mechatronics engineering

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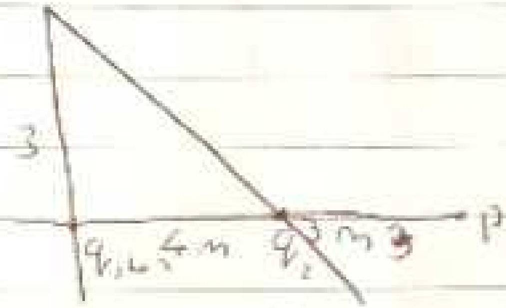
Section A

Question Two

1) Electric field is the region in which surrounds an electric charge and exerts force on other charges while

Electric field intensity is the measure of the strength of an electric field at any point

2b) $Q_1 = 8 nC$



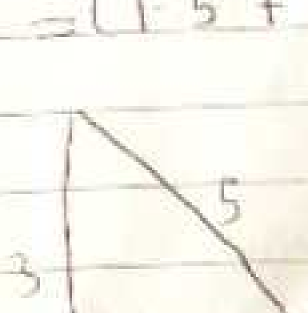
$$E_1 = \frac{kQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2} = 1.469 N/C$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{3^2} = 12 N/C$$

$$E_{net} = \vec{E_1} + E_2$$

$$= (1.5 + 12) N/C = 13.5 N/C$$

(1)



$c^2 = a^2 + b^2$

$c = 4^2 + 3^2$

$c^2 = 16 + 9$

$c^2 = \sqrt{25} = 5$

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$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8N/C$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32N/C$

vector	θ	x-comp	y-comp
$E_1 = 8N/C$	90°	0N/C	8 N/C
$E_2 = 4.32N/C$	36.84	-3.45N/C	2.59N/C
		$\Sigma x = 3.5N/C$	$\Sigma y = 10.59N/C$

$E_R = \sqrt{\Sigma y^2 + \Sigma x^2}$

$= 11.126N/C$

$= 11.13 N/C$

Question Three

a) Volume charge density $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

b) Surface charge density $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

c) linear charge density $\lambda = \frac{dQ}{dL} = \lambda dL$

b) Electric potential difference.

This can be defined as the work done per unit charge carried from one point to

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another- Electric potential due to a single point charge

$$V_{rB} - V_{rA} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

Q = Point charge

V = Electric potential

r_B = distance from Q to B

r_A = distance from Q to A

Due to several point charge

$$V = \Sigma V_{p} = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r} + \frac{Q_2}{r_2}\right]$$

where V = Electric potential

Q = Point charge

r = distance of Q

(c) $Q_1 = 10\mu C$, $Q_2 = -2\mu C$, $x = 0$, $x = 6$, $V = 0$

$$V_p = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right)$$

$$V_p = 9\times10^9\left(\frac{10\times10^{-6}}{6 + x} + \frac{-2\times10^{-6}}{x}\right)$$

$$0 = 9\times10^9\left(\frac{10\times10^{-6}}{6 + x} + \frac{-2\times10^{-6}}{x}\right)$$

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$0 = \frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}$

$\frac{10\times10^{-6}}{4+x} = \frac{2\times10^{-6}}{x}$

$10\times10^{-6}x = (4+x)(2\times10^{-6})$

$10\times10^{-6}x = 8\times10^{-6} + 2\times10^{-6}x$

$8\times10^{-6} = 10\times10^{-6}x - 2\times10^{-6}x$

$8\times10^{-6} = 8\times10^{-6}x$

$x = \frac{8\times10^{-6}}{8\times10^{-6}}$

$x = 1$

∴ Position along the x axis is 1m

where $v = 0$

$v = k\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right)$

$= \frac{10\times10^{-6}}{4-x} = \frac{2\times10^{-6}}{x}$

$(4-x)(2\times10^{-6}) = 10\times10^{-6}x$

$8\times10^{-6} - 2\times10^{-6}x = 10\times10^{-6}x$

$8\times10^{-6} = 10\times10^{-6}x + 2\times10^{-6}x$

$8\times10^{-6} = 12\times10^{-6}x$

$x = \frac{8\times10^{-6}}{12\times10^{-6}}$

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$x = 0.67$

$\therefore$ Position of $v = 0$ is $0.67m$.

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Question 4

a) A magnetic flux is defined as the strength of the magnetic field be represented by lines of force.

b) $m = 9 \times 10^{-2}$ kg $\quad \theta = 2.5 \times 10^{-1}$ weber/m²

$r = 1.4 \times 10^{-7}$ m

angular speed = cyclotron frequency

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

$$= \frac{1.6 \times 10^{-9} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$w = \cancel{6222.222\ T^{-1}}\ 6.22 \times 10^{10} e^{-1}$

c) we are given

i) mass $= 9 \times 10^{-2}$ kg

ib) a radius $= 1.4 \times 10^{-7}$ m

ic) ~~we~~ The particle of radius 1.6×10^{-7} m circulates at $6222.222\ T^{-1}$ in the type of accelerator with a mass of 9×10^{-2} kg

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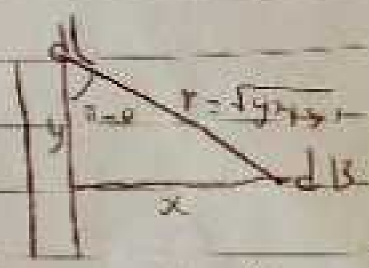
Question five

a) Biot - Savart law

This state that the magnetic field is directly proportional to the product permeability of free space (μ), the current I, the change in length the radius and inversely proportional to square of radius. Mathematically $d\vec{B} = \frac{\mu_0 I\, d\vec{l} \times \hat{r}}{4\pi r^2}$

b) 

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

$$B = \int \frac{\mu_0 I \sin\theta\, dl}{4\pi r^2} \quad , \mu_0 = \text{Permeability of free space}$$

$$B = \int \frac{\mu_0 I \sin\theta}{4\pi r^2} = \int \frac{\mu_0 I\, x}{\sqrt{y^2 + x}} \frac{dl}{(y^2 + x^2)}$$

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

$dl \equiv dy$

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$$B = \frac{N_0 I}{4\pi} \int_{-a}^{a} \frac{x}{(y^2+x^2)^{\frac{3}{2}}} \, dy$$

using Special integrale

$$\int \frac{dy}{(x^2+y^2)^{\frac{3}{2}}} = \frac{1}{x^2}\left[\frac{y}{[x^2+y^2]^{\frac{1}{2}}}\right]_{-a}^{a}$$

$$B = \frac{N_0 I}{4\pi} \frac{1}{x^2}\left[x \cdot \frac{y}{(x^2+y^2)^{\frac{1}{2}}}\right]_{-a}^{a}$$

$$B = \frac{N_0}{4\pi} \frac{1}{x^2} x \left[\frac{2a}{(x^2+a^2)^{\frac{1}{2}}}\right]$$

$a \geq 0$

$$B = \frac{N_0 I}{4\pi x}\left[\frac{x(2)}{a}\right]$$

$$B = \frac{N_0 I}{2\pi x}$$

$$B = \frac{N_0 I}{2\pi r}$$

$r = x$