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Course: Phy 102

3 Volume charge density, $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

4 Surface charge density $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

5 Linear charge density $\lambda = \frac{dQ}{dl} \rightarrow dQ = \lambda dl$

Where

Q = Charge, V = Volume, L = Length, A = Area

b Electric Potential difference equation

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

where Q = Point charge

r_B = distance of Q to point B

r_A = distance of Q to point A

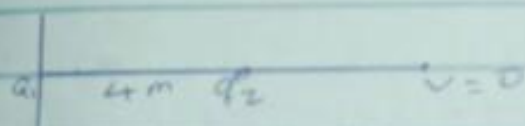
Due to several point charges

$$V_P = \frac{1}{4\pi\epsilon_0} \left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right] \dots$$

Where V = electric potential

Q = Point charge

r = distance of Q



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

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

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

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

Applying Biot-Savart law, we find magnitude of the field

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

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

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

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

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

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

Substitute (1) into (1)

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

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

$$dl = dy ; B = \frac{\mu_0 I x}{4\pi} \int_{-a}^a \frac{1}{(x^2 + y^2)^{\frac{3}{2}}} \dots \dots \textcircled{11}$$

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

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

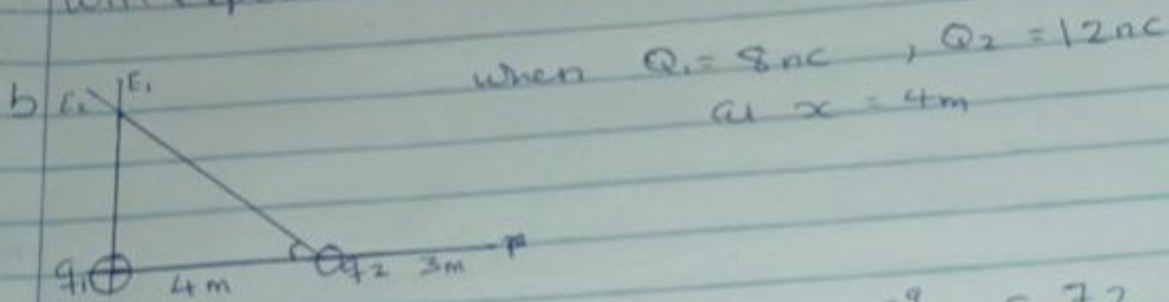
$$B = \frac{\mu_0 I}{4\pi x} = \frac{\mu_0 I}{2\pi x}$$

Section A

2a Electric Field

Electric field is a region of space in which an electric charge will experience an electric force.

Electric Field Intensity can be defined as the force per unit charge.



$$E_1 = \frac{kQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{4^2} = \frac{72}{16}$$

$$= 1.469 \text{ N/C} \approx 1.5 \text{ N/C}$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{3^2} = \frac{108}{9}$$

$$= 12 \text{ N/C}$$

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

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

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

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

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

$$x = \frac{8 \times 10^{-6}}{8 \times 10^{-6}} = 1 \text{ m}$$

∴ position along the x-axis is 1 m

where $v = 0$

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

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

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

$$x = 4 - x$$

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

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

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

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

$$x = \frac{8 \times 10^{-6}}{12 \times 10^{-6}} = 0.67 \text{ m}$$

$$12 \times 10^{-6}$$

Position of $v=0$ is 0.67 m

Section B

Magnetic flux is defined as the strength of the magnetic field which can be represented by the line of forces. It is denoted by Φ .

Ab $M_e = 9.11 \times 10^{-31} \text{ kg}$, $r = 1.4 \times 10^{-7} \text{ m}$, $B = 3.5 \times 10^{-1} \text{ W/m}^2$

Cyclotron frequency = Angular speed $\omega = 1.6 \times 10^{-19}$

$$F_B = \frac{q v B}{r} = \frac{M_e v^2}{r}$$

$$M_e v = q B r$$

$$v = \frac{q B r}{M_e} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1} \times 1.4 \times 10^{-7}}{9.11 \times 10^{-31}}$$

$$v = 8.0 \times 10^{-3} \text{ m/s}$$

$$\omega = \frac{v}{r} = \frac{qB}{m_e} = \frac{1.6 \times 10^{-19} \times 2.6 \times 10^{-1}}{9.1 \times 10^{-31}}$$

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

Mass of electron = $9.1 \times 10^{-31} \text{ kg}$

$$\text{radius} = 1.4 \times 10^{-3} \text{ m}$$

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

and we were asked to find the cyclotron frequency in 4b which is the same thing as angular speed. It is called cyclotron frequency because it is a frequency of an acceleration called cyclotron.

Recall ω = angular speed

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

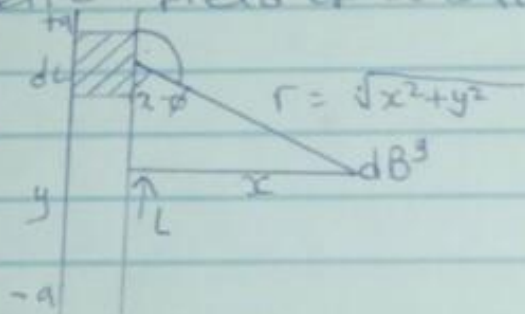
Since cyclotron frequency = angular speed

The cyclotron frequency = $6.14 \times 10^{10} \text{ s}^{-1}$ having a unit of $\frac{1}{\text{s}}$ 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 charge (I), the change in length, the radius and inversely proportional to the square of radius (r^2). Mathematically

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

b Magnetic Field of a straight current carrying conductor



A section of a straight current carrying conductor