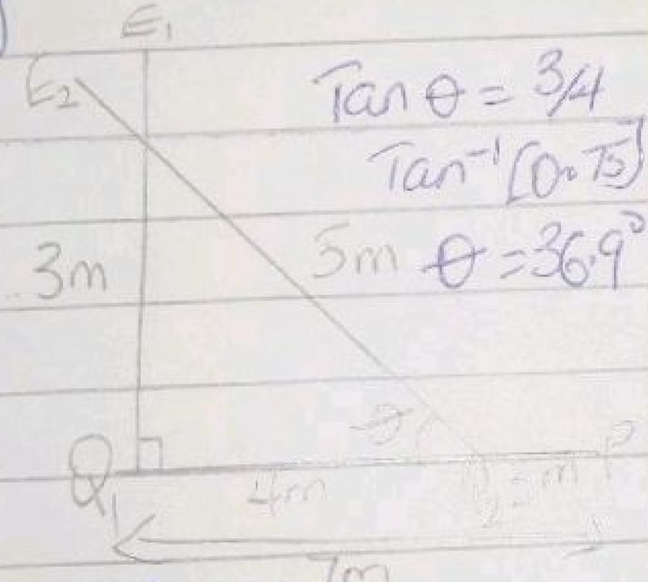
$$q = -11\,\mu C$$

2a] Electric field is a region around a charged particle or object within which a force would be exerted on other charged particles or objects.

while

Electric field intensity is the measure of intensity or strength of electrical force per unit charge at any given point in the electric field. It is denoted by the letter E and its unit is Newton per Coulomb [N/C]

2b]



$\tan\theta = 3/4$

$\tan^{-1}[0.75]$

5m $\theta = 36.9^0$

$E_p = EQ_1 + EQ_2$

$EQ_1 = \frac{KQ}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2}$

$= 1.469 N/C$

$EQ_2 = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12 N/C$

$Ep_{net} = 1.469 + 12 = 13.5 N/c$

ii) $E_{net}Q = \vec{E_1} + \vec{E_2}$

$E_1 = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8 N/C$

$E_2 = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2}$

$= 4.32 N/C$

Vector	Angle	x Comp.	y comp.
$E_1 = 8 N/C$	90^0	$8\cos 90^0 = 0$	$8\sin 90^0 = 8$
$E_2 = 4.32 N/C$	36.9^0	$-4.32\cos 36.9^0 = -3.45$	$4.32\sin 36.9^0 = 2.59$

$\Sigma f_x = -3.45$ $\Sigma f_y = 10.59$

$E_{net}Q = \sqrt{[-3.45^2] + [10.59]^2}$

$= 11.14 N/C$

4a] Magnetic Flux is defined as the number of magnetic field lines passing through a given closed surface. It is denoted by ϕ or ϕ_B and is given by;

$$\phi_B = BA = BA\cos\theta$$

4b] $M = 9.11 \times 10^{-31}$ Kg $r = 1.4 \times 10^{-7}$ m $B = 3.5 \times 10^{-1}$ weber/m²

$\theta = 90^\circ$ $\omega = ?$ $q = -1.60 \times 10^{-19}$ C

$$\omega = \frac{qB}{m_e}$$

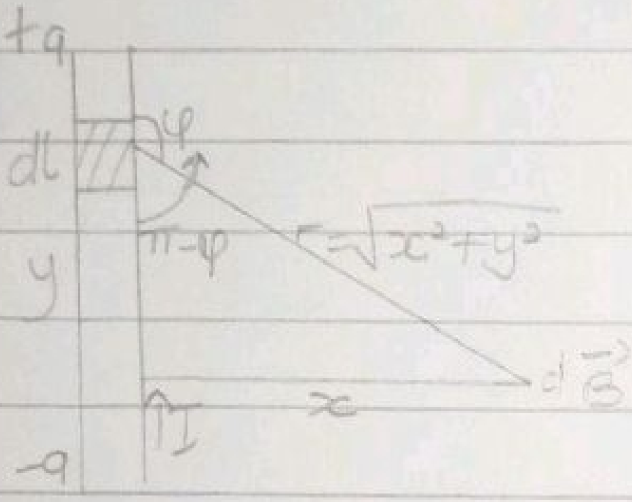
$$\omega = \frac{-1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = -6.147 \times 10^{10} \text{ rad/sec}$$

4c] The cyclotron frequency of the moving electron is negative which means the charge particle electron circulates in a negative or opposite direction at the same angular frequency.

5a] Biot-Savart law ~~states~~ is an equation that describes the magnetic field created by a current-carrying wire and allows you to calculate its strength at various points and we also replace the electric field E with a magnetic field element dB because a moving charge produces a magnetic field, not an electric field

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

Solution



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

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

$$\sin[\pi - \varphi] = \sin\theta$$

$$\therefore B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin[\pi - \varphi]}{r^2}$$

from diagram, $r^2 = x^2 + y^2$ [Pythagoras theorem]

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin[\pi - \varphi]}{x^2 + y^2} \quad \text{— ①}$$

But $\sin[\pi - \varphi]$

$$= \frac{x}{\sqrt{x^2+y^2}} = \frac{x}{[x^2+y^2]^{1/2}} \quad \text{— ②}$$

Substitute ② into ①, we have

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

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

Recall $dl = dy$

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

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

equ. ③

Using special integrals

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

Equation ③ becomes

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

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

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

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 larger than x,

$$[x^2 + a^2]^{1/2} \cong a, \text{ as } a \to \infty$$

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

In a physical situation, we have axial symmetry about the y-axis. Thus, at all points in a circle of radius r, around the conductor, the magnitude of B is $B = \frac{\mu_0 I}{2\pi r}$