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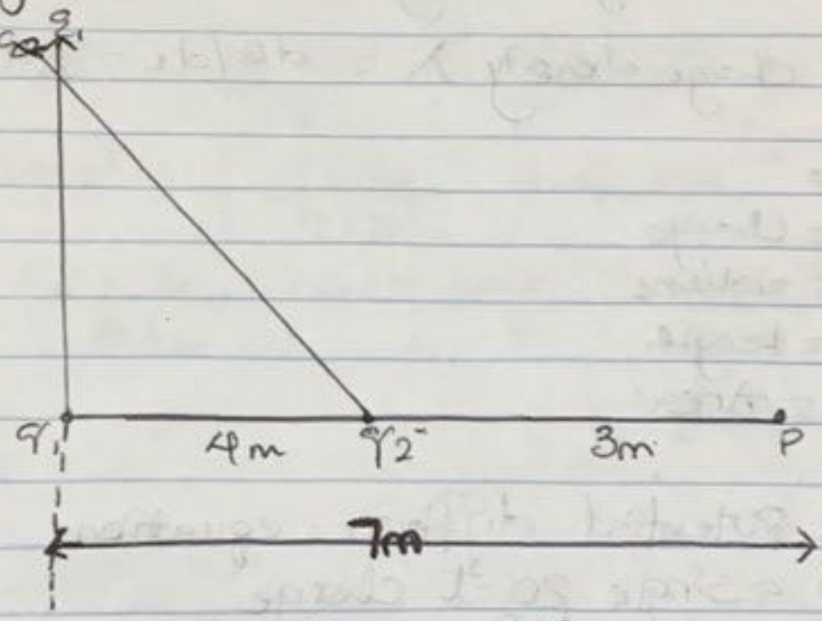
Department: Medicine & Surgery
Course: Medicine And Health Sciences
Course Code: PHY 102

2a. Electric field:
It is a region of space 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 $x = 4m$.
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)

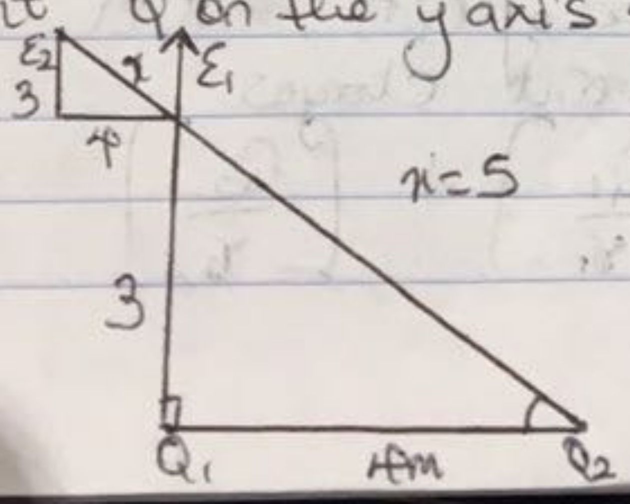


$$E_1 = \frac{KQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2} = 1.469N/C \approx 1.5N/C$$

$$E_2 = \frac{KQ_2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{7^2} = 12N/C$$

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

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



$$E_1 = \frac{KQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2} = 8N/C$$

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

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

$$f_{net} = \sqrt{\Sigma f_x^2 + \Sigma f_y^2} = \sqrt{(-3.45)^2 + 10.59^2}$$
$$f_{net} = 11.12 N/C$$

3. Formulation of identity 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

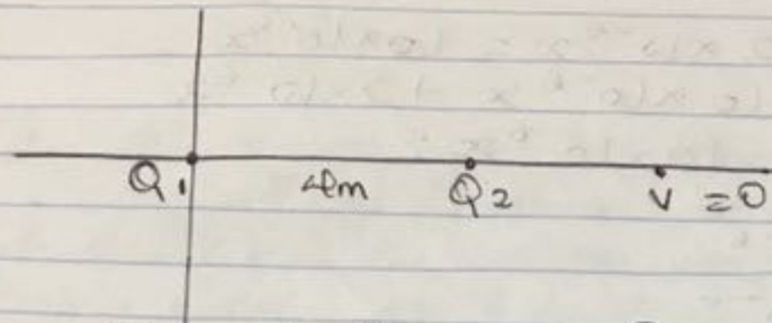
- due to several point charges

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

-comps
8 N/C
-59 N/C
y = 10.59 N/C

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 $V = 0$



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

recall $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 k$

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

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

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

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

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

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

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

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

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

$$x = 1$$

∴ position along the x-axis is 1m where $V = 0$

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

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

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

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

$$8\times10^{-6} - 2\times10^{-6}x = 10\times10^{-6}x$$
$$8\times10^{-6} = 10\times10^{-6}x + 2\times10^{-6}x$$
$$8\times10^{-6} = 12\times10^{-6}x$$

$$x = \frac{8\times10^{-6}}{12\times10^{-6}}$$
$$x = 0.67m$$

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

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

$$\phi = B \cdot dA$$

4b. $M_e = 9.11\times10^{-31}Kg$
$r = 1.4\times10^{-2}m$
$B = 3.5\times10^{-1} N/m^2$.

Cyclotron frequency = angular speed $q = 1.6\times10^{-19}$
$$F_B = qvB = \frac{M_e v^2}{r}$$

$$M_e v = qBr$$

$$v = \frac{qBr}{M_e} = \frac{1.6\times10^{-19}\times3.5\times10^{-1}\times1.4\times10^{-7}}{9.11\times10^{-31}}$$

$$v = 8.61\times10^{-3}\ m/s$$

$$\omega = \frac{v}{r} = \frac{qB}{M_e} = \frac{1.6\times10^{-19}\times3.6\times10^{-4}}{9.11\times10^{-31}}$$

$$\omega = 6.14\times10^{10}\ s^{-1}$$

4c In 4b we were given parameters: Mass of electron 9.11×10^{-31} kg, radius $= 1.4\times10^{-7}$ m, $B = 3.5\times10^{-1}$ wb/m². Asked to find the cyclotron frequency also known as Angular speed. It is cyclotron frequency because it is frequency of an accelerator called CYCLOTRON.

Recall ω = Angular speed

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

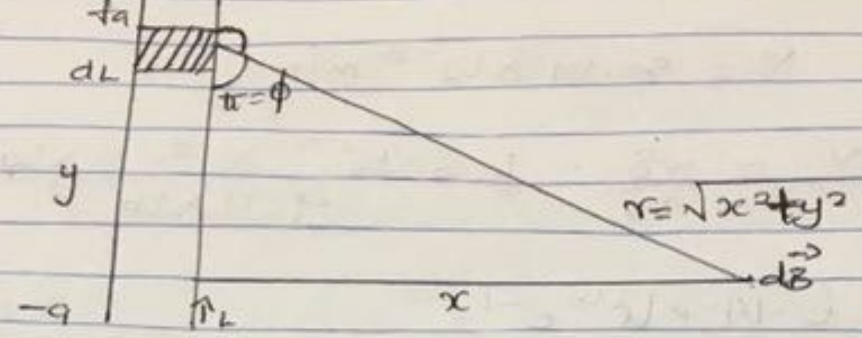
Since cycle from frequency = Angular speed.
The cyclotron frequency $= 6.14\times10^{10}\ s^{-1}$ having a unit of $\frac{1}{T}$ which is the unit of frequency dimensionally.

5a 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 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 $= 4\pi\times10^{-7}$ 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:

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

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

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

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)

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

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

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