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ANSWERS TO NOS 1, 3, 4 & 5.

1a) CHARGING BY INDUCTION

Electric charges can be obtained on an object without touching it, by a process called electrostatic induction. Consider a negatively charged rubber rod brought near a neutral conducting sphere that is insulated, so that there is no conducting path to ground. 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 farthest away from the rod (fig 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 (fig B) some of the electrons leave the sphere and travel to the earth. If the wire to ground is then removed (fig C) the conducting sphere is left with an excess of induced positive charge. Finally when the rubber rod is removed from the vicinity of the sphere (fig D) the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere

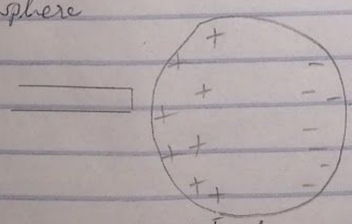


Fig A

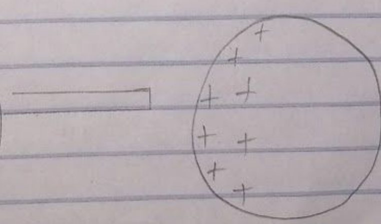


Fig C

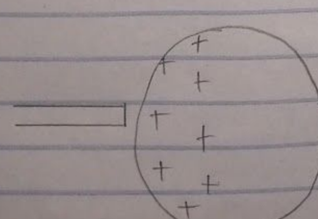


Fig B

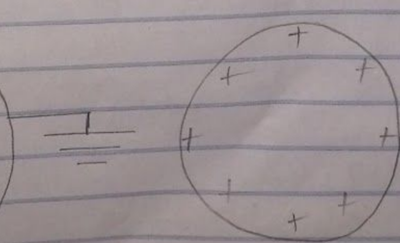


Fig D

1b) $k = 9 \times 10^{9}\ Nm^{2}/C^{2}$

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

$F = 1N$

$r = 2m$

$q_1 = ?$

$q_2 = ?$

$$F = \frac{kq_1q_2}{r^2}$$

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

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

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

Quadratic equation

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

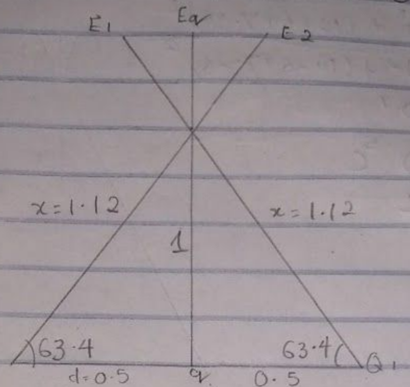
$q_1 = 0.0000111\ C \simeq 1.11 \times 10^{-5} C$

$q_2 = 0.000038 C \simeq 3.8 \times 10^{-5} C$

k) $Q_1 = Q_2 = 8\mu C$

$r = 0.5m$

If electric field at a point P is 0



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

$x^2 = 1 + 0.25$

$x^2 = 1.25$

$x = \sqrt{1.25}$

$x = 1.12$

$\tan\theta = \frac{opp}{adj}$

$\tan\theta = 1/0.5$

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

$\theta = 63.4^\circ$

$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2}$$

$$= 57397.96$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2}$$

$$= 57397.96$$

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

VECTOR	ANGLE	X COMPONENT	Y COMPONENT
$E_1 = 57397.96$	63.4°	$E_1\cos\theta = 25700.46$	$E_1\sin\theta = 51322.63$
$E_2 = 57397.96$	63.4°	$E_2\cos\theta = 25700.46$	$E_2\sin\theta = 51322.63$
$E_q = 9\times10^9 q$	90°	$E_q\cos\theta = 0$	$E_q\sin\theta = 9\times10^9 q$
		$\sum x = 51400.92$	$\sum y = 102647.26$

$E_q = \sqrt{(51400.92)^2 + (102647.26)^2}$

recall $E_q = 9\times10^9 q$

$9\times10^9 q = \sqrt{(51400.92)^2 + (102647.26)^2}$

$$q = \frac{\sqrt{(51400.92)^2 + (102647.26)^2}}{9\times10^9}$$

$q = 1.28\times10^{-5}C$

$q = 0.128\mu C$

3a) i Volume charge density, $\rho_q = \frac{Q}{V} = \rho_q = \frac{dQ}{dV}$

ii) Surface charge density, $\sigma_q = \frac{Q}{A} = \sigma_q = \frac{dQ}{dA}$

iii) Linear charge density, $\lambda_q = \frac{Q}{l}, = \lambda_q = \frac{dQ}{dl}$

3b) Electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to another, measured in volts (V) or Joules per coulomb (J/C)

$$dW = F.dl \quad — ①$$

but $F = -q_0E$ — ②

substitue equation ② in equation ①

$$dW = -q_0Edl$$

Total work done in moving test charge from a point A to a point B is

$$W(A \to B)_{A_1} = -q_0\int^{B} Edl \quad — ③$$

(4) Ma
rep
sym

4b) ma
ra
ma
cha
cy

4c) A
bec
spe

fro

from the definition it follows that

$$V_B - V_A = \frac{W(A \to B)\ Ag}{q_0} \quad — ⑤$$

substituting ④ in ⑤

$$V_B - V_A = -\int_A^B E dl \quad — ⑥$$

4) Magnetic flux is the strength of magnetic field represented by lines of force, usually represented by the symbol Φ, weber.

4b) mass of electron, $m = 9.11 \times 10^{-31}$ Kg
radius, $r = 1.4 \times 10^{-7}$ m
magnetic field, $B = 3.5 \times 10^{-1}$ Φm^{-2}
charge of electron, $q = 1.6 \times 10^{-19}$
cyclotron frequency = ?

angular speed, $\omega = \frac{v}{r} = \frac{qB}{m}$

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

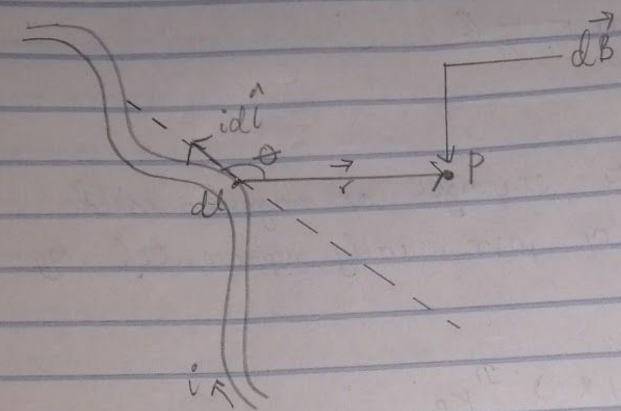
$$= 6.15 \times 10^{10}$$

4c) Angular speed, w is often referred to as cyclotron frequency because the charge particle circulates at this angular speed/frequency in the type of accelerelator called cyclotron

$\therefore$ angular speed = cyclotron frequency

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

(5) Biot-Savart law is an equation that describes the magnetic field created by a current-carrying wire, and is based on observations from the diagram below 5b)



1.) The vector $d\vec{B}$ is perpendicular to both $\vec{dl}$ and the unit vector $\hat{r}$ directed from $\vec{dl}$ toward P

2) The magnitude of $d\vec{B}$ is inversely proportional to r^2, where r is the distance from $\vec{dl}$ to P

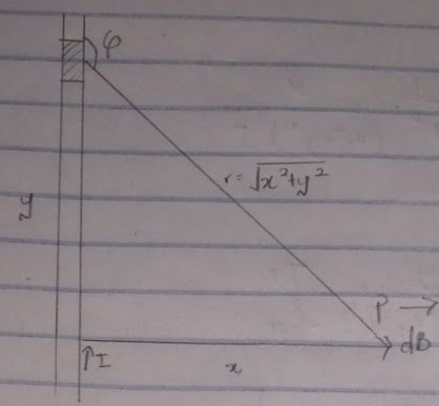
3) The magnitude of $d\vec{B}$ is proportional to the current I and to the magnitude of the length element $\vec{dl}$

4) The magnitude of $d\vec{B}$ is proportional to where θ is the angle between $\hat{r}$ and dl.

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

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

5b)



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

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

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

From the diagram $r^2 = x^2+y^2$

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

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

substituting $(**)$ into $(*)$ we get

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

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

Recall $dl = dy$

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

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

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

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

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

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

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

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

At all points in a circle of radius r, around a conductor, the magnitude of B is

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