Soln

An electron(mass) $= 9.11 \times 10^{-31}$ kg $Q = 1.6 \times 10^{-19}$

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

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

$M_e = 9.11 \times 10^{-31}$ kg

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

$B = 3.5 \times 10^{-1}$ Wb/m^2 $q = 1.6 \times 10^{-19}$

Cyclotron frequency = angular speed

$F_B = qvB = \frac{m_e v^2}{r}$

$M_e v = qBr$

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

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

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

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

(c) Discuss your answers in 4b above

In 4b, parameters were given, Mass of electron $= 9.11 \times 10^{-31}$ kg Radius $= 1.4 \times 10^{-7}$ m, $B = 3.5 \times 10^{-1}$, cyclotron frequency $= 1.6 \times 10^{-19}$

We were asked to find the cyclotron frequency which is also known as angular speed. It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron.

Recall, ω = angular speed

$\omega = \frac{qB}{m_e}$ Since cyclotron frequency = angular speed

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

$$0 = 9\times10^{9}\left(\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right)$$

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

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

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

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

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

$$x = \frac{8\times10^{-6}}{8\times10^{-6}} \quad x = 1$$

∴ position along the x-axis is 1m.

where $V = 0$

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

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

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

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

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

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

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

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

position of $V = 0.67m$ //

Question 5

(a) State the Biot-Savart law?

Biot-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

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\hat{r}}{r^2} \quad \text{—— (1)}$$

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Where μ_0 is a constant called permeability of free space

$\mu_0 = 4\pi \times 10^{-7}\, T \cdot m/A$

r = radius B = magnetic field I = steady current dl = length of wire units is N/m^2

5b) Using the Biot-Savart law, show the magnitude field of a straight current-carrying conductor is given as:

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

Magnitude field of a straight current carrying conductor. Applying Bio-Savart law (dB) we find the magnitude of the field (dB) from the diagram.

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

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

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

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

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

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

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

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

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

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

$$\int \frac{dy}{(x^2+y^2)^{3/2}} \quad B = \frac{\mu I}{4\pi x} \frac{2a}{(x^2+y^2)^{1/2}} \quad (x^2+a^2) = 1/2 = a \quad B = \frac{\mu_0 I}{2\pi x} = \frac{\mu_0}{2\pi}$$

Question 3

3(i) State the formulation of the following identities of charges.

(i) Volume charge density: $\rho = \frac{dQ}{dv} \rightarrow dQ = \rho\, dv$

(ii) Surface charge density: $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma\, dA$

(iii) Linear charge density: $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda\, dL$

(b) Explain with appropriate equations, the electric potential difference.

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

Electrical potential 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 is the point charge point, V = electrical potential

r_B is the distance of Q to B

r_A is the distance of Q to A

Due to several point charges

$$V \quad \sum V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{r}\right] + \left[\frac{Q_2}{r_2}\right]$$

Where V = electric potential

Q = point charge

r = distance of Q

(c) $Q_1 = 10nC \quad Q_2 = -2nC \quad x = 0$

$x = 4m$

position along the axis. Q | 4m — $x = 0$

When $x = 0$

$$V_P = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right) \quad \text{recall } \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$$

$$V_P = k\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right) \quad V_P = 9 \times 10^9\left(\frac{10 \times 10^{-6}}{4+x} + \frac{-2 \times 10^{-6}}{x}\right)$$

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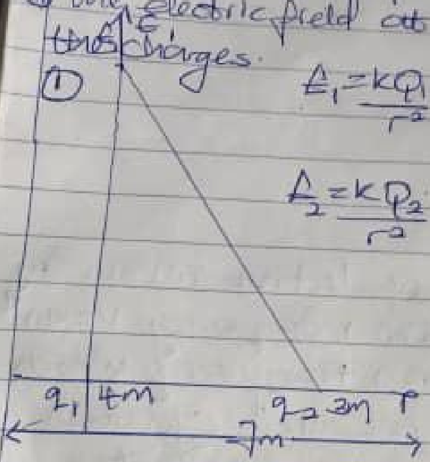
Question 2

(a) Distinguish between the terms electric field and electric field intensity.

Electric field is a region of space in which an electric charge will experience an electric force
While
Electric field intensity is the force per unit charge.

(b) A positive charge $Q_1 = 8nC$ is at the origin, and a second positive charge $Q_2 = 12nC$ is on the x-axis at $x = 4m$. find
(i) The net electric field at a point P on the x-axis at $x = 7m$.
(ii) the electric field at a point Q on the y axis at $y = 3m$ due to the charges.

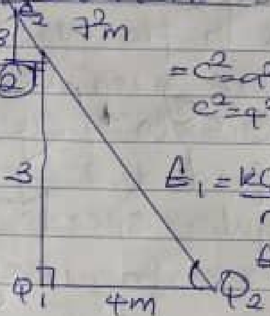
(i)



$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 Nm^2 \times 8\times10^{-9}}{7^2 m} = 1.469 N/C = 1.5 N/C$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 Nm^2 \times 12\times10^{-9}}{7^2 m} = 12 N/C$

(2)



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

$c^2 = 4^2 + 3^2 = 16 + 9$ $c^2 = \sqrt{25}$

$c = 5$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8 N/C$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-19}}{5^2}$
$= 4.32 N/C$

Question 4

(a) What is magnetic flux?

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

(b) An electron with a rest mass of $9.11\times10^{-31} kg$ moves in a circular orbit of radius $1.4\times10^{-7} m$ in a uniform magnetic field of 3.5×10^{1} weber/meter square perpendicular to the speed with which electron moves. find the cyclotron frequency of moving electron.