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SECTION A.

2a ELECTRIC FIELD - This is a region around a charge in which it exerts electrostatic force on another charges.

ELECTRIC FIELD INTENSITY - This can be defined as the strength of electric field at any point in space. It can also be said to be the force per unit charge.

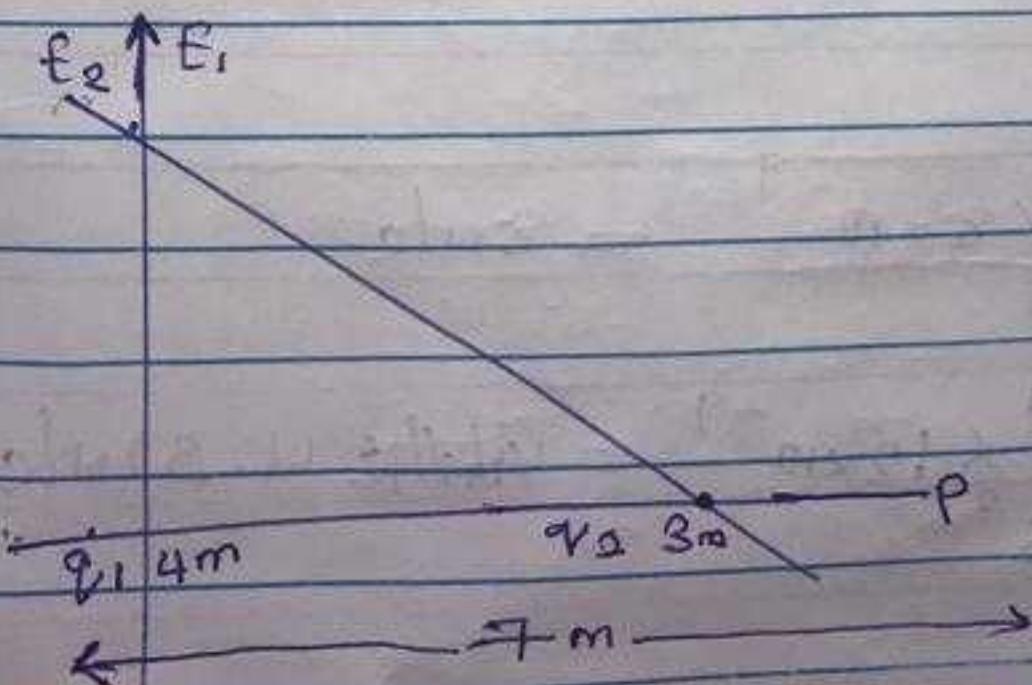
2b $Q_1 = 8\text{nC}$ - Origin

$Q_2 = 12\text{nC}$ - x axis

$\infty = 4\text{m}$.

i net electric field at point P on the x axis at $x = 7\text{m}$

ii electric field at point Q on the y . axis at $y = 3\text{m}$ due to the charges.

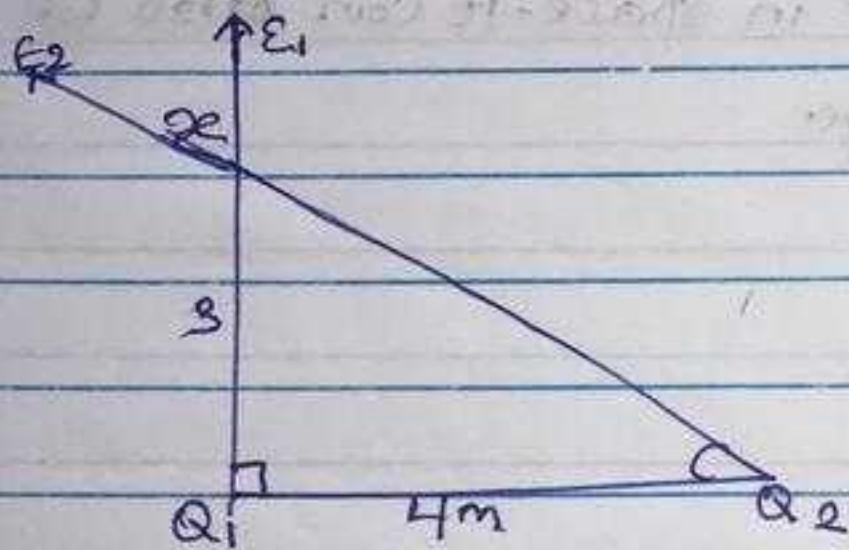


$$E_1 = \frac{KQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2} = 1.469 \text{ N/C} \approx 1.5 \text{ N/C}$$

$$E_2 = \frac{KQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{5^2} = 1.08 \text{ N/C}$$

$$E_{\text{net}} = E_1 + E_2 \\ = (1.5 + 1.08) \text{ N/C} = 18.5 \text{ N/C}$$

ii) E at point Q on the y axis's at $y = 3$ due to the charge



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

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

$$c^2 = 16 + 9$$

$$c^2 = \sqrt{25} = 5$$

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

$$E_2 = \frac{KQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{5^2} = 4.32 \text{ N/C}$$

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

$E_{\text{net}} = \sqrt{E_{fx}^2 + E_{fy}^2}$
 $= 11.12 \text{ N/C} = 11.13 \text{ N/C}$

- iii Volume charge density, $\rho = \frac{dQ}{dV} = \rho dV$
- ii Surface charge density $\sigma = \frac{dQ}{dA} = \sigma dA$
- iii Linear charge density $\lambda = \frac{dQ}{dL} = \lambda dL$

3b THE ELECTRIC POTENTIAL DIFFERENCE

The difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to the other.

Electric potential due to a single point charge.

$$V_B - V_A = \frac{Q}{4\pi\epsilon_0} \left(\frac{1}{r_B} - \frac{1}{r_A} \right)$$

where Q is the point charge

V = electric potential

r_B = distance of Q to nB

r_A = distance of Q to nA

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

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

$$x = 1$$

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

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

$$0 = \left(\frac{10 \times 10^{-6}}{4-x} + \frac{-2 \times 10^{-6}}{x} \right)$$
$$= \cancel{2 \times 10^{-6}} = 10 \times 10^{-6}$$
$$\cancel{x} \quad \cancel{4-x}$$

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

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

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

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

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

$$\infty = 0.67$$

∴ Position of $V=0$ is 0.67m.

Due to several point charges

$$V = \sum V_p = \frac{1}{4\pi\epsilon_0} \left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right]$$

where V = electrical potential

Q = point charge

r = distance of Q .

Sc. $Q_1 = 10 \text{ NC}$

$Q_2 = -2 \text{ NC}$

$x = 0$

$x = 4$ position along the axis when $x = 0$

$$V_p = \frac{1}{4\pi\epsilon_0} \left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right) \quad \text{Recall, } \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N} \cdot \text{C}^{-2}$$

$$V_p = 9 \times 10^9 \left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right)$$

$$V_p = 9 \times 10^9 \left(\frac{10 \times 10^{-6}}{4+x} + \frac{-2 \times 10^{-6}}{x} \right)$$

$$\Theta = 9 \times 10^9 \left(\frac{10 \times 10^{-6}}{4+x} + \frac{-2 \times 10^{-6}}{x} \right)$$

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

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

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

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

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

SECTION B

4a. MAGNETIC FLUX

This is defined as the strength of magnetic field represented by lines of force. It is usually represented by the symbol Φ .

$$4b. \text{An electron (mass)} = 9.11 \times 10^{-31} \text{ kg}$$

$$q = 1.6 \times 10^{-19} \text{ (constant)}$$

$$\text{Radius} = 1.4 \times 10^{-7} \text{ m}$$

$$\text{Magnetic field} = 3.5 \times 10^{-1}$$

$$r = 1.4 \times 10^{-7} \text{ m}$$

$$B = 3.5 \times 10^{-1} \text{ T/m}^2$$

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

$$F_B = qvB = me\nu^2$$

$$MeV = \nu B r$$

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

$$\nu = \frac{7.84 \times 10^{-27}}{9.11 \times 10^{-31}} = 8.61 \times 10^{-3} \text{ m/s}$$

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

$$\omega = 6.14 \times 10^{10} \text{ rad}^{-1}$$

In Qb, we were given mass of electron = 9.11×10^{-31} kg, radius = 1.4×10^{-9} m, $B = 3.5 \times 10^{-3}$, cyclotron frequency = 1.8×10^{19} and we were asked to find the cyclotron frequency which is also known as angular speed. It is called cyclotron frequency because it has a frequency called cyclotron.

Recall, ω = angular speed

$$\omega = \frac{qB}{m_e} \text{ since cyclotron frequency} = \text{angular speed.}$$

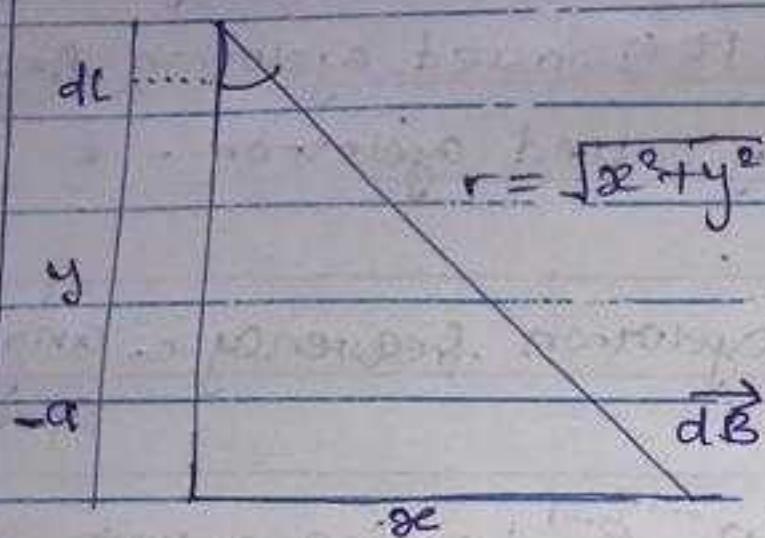
The cyclotron frequency = $6.14 \times 10^{10} \text{ s}^{-1}$ having a unit of Hz which is the unit of frequency dimensionally.

5a. Biot - 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,

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

where μ_0 (permeability of free space) = $4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$
 r = radius, $d\vec{B}$ = magnetic field, I = steady current; dL = length of wire. Unit is Wb/m^2 .

6b. Magnetic field of a straight current carrying conductor.



A section of a straight current carrying conductor

Applying Biot-Savart law ($d\vec{B}$) we find the magnitude of the field ($d\vec{B}$) from the diagram

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

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

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

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

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

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

Substituting (ii) into (i).

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

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

Recall, $dx = dy$

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

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

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

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

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