Usman Zainab Damilola
19/MHS01/426
MBBS
PHY102 COVID19 ASSIGNMENT

- 1a Explanation
- Charging by Induction:
  Electric charges can be obtained on an object without touching it, by a process called 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 (fig. 1.3a). The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from this location. If a grounded conducting wire is then connected to the sphere, as in (fig. 1.3b), some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed (fig 1.3c), the conducting sphere is left with an excess of induced negative charge.
  Finally, when the rubber rod is removed from the vicinity of the sphere (fig. 1.3d), the induced negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.
  Diagram:

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

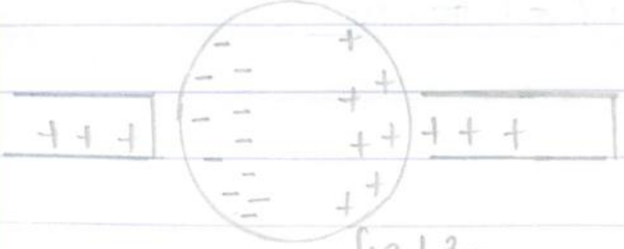


fig 1.3a

fig 1.3c

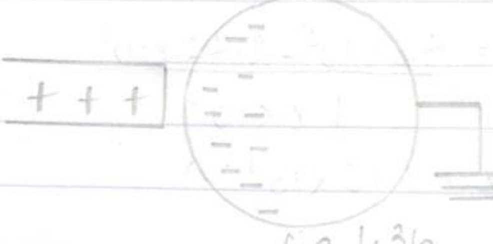


fig 1.3b

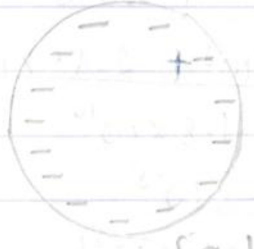


fig 1.3d

1b $q_1 + q_2 = Q_{Total} = 5.0 \times 10^{-5} C$

$f = 1.0N$

$r = 2.0m$

$q_1 = ?\ , \ q_2 = ?$

$q_1 + q_2 = 5.0 \times 10^{-5} C$

$q_1 = 5.0 \times 10^{-5} C - q_2$

$K = 9 \times 10^{9} Nm^2/c^2$

from Coulomb's law, $f = \dfrac{kq_1 q_2}{r^2}$

$$\frac{1.0}{1} = \frac{(9 \times 10^9)(5.0 \times 10^{-5} - q_2)(q_2)}{2^2}$$

$(9 \times 10^9)(5.0 \times 10^{-5} - q_2)(q_2) = 4$

$(4.5 \times 10^5 - 9 \times 10^9 q_2) q_2 = 4$

$4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2 = 4$

$9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$

Solving quadratically; $a = 9 \times 10^9$, $b = -4.5 \times 10^5$, $c = 4$

Using formula method; $x = \dfrac{b^2 \pm \sqrt{b^2 - 4ac}}{2a}$

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

$$x = \frac{4.5\times10^5 \pm \sqrt{(2.025\times10^{11} - 1.44\times10^{11}}}{1.8\times10^{10}}$$

$$x = \frac{4.5\times10^5 \pm \sqrt{5.85\times10^{10}}}{1.8\times10^{10}}$$

$$x = \frac{4.5\times10^5 \pm 2.42\times10^5}{1.8\times10^{10}}$$

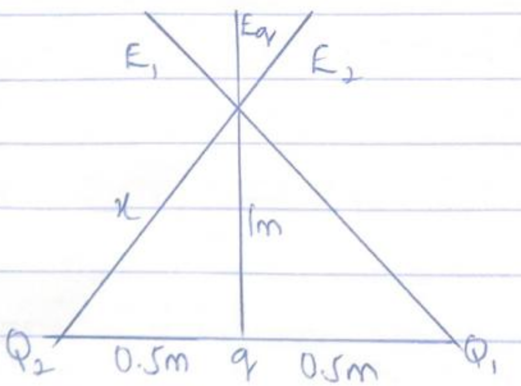
$x = \frac{4.5\times10^5 + 2.42\times10^5}{1.8\times10^{10}}$ or $x = \frac{4.5\times10^5 - 2.42\times10^5}{1.8\times10^{10}}$

$x = 3.84\times10^{-5}$ $x = 1.16\times10^{-5}.$

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

$q_2 = 1.16\times10^{-5}C.$

1c



$d = 0.5m$

$Q_2 = Q_1 = 8\times10^{-6}C$

$E_2 = E_1$

Using Pythagoras theorem

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

$$x = \sqrt{1^2 + 0.5^2} = \sqrt{1.25}$$

$$x = 1.12m$$

$\text{Tan}\,\theta = \frac{\text{Opp}}{\text{Adj}}$ $\theta = \text{Tan}^{-1}\left(\frac{1}{0.5}\right) = 63.43°$

$\therefore \theta = 63.43°$

1c contd. and 4a

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = \frac{72000}{1.2544} = 57397.95918 N/C$

$E_1 = E_2 = 57397.95918 N/C$

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

Vector	Angle	X-component	Y-Component
$E_1 = 57397.95918$	63.4°	$-E_1\cos\theta = 57397.95918\cos63.4^\circ = -25700.45785 N/C$	$E_1\sin\theta = 57397.95918\sin63.4^\circ = 51322.62839 N/C$
$E_2 = 57397.95918$	63.4°	$E_2\cos\theta = 57397.95918\cos63.4^\circ = 25700.45785 N/C$	$E_1\sin\theta = 57397.95918\sin63.4^\circ = 51322.62839 N/C$
$E_q = 9\times10^9 q$	90°	$E_q\cos\theta = 9\times10^9 q\cos90^\circ = 0 N/C$	$E_q\sin\theta = 9\times10^9 q\sin90^\circ = 9\times10^9 q N/C$
		$\Sigma E_x = 0 N/C$	$\Sigma E_y = 102645.2568 + 9\times10^9 q N/C$

$E = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$

$= \sqrt{0^2 + (102645.2568 + 9\times10^9 q)^2}$

$E = 102645.2568 + 9\times10^9 q$

Since Electric field at P is 0, $E = 0$

$0 = 102645.2568 + 9\times10^9 q$

$-102645.2568 = 9\times10^9 q$

$q = \frac{-102645.2568}{9\times10^9}$

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

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

$q = -11.4 \mu C$.

4a What is Magnetic flux?

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 given as $\phi = B.dA$.

4b An electron with a rest mass of $9.11\times10^{-31}kg$ moves in a circular orbit of radius $1.4\times10^{-7}m$ in a uniform magnetic field of 3.5×10^{-1} Weber/meter square, perpendicular to the speed with which electron moves. Find the cyclotron frequency of the moving electron.

Sol

$M_e = 9.11\times10^{-31}kg$

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

$B = 3.5\times10^{-1}T$

$\theta = 90^\circ$

$V_e = 3\times10^{8}ms^{-1}$

$\omega = ?$

$q = 1.6\times10^{-19}C$

The cyclotron frequency is also called angular speed (ω)

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

$\omega = \frac{1.6\times10^{-19}\times3.5\times10^{-1}}{9.11\times10^{-31}}$

$\omega = \frac{5.6\times10^{-20}}{9.11\times10^{-31}}$

$\omega = 6.15\times10^{10}rads^{-1}$

$\therefore$ Cyclotron frequency $= \underline{\underline{6.15\times10^{10}rads^{-1}}}$

4c Discuss your answer in 4b above.

In the question we were given parameters such as

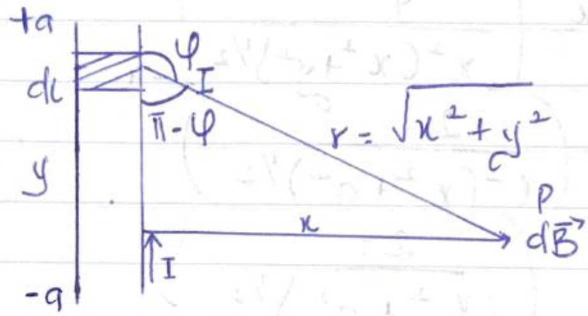
i) Mass of electron (m) $= 9.11\times10^{-31}kg$

ii) A radius of $1.4\times10^{-7}m$

iii) Magnetic field of 3.5×10^{-1} weber/meter^2

and you are asked to find the cyclotron frequency which is often referred to as angular speed (ω). It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron. Since cyclotron frequency = Angular speed (ω). Using the formula $\omega = \frac{v}{r} = \frac{qB}{m}$ we can derive the cyclotron frequency.

56)



A Section of a straight current carrying conductor

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

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

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

Substituting (**) into (*), 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 $dl = dy$

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

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

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 (***) 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 larger than x,

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

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

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

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

This equation defines the magnetic field of flux density B near a long, straight current carrying conductor.

State Biot-Savart law

5a Mathematically, Biot savart Law;

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

where μ_0 is a constant called Permeability of free space

$$\mu_0 = 4\pi \times 10^{-7}\,\text{T.m/A}.$$

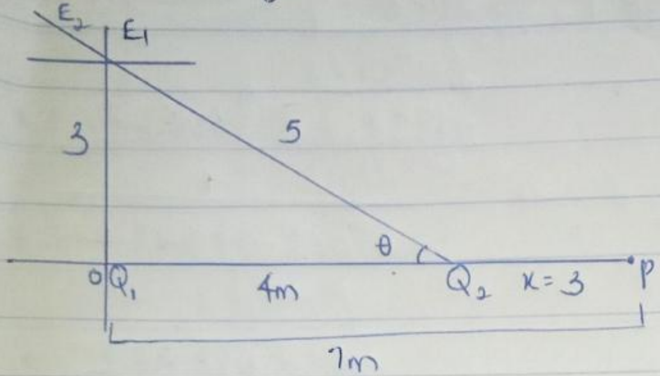
Biot Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length (dl) and the radius and inversely proportional to the square of radius (r^2).

2

2a) Distinguish between the terms Electric field and electric field intensity.

Electric field is the region of space in which an electric charge will experience an electric force WHILE Electric field intensity is the force per unit charge. Its unit is Newton per coulomb (N/C).

2b



$\tan\theta = \frac{opp}{Adj}$ $\theta = \tan^{-1}\left(\frac{opp}{Adj}\right) = \tan^{-1}\left(\frac{3}{4}\right) = \tan^{-1}(0.75) = 36.9^\circ$

$\therefore \theta = 36.9^\circ$.

i) $E_{net} = E_1 + E_2$

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 3\times10^{-9}}{7^2} = 1.469 N/C$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9\times12\times10^{-9}}{3^2} = 12N/C$

$E_{net} = (12 + 1.469) N/C$

$E_{net} = 13.469 N/C \simeq 13.5 N/C$

ii) $E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9\times12\times10^{-9}}{5^2} = 4.32 N/C$

Vector	Angle	X-component	Y-component
$E_1 = 8N/C$	90°	$E\cos\theta = 0$	$E\sin\theta = 8\sin 90^\circ = 8$
$E_2 = 4.32N/C$	36.9°	$-E\cos\theta = -4.32\cos 36.9^\circ = -3.45$	$E\sin\theta = 4.32\sin 36.9^\circ = 10.59$
		$\Sigma E_x = -3.45 N/C$	$\Sigma E_y = 10.59 N/C$

$E_{net} = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$

$E_{net} = \sqrt{(-3.45)^2 + (10.59)^2} = \sqrt{11.9025 + 112.1481}$

$E_{net} = \sqrt{124.0506}$

$E_{net} = 11.13 N/C$