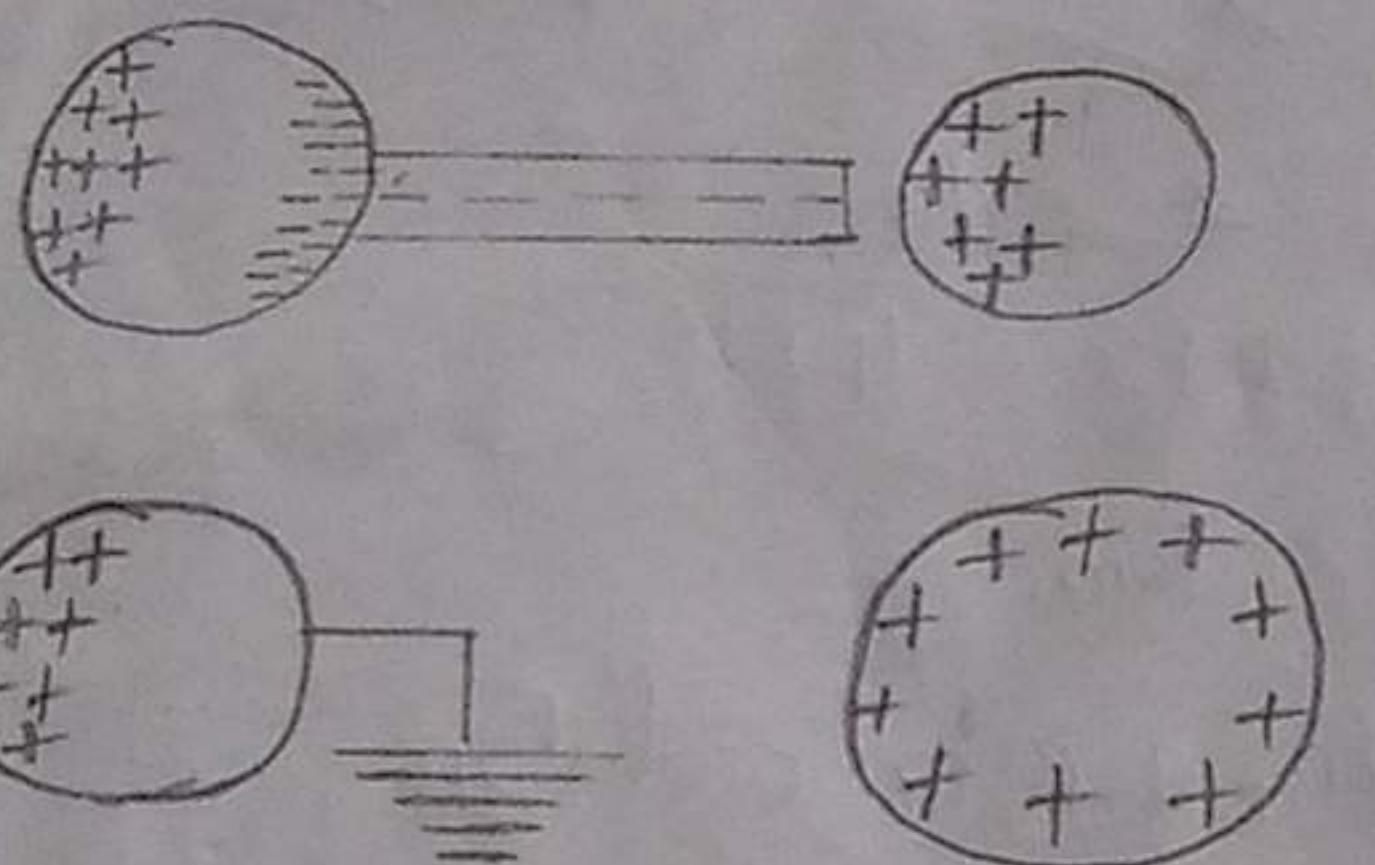


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Assignment
Section A

- ① Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction

Soln



Electric charges are obtained on an object without touching it, by a process called electrostatic induction.

The repulsive force between the electrons in the rod and those in the sphere causes redistribution of charges on the sphere. So that some electrons move to the side of the sphere farthest away from the rod.

The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from the location, if a grounded conducting wire is then connected to the sphere, some of the electrons leave the sphere and travel to the earth. If the wire to ground is then removed, the conducting sphere is left with an excess of induced positive charge.

Finally, when the rubber rod is removed from the sphere the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

(B)

- ⑥ Each of two small spheres is (repelled) charged positively, the combined charge being $5.0 \times 10^{-5} \text{ C}$. If each sphere is repelled from the other by a force of 1.0 N when the spheres are 2.0 m apart, calculate the charge on each sphere.

Soln

$$q_1 + q_2 = 5.0 \times 10^{-5} \text{ C}$$

$$F = 1.0 \text{ N}$$

$$r = 2.0 \text{ m}$$

$$q_1 = ?, q_2 = ? \text{ but } q_1 = 5.0 \times 10^{-5} \text{ C} - q_2$$

Calculate the charge on each sphere?

Recall that

$$k = 9 \times 10^9$$

$$F = \frac{k q_1 q_2}{r^2}$$

$$1.0 = \frac{9 \times 10^9 (5.0 \times 10^{-5} \text{ C} - q_2) q_2}{2^2}$$

$$1.0 = \frac{9 \times 10^9 (5.0 \times 10^{-5} \text{ C} - q_2) q_2}{4}$$

$$1.0 = \frac{4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2}{4}$$

$$4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2 = 4$$

$$9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$$

It is an quadratic equation

$$q_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$q_2 = \frac{(-4.5 \times 10^5) \pm \sqrt{(-4.5 \times 10^5)^2 - 4(9 \times 10^9 \times 4)}}{2 \times 9 \times 10^9}$$

$$q_2 = \frac{4.5 \times 10^5 \pm \sqrt{2.025 \times 10^{11} - 4(3.6 \times 10^{10})}}{1.8 \times 10^{10}}$$

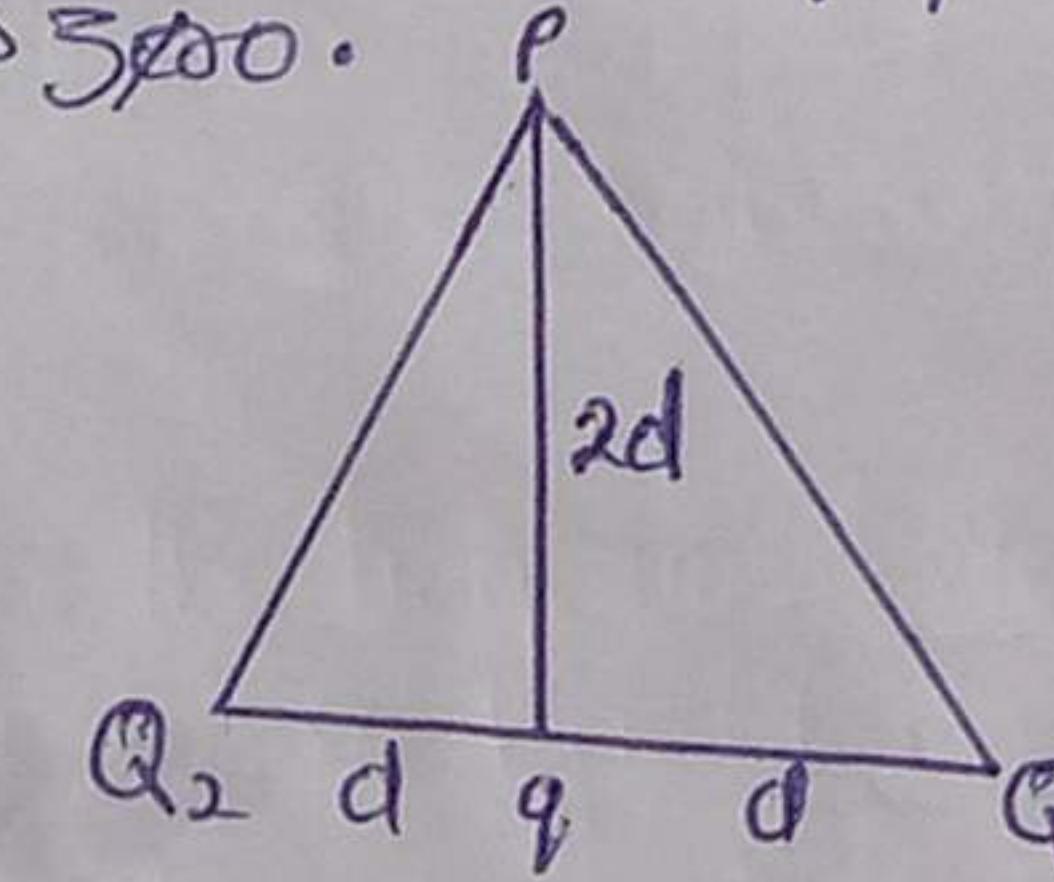
$$q_2 = \frac{4.5 \times 10^5 \pm \sqrt{5.85 \times 10^5}}{1.8 \times 10^{10}}$$

$$q_1 = \frac{4.5 \times 10^5 - 2.41 \times 10^5}{1.8 \times 10^{10}} \text{ or } q_2 = \frac{4.5 \times 10^5 + 2.41 \times 10^5}{1.8 \times 10^{10}}$$

$$q_1 = 1.1 \times 10^{-5} \text{ C} \text{ or } q_2 = 3.8 \times 10^{-5} \text{ C}$$

(C)

- ⑦ Three charges were positioned as shown in the figure below. If $Q_1 = Q_2 = 8 \mu\text{C}$ and $d = 0.5 \text{ m}$, determine q if the electric field at P is 5 kN/C .



Soln

$$E_{\text{net}} = 0$$

$$x^2 = 0.5^2 + (2 \times 0.5)^2$$

$$x^2 = 0.25 + 1$$

$$x^2 = 1.25$$

$$x = \sqrt{1.25}$$

$$x = 1.12$$

$$E_{\text{net}} = 0$$

$$E_1 = \frac{k q_1}{x^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5.74 \times 10^4 \text{ N/C}$$

$$\tan \theta = \frac{\text{opp}}{\text{adj}}$$

$$\tan \theta = \frac{2d}{d}$$

$$\tan \theta = \frac{1}{0.5}$$

$$\theta = \tan^{-1}(2)$$

$$\theta = 63.4^\circ$$

$$E_1 x = 5.74 \times 10^4 \text{ N/C} \cos 63.4^\circ$$

$$E_1 x = 2.57 \times 10^4 \text{ N/C}$$

$$E_{1y} = 5.74 \times 10^4 \text{ N/C} \sin 63.4^\circ$$

$$E_{1y} = 5.13 \times 10^4 \text{ N/C}$$

$$E_{2x} = -2.57 \times 10^4 \text{ N/C}$$

$$E_{2y} = 5.13 \times 10^4 \text{ N/C}$$

$$E_q = \frac{k q}{x^2} = \frac{9 \times 10^9 \times q}{(2 \times 0.5)^2} = 9 \times 10^9 q / 10 \text{ C}$$

$$E_q x = 0$$

$$E_q y = 9 \times 10^9 q$$

Ans

$$E_{\text{net}} = 0$$

$$E_{\text{net}} = \sqrt{(E_{1x} + E_{2x})^2 + (E_{1y} + E_{2y})^2}$$

$$0 = \sqrt{(2.57 \times 10^4 - 2.57 \times 10^4)^2 + (5.13 \times 10^4 + 5.13 \times 10^4)^2} \\ \sqrt{9 \times 10^9}$$

$$0 = 0 + \sqrt{(1.03 \times 10^5 + 9 \times 10^9 q)^2}$$

$$0 = 0 + \sqrt{(1.03 \times 10^5 + 9 \times 10^9 q)^2}$$

$$0 = 1.03 \times 10^5 + 9 \times 10^9 q$$

$$-1.03 \times 10^5 = 9 \times 10^9 q$$

$$q = -1.14 \times 10^{-5}$$

$$q = -1.14 \times 10^{-6} \text{ C}$$

~~soln~~

- ④ State the formation of the following identities of charges

① The volume charge density, $\rho = \frac{dQ}{dv} \rightarrow dQ = \rho dv$

② Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

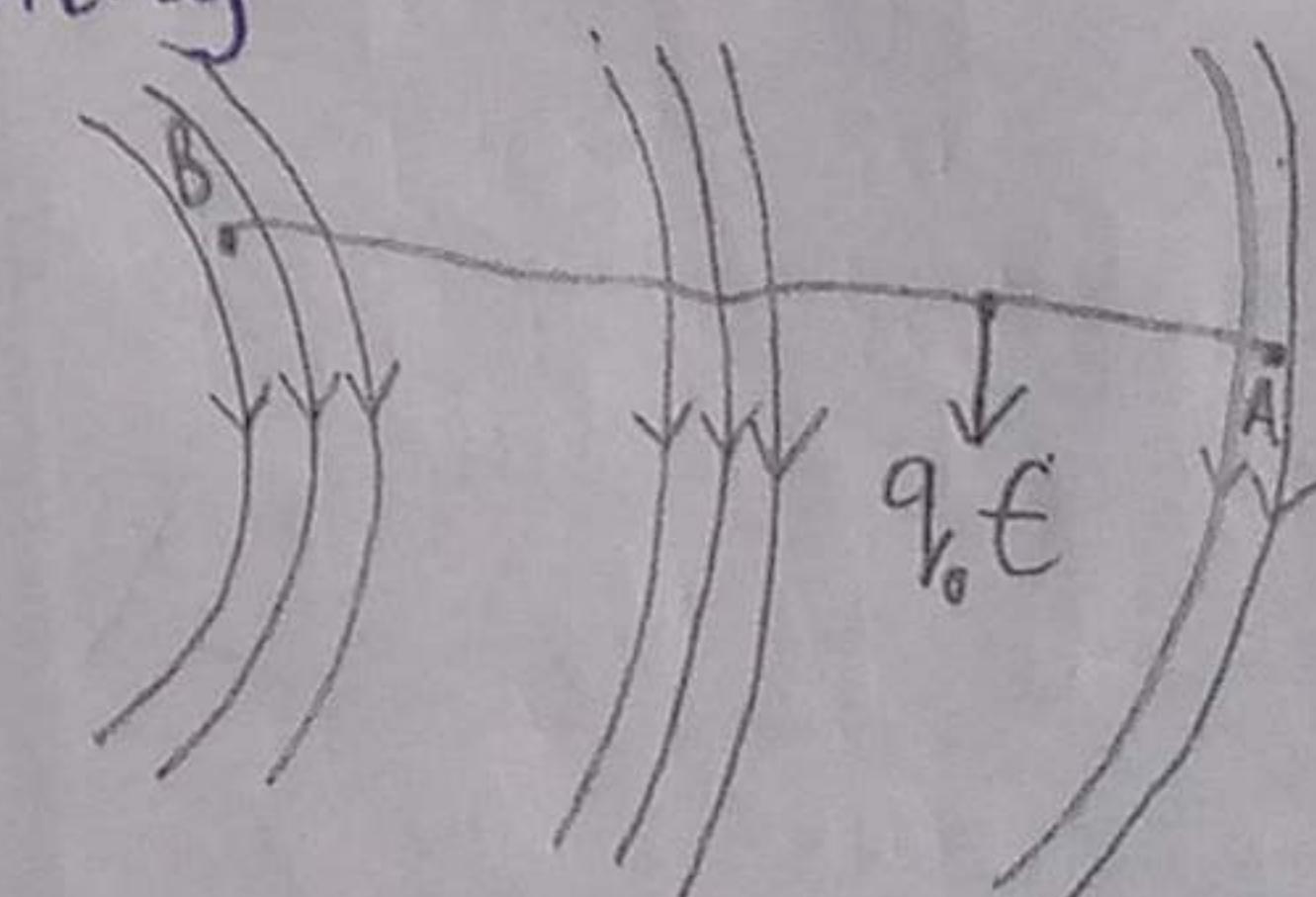
③ Linear charge density, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$

- ⑤ Explain with appropriate equations, the electric potential difference

~~soln~~

The electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical force when a charge is transported from one point to the other. It is measured in volt (V) or Joules per Coulomb (J/C).

Electric potential difference is a scalar quantity



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3b cont.

Consider the diagram above, suppose a test charge q_0 is moved field E . The electric field E exerts a force $F = q_0 E$ on the charge.

To move the test charge from A to B at constant velocity, an external force of $F = -q_0 t$ must act on the charge. Therefore, the elemental work done dW is given as

$$dW = F \cdot dt \quad \text{--- (1)}$$

But

$$F = -q_0 t \quad \text{--- (2)}$$

Substituting equ (2) in (1) yields $dW = -q_0 t dt$

Then total work done in moving test charge from A to B is

$$W(A \rightarrow B)_{\text{ng}} = -q_0 \int_A^B t dl \quad \text{--- (3)}$$

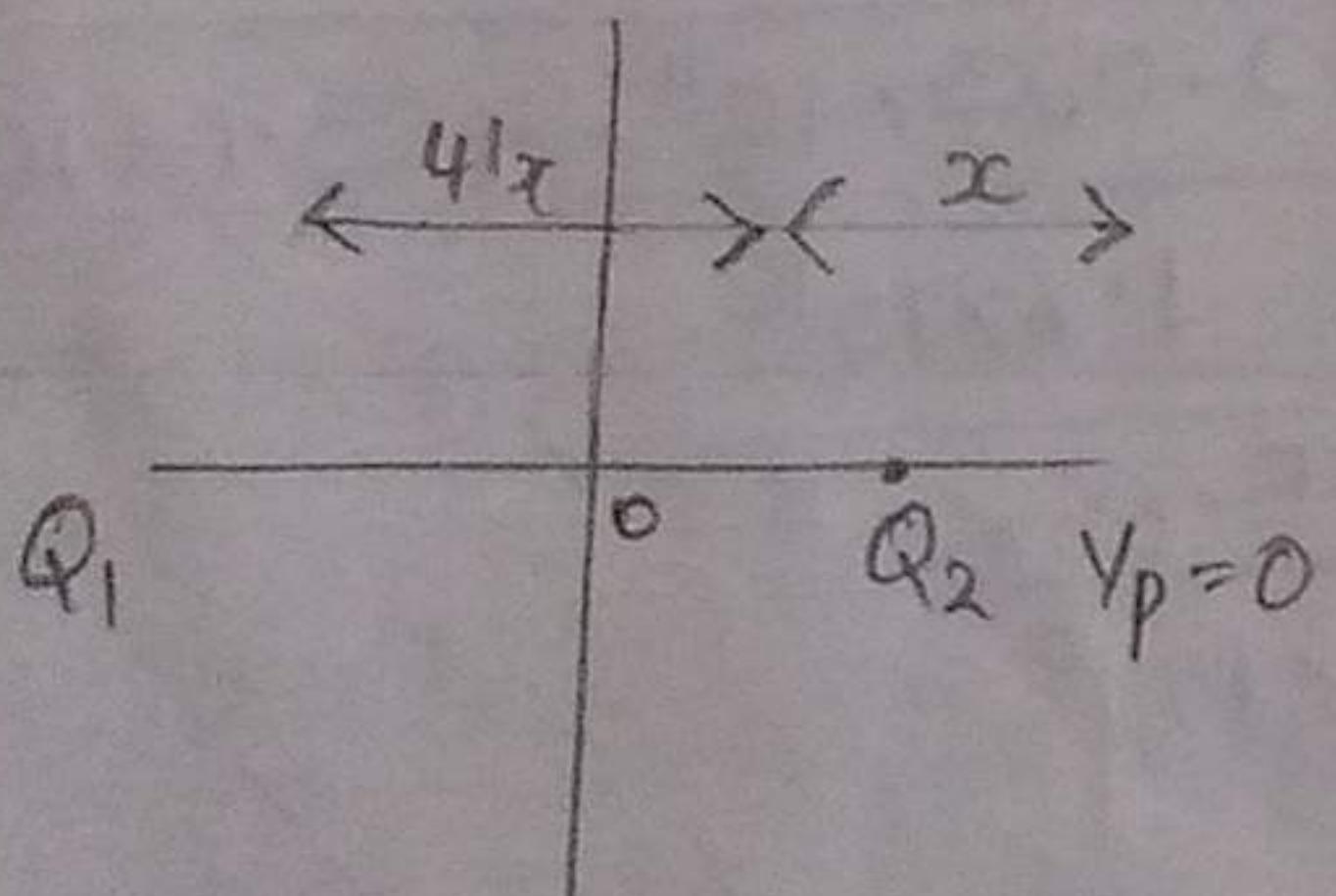
From the definition of electric potential difference, it follows that

$$V_B - V_A = \frac{W(A \rightarrow B)_{\text{ng}}}{q_0} \quad \text{--- (4)}$$

Putting equ (4) in (3) yields

$$V_B - V_A = - \int_A^B t dl$$

3c)



$$\begin{aligned} r_1 &= 4+x, Q_1 = 10 \times 10^{-6} \text{ C} \\ r_2 &= x, Q_2 = -2 \times 10^{-6} \text{ C} \\ V_p &= k \left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right] \end{aligned}$$

$$\begin{aligned} 0 &= 9 \times 10^9 \left[\frac{10 \times 10^{-6} x + (4+x)(-2 \times 10^{-6} x)}{x(4+x)} \right] \\ 0 &= 9 \times 10^9 \left[\frac{10 \times 10^{-6} x - 8 \times 10^{-6} - 2 \times 10^{-6} x}{x(4+x)} \right] \\ 0 &= 9 \times 10^9 \left[\frac{8 \times 10^{-6} x - 8 \times 10^{-6}}{x(4+x)} \right] \end{aligned}$$

$$0 = 7.2 \times 10^4 x - 7.2 \times 10^4$$

$$-7.2 \times 10^4 x = -7.2 \times 10^4$$

$$\frac{-7.2 \times 10^4 x}{-7.2 \times 10^4} = \frac{-7.2 \times 10^4}{7.2 \times 10^4}$$

$$x_2 = x_1 = 1 \text{ m}$$

$$x_1 = 4+x = 4+1$$

$$x_1 = 5 \text{ m}$$

Positions are 1m and 5m

Section B

(4) (a) What is Magnetic flux?

Soln

It is defined as the strength of the magnetic field which can be represented by lines of forces. It is represented by symbol Φ .

Mathematically given as $\Phi = B \cdot dA$

(b) An electron with a rest mass of 9.11×10^{-31} kg moves in a circular orbit of radius 1.4×10^{-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 the moving electron.

Soln

$$M = 9 \times 10^{-31} \text{ kg}$$

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

$$B = 3.5 \times 10^{-1} \text{ weber/meter}$$

Cyclotron frequency = angular speed

$$\omega = \frac{v}{r} = \frac{qB}{m}$$

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$\omega = 6222222222.2222 T^{-1}$$

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4(c)

In the question we were given parameters such as

(i) Mass of electron = 9.1×10^{-31} kg

(ii) A radius of 1.4×10^{-7} m

(iii) A magnetic field of 3.5×10^{-1} weber/meter square and you are asked to find the cyclotron frequency because it is a frequency of an accelerated cyclotron.

Recall that angular speed is given as

$$\omega = \frac{v}{r} = \frac{qB}{m}$$

$$\text{Substituting we have } \omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$\frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = 6222222222.2222 T^{-1}$$

So since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $6222222222.2222 T^{-1}$ having a unit as $1/T$ which is equal to the unit of frequency dimensionally

5(a) State the Biot-Savart Law

It states that the magnetic field is directly proportional to the product permeability of space (μ), the current (I), the change in length, the radius and inversely proportional to square of radius (r^2). It can be represented mathematically by

$$\vec{dB} = \frac{\mu_0 I \vec{dl} \times \hat{r}}{r^2}$$

where μ_0 is a constant called permeability of free space

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

The unit of B is weber/meter square

(b) Using the Biot-Savart Law, show that the magnitude of the magnetic field of a straight current-carrying conductor is given as

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

Soln

Magnetic field of a straight current carrying conductor

A section of a straight current carrying conductor applying the Biot-Savart law, we find the magnitude of the field \vec{dB}

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

$$\sin(\pi-4) = \sin 4$$

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

from diagram, $r^2 = x^2 + y^2$ (Pythagoras theorem)

$$B = \frac{\mu_0 I}{4\pi} \int_a^a \frac{dl \sin(\pi-4)}{x^2 + y^2} \quad \text{--- (1)}$$

$$\text{But } \sin(\pi-4) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}} \quad \text{--- (2)}$$

Substituting (2) into (1) we have

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

Recall $dl = dy$

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

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

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