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MATRIC NO:- 19/MHS01/295
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1a) Induction occurs when an object obtains electric charge without touching it. A positively charged rubber rod is 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 cause a re-distribution of charges on the sphere so that some electrons move to the side of the sphere closest to the rod. (Fig a). The region of the sphere closest to the positively charged rod has excess negatively charge because of the migration of electrons towards this location. If a grounded wire is then connected to the sphere (Fig b), some of the positive charge leave the sphere and travel to the earth. When the wire is removed (Fig c), the conducting sphere is left with an excess of induced positive charge. When the rubber rod is removed from the vicinity of the sphere (Fig d), the negative charges get distributed over the surface of the sphere.

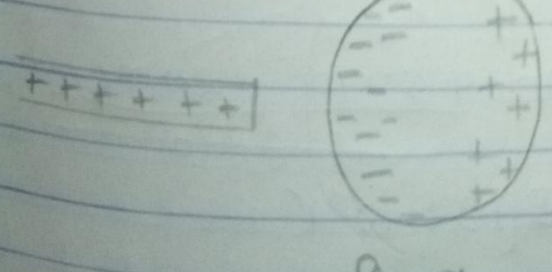


fig a

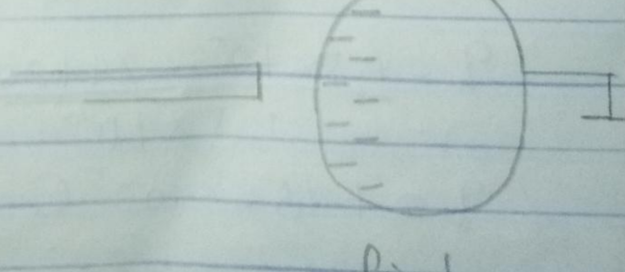
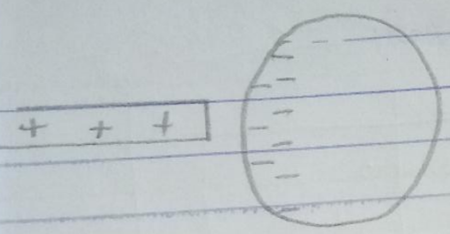
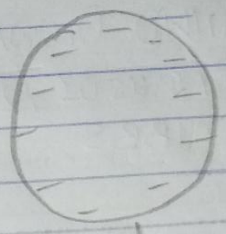


fig b



figC



figd

1b) $q_1 + q_2 = 5.0\times10^{-5}\,C$, $F = 1.0N$, $d = 2m$

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

$F = \dfrac{Kq_1q_2}{r^2}$

$1 = \dfrac{9\times10^{9}\times q_1\times5.0\times10^{-5} - q_1}{2^2}$

$4 = 4.5\times10^{5}q_1 - 9.0\times10^{9}q^2$

$9.0\times10^{9}q^2 - 4.5\times10^{5}q + 4 = 0$

$q = \dfrac{-b \pm \sqrt{b^2-4ac}}{2a}$

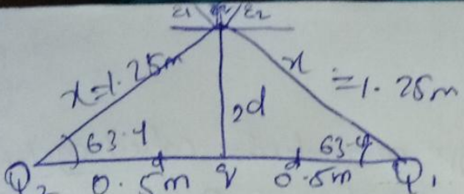
$q = \dfrac{-(-4.5\times10^{5}) \pm \sqrt{(-4.5\times10^{5})^2 - 4\times9.0\times10^{9}\times4}}{2\times9.0\times10^{9}}$

$q = \dfrac{4.5\times10^{5}\sqrt{5.85\times10^{10}}}{1.8\times10^{10}}$

$q = \dfrac{4.5\times10^{5} - 241867.7}{1.8\times10^{10}}$ or $\dfrac{4.5\times10^{5} + 241867.7}{1.8\times10^{10}}$

$q_1 = 1.156\times10^{-5}C$ or $3.843\times10^{-5}C$

1c)



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

$x = \sqrt{1+0.25}$

$x = 1.25m$

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

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

$\theta = 63.4^\circ$

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = 57397.96N/C$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9\times8\times10^{-6}}{1.12^2} = 57397.96N/C$

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

Vector	θ	x component	
E_1	63.4°	$57397.96\cos 63.4 = -25700.45$	$E_1\sin 63.4 = 51322.8$
E_2	63.4°	$E_2\cos 63.4 = 25700.45$	$E_2\sin 63.4 = 51322.8$
E_q	90°	$E_q\cos 90 = 0$	$E_q\sin 90 = 9\times10^9 q$
		$Ex = 0$	$Ey = 102645.26 + 90\times10^9 q$

$\text{Magnitude} = \sqrt{Ex^2 + Ey^2}$

$E_p = \sqrt{0^2 + (102645.26 + 9.0\times10^9 q)^2}$

Since $E = 0$

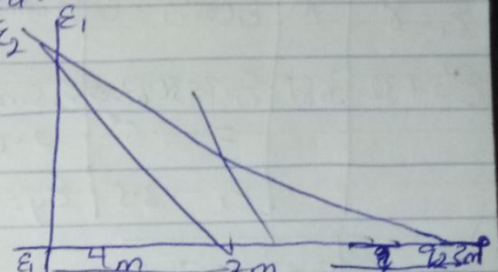
$0 = 102645.26 + 9\times10^9 q$

$q = -\frac{102645.26}{9\times10^9} = -1.14\times10^{-5}C$

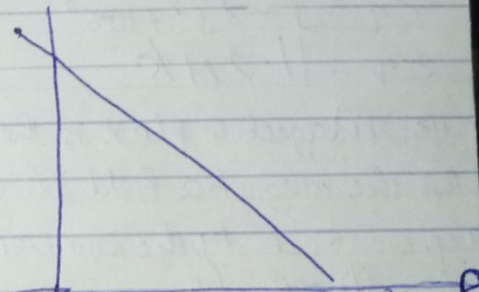
$q = -11.4\mu C$

2a.) Electric field is a region of space in which an electric charge will experience an electric force while electric field intensity is the force per unit charge. It is the magnitude of the field.

2b)



2b.



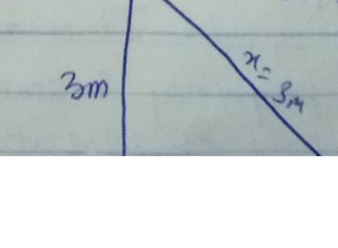
i) $E_1 = \frac{kq_1}{r^2} = 9\times10^9 \times 8\times10^{-9} = 1.5N/C$

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

$E_{net} = 12 + 1.5$

$= 13.5N/C$

ii.



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

$x = 5$

$\theta = \sin^{-1} 3/5$

$\theta = 36.87^\circ$

$$\varepsilon_1 = \frac{kq}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8\,N/C$$

$$\varepsilon_2 = \frac{kq}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 4.32\,N/C$$

Vector	θ	x-component	y-component
$\varepsilon_1 = 8$	90°	$\varepsilon_1 \cos 90^\circ = 0$	$\varepsilon_1 \sin 90^\circ = 8$
$\varepsilon_2 = 4.32$	36.87°	$\varepsilon_2 \cos 36.87 = -3.5^\circ$	$\varepsilon_2 \sin 36.87 = 2.6$
		$\varepsilon_x = -3.5$	$\varepsilon_y = 10.6$

$$\varepsilon_q = \sqrt{\varepsilon x^2 + \varepsilon y^2}$$
$$\varepsilon_q = \sqrt{-3.5^2 + 10.6^2}$$
$$\varepsilon_q = 11.2\,N/C$$

4a.) Magnetic flux is the strength of the magnetic field which is represented by the symbol Φ.

$$\Phi = B \cdot dA$$

4b.) $m = 9.11\times10^{-31}\,kg$,
$r = 1.4\times10^{-2}\,m$, $B = 3.5\times10^{-1}$ tesla

$$\omega = \frac{qB}{m} = \frac{1.6\times10^{-11} \times 3.5\times10^{-1}}{9.11\times10^{-31}}$$

$$W = 6.147\times10^{10}\ rad/s$$

c.) You were asked to find the cyclotron frequency which is also referred to as angular speed. It is called cyclotron frequency because the charge particle circulates at the angular speed / frequency in the type of accelerator called cyclotron.

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

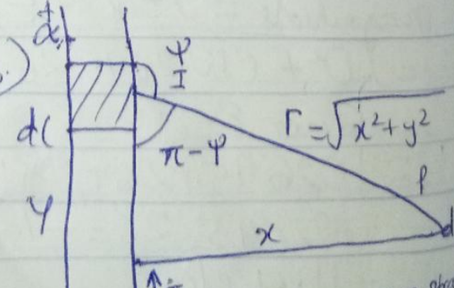
So we have $\omega = \frac{1.6\times10^{-11} \times 3.5\times10^{-1}}{9.11\times10^{-31}}$

$$\omega = 6.147\times10^{10}\ rad/s$$

$\therefore$ Since angular speed is also cyclotron frequency, the cyclotron frequency is 6.147×10^{10} rad/s

5a.) Bio-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 the point to the wire.

5b.)



A section of a straight current carrying conductor

Applying ... the magn... $B = $ ...
Sin ...
$\therefore B = $ ...
from ...
$B = $ ...
But sin ...
Substitut...
$B = $ ...
$B = $ ...
Recal...
$B = $ ...
$B = $ ...
Using ...
$\int \frac{dy}{(x^2+y}$ ...
Equa...

Applying 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 the diagram, $r^2 = x^2 + y^2$

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

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

Substituting eq (2) into (3) 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 $dl = dy$

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

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

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 (3) becomes

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

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

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

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

When a is much larger than x, $(x^2+a^2)^{1/2} \simeq a$, as $a \to \infty$

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

In physical situations, we have axial symmetry about the y-axis. Thus, at all points on a ~~circle~~ circle of radius r, around the conductor, the magnitude of B is

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