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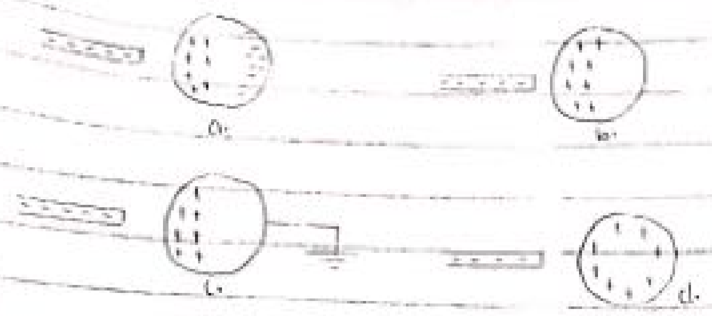
DEPARTMENT - MEDICINE AND SURGERY
NO 1A

Q. CHARGING BY INDUCTION



Electric charges can be obtained on an object without touching it, by a process called electrostatic induction.

As shown above, a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to ground as shown above. 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 furthest from the rod in figure a. 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 conducting wire is then connected to the sphere as in figure b, some of the electrons leave the sphere and travel to the earth. If the wire to the ground is then removed as in Figure c, the conducting sphere is left with an excess of induced positive charge.

Finally, when the rubber is removed from the vicinity of the sphere as in Figure d, the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

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NO 1B

b. $F = 1.0N$, $Q = q_1 + q_2 = 5.0\times10^{-5}$, $r = 2.0m$, $q_1 = ?$, $q_2 = ?$, $k = 9\times10^9$

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

$1.0 = \frac{9\times10^9 q_1 q_2}{2^2}$

$1.0 = \frac{9.0\times10^9 q_1 q_2}{4}$

$\frac{4}{9\times10^9} = \frac{\cancel{9\times10^9} q_1 q_2}{\cancel{9\times10^9}}$

$q_1 q_2 = 4.44\times10^{-10} C$

So, $q_1 q_2 = 4.44\times10^{-10}$ — eqn ①

$q_1 + q_2 = 5.0\times10^{-5}$ — eqn ②

$q_1 = 5.0\times10^{-5} - q_2$ — eqn ③

Put eqn ③ into eqn ①

$q_1 q_2 = 4.44\times10^{-10}$

$(5.0\times10^{-5} - q_2) q_2 = 4.44\times10^{-10}$

$-q_2^2 + 5.0\times10^{-5} q_2 = 4.44\times10^{-10}$

$-q_2^2 + 5.0\times10^{-5} q_2 - 4.44\times10^{-10} = 0$

Using: $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$\frac{-(5.0\times10^{-5}) \pm \sqrt{(5.0\times10^{-5})^2 - 4(-1)(-4.44\times10^{-10})}}{2(-1)}$$

$= 1.1\times10^{-5}$ or 3.8×10^{-5}

$\therefore q_1 = 1.1\times10^{-5} C$, $q_2 = 3.8\times10^{-5} C$

OR $q_1 = 3.8\times10^{-5} C$, $q_2 = 1.1\times10^{-5} C$

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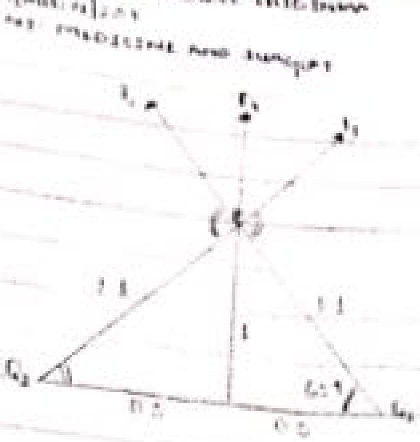
NO 16

1.



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

$x^2 = 1.25$

$x = 1.1$

$\tan\theta = \frac{1}{0.5} = 2$

$\theta = \tan^{-1} 2, \ \theta = 63.4$

$F_R = F_1 + F_2 + F_q$

$F_1 = \frac{kq_1}{r^2}$

$= \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2} = \frac{72000}{1.2544}$

$= 59504N$

$F_2 = \frac{kq_2}{r^2}$

$= \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2} = \frac{72000}{1.2544}$

$= 59504N$

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

$= \frac{9\times10^9 \times q}{1^2}$

$= 9\times10^9 q \ N$

VECTOR	ANGLE	X-COMPONENT	Y-COMPONENT
$F_1 = 59504N$	$63.4°$	$-59504 \cos 63.4°$ $= 26643N$	$59504 \sin 63.4°$ $= 53205N$
$F_2 = 59504N$	$63.4°$	$59504 \cos 63.4$ $= 26643N$	$59504 \sin 63.4$ $= 53205N$
$F_q = 9\times10^9 q \ N$	$90°$	$9\times10^9 q \cos 90$ $= 0$	$9\times10^9 q \sin 90°$ $= 9\times10^9 q$
		$\Sigma F_x = 0$	$\Sigma F_y = 106410 + F_q$

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NO 1C CONT'D

c. $T_P = 80^2 + (106410 + 9\times10^9 q)^2$

$T_P = 106410 + 9\times10^9 q$

Recall, $T_P = 0$

$106410 + 9\times10^9 q = 0$

$$\frac{9\times10^9 q}{9\times10^9} = \frac{-106410}{9\times10^9}$$

$q = -1.1\times10^{-5}$

$q = -11\times10^{-6}C$ or $-11\mu C$

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NO 2A

a. - An Electric field is a region of space in which an electric charge will experience an electric force.

- Since force is a vector quantity, the electric field is also a vector quantity;
- Any particle with a charge creates an electric field.

WHILE,

- Electric Field Intensity, is the force experienced by a test charge in an electric field
- Therefore it can be defined as force per unit charge. Mathematically,

$E = \frac{F}{q_0}$; F - Force , q_0 - test charge.

- It is measured in Newton per Columb (NC^{-1})
- The dimensions are $MLT^{-3}I^{-1}$

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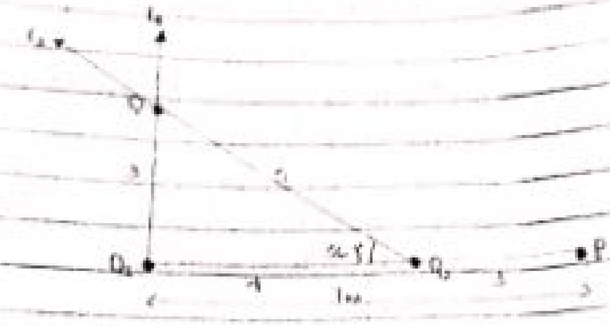

$r^2 = 3^2 + 4^2 = 25$

$r = 5m$

$\tan\theta = \frac{3}{4} = 0.75$

$\theta = \tan^{-1} 0.75 = 36.9°$

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

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = \frac{72}{49}$

$= 1.469NC^{-1}$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = \frac{108}{9}$

$= 12NC^{-1}$

$E_{net}P = 1.469 + 12.0$

$= 13.469NC^{-1} \approx 13.5NC^{-1}$

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

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = \frac{72}{9} = 8.0NC^{-1}$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = \frac{108}{25} = 4.320NC^{-1}$

VECTOR	ANGLE	X-COMPONENT	Y-COMPONENT
$E_1 = 8.0NC^{-1}$	90°	$8.0\cos 90°$ $= 0°$	$8.0\sin 90°$ $= 8.0$
$E_2 = 4.32$	36.9°	$-4.32\cos 36.9$ $= -3.45$	$4.32\sin 36.9$ $= 2.59$
		$\Sigma_{Ex} = -3.45$	$\Sigma E_y = 10.59$

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

$= \sqrt{(-3.45)^2 + (10.59)^2}$

$= \sqrt{(11.90) + (112.14)}$

$= \sqrt{124}$

$= 11.14NC^{-1}$

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NO 4 A, B

a. Magnetic flux is defined as the strength of a magnetic field represented by lines of force. It is usually represented by the symbol ϕ.
The symbol $\phi = \vec{B} \cdot d\vec{A}$, where B is the magnitude of the magnetic field and $d\vec{A}$ is the area on an arbitrary shaped surface.
$\phi = BA\cos\theta$

i. The flux through the plane is zero when magnetic field is parallel, $\theta = 90$, to the plane surface.

ii. The flux through the plane is maximum when the magnetic field is perpendicular, $\theta = 0°$, to the plane.

b. Cyclotron frequency, $\omega = ?$, mass $= 9.11 \times 10^{-31}$ kg, radius $= 1.4 \times 10^{-4}$ m, $B = 3.5 \times 10^{-1}$ Tesla
Perpendicular, $\theta = 90°$, $q = 1.6 \times 10^{-19}$

$F_B = qVB\sin\theta$, $\theta = 90°$

$F_B = qVB$

$F_B = qVB = \frac{mv^2}{r}$

Since the electron moves in a circular orbit, $r = \frac{mv}{qB}$ becomes

$m_e v = qBr$

$v = \frac{qBr}{m_e}$

$V = \frac{(1.6 \times 10^{-19}) \times (3.5 \times 10^{-1}) \times (1.4 \times 10^{-4})}{9.11 \times 10^{-31}} = 7.84 \times 10^{-24}$

$= 8.606 \times 10^{13}\ ms^{-1}$

Hence, angular speed i.e cyclotron frequency:

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

$= \frac{(1.6 \times 10^{-19}) \times (3.5 \times 10^{-1})}{9.11 \times 10^{-31}}$

$= \frac{5.6 \times 10^{-20}}{9.11 \times 10^{-31}}$

$= 6.147 \times 10^{10}\ rads^{-1}$

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c. Cyclotron frequency is the frequency of a charged particle moving perpendicular to the direction of a uniform magnetic field B.
The net force experienced by a charged particle by Newton's second law i.e. $F = ma$.
Because the motion of the charged particle is a uniform circular motion, we replace the acceleration a with centripetal acceleration. So, it is given by the equality of centripetal force and magnetic Lorentz force:

$$F_B = qvB = \frac{mv^2}{r}.$$

The radius of the circular path is given as: $r = \frac{mv}{qB}$.

The angular speed i.e. cyclotron frequency of the particle is given as:

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

So, from above, the electron of mass 1.6×10^{-19} kg moving perpendicular at 90° to the magnetic field of 3.5×10^{-1} tesla in a circular motion of circular path radius 1.4×10^{-7} m. It is used to derive the cyclotron frequency from: $\omega = \frac{qB}{m}$ which therefore gives 6.197×10^{10} rads^{-1}.

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NO 5 A

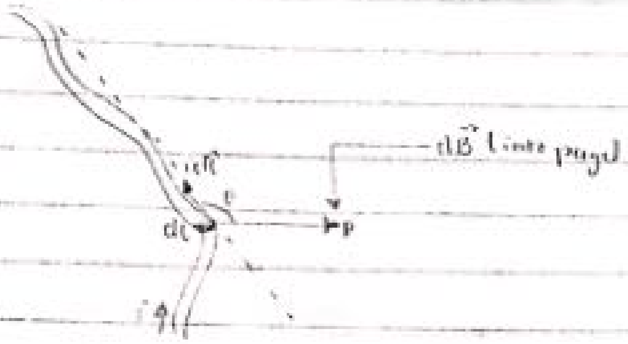
a. Biot-Savart Law states that:

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

Where μ_0 is a constant called Permeability of free space. Given as:

$$\mu_0 = 4\pi \times 10^{-12} \, T \cdot m/A$$

The Biot-Savart Law is based on the following observation for the magnetic field at point P associated with a length element $d\vec{l}$ of a wire carrying a steady current:



DESCRIPTIVE COMMENTARY FOR THE BIOT-SAVART EXPERIMENT

1. The vector $d\vec{B}$ is perpendicular both to $d\vec{l}$ (which points in the direction of the current) and to the unit vector $\hat{r}$ directed from $d\vec{l}$ toward P.
2. The magnitude of $d\vec{B}$ is inversely proportional to r^2, where r is the distance from $d\vec{l}$ to P.
3. The magnitude of $d\vec{B}$ is proportional to the current I and to the magnitude of the length element $d\vec{l}$.
4. The magnitude of $d\vec{B}$ is proportional to $\sin\theta$, where θ is the angle between $\hat{r}$ and $d\vec{l}$.

These observations are summarized in the mathematical expression known as Biot-Savart Law.

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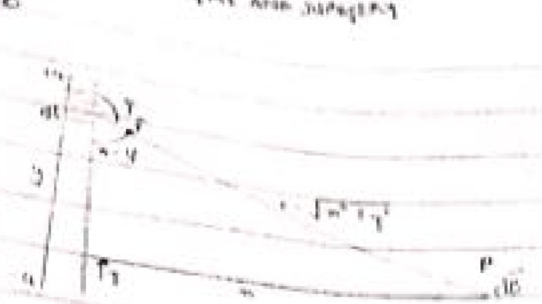

A SECTION OF A STRAIGHT CURRENT CARRYING CONDUCTOR

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

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

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

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

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

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin(\pi-\psi)}{x^2+y^2} \quad - \text{eqn } ①$$

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

Substituting ② into ①

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

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

Recall $dl = dy$

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

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

Using special integrals:

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

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NO 3B (CONT'D)

∴ 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 longer than x,

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

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

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:

$$B = \frac{\mu_0 I}{2\pi r} \qquad \text{- eqn (Z)}$$

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