Sub (xx) into (x)

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

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

But $dl = dy$

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

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

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 (xxx) 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 $k = 9 \times 10^9$

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

$F = 1N$

$d = 2m$

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

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

$\cancel{4 = 9 \times 10^9 (q_1 q_2)}$

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

$4 = 4.5 \times 10^5 q_1 + 9 \times 10^9 q^2$ → using quadratic equation

$9 \times 10^9 q^2 - 4.5 \times 10^5 q_1 + 4 = 0$

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

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

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

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 $x$,

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

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

In a physical situation, we have axial symmetry above the y-axis, Thus, at all points in a circle of radius, r, around the conductor the magnitude of B is

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{——— (7)}$$

Equation (7) defines the magnitude of the magnetic field of flux density B near a long straight current carrying conductor.

2 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 ~~charge~~ strength is defined as the force per unit charge, it is the magnitude of electric field

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


$$E_1 = \frac{kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2} = 1.469 NC^{-1}$$

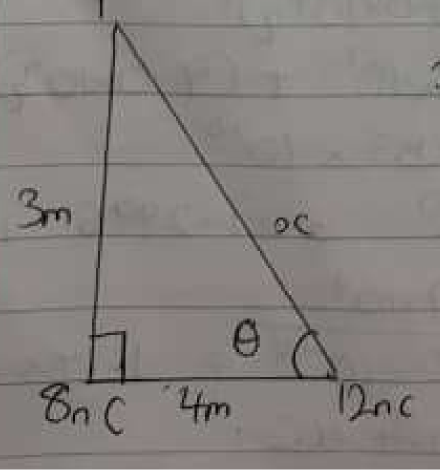
$$E_2 = \frac{kq_2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{3^2} = 12 NC^{-1}$$

$$F_{net} = E_1 + E_2 = 1.469 NC^{-1} + 12 NC^{-1} = \cancel{13.146}$$

$$13.469 NC^{-1}$$

$$E_{net} = 13.5 NC^{-1}$$

bii




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

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

$$x = 5m$$

$$\theta = \sin^{-1}(3/5) = 36.9^\circ$$

$$\omega = \frac{qB}{m} = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times 10^{-31}}$$

$$\omega = \cancel{6222222.2222}\,T^{-1}$$

$$62222222222.22222T^{-1}$$

4c In the question

mass of electron $= 9.11\times10^{-31}kg$

radius $= 1.4\times10^{-7}m$

magnetic field $= 3.5\times10^{-1}weber/m^2$

We were asked to find cyclotron frequency which is equal to angular speed.

It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron.

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

Substituting we have $\omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6\times10^{-10} \times 3.5\times10^{-10}}{9.11\times10^{-31}}$

$= 62222222222.22222T^{-1}$

So since cyclotron frequency is equal to angular speed the cyclotron frequency is ~~the~~ $62222222222.22222T^{-1}$, having a unit as $1/T$ which is equal to the unit of frequency dimensionally.

$$\mathcal{E}_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8NC^{-1}$$

$$\mathcal{E}_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 4.32NC^{-1}$$

| Vector | Angle | x component | y component |
|---|---|---|---|
| $8NC^{-1}$ | $90°$ | $8 \times \cos 90 = 0NC^{-1}$ | $8 \sin 90 = 8NC^{-1}$ |
| $4.32NC^{-1}$ | $36.9°$ | $4.32 \cos 36.9 = 3.45$ | $4.32 \sin 36.9 = 2.60NC^{-1}$ |
| | | $\mathcal{E}_x = 3.45NC^{-1}$ | $\mathcal{E}_y = 10.60NC^{-1}$ |

$$\mathcal{E}_{net} = \sqrt{\Sigma \mathcal{E}_x^2 + \Sigma \mathcal{E}_y^2}$$

$$\mathcal{E}_{net} = \sqrt{3.45^2 + 10.60^2} = \sqrt{124.2625}$$

$$\mathcal{E}_{net} = 11.142NC^{-1} \simeq 11.5NC^{-1}$$

Section B

4a Magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol.

b $m = 9\times10^{-31} kg$

$r = 1.4\times10^{-7} m$

$B = 3.5\times10^{-1} w/m^2$

Cyclotron frequency = angular speed.

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

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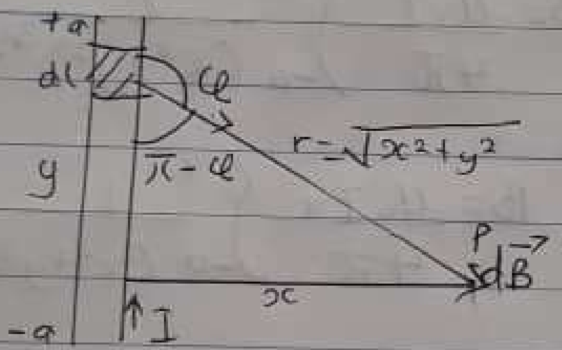
19/MHS01/088
Physics 102

1a Electric charges can be obtained without touching it, by a process called ~~electrost~~ electrostatic induction. Consider a positively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to ground as shown below. The repulsive force between the protons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some protons move to the side of the sphere farthest away from the rod. The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of ~~phot~~ protons away from this location. If a grounded conducting wire is then connected to the sphere, some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed, the conducting sphere is left with ~~on~~ an excess of induced negative charge.
Finally, when ~~the~~ the rubber is removed from the vicinity of the sphere, the induced negatively charge ~~rem~~ remains on the ungrounded sphere and becomes uniformly distributed over the ~~surp~~ surface of the sphere.

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

b Magnetic field of a straight current carrying conductor:




Applying the Biot - Savart law, we find magnitude of field dB

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

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

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

from diagram $r^2 = x^2 + y^2$

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

But $\sin(\pi - \theta) = \dfrac{x}{\sqrt{x^2+y^2}} = \dfrac{x}{(x^2+y^2)^{1/2}}$ ←—— **

$$\mathcal{E}_1 = \mathcal{E}_2 = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-6}C}{1.12m^2} = 5.74\times10^4 NC^{-1}$$

$$\mathcal{E}_1 = \mathcal{E}_2 = 5.74 \times 10^4 NC^{-1}$$

$$\mathcal{E}_q = \frac{9\times10^9 Nm^2C^{-2} \times q}{1^2} = 9\times10^9 q\ NC^{-1}$$

| Forces ($NC^{-1}$) | Angles | x component | y component |
|---|---|---|---|
| $5.74\times10^4$ | $63.43°$ | $5.74\times10^4 \cos 63.43 = +2.57\times10^4$ | $5.74\times10^4 \sin 63.43 = 5.13\times10^4$ |
| $5.74\times10^4$ | $63.43°$ | $5.74\times10^4 \cos 63.43 = -2.57\times10^4$ | $5.74\times10^4 \sin 63.43 = 5.13\times10^4$ |
| $9\times10^9 q$ | $90°$ | $9\times10^9 q \cos 90° = 0$ | $9\times10^9 q \sin 90° = 9.0\times10^9 q$ |
| | | $\Sigma x = 0 Nc$ | $\Sigma y = 1.026\times10^5 NC^{-1} + 9.0\times10^9 q$ |

$$\mathcal{E}_q = \sqrt{\Sigma x^2 + \Sigma y^2}$$

$$\sqrt{(0)^2 + ((1.026\times10^5)^2 + (9.0\times10^9 q)^2)}$$

$$\sqrt{1.053\times10^{10} + (9.0\times10^9)^2}$$

But $\mathcal{E}q = 0$

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

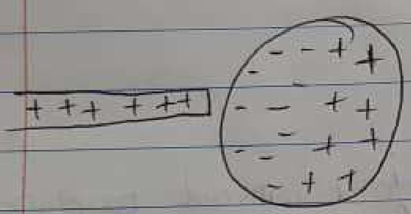
$$0 = 1.053\times10^{10} + (9.0\times10^9 q)^2$$

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

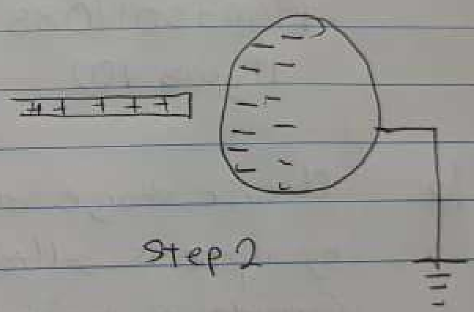
$$q^2 = \frac{1.053\times10^{10}}{9.0\times10^9} = 1.2996\times10^{-10}$$

$$q = \sqrt{1.2996\times10^{-10}} = 1.14\times10^{-5}C$$

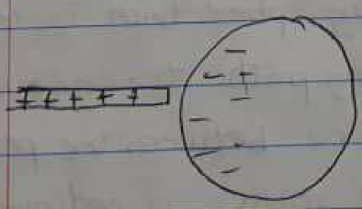
$q = 11.4\ \mu C$.



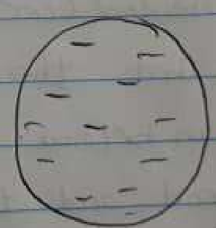
Step 1



Step 2

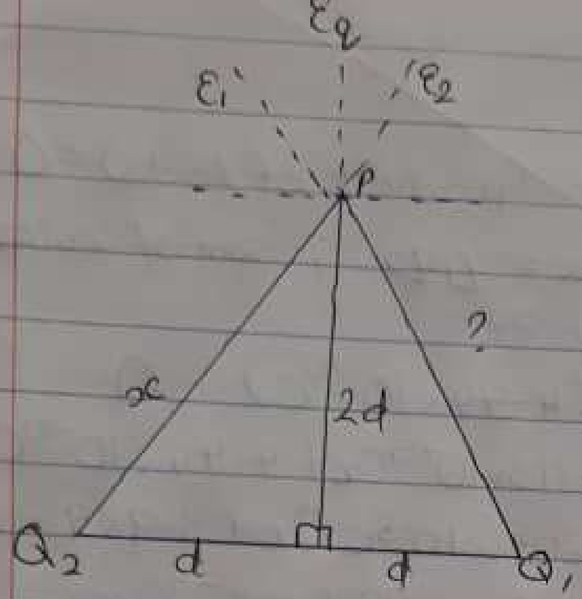


Step 3



The negatively charged sphere.

C




$Q_1 = Q_2 = 8\mu c$ ; Electric field at $P = 0$

To find 'x' using Pythagoras:

$x = \sqrt{2d^2 + d^2}$

$x = \sqrt{1^2 + 0.5^2}$

$x = \sqrt{1 + 0.25} = \sqrt{1.25}$

$x = \sqrt{\phantom{1}}\ 1.12m$

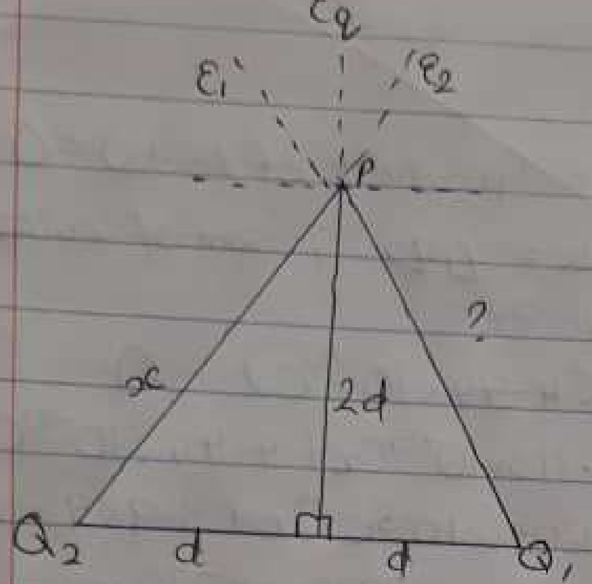
$\sin\theta = \frac{2d}{1.12}$ , $\cancel{\theta = 63}$ $\theta = 63.43°$

$\cos\theta = \frac{d}{1.12}$ ; $\theta = 26.56°$

$E = \frac{kq}{r}$

$Q_1 = Q_2$ Note $E = E_2$

C

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$\cos\theta = \frac{d}{1.12}$ ; $\theta = 26.56°$

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