SECTION B

4a Magnetic flux is defined as the strength of the magnetic field which can represented by line of force. It is defined as ϕ

$$\phi = B \cdot dA$$

4b $m_e = 9.11 \times 10^{-31}$ kg, $r = 1.4 \times 10^{-7}$ m, $B = 3.5 \times 10^{-1}$ W/m^2.

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

$$F_B = qvB = \frac{m_e v^2}{r}$$

$$m_e v = qBr$$

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

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

$$\omega = \frac{v}{r} = \frac{qB}{m_e} = \frac{1.6 \times 10^{-19} \times 3.6 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$w = 6.14 \times 10^{10} s^{-1}$$

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 ω is a frequency of an accelator called cyclotron.

Recall ω = angular speed.

$\omega = \frac{qB}{m_e}$ Since cyclotron frequency = angular speed. the cyclotron frequency $= 6.14 \times 10^{-10} s^{-1}$ having a unit of $\frac{1}{T}$ which is the unit of frequency dimensionally.

5a

a Bio - savart law states that the magnetic field is directly proportional to the product permeability of free space (μ_0) the current (I), the change in length the radius (r^2). mathematically

$$d_B = \frac{\mu_0 I \, d\vec{l} \times \hat{r}}{4\pi r^2}$$

Where μ_0 = permeability free space $= 4\pi \times 10^{-7}$ T·m/A, r = radius

$d\hat{B}$ = magneticfield I = steady current, dl = length of wire

that is w/m^2

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

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

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

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

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

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

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

$$x = 1$$

$\therefore$ position along the x-axis is 1m.

Where $V = 0$

$$V = k\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

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

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

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

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

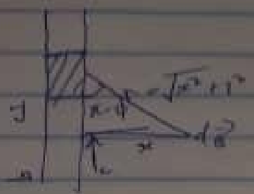
$$8\times10^{-6} = 10\times10^{-6}x + 2\times10^{-6}x$$

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

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

$$x = 0.67m$$

$\therefore$ position of $V = 0$ is 0.67 m magnetic field of straight current carrying conductor



A section of a straight current carrying conductor.

Applying Bio-savart law, we find the magnitude of the field $(d\vec{B})$ from the diagram.

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

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

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

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

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

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

Substitute (ii) into (i)

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

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

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

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

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

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

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SECTION A

2a) ELECTRIC FIELD

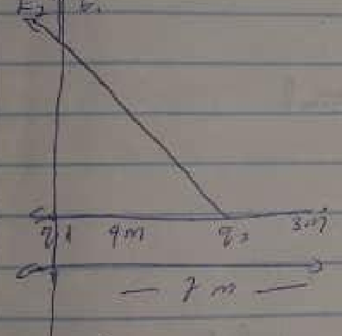
It is a region of space in which an electric charge will experience an electric force

ELECTRIC FIELD INTENSITY

It is the force per unit charge

2b) $q_1 = 8nc$ at origin, $q_2 = 12nc$ on x-axis at $x = 4m$.
net electric field at point p on the axis at $x = 7m$.
ii electric field at a point Q on the $y = 3m$ due to the charge

1

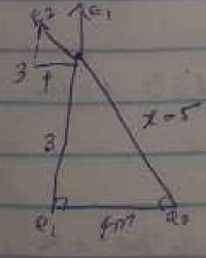


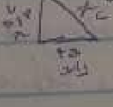
$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{7^2} = 1.469N/C \approx 1.5N/C$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{7^2} = 12N/C$$

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

a.i) $\vec{E}$ at point Q on the y axis at $y = 3m$ due to charge





$c^2 = a^2 + b^2$
$12 = 4^2 + 3^2$
$c = 5$

$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{5^2} \quad \vec{E}_1 = 8N/C$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^{9}\times12\times10^{-9}}{5^2} = 4.32N/C$$

vector	Angle	x-comp	y-comp
$E_1 = 8N/C$	90°	$0N/C$	$8N/C$
$E_2 = 4.32$	36.87°	$-3.45N/C$	$2.59N/C$
		$E_x = -3.45N/C$	$E_{fy} = 10.59N/C$

$E_{net} = \sqrt{E_x^2 + E_y^2}$
$E_{net} = 11.12N/C$

where Q = charge

V = Volume

L = length

A = Area

5. Formulation of distribution of charges

i. Volume charge density $\rho = \frac{dQ}{dV} = dQ = \rho dV$

ii. surface charge density $\sigma = dQ/dA = dQ = \sigma dA$

iii. Linear charge density $\lambda = dQ/dL = dQ = \lambda dL$

6. electric potential difference equation ~~due~~ ~~to a~~ sm

. 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.

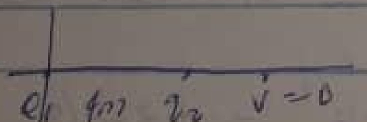
$$V_p = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1}\right] + \frac{Q_2}{r_2}\Big]$$

where V = electric potential

Q = point charge

r = distance of Q

c. point charge $Q_1 = 10\mu C$ $Q_2 = -2\mu C$ along x-axis $x = 0$, $x = 4m$ respectively find the 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 $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 = K$.

$$V_p = K\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

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