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Physics 102

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⇒ Section A

2. Electric field is a region of space in which an electric charge will experience an electric force. While Electric Field Intensity can be defined as the force per unit charge.

b) $q_1 = 8nc$, $q_2 = 12nc$
$r_1 = 4m$ $Q = ?$
$r_2 = 3m$ $P = ?$

$E_1 = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{4^2} = 4.5\times10^3 NC^{-1}$

$E_2 = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{9\times10^9 \times 12\times10^{-6}}{3^2} = 12\times10^3 NC^{-1}$

$E_P = E_1 + E_2 = 4.5\times10^3 + 12\times10^3 = 16.5\times10^3 NC^{-1}$

Net charge $= 12 + 8 = 20\mu C$

$F = 2E = 20\times10^{-6} \times 16.5\times10^3$
$= 0.33N$

$Q = \frac{20\times10^{-6} \times 9\times10^9}{3^2} = 20\times10^3 NC^{-1}$

To get the electric charge recall,

$F = \frac{Q_P}{4\pi\varepsilon_0 r^2} = 9\times10^9 \times \frac{Q_P}{r^2}$

$Q_P = \frac{E\times r^2}{4\times10^9} = \frac{16.5\times10^3 \times 7^2}{9\times10^9}$
$= 8.98\mu C$

$E_P = \frac{9\times10^9 \times 89.8 \times10^{-6}}{3^2}$

$E_P = 89.8 NC^{-1}$

3a 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 density, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$

b Electric potential 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. It is measure in volt (v) or joules per coulomb (j/c). It's a scaler quantity.

Electric potential = $\frac{\text{work done}}{\text{charge}}$

$$V = \frac{W}{Q}$$

C. $Q_1 = 10\mu C$ $Q_2 = -2\mu C$

$x = 0$ and $x = 4m$

$V = 0$

Sol:-

4a Magnetic flux is the surface integral of the normal component of the magnetic field flux density B passing through that surface.

b $m = 9.11 \times 10^{-31} kg$
$r = 1.4 \times 10^{-7} m$
Mag. field $= 3.5 \times 10^{-1}$

Sol:
Angular speed $= \omega = V/r = \frac{qB}{m}$
$\omega = \frac{V}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$

$\frac{qB}{m} = \frac{1.6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$
$= 6.147091109 \times 10^{10}$

4c In the question above we were given parameters such as;
i mass of the electron $= 9.11 \times 10^{-31} kg$
ii A radius of $1.4 \times 10^{7} m$
iii magnetic field of 3.5×10^{-10} weber/meter square.
and we were asked to find the cyclotron frequency which is also angular speed.
Recall that angular speed $= \omega = V/r = \frac{qB}{m}$
$\therefore \frac{qB}{m} = \frac{1.6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$

$\frac{qB}{m} = 6.147091109 \times 10^{10}$
So since cyclotron is angular speed the cyclotron frequence is equal to 6.147091109 $\times 10^{10}$ having a unit is $1/s$ which is the unit of frequency dimensionally

5a

~~The Biot-Savart law is based on the following.~~

The Biot-Savart law states that it is a mathematical expression which illustrates the magnetic field produced by a stable electric current in the particular electro-magnetism of physics.

b Applying Biot Savart law to show the magnitude.

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

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

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

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

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

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

Substituting ii into i we have

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

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

Recall $dl = dy$

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

Using special integrals:

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

Equation (iii) therefore becomes

$$B = \frac{\mu_0 I x}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$$

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

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

When the length $2a$ of the conductor is very great in comparison to its distance x from point P, we consider it infinitely long. That is when a is much larger than x.

$$(x^2+a^2)^{1/2} \cong a, \text{ as } a \to \infty$$

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