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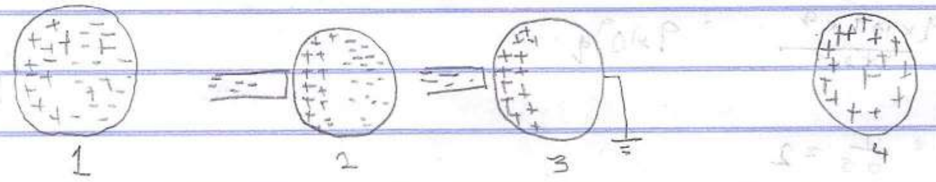
19/ENG05/012
Mechatronics Engineering

1 a) If a negatively charged rod is brought near a neutral sphere, the electrons in the rod will attract the positively charged ~~ions~~ and push away the negative charges.
The negative charges in the rod can easily be grounded since they are all together leaving only positive charges.
When the rod is removed only positive charges will remain in the sphere



b) $q_1 + q_2 = 5.0 \times 10^{-5} C$ $F = 1N$ $r = 2.0 m$

$F = \frac{kq_1q_2}{r^2}$ let $q_1q_2 = q_p$

$q_p = Fr^2/k = \frac{1 \times 2^4}{9 \times 10^9}$

$= 4.44 \times 10^{-10} C^2$

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

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

$\therefore (5.0 \times 10^{-5} - q_2) q_2 = 4.44 \times 10^{-10} C$

$5.0 \times 10^{-5} q_2 - q_2^2 = 4.44 \times 10^{-10} C$

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

$q_2 = \frac{(5.0 \times 10^{-5}) \pm \sqrt{(5 \times 10^{-5})^2 - 4.44 \times 10^{-10}}}{2}$

$q_2 = \underline{3.840 \times 10^{-5}}$

$q_1 = 5.0 \times 10^{-5} - 3.84 \times 10^{5}$

$= \underline{1.16 \times 10^{5}}$

$\underline{q_1 = 1.16 \times 10^{5} C}$ $q_2 = \underline{3.84 \times 10^{-5}} C$

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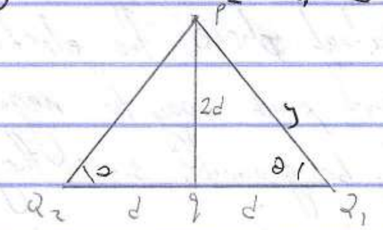
c) $Q_1 = Q_2 = 8\mu C \quad d = 0.5 \quad P = 0$



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

$x = 1.12m$

$$\mathcal{E}_1 = \frac{F(N)}{Q_0(C)} = \frac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = \frac{kq}{r^2}$$

$= 57397.959$

Since $Q_1 = Q_2 \quad \mathcal{E}_1 = \mathcal{E}_2$

$$\mathcal{E}_q = \frac{9\times10^9 \times q}{2\times0.5} = 9\times10^9 q$$

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

$\theta = \tan^{-1}(2) = 63.45$

Vector	θ	x	y
$\mathcal{E}_1$	63.45	$\mathcal{E}_1\cos\theta = 25675.15$	$\mathcal{E}_1 y\sin\theta = 51336.08$
$\mathcal{E}_2$	63.45	$\mathcal{E}_2 x\cos\theta = -25673.15$	$\mathcal{E}_2\sin\theta = 51336.08$
$\mathcal{E}_q$	90	$\mathcal{E}_q\cos\theta = 0$	$\mathcal{E}_q\sin\theta = 9\times10^9 q$
$\mathcal{E}$		$\mathcal{E}_x = 0$	$\mathcal{E}_y = 102672.16 + 9\times10^9 q$

Magnitude $\sqrt{\mathcal{E}_x^2 + \mathcal{E}_y^2} = \sqrt{0^2 + (102672.16 + 9\times10^9 q)^2}$

$= 102672.16 \times 9\times10^9 q$

$\mathcal{E}_y = 102672.16 + 9\times10^9 q = 0$

$\therefore q = \frac{-102672.16}{9\times10^9}$

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

$= -11.4\mu C$

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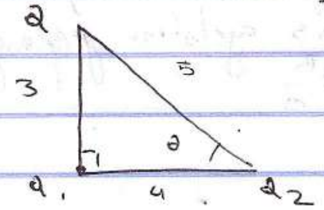
3 a) An electric field is the region of space in which an electric force can be felt while; the electric field intensity ~~is~~ refers to the stidnght of the force exerted on charges within the electric field.

b) $q_1 = 8nC$ $Q_2 = 12nC$ $d = 4m$

i) $E_1 = \frac{Q_1}{4\pi\varepsilon_0 r^2} = \frac{8\times10^{-9}\times9\times10^{9}}{(\cancel{4})^2} = \cancel{1.132\times10^{-10}\ N/C}$ $1.4694\ \cancel{\times10^{-17}}\ N/C$

$\mathcal{E}_2 = \frac{Q_2}{4\pi\varepsilon_0 r^2} = \frac{12\times10^{-9}\times9\times10^{9}}{3^2} = \cancel{1.2\times10^{-17}}$ 12

$\Sigma\mathcal{E} = \mathcal{E}_1 + \mathcal{E}_2 = \cancel{1.34694\times10^{-17}\ N/C}$ $13.469\ N/C$

ii) 

$\tan\theta = \frac{3}{\cancel{5}4}$

$\therefore \theta = 36.87°$

$\mathcal{E}_1 = \frac{8\times10^{9}\times9\times10^{9}}{3^2} = 8$ $\mathcal{E}_2 = \frac{9\times10^{9}\,(12\times10^{-9})}{5^2} = 4.32$

Vector	θ	x	y
$\mathcal{E}_1 = 8$	90	$\mathcal{E}_1\cos 90 = 0$	$\mathcal{E}_1\sin 90 = 8$
$\mathcal{E}_2 = 4.32$	36.87	$\mathcal{E}_2\cos 36\times 89 = 3.456$	$\mathcal{E}_2\sin 36.87 = 2.592$
		$\Sigma\mathcal{E}_x = 3.456$	$\Sigma\mathcal{E}_y = 10.592$

$\mathcal{E} = \sqrt{\Sigma\mathcal{E}_x^2 + \Sigma\mathcal{E}_y^2}$

$= \sqrt{3.456^2 + 10.592^2}$

$= \underline{11.14156183\ N/C}$

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4 a) Magnetic flux is defined as the strength of the magnetic field which can be represented by lines of forces

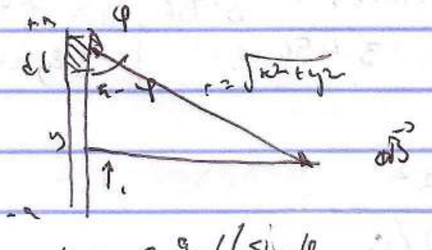
b) $m = 9.11 \times 10^{-31} kg$ $r = 1.4 \times 10^{-7} m$ $B = 3.5 \times 10^{-1} weber/m^2$

$$\omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$$\therefore \omega = \underline{6.222 \times 10^{10} T^{-1}}$$

c) - The mass radius and magnetic flux were given as $9.11 \times 10^{-31} kg$, $1.4 \times 10^{-7} m$ and $3.5 \times 10^{-1} weber/m^2$ respectively.
- Angular speed is the same as cyclotron frequency which we are asked to find and $\omega = \frac{v}{r} = \frac{qB}{m}$

5 a) Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length & radius and inversely proportional to the square of the radius (r^2)

b) 

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

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

$$r^2 = x^2 + y^2$$

$$\therefore B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin(\pi - \varphi)}{x^2 + y^2} \quad \text{but} \quad \sin(\pi - \varphi) = \frac{x}{\sqrt{x^2+y^2}} = \frac{x}{(x^2+y^2)^{1/2}}$$

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

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

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

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

Using Special Integrals

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

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

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

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

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

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