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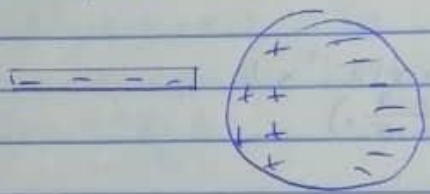
19/MHS01/022
Medicine and Health Sciences
Medicine and Surgery
PHY 102 Assignment (Covid-19 holiday)

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

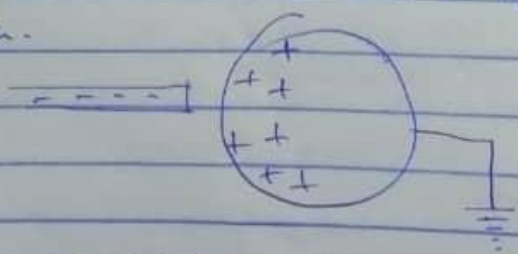
Answer:

Electric charge can be obtained on an object without touching it by a process called electrostatic Induction

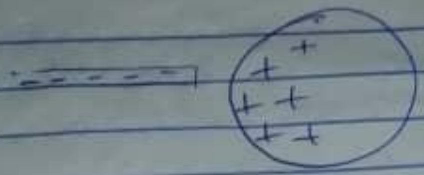
i) Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to the ground. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charge on the sphere so that some electrons move to the side of the sphere farthest away from the rod.



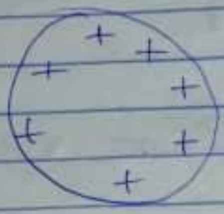
ii) The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded wire is then connected to the sphere, some of the electrons leave the sphere and travel to the earth.



iii) If the wire to ground is then removed, the conducting sphere is left with an excess of induced positive charge



iv) 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



b) $K = 9 \times 10^9$

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

$F = 1.0N$

$r = 2m$

charge on each sphere?

Recall that

$$F = \frac{k q_1 q_2}{r^2}$$

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

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

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

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

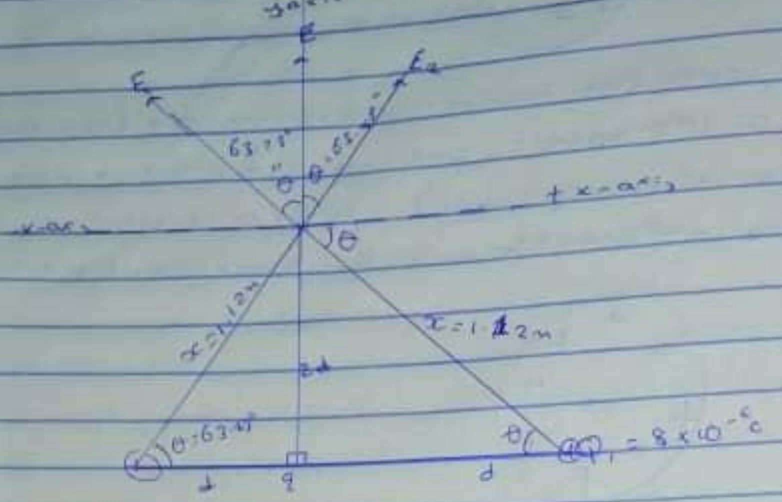
$$q_1 = 0.0000111 C$$

$$q_2 = 0.000038C$$

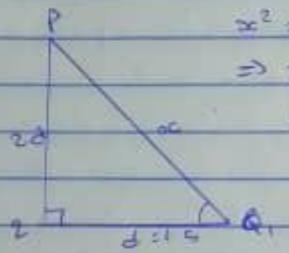
$$\simeq q_1 = 1.11 \times 10^{-5} C$$

$$\simeq q_2 = 3.8 \times 10^{-5} C$$

1C



Using Pythagoras theorem



$x^2 = 1^2 + (0.5)^2 = 1.25$

$\Rightarrow x = \sqrt{1.25} = 1.12m$

$\tan\theta = \left(\frac{1}{0.5}\right) \Rightarrow \theta = \tan^{-1} 2$

$\therefore \theta = 63.43°$

For $E_1 = \frac{kq_1}{r^2} = (9\times10^9 Nm^2/C^2) \times \left(\frac{8\times10^{-6}C}{(1.12m)^2}\right) = \frac{72000}{1.2544}$

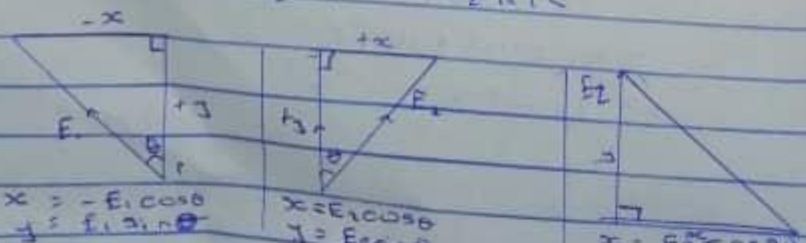
$\therefore E = 57397.9592\ N/C$

For $E_2 = \frac{kq_2}{r^2} = (9\times10^9 Nm^2/C^2) \times \left(\frac{8\times10^{-6}C}{(1.12m)^2}\right) = \frac{72000}{1.2544}$

$E_2 = 57397.9592\ N/C$

For $E_q = \frac{kq}{r^2} = (9\times10^9 Nm^2/C^2) \times \left(\frac{qC}{(1m)^2}\right) = 9.0\times10$

$E_q = 9.0\times10^9 q\ N/C$



$x = -E_1\cos\theta$
$y = E_1\sin\theta$

$x = E_2\cos\theta$
$y = E_2\sin\theta$

$x = E_q\cos 90$
$y = E_q\sin 90$

S/N	vector	Angle	x - component	y - component
1)	$E_1 = 57397.9592$	$63.43°$	$-E_1 \cos\theta = -57397.9592 \cos 63.43$	$E_1 \sin\theta = 57397.9592 \sin 63.43$
			$= -25700.4579 N/C$	$= 51336.0781 N/C$
2)	$E_2 = 57397.9592$	$63.43°$	$E_2 \cos\theta = 57397.9592 \cos 63.43$	$E_2 \sin\theta = 57397.9592 \sin 63.43$
			$= 25700.4579 N/C$	$= 51336.0781 N/C$
3)	$E_q = 9.0 \times 10^9 q$	$90°$	$E_q \cos 90 = 9.0 \times 10^9 q \cos 90$	$E_q \sin 90 = 9.0 \times 10^9 q \sin 90$
			$= 0 N/C$	$= 9.0 \times 10^9 q N/C$
			$\sum E_x = 0 N/C$	$\sum E_y = 102672.1562 + 9.0 \times 10^9 q N/C$

The magnitude of resultant electric field E_p at point P is

$$E_p = \sqrt{(\sum E_x)^2 + (\sum E_y)^2}$$

$$E_p = \sqrt{(0)^2 + (102672.1562 + 9.0 \times 10^9 q)^2}$$

$$E_p = \sqrt{0 + (102672.1562 + 9.0 \times 10^9 q)^2}$$

$$E_p = 102672.1562 + 9.0 \times 10^9$$

but charge at $P = 0$

$$\Rightarrow E_p = 0 = 102672.1562 + 9.0 \times 10^9 q$$

$$= -102672.156 = 9.0 \times 10^9 q$$

$$q = \frac{-102672.1562}{9.0 \times 10^9 q}$$

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

$$q = -11 \times 10^{-6} C = -11 \mu C$$

2) Electric field is the region of space in which an electric charge will experience an electric force. While Electric field strength (Intensity) is force per unit charge mathematically

$$E = \frac{F(N)}{q_0(C)}$$

Finding x - using pythagoras theorem

$$x^2 = 3^2 + 4^2$$

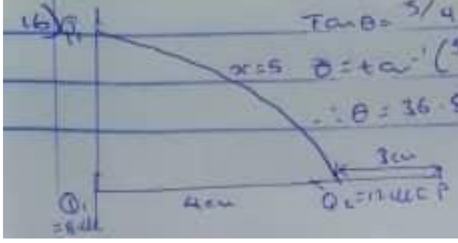
$$x = \sqrt{3^2 + 4^2} = 5$$

Let E be electric field at P as a result of Q, $k = 9 \times 10^9 N/C$

$$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{7^2} = 1.469 N/C$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-6}}{3^2} = 12 N/C$$

1b)



$\tan\theta = 3/4$

$\theta = \tan^{-1}(3/4)$

$\therefore \theta = 36.8°$

Electric field intensity $= E_1 + E_2$

$= 1.469 + 12 = 13.469 N/C$

(4) The magnetic flux is defined as the strength of magnetic field represented by lines of force. It is usually represented by the symbol ϕ

b) $m = 9.11 \times 10^{-31}$ kg

$r = 1.4 \times 10^{-1}$ m

$B = 3.5 \times 10^{-1}$ weber/meter^2

Cyclotron frequency = angular speed.

~~ω~~ = From the equation $v = \omega r$

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

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 9.11 \times 10^{-31}}$$

$$\omega = 6222222\ 22 \cancel{4} T^{-1}$$

c) The unknown was the f cyclotron frequency which is equal or the same thing as angular speed. Cyclotron frequency is the frequency of an accelerator called cycloton. Since cycloton frequency is equal to angular speed, the cycloton frequency is equal to the unit of frequency dimensionally.

b)

Vector	Angle	X-component	Y-component
$E_1 = 1.469 N/C$	$90°$	$E_{1x} = 1.469 \cos 90°$ $= 0$	$E_{1y} = 1.469 \sin 90°$ $= 1.4894$
$E_2 = 12 N/C$	$36.8°$	$E_{2x} = 12 \times \cos 36.8$ $= 9.6$	$E_{2y} = 12 \times \sin 36.8$ $= 7.188$
		$\Sigma f_x = 9.6 N/C$	$\Sigma f_y = 8.677 N/C$

The magnitude of resultance electric field E at point P is

$$E = \sqrt{\Sigma f_x^2 + \Sigma f_y^2}$$

$$= \sqrt{9.6 - 8.677^2}$$

$$\therefore E = 0.960 N/C$$

3) a) Biot-Savart law states that the magnetic field at a point of a wire carrying a current is directly proportional to the length of the wire and current and inversely proportional to the squares of distance between length and the point.

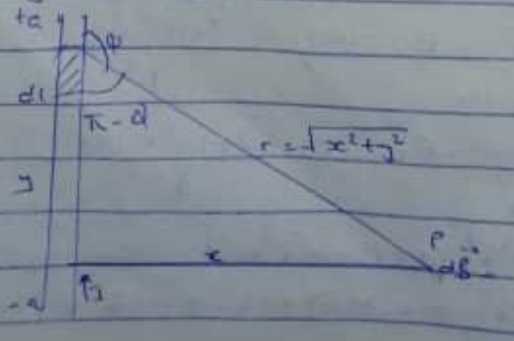
The expression is given by:

$$d\vec{B} = \frac{\mu_0 I d\vec{l} \times \hat{r}}{4\pi r^2}$$ where $\mu_0 = 4\pi \times 10^{-7} T.m/A$ called permeability of free space

b) From biot-savart law

$$dB = \frac{\mu_0}{4\pi}\int \frac{I d\vec{l} \sin\theta}{r^2}$$

Applying the law to the magnetic field of a straight line carrying conductor.



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

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

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

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

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

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

Substituting equation two 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 $dl = dy$

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

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

Using special integrals

Equation (iii) therefore 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 longer than x.

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

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