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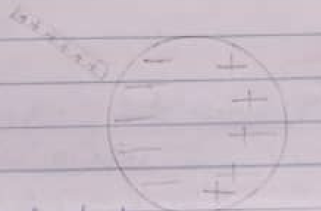
DEPT: MBBS
MATRIC NO: 18/MHS01/300
COURSE: PHY 102

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

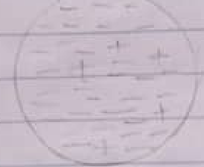
Answer

In order to produce a negatively charged sphere by induction, a positively charged rod is brought near an uncharged or neutral conducting sphere that has been insulated so that there is no conducting path to the ground. A redistribution of charges occurs as negative charges move toward the direction of the positively charged rod and positive charges move away from it to the other side of the sphere. Now when the sphere is earthed, the electrons from earth flow to the sphere through the conducting wire to neutralize the positive charge in the sphere. When the conducting wire and the positively charged rod are removed, the negative charges get distributed over the metal surface and the sphere gets negatively charged.



Positively charged rod is brought near an uncharged sphere and charge are redistributed

when the sphere is earthed, negative charges flows into the sphere to neutralize the positive charges, making the sphere negatively charged.



The charges in the sphere are distributed around it as the positively charged rod and grounded conducting wire are removed.
The sphere now has more negative charges and thus becomes ~~positively~~ negatively charged.

b. Each of two small sphere is charged positively, the combined charge being $5.0\times10^{-5}C$. If each sphere is repelled from the other by a force of 1.0N when the spheres are ~~positioned~~ 2.0m apart, calculate the charge on each sphere.

Answer

Combined charge $= 5.0\times10^{-5}C$ $\therefore$ $q_1 + q_2 = 5.0\times10^{-5}C$ — — — (i)

then, $q_1 = 5.0\times10^{-5} - q_2$ — — — — (ii)

Remember that $F = \frac{kq_1q_2}{r^2}$ — — — (iii)

Replacing q_1 with $5.0\times10^{-5} - q_2$ in (iii), we have:

Using pythagoras theorem, we have:

$r^2 = d^2 + (2d)^2$

$r^2 = 0.5^2 + 1^2$

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

$r = \sqrt{0.25 + 1}$

$r = \sqrt{1.25}$

$r = 1.12m$

finding the angle, we have:

$\tan\theta = \frac{1}{0.5}$

$\tan\theta = 2$

$\theta = \tan^{-1} 2$

$\theta = 63.43^0$

$E_1 = \frac{kq_1}{r^2} \Rightarrow \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} \Rightarrow \frac{7.2\times10^4}{1.2544}$

$E_1 = 57398$

$E_2 = \frac{kq_2}{r^2} \Rightarrow \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} \Rightarrow \frac{7.2\times10^4}{1.2544}$

$E_2 = 57398$

$E_q = \frac{kq}{r^2} \Rightarrow \frac{9\times10^9 \times q}{1}$ where distance btw q and P = 2d = 1

$E_q = 9\times10^9 q$

vector(E)	Angle(θ)	x component (horizontal)	y component (vertical)
57398	63.43°	$E_1\cos\theta = 25674$	$E_1\sin\theta = 51336$
57398	63.43°	$E_2\cos\theta = -25674$	$E_2\sin\theta = 51336$
$9\times10^9 q$	90°	$E_q\cos\theta = 0$	$E_q\sin\theta = 9\times10^9 q$
		$\Sigma f_x = 0$	$\Sigma f_y = 102672 + 9\times10^9 q$

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

$E_p = \sqrt{0^2 + (102672 + 9\times10^9 q)^2}$

$E_p = \sqrt{(102672 + 9\times10^9 q)^2}$

$E_p = 102672 + 9\times10^9 q$

But from the question, E_p = Zero = 0

$\therefore 0 = 102672 + 9\times10^9 q$

$\therefore 9\times10^9 q = -102672$

$q = \frac{-102672}{9\times10^9}$

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

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

$q = -11\mu C$

2. a. Distinguish between the terms: electric field and electric field intensity

Answer

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 and can be mathematically represented as $E = \frac{F}{q}\frac{(N)}{(C)}$ measured in Newton per Coulomb (N/C).

b. A positive charge $Q_1 = 8nC$ is at the origin, and a second positive charge $Q_2 = 12nC$ is on the x-axis at $x = 4m$. Find

i. The net electric field at a point P on the x axis at $x = 7m$.

ii. The electric field at a point Q on the y axis at $y = 3m$ due to the charges.

Given that $F = 1.0N$ and $r = 2.0m$, (iii) becomes:

~~...~~ $F = \frac{k \times (5.0 \times 10^{-5} - q_2) q_2}{r^2} \Rightarrow 1.0 = \frac{9 \times 10^9 (5.0 \times 10^{-5} - q_2) q_2}{(2)^2}$

$1 = \frac{9 \times 10^9 (5.0 \times 10^{-5} q_2 - q_2^2)}{4} \Rightarrow 1 = \frac{4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2}{4}$

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

Rearranging, we have that: $9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$ — — — (iv)

Using the quadratic formula, we have:

$q_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ Where $a = 9 \times 10^9$, $b = -4.5 \times 10^5$, $c = 4$

$q_2 = \frac{4.5 \times 10^5 \pm \sqrt{(-4.5 \times 10^5)^2 - 4(9 \times 10^9)(4)}}{2(9 \times 10^9)}$

$q_2 = \frac{4.5 \times 10^5 \pm \sqrt{2.025 \times 10^{11} - 1.44 \times 10^{11}}}{1.8 \times 10^{10}}$

$q_2 = \frac{4.5 \times 10^5 \pm \sqrt{5.85 \times 10^{10}}}{1.8 \times 10^{10}} \Rightarrow q_2 = \frac{4.5 \times 10^5 \pm 2.4 \times 10^5}{1.8 \times 10^{10}}$

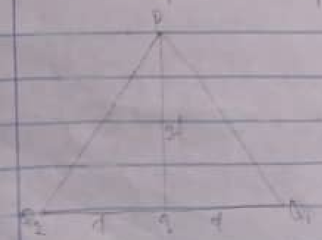
$q_2 = \frac{4.5 \times 10^5 + 2.4 \times 10^5}{1.8 \times 10^{10}}$ or $q_2 = \frac{4.5 \times 10^5 - 2.4 \times 10^5}{1.8 \times 10^{10}}$

$q_2 = \frac{6.9 \times 10^5}{1.8 \times 10^{10}}$ or $q_2 = \frac{2.1 \times 10^5}{1.8 \times 10^{10}}$

$q_2 = 3.83 \times 10^{-5} C$ or $q_2 = 1.17 \times 10^{-5} C$

$\therefore q_2 = 3.83 \times 10^{-5} C$ and $q_1 = 1.17 \times 10^{-5} C$ or vice versa.

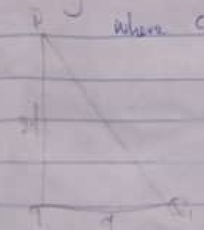
c. Three charges were positioned as shown in the figure below. If $Q_1 = Q_2 = 8\mu C$ and $d = 0.5m$, determine q if the electric field at P is zero.



~~...~~

Taking one side of the triangle, we have that.

where $d = 0.5$



5. State the Biot-Savart law

Answer

The Biot-Savart law states that the magnetic intensity at any point due to a steady current in an infinitely long straight wire is directly proportional to the current and inversely proportional to the distance from point to wire.

It can be discerned from this law that:

i. The vector $d\vec{B}$ is perpendicular both to $d\vec{l}$ and to the unit vector $\vec{r}$

ii. The magnitude of $d\vec{B}$ is inversely proportional to r^2

iii. The magnitude of $d\vec{B}$ is proportional to $\sin\theta$,

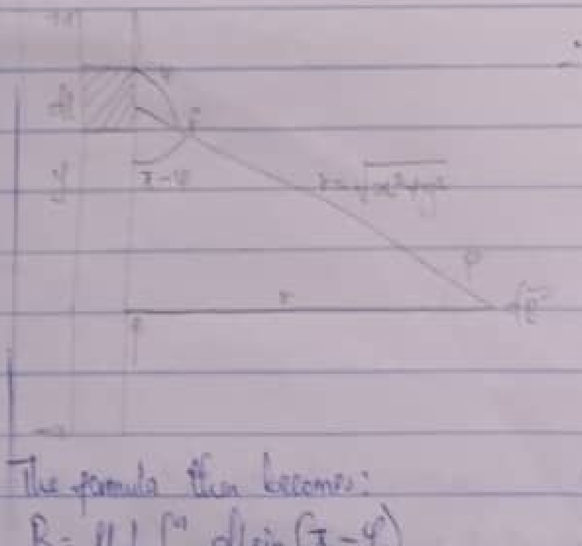
iv. The magnitude of $d\vec{B}$ is proportional to the current I

6. Using the Biot-Savart law, show that the magnitude of the magnetic field of a straight current-carrying conductor is given as $B = \dfrac{\mu_0 I}{2\pi r}$

Answer

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

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



considering the diagram $\sin(\pi - \varphi) = \sin\theta$

$\therefore$ the formula becomes:

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

Also from the diagram, $r^2 = x^2 + y^2$ (pythagoras theorem)

The formula then becomes:

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

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

Replacing the equivalent, we have:

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

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

But recall that $dl = dy$

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

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

Using special integral:

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

The equation now 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 lenght $2a$ 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,

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

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

Taking $q_1 = 8nC = 8\times10^{-9}$ and $q_2 = 12nC = 12\times10^{-9}$, we know that:

due to q_1, E_P becomes:

$$E_{P_1} = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = \frac{72}{49}$$

$E_{P_1} = 1.47$ N/C

due to q_2, E_{P_2} becomes:

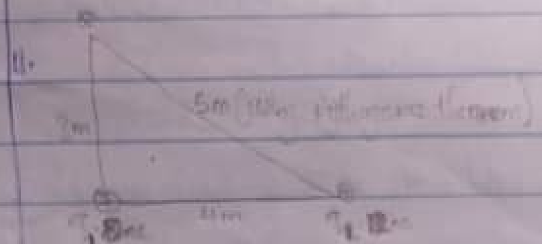
$$E_{P_2} = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = \frac{108}{9}$$

$E_{P_2} = 12$ N/C

Net electric field at $P = E_{P_1} + E_{P_2}$

$= 1.47 + 12 = \underline{13.47 \text{ N/C}}$

11.



Using pythagoras theorem to find r_2 we have:

$r_2 = \sqrt{4^2 + 3^2} \Rightarrow r_2 = \sqrt{16+9}$

$r_2 = \sqrt{25} \Rightarrow r_2 = 5m$

due to $q_1 = E_{Q_1}$ becomes:

$$E_{Q_1} = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = \frac{72}{9}$$

$E_{Q_1} = 8$ N/C

due to $q_2 = E_{Q_2}$ becomes:

$$E_{Q_2} = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = \frac{108}{25}$$

$E_{Q_2} = 4.32$ N/C

Net electric field at $Q = E_{Q_1} + E_{Q_2}$

$= 8 + 4.32 = \underline{12.32 \text{ N/C}}$

4. a. What is magnetic flux

Answer

Magnetic flux is defined as the number of magnetic field lines passing through a given closed surface. It gives the measurement of the total magnetic field that passes through a given surface area.

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

Answer

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

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

magnetic field $(B) = 3.5\times10^{-1}$ wb/m²

Using the formula for angular speed of a charge particle in a magnetic field, we know:

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

$$\omega = \frac{qB}{m} = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times10^{-31}} = \frac{5.6\times10^{-20}}{9.11\times10^{-31}}$$

$\omega = \underline{6.15 \times 10^{10} \text{ rad/s}}$

c. Discuss your answer in the above

Answer

Because the electron is moving in a circular orbit, the formula $\omega = \frac{v}{r}$ is used. But $r = mv/qB$. Replacing it, the formula $\omega = \frac{qB}{m}$ is deduced.

Replacing figures, 6.15×10^{10} rad/s was the speed of the electron which suggests that the moving electron circulates the [illegible] 61500000000 turns per second because of its small mass.

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 :

$$B = \frac{\mu_0 I}{2\pi r}$$ $\Rightarrow$ This equation defines the magnitude of the magnetic field of flux density B near a long, straight current-carrying conductor.