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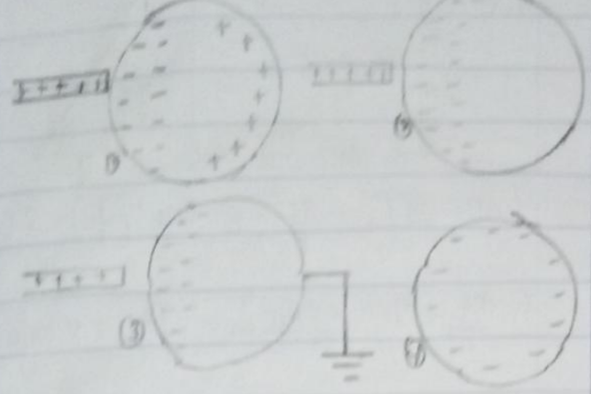
Matric number: 19/MHS01/421

1)(a)



A positively charged rubber rod is brought near a neutral conducting sphere. There is a repulsion and attraction mechanism causing the region of the sphere nearest the positively charge to be negative. If a grounded conducting wire is then connected to the sphere (3), some of the protons leave the sphere and travel to the earth. If the wire is removed, the conducting sphere is left with protons and it is evenly distributed when the rubber rod is removed.

b) $q_1 + q_2 = 5.0 \times 10^{-5} C$; $F_e = 1.0 N$

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

$F_e = \dfrac{K q_1 q_2}{r^2}$

$1 = \dfrac{8.9 \times 10^9 \times (5 \times 10^{-5} - q_2)(q_2)}{2^2}$

$4 = 8.9 \times 10^9 \times 5 \times 10^{-5} q_2 - q_2^2$

$4.45 \times 10^{-10} = 5 \times 10^{-5} q_2 - q_2^2$

$q_2^2 - 5 \times 10^{-5} q_2 + 4.45 \times 10^{-10} = 0$

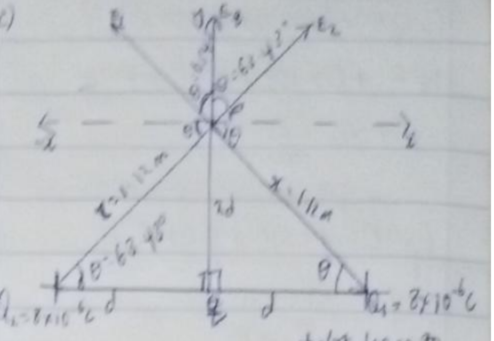
$\therefore q_2 = 3.89 \times 10^{-5}$

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

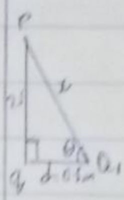
$q_1 = 5 \times 10^{-5} - 3.89 \times 10^{-5}$

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

(c)



* Not drawn to scale



$x^2 = 2(0.5)^2 + (0.5)^2 = 1.25$

$x = 1.12 m$

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

$\theta = \tan^{-1}(2) = 63.43°$

$E_1 = \dfrac{K q_1}{r^2} = (8.9 \times 10^9) \times \dfrac{(8 \times 10^{-6})}{(1.12)^2}$

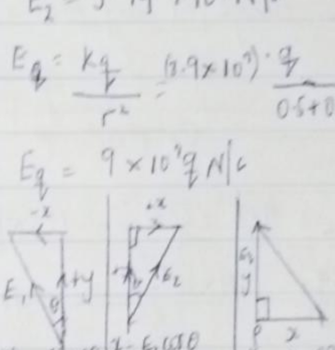
$E_1 = 5.74 \times 10^4 NC^{-1}$

$E_2 = \dfrac{K q_2}{r^2} = (8.9 \times 10^9) \times \dfrac{(8 \times 10^{-6})}{(1.12)^2}$

$E_2 = 5.74 \times 10^4 N/C$

$E_q = \dfrac{K q}{r^2} = (8.9 \times 10^9) \cdot \dfrac{q}{0.5 + 0.5}$

$E_q = 9 \times 10^9 q\ N/C$



$x = -E_1\cos\theta$, $y = E_1\sin\theta$ | $x = E_2\cos\theta$, $y = E_2\sin\theta$ | $x = E_q\cos 90$, $y = E_q\sin 90$

S/N	Vector	Angle	x-Component	y-component
1)	$E_1 = 5.74 \times 10^4$	63.43°	$-E_1\cos\theta$ $5.74 \times 10^4 \cdot \cos 63°$ $= -25700.5 N/C$	$E_1\sin\theta =$ $5.74 \times 10^4 \cdot \sin 63°$ $= 51336.1 N/C$
2)	$E_2 = 5.74 \times 10^4$	63.43	$E_2\cos\theta$ $5.74 \times 10^4 \cos 63°$ $= 25700.5 N/C$	$E_2\sin\theta$ $5.74 \times 10^4 \sin 63°$ $= 51336.1 N/C$
3)	$E_q = 9 \times 10^9 q$	90°	$E_q\cos 90°$ $= 0 N/C$	$E_q \sin 90°$ $9 \times 10^9 q\ N/C$
			$\Sigma E_x = 0 N/C$	ΣE_y $= (1.0 \times 10^5 + 9 \times 10^9$

The magnitude of resultant electric fiel

E_p at point is, $E_p = \sqrt{(\Sigma E_x)^2 + (\Sigma E_y)^2}$

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$E_p = \sqrt{(0)^2 + (1026\,72.15 + 9.0\times10^{9}q)^2}$

$E_p = 1.0\times10^{5} + 9.0\times10^{9}q$

but the $\underset{p>0}{\Delta}$

$E_p = 0 = 1.0\times10^{5} + 9.0\times10^{9}q$

$q = \frac{-1.0\times10^{5}}{9.0\times10^{9}}$

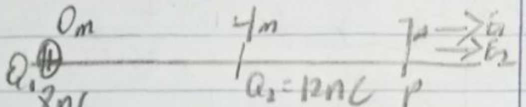
$q = -1.14\times10^{-5}C$

$q = \cancel{-11\mu}\ -11\mu C$

2)

Electric field	Electric field intensity
This is a region around a charge in which it exerts electrostatic force on another charge	It is defined as force per unit charge. It is the strength of a electric field at any point in space.

b) i)



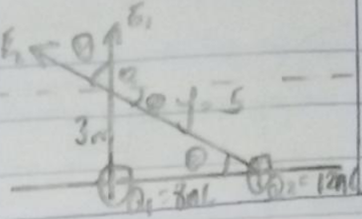
$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{7^2} = 1.5N|C$

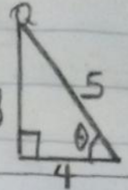
$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^{9}\times12\times10^{-9}}{3^2} = 12N|C$

Vector	Angle	X-component	Y-component
$E_1 = 1.5N\|C$	0	$E_1\cos\theta = 1.5\cos\theta = 1.5$	$E_1\sin\theta = 1.5\sin\theta = 0$
$E_2 = 12N\|C$	0	$E_2\cos\theta = 12\cos\theta = 12$	$E_2\sin\theta$ $12\sin\theta = 0$
		$\sum E_x = 13.5N\|C$	$\sum E_y = 0$

$E_{net} = \sqrt{(13.5)^2 + (0)^2}$

$E_{net} = 13.5N|C$





$\tan\theta = \frac{opp}{adj} = \frac{3}{4}$; $\theta = \tan^{-1}\left(\frac{3}{4}\right) = 37°$

$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{3^2} = \frac{72}{9} = 8.0N|C$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^{9}\times12\times10^{-9}}{5^2} = \cancel{4N}\ 4.32N|C$

Vector	Angle	X-component	Y-component
$E_1 = 8N\|C$	$90°$	$E_1\cos\theta = 8\cos90° = 0$	$E_1\sin\theta = 8\sin90° = 8N\|C$
$E_2 = 4.32N\|C$	$37°$	$E_2\cos\theta = 4.32\cos37 = -3.456N\|C$	$E_2\sin\theta = 4.32\sin37° = 2.592N\|C$
		$\sum E_x = -3.456N\|C$	$\sum E_y = 10.592N\|C$

$E = \sqrt{(\sum E_x)^2 + (\sum E_y)^2} = \sqrt{(-3.456)^2 + (10.592)^2}$

$E = 11.2N|C$

4) Magnetic flux is defined as the strength of magnetic field represented by lines of force. It is usually represent by the symbol ϕ.

b) $F_B = qvB\sin\theta$; where $\theta = 90°$

$F_B = qvB$

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

$q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$

$qB = \frac{mv}{r}$

$v = \frac{qBr}{m} = \frac{1.6\times10^{-19}\times3.5\times10^{-1}\times1.4\times10^{-7}}{9.11\times10^{-31}}$

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$V = 8.6\times10^{3}\,m/s$

but $\omega = \frac{V}{r}$

$$\omega = \frac{8.6\times10^{3}}{1.4\times10^{-7}}$$

$$\omega = 6.14\times10^{10}\,rad/s$$

c) The electron moves in a circular orbit in a plane perpendicular to ~~its~~ its direction of motion moving with the velocity v. The electron particle has a constant magnitude qvB.

$\therefore$ if $qvB = \frac{mv^2}{r}$ $\left(a = v^2/r\right)$

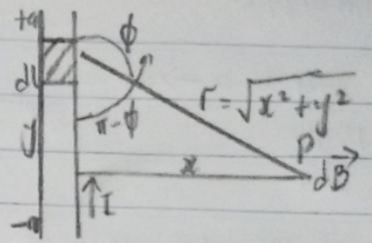
due to its centripetal acceleration, then velocity $= \frac{qBr}{m}$

Now, the angular speed $\omega = \left(\frac{v}{r}\right)$ is often referred to as the cyclotron frequency because the charge particle circulates at this angular frequency in the type of accelerator called cyclotron.

5a 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.

Mathematically; $\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,\vec{dl}\times r}{r^2}$

b)



Using Biot-Savart law, the magnitude of $\vec{dB}$ is given as $\frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{dl\sin\phi}{r^2}$

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

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

from the diagram; $r^2 = x^2+y^2$

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

but $\sin(\pi-\phi) = \frac{x}{\sqrt{x^2+y^2}} = \frac{x}{(x^2+y^2)^{1/2}}$ --- (ii)

Substituting (ii) into (i)

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

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

but $dl = dy$

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

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

Using special integrals:

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

Eqn (3) becomes;

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

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

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

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

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

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;

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