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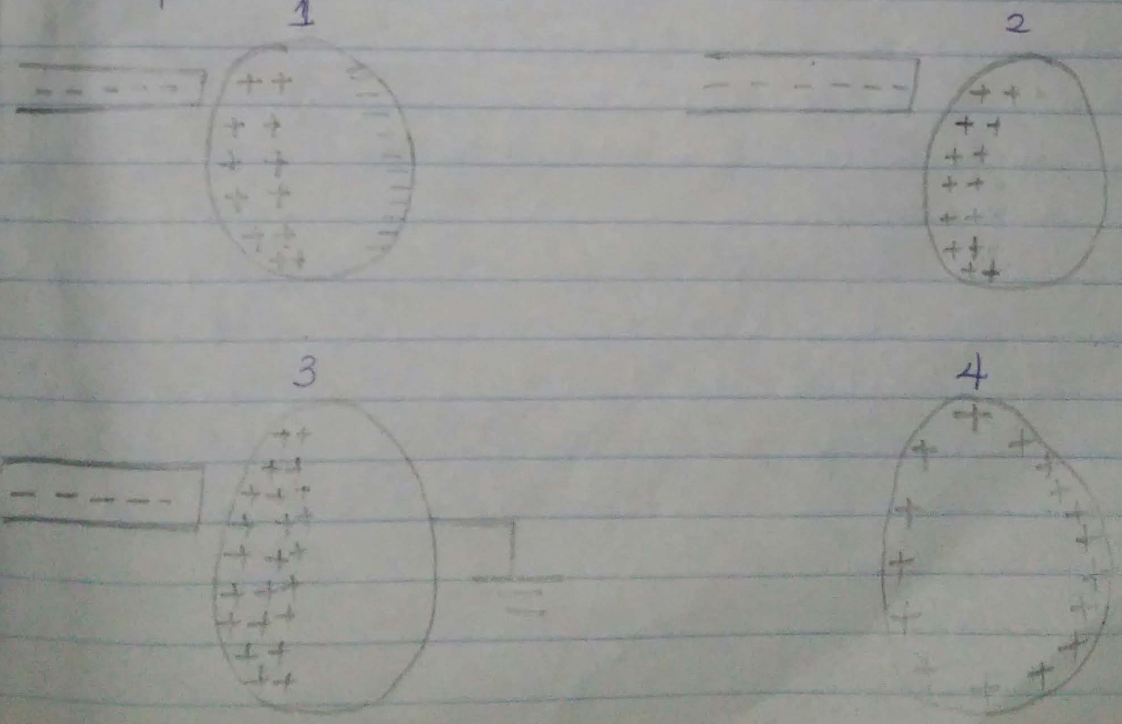
19/ENG05/051
MECHATRONICS ENGINEERING
PHY 102 ASSIGNMENT

① Consider a negatively charged rubber rod brought near a neutral/uncharged conducting sphere that is insulated so that there is no conducting path to the ground. The explosive force between the electrons in the rod and those in the sphere causes a redistribution of charges in the sphere so that some of the electrons move to the side of the sphere farthest away from the rod.

The region of the sphere nearest the relatively charged rod has an excess amount of positive charges because of the migration of electrons away from its location. If a grounded conducting wire is connected to the sphere, some of the electrons leave the sphere and travel to the earth. If the wire to ~~that~~ the ground is then removed, the conducting sphere is left with an excess of induced positive charge.

Finally, when the rubber band is removed from the sphere the induced positive charges remains on the ungrounded sphere and becomes uniformly distributed over the ~~sphere~~ surface of the sphere.



(14) $q_1 + q_2 = 5 \times 10^{-5} C$

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

$F = \frac{KQ_1Q_2}{r^2}$

$1 = \frac{9 \times 10^9 q_1 q_2}{2^2}$

$4 = [9 \times 10^9 \times (5 \times 10^{-5} - q_2)(q_2)]$

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

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

$0 = -9 \times 10^9 q_2^2 + 4.5 \times 10^5 q_2 - 4$

$9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$

Using quadratic formula,

$x = \frac{b \pm \sqrt{b^2 - 4ac}}{2a}$

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

$q_2 = \frac{-4.5 \times 10^5 \pm \sqrt{2.02 \times 10^{11} - 4(3.60 \times 10^{10})}}{1.80 \times 10^{10}}$

$q_2 = \frac{-4.5 \times 10^5 \pm \sqrt{2.02 \times 10^{11} - 1.44 \times 10^{11}}}{1.80 \times 10^{10}}$

$q_2 = \frac{-4.5 \times 10^5 \pm \sqrt{5.80 \times 10^{10}}}{1.80 \times 10^{10}}$

$q_2 = \frac{-4.5 \times 10^5 \pm 2.41 \times 10^5}{1.80 \times 10^{10}}$

$q_2 = \frac{-4.5 \times 10^5 + 2.41 \times 10^5}{1.80 \times 10^{10}}$ or $\frac{-4.5 \times 10^5 - 2.41 \times 10^5}{1.80 \times 10^{10}}$

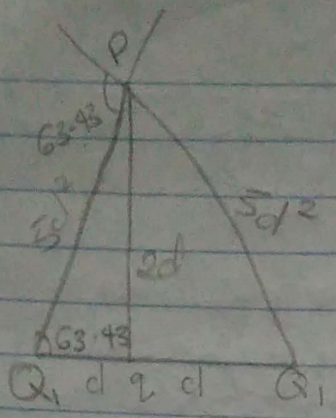
$= \frac{-209000}{1.80 \times 10^{10}}$ or $\frac{-691000}{1.80 \times 10^{10}}$

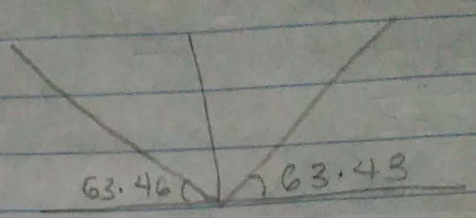
$q_2 = -1.16 \times 10^{-5}$ or -3.84×10^{-5}

$\therefore q_1 = 5 \times 10^{-5} - (-1.16 \times 10^{-5})$ or $5 \times 10^{-5} - (-3.84 \times 10^{-5})$

$= 6.16 \times 10^{-5}$ or 8.84×10^{-5}

(c)





d = 0.5

$\sqrt{2d^2 + d^2} = d\sqrt{5}$, $\tan\theta = \frac{2d}{d}$

$\tan^{-1}(2) = 63.48°$

$E_1 = E_2 = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times (8\times10^{-6})}{(d\sqrt{5})^2} = \frac{9\times10^9\times8\times10^{-6}}{(0.5\sqrt{5})^2}$

$= 57600\ N/C$

$E_q = \frac{Kq}{r^2} = \frac{9\times10^9 \times q}{(2d)^2} = \frac{9\times10^9 q}{[2(0.5)]^2} = \frac{9\times10^9 q}{1}$

$= 9\times10^9 q\ N/C$

Vector	θ	x-component
$E_1 = 57600 N/C$	63.43°	57600 cos 63.43 = -25764
$E_2 = 57600 N/C$	63.48°	57600 cos 63.43 = +25764
$E_q = 9\times10^9 q$ N/C	90°	$9\times10^9 q$ cos 90 =
		$E_{fx} = 0$

$E_{net} = \sqrt{E_{fx}^2 + E_{fy}^2}$

but E_{net} at point P = 0

$\therefore 0 = \sqrt{0^2 + (103033.6 + 9\times10^9 q)^2}$

$0 = 103033.6 + 9\times10^9 q$

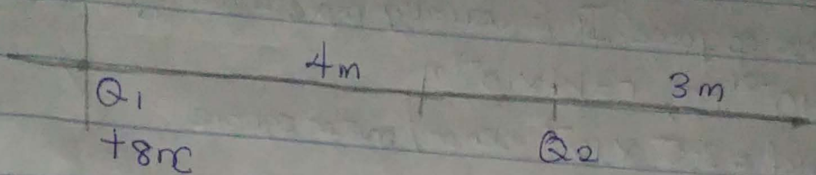
$q = \frac{-103033.6}{9\times10^9}$

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

$= -11.4\ \mu C$

(2) An electric field is a region or space in which an electric Charge will experience an electric force while electric field intensity is the per unit change experienced by a charge In an electric field

b(i)

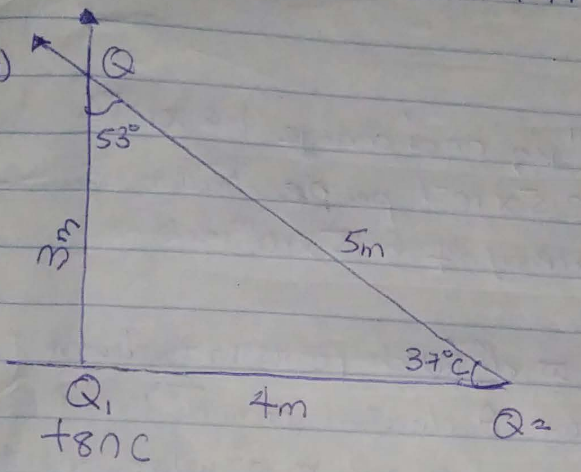


$$E_1 = \frac{KQ_1}{r^2} = \frac{(9\times10^9)\times(8\times10^{-9})}{7^2} = 1.47\,N/C$$

$$E_2 = \frac{KQ_2}{r^2} = \frac{(9\times10^9)\times(12\times10^{-9})}{3^2} = 12\,N/C$$

$E_{net} = 1.47 + 12 = 13.47\,N/C$

(ii)



$$E_1 = \frac{KQ_1}{r^2} = \frac{9\times10^9\times(8\times10^{-9})}{3^2} = 8\,N/C$$

$$E_2 = \frac{KQ_2}{r_2} = \frac{(9\times10^9)\times(12\times10^{-9})}{5^2} = 4.32\,N/C$$

Vector	Angle	X-component	Y-component
$E_1 = 8\,N/C$	90°	$8\cos 90° = 0$	$8\sin 90 = +8$
$E_2 = 4.32\,N/C$	37°	$4.32\cos 37° = -3.45$	$4.32\sin 37° = +2.6$
		$\Sigma E_x = -3.45\,N/C$	$\Sigma E_y = 10.6\,N/C$

The resultant, E,

$$E = \sqrt{\sum E_x^2 + \sum E_y^2} = \sqrt{(3.45)^2 + (10.6)^2}$$
$$= \underline{11.15\ N/C}$$

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

(b) $m_e = 9.11 \times 10^{-21}\ kg$, $r = 1.4 \times 10^{-7} m$

magnetic field $= 3.5 \times 10^{-1}$ weber / meter square

$\theta = 90^\circ$

$\sin\theta = 1$

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

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

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

(c) An electron of mass 9.11×10^{31} kg and charge 1.6×10^{-19}C in motion in a magnetic field of 3.5×10^{-1} perpendicular with the field will have an angular frequency of 6.15×10^{10} rad/s.

(5a) The vector $\vec{dB}$ is perpendicular to $d\hat{l}$ (which points in the direction of the current) and to the unit vector $\hat{r}$ directed from $\vec{dl}$ toward P.

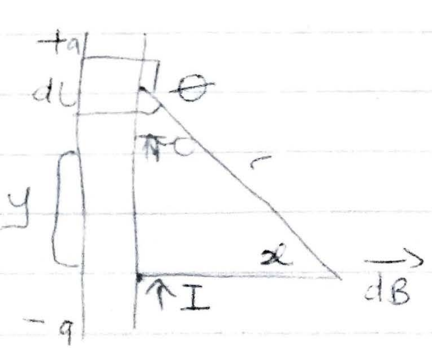
(ii) The magnitude of $\vec{dB}$ is inversely proportional to r^2 where r is the distance from $\vec{dl}$ to P

(iii) The magnitude of $\vec{dB}$ is proportional to the current I and to the magnitude of the length element $\vec{dl}$

(iv) The magnitude of $\vec{dB}$ is proportional to θ, where θ is the angle between $\hat{r}$ and $\vec{dl}$

That is the Biot - Savart Law

(b)



$$r = \sqrt{y^2 + x^2}$$

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

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

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

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

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

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

$(x^2+a^2)^{1/2} \Rightarrow a$

$$B = \frac{\mu_0 I}{2\pi x} \frac{\cancel{a}}{(\cancel{a^2})^{1/\cancel{2}}}$$

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

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