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SECTION A

2a) Electric field & electric intensity

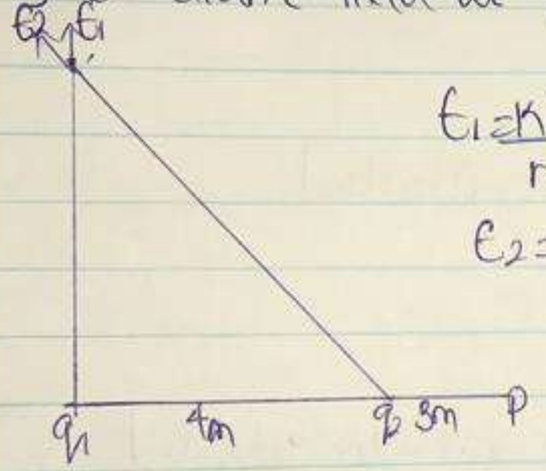
Electric field is a region of space which an electric charge will experience an electric force.

WHILE

Electric field intensity is the force per unit charge.

b) $q_1 = 8nc$ at origin, $q_2 = 12nc$ on x-axis at $x = 4m$

i) net electric field at point P on the x-axis at $x = 7m$

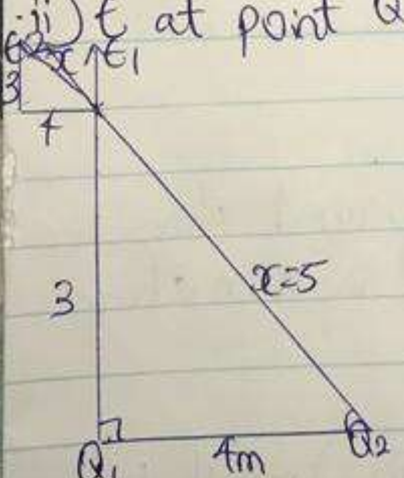


$$E_1 = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.469N/C \simeq 1.5N/C$$

$$E_2 = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{7^2} = 12N/C$$

$$E_{net} = \vec{E}_1 + \vec{E}_2 = 1.5 + 12N/C = 13.5N/C$$

ii) $\vec{E}$ at point Q on the y-axis at $y = 3m$ due to the charges



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

$$E_2 = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 4.32N/C$$

Vector	angle	x-component	y-component
$E_1 = 8N/C$	$90°$	$0N/C$	$8N/C$
$E_2 = 4.32$	36.87	$-3.45N/C$	$2.59N/C$
		$\Sigma f_x = -3.45N/C$	$\Sigma f_y = 10.59N/C$

$$E_{net} = \sqrt{\Sigma f_x^2 + \Sigma f_y^2}$$

$$E_{net} = 11.12N/C$$

QUESTION 3

3) Formulation of identities of charge

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

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

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

b) Electric potential difference equation due to a single point charge

$$V_B - V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

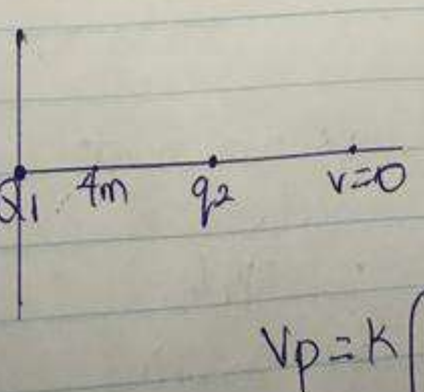
where Q = point charge V = electric potential
r_B = distance of Q to point B
r_A = distance of Q to point A

due to several point charges

$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$ where V = electric potential
Q = point charge
r = distance of Q

~~QUESTION~~ 3

c) Point charge $Q_1 = 10\mu C$ & $Q_2 = -2\mu C$ are arranged along the x axis at $x=0$ and $x=4m$ respectively. Find position along the x-axis where $V=0$



$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$ recall $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 = k$

$$V_P = k\left[\frac{Q_1}{r_1} + \frac{Q_2}{r^2}\right]$$

$$V_P = 9\times10^9 \times \left[\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right]$$

$$0 = 9\times10^9 \times \left[\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right]$$

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

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

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

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

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

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

$$x = 1$$

∴ Position along the x-axis is 1m

where $v=0$

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

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

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

$$\cancel{8\times10^{-6}}\ (4-x)(2\times10^{-6}) = 10\times10^{-6}x$$

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

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

$$8\times10^{-6} = 1.2\times10^{-5}x$$

$$x = \frac{8\times10^{-6}}{1.2\times10^{-5}}$$

$$x = 0.67\text{m}$$

∴ Position of $v=0$ is 0.67m

SECTION B

QUESTION 4

4a) Magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is denoted as Φ.

$$\Phi = B . dA$$

4b) $M_e = 9.11 \times 10^{-31}$ Kg, $r = 1.4 \times 10^{-7}$ m ; $B = 3.5 \times 10^{-1}$ weber/m^2.

Cyclotron frequency = angular speed $q = 1.6 \times 10^{-19}$

$$F_B = qVB = \frac{M_e v^2}{r^2}$$

$$M_e v = qBr$$

$$v = \frac{qBr}{M_e} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1} \times 1.4 \times 10^{-7}}{9.11 \times 10^{-31}}$$

$$v = 8.61 \times 10^{-3} m/s$$

$$W = \frac{V}{r} = \frac{qB}{M_e} = \frac{1.6 \times 10^{-19} \times 3.6 \times 10^{4}}{9 \times 11 \times 10^{-31}}$$

$$W = 6.14 \times 10^{10} C^{-1}$$

4c) In 4b we were given parameters; mass of electron $= 9.11 \times 10^{-31}$ Kg, radius $= 1.4 \times 10^{-7}$ m, $B = 3.5 \times 10^{-1}$ w/m^2

And we were asked to find the cyclotron frequency which is the same thing as angular speed. It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron.

Recall w = angular speed.

$w = \frac{qB}{M_e}$ since cyclotron frequency = angular speed.

The cyclotron frequency $= 6.14 \times 10^{-10} C^{-1}$ having a unit of $\frac{1}{T}$ which is the unit of frequency dimensionally.

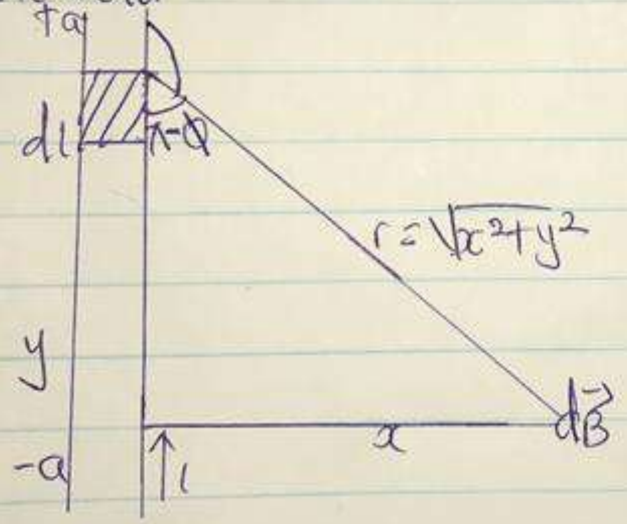
QUESTION 5

a) Bio-savart law states that the magnetic field is directly proportional to the product permeability of free space ~~sp~~ (μ) the current (I), the change in length, the radius and inversely proportional to square of radius (r^2). Mathematically;

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

where μ_0 (permeability of free space) $= 4\pi \times 10^{-7}$ T. m/A; r = radius $d\vec{B}$ = magnetic field I = steady current; dL = length of wire Unit is w/m².

5b) Magnetic field of a straight current carrying conductor



Applying Bio-savart law, we find the magnetic of the field from the diagram,

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

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

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

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

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

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

Substitute (ii) into (i)

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

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

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

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

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

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