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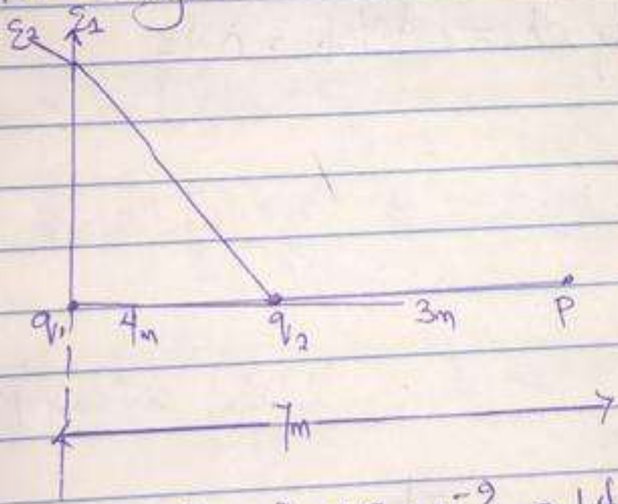
Course Code: Phy 102.

2a Electric field	Electric field intensity
It is a region of space which an electric charge will experience an electric force	It is the force per unit charge

2b $q_1 = 8nC$ at origin, $q_2 = 12nC$ on the x axis at $x = 4m$
(i) Net electric field at point P on the x axis at $x = 7m$
(ii) Electric field at a point Q on the y axis at $y = 3m$ due to the charges.

(i)

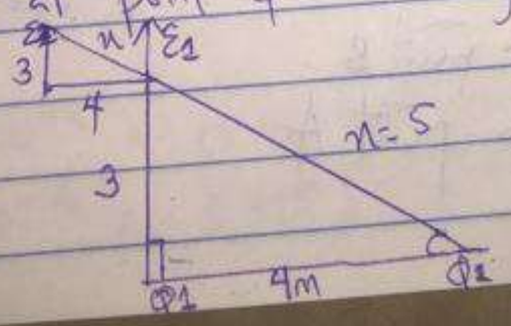


$E_1 = \frac{Kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2} = 1.469\ N/C \simeq 1.5 N/C$

$E_2 = \frac{Kq_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{7^2} = 12 N/C$

(i) $\vec{E}_{net} = \vec{E_1} + \vec{E_2} = 1.5 + 12 = 13.5 N/C$

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



$E_1 = \frac{Kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2}$

$= 8 N/C$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\ N/C$

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

$E_{net} = \sqrt{\Sigma f_x^2 + \Sigma f_y^2} = \sqrt{(-3.45)^2 + 10.59^2}$

$E_{net} = 11.12N/C$

3) Formulation of density of charges

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

b) Surface charge density $\sigma = dq/dA = \sigma dA$

c) Linear charge density $\lambda = dq/dL = \lambda dL$

WHERE

q - charge

V - Volume

L - Length

A - Area

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

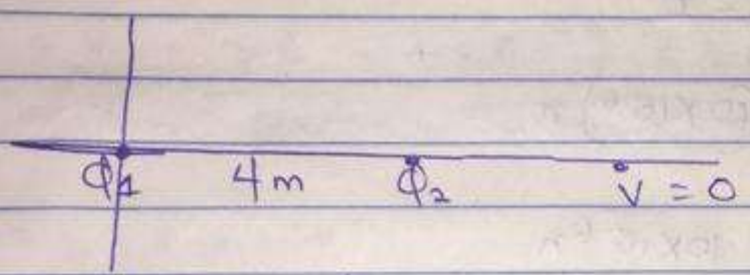
r_A - distance of q to point A

- due to several point charges

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

where V - Electric potential
Q - Point charge
r - distance of Q

3c point charges $Q_1 = 10\mu C$ $Q_2 = -2\mu C$ along x axis $x = 0$ and $x = 4m$ 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 $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 = k$

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

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

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

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

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

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

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

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

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

$n = 1$

$\therefore$ Position along the n-axis is 1m

where $V = 0$

$$V = k\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$

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

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

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

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

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

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

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

$n = 0.67$m

$\therefore$ 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 force. It is denoted by ϕ

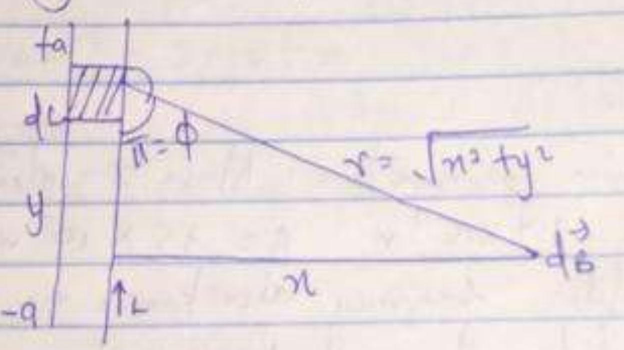
$$\phi = B \cdot dA$$

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 of radius (r^2). Mathematically

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

Where μ_0 = Permeability of free space $= 4\pi \times 10^{-7}$ Tm/A
r = radius $d\hat{B}$ = magnetic field I = steady current
dL = length of wire (unit is W/m²)

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

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

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

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

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 $q = 1.6 \times 10^{-19}$

$F_B = qvB = \frac{M_e V^2}{r}$

$M_e V = qBr$

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

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

$W = \frac{V}{r} = \frac{qB}{M_e} = \frac{1.6 \times 10^{-19} \times 3.6 \times 10^{-4}}{9.11 \times 10^{-31}}$

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

4c) In 4b we were given parameters: Mass of electron $9.11 \times 10^{-31} kg$ radius $= 1.4 \times 10^{-7} m$ $B = 3.5 \times 10^{-1} w/m^2$
Asked to find the cyclotron frequency also known as Angular speed. It is cyclotron frequency because it is frequency of an accelerator called CYCLOTON

Recall w = Angular speed

$W = \frac{qB}{M_e}$

Since cycle from frequency = Angular speed
The cyclotron frequency $= 6.14 \times 10^{-10} e^{-1}$ having a unit of $\frac{1}{T}$ which is the unit of frequency dimensionally

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

Substitute (ii) into (i)

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

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

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

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

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

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