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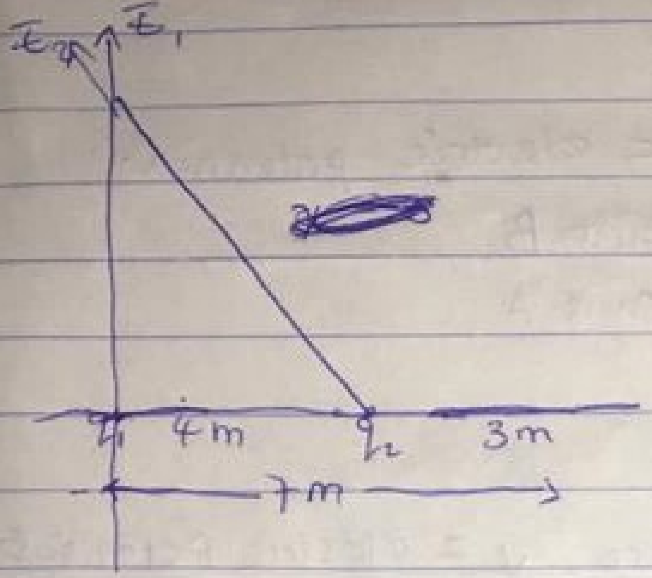
Section A.

2a An electric field is a region of space in which an electric charge will experience an electric force while Electric field intensity is the per unit charge ~~unt~~ unexperienced by a charge in an electric field

b) i



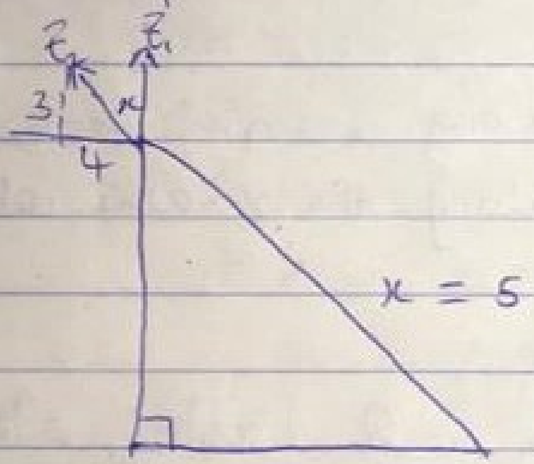
$$E_1 = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2}$$

$$= 1.469\ N/C \simeq 1.5\ N/C$$

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

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

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



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

$$c^2 = 4^2 + 3^2$$

$$c = 5$$

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

$$E_2 = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\ N$$

Vector	angle	x - comp	y - comp
$E_1 = 8\ N/C$	$90°$	$0\ N/C$	$8\ N/C$
$E_2 = 4.32$	$36.87°$	$-3.45\ N/C$	$2.59\ N/C$
		$E_{fx} = -3.45\ N/C$	$E_{fy} = 10.59\ N/C$

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

$$= 11.12\ N/C.$$

3a) 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 $\lambda = dQ/dL = dQ = \lambda dL$

b) Electrical Potential difference

- due to 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 $\quad V$ = electric potential.
r_B = distance of Q to point B
r_A = distance of Q to point A

- due to several Point Charges

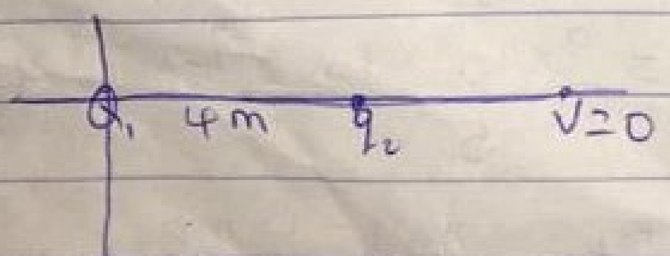
$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r} + \frac{Q_2}{r_2}\right]$$

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 whe[re] $V = 0$.

Solution

$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q}{r_2}\right] \quad \text{recall } \frac{1}{4\pi\varepsilon_0} = 9\times$$



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

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

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

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

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

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

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

$$8 \times 10^{-6} = 8 \times 10^{-6} x$$

$$x = \frac{8 \times 10^{-6}}{8 \times 10^{-6}}$$

$$x = 1$$

$\therefore$ - Position alon the x-axis is 1m where $V = 0$

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

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

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

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

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

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

$$8 \times 10^{-6} = 12 \times 10^{-6} x$$

$$x = \frac{8 \times 10^{-6}}{12 \times 10^{-6}}$$

$$x = 0.67m$$

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

Section B

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.

$$\phi = B \cdot d_A$$

b $m_e = 9.11 \times 10^{-31}$ kg, $r = 1.4 \times 10^{-7}$ m; $B = 3.5 \times 10^{-1}$ w/m²

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

$$F_B = qV_B = \frac{m_e V^2}{r}$$

$$m_e v = qBr$$

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

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

$$w = \frac{v}{r} = \frac{qB}{m_e} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

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

c in 4b, we were given parameters; and we were asked to find the cycloton frequency which is the same thing as angular speed is called cycloton frequency becauce it is a frequency of an accel called cyclotion.

Recall w = angular speed

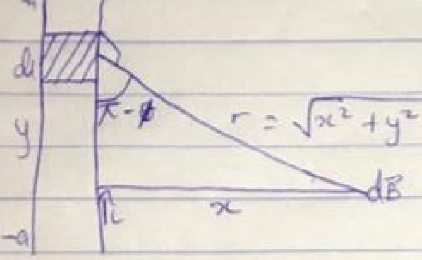
$w = \frac{qB}{m_e}$. since cyclotton frequency = angular speed. The cyclotion frequency $= 6.14 \times 10^{-10} e^{-1}$ having a unit f which is the unit of a frequncy dimensionally.

5a) Bio-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, the radius and inversely proportional to square radius (r^2). Mathematically;

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

where μ_m (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/m^2.

5b Magnetic field of a 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,

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

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

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

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

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

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

Substitute ② into ①

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

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

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

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

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

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