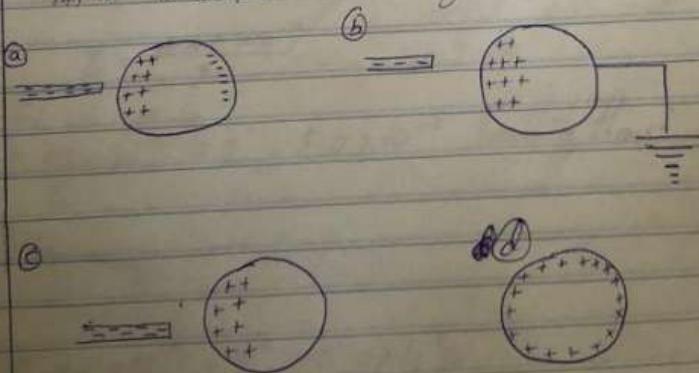


Name: Adi Rejoice Suman
Matric No.: 19/MAT/01/042
Department: Medicine and Surgery
Course: Phy 102

10. When a positively charged rod is brought near a neutral sphere but it doesn't make contact with it, there is a repulsion between the positive charges in the rod and those in the sphere. This repulsive and attractive forces cause a redistribution of the positive and negative charges with the negative charges moving to the part of the sphere closer to the rod and the positive charges move away from the part of the sphere close to the rod. Then a grounded conducting wire is connected to the part of the sphere farther from the rod and the positive charges travel to the earth.

Then the rod and ground are removed and the negative charges redistribute themselves evenly over the surface of the sphere. This is illustrated in the diagrams below:



$$16. q_1 = ? \quad q_2 = ? \quad F = 1.0N \quad r = 2.0m$$

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

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

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

$$q_1 q_2 = \frac{Fr r^2}{K} \quad K = 8.9875 \times 10^9 N m^2/C^2$$

$$\frac{q_1 q_2}{8.9875 \times 10^9} = \frac{1 \times 2^2}{r^2}$$

$$\frac{q_1 q_2}{8.9875 \times 10^9} = 4$$

$$q_1 q_2 = 4 \times 8.9875 \times 10^9$$

$$q_1 q_2 = 4.45 \times 10^{-10} C^2$$

$$q_1 \cdot q_2 = 4.45 \times 10^{-10} \quad \text{--- } i$$

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

From eqn i,

$$q_1 = \frac{4.45 \times 10^{-10}}{q_2} \quad \text{--- } iii$$

Put iii in ii,

$$\frac{4.45 \times 10^{-10}}{q_2} + q_2 = 5.0 \times 10^{-5} \quad \text{[Multiply through by } q_2 \text{]}$$

q_2

~~q_2~~

$$4.45 \times 10^{-10} + q_2^2 = 5.0 \times 10^{-5} q_2$$

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

$$q_2 = \frac{(5 \times 10^{-5})^2 \pm \sqrt{(5 \times 10^{-5})^2 - 4(1 \times 4.45 \times 10^{-10})}}{2 \times 1}$$

$$q_2 = -5 \times 10^{-5} + 0.00002682812$$

$$q_2 = 1.158574 \times 10^{-5} \text{ and } 3.841406 \times 10^{-5}$$

$$\therefore \text{from } q_1 = \frac{4.45 \times 10^{-10}}{z_2}$$

$$q_1 = \frac{4.45 \times 10^{-10}}{1.158574 \times 10^{-5}} = 3.84 \times 10^{-5} C$$

$$q_1 = \frac{4.45 \times 10^{-10}}{3.84 \times 10^{-5}} = 1.16 \times 10^{-5} C$$

c. ~~$F = k \frac{q_1 q_2}{r^2}$~~ $q_1 = q_2 = 8 \times 10^{-6} C$; $r = 0.5m$

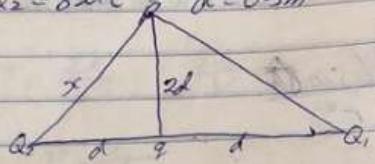
$$F = \cancel{k} \times 10^9 \times (8 \times 10^{-6})^2$$

$$F_{gg} = \frac{9 \times 10^9 \times (8 \times 10^{-6})^2}{0.5^2}$$

$$= 2.304$$

$$T_{gg} =$$

$$1c. Q_1 = Q_2 = 8 \mu C \quad d = 0.5m$$



From Pythagoras theorem

$$x^2 = 1^2 + 0.5^2$$

$$x = \sqrt{1 + 0.25}$$

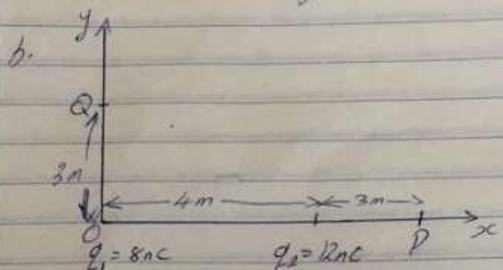
$$x = 1.12m$$

$$F_{Q_1 Q} = \frac{(9 \times 10^9)(8 \times 10^{-6})(9)}{0.5^2}$$

$$F_{Q_1 Q} = 288000 \text{ N}$$

$$F_{Q_2 Q_2} = \frac{(9 \times 10^9)(8 \times 10^{-6})(8 \times 10^{-6})}{1^2}$$
$$= 0.576 \text{ N}$$

2a. 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 of a test charge.



$$i) E_1 = \frac{Kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8.0 \times 10^{-9}}{7^2} \\ = 1.47 \text{ N/C}$$

$$E_2 = \frac{Kq_2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{3^2} \\ = 12 \text{ N/C}$$

$$E_{\text{tot}} = E_1 + E_2 \\ = 1.47 + 12 = 13.47 \\ \approx 13.5 \text{ N/C}$$

$$ii) E_1 = \frac{Kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8.0 \times 10^{-9}}{3^2} = 8 \text{ N/C}$$

$$E_2 = \frac{Kq_2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{7^2} = 2.2 \text{ N/C}$$

$$E_{\text{tot}} = E_1 + E_2 \\ = 8 + 2.2 \\ = 10.2 \text{ N/C}$$

4a. Magnetic flux is the number of magnetic field lines passing through a given closed surface. It is the surface integral of the normal component of the magnetic field flux density B passing through the surface.

$$b. \text{ Mass of electron} = 9.11 \times 10^{-31} \text{ kg} \quad r = 1.4 \times 10^{-9} \text{ m}$$

$$B = 3.5 \times 10^{-1} \text{ T/m}^2 \quad \theta = 90^\circ$$

$$q = 1.602 \times 10^{-19} \text{ C}$$

$$F = qvB \sin \theta$$

$$F = \frac{mv^2}{r} \Rightarrow qvB = \frac{mv^2}{r}$$

$$qvB = mv/r$$

$$r = \frac{mv}{qvB} \Rightarrow T = \frac{2\pi r}{v}$$

$$\therefore f = \frac{1}{T}$$

$$\therefore f = \frac{qvB}{2\pi m} = \frac{1.602 \times 10^{-19} \times 3.5 \times 10^{-1}}{2\pi \times \frac{9.11 \times 10^{-31}}{7}} \text{ Hz}$$

$$f = \underline{\underline{9.79 \times 10^9 \text{ Hz}}} \quad f = \underline{\underline{9.79 \times 10^9 \text{ Hz}}}$$

c. The force of the electron is directed towards the centre of the circle since the field is perpendicular to the velocity. $F = qvB$.

$$\text{The net force experienced, } \Sigma F = F_c = ma$$

$$\text{Since the motion is uniform, } a = \frac{v^2}{r}$$

$$f = \frac{ma}{r} = \frac{qvB}{r} = \frac{mv^2}{r}$$

$$r = \frac{mv}{qvB}$$

$r \propto mv$ due to linear momentum

$$\text{But angular speed, } \omega = \frac{V_r}{r} = \frac{gB}{m}$$

$$\text{and Period, } T = \frac{2\pi}{\omega} = \frac{2\pi r}{V} = \frac{2\pi m}{gB}$$

$$\text{and since, } f = \frac{1}{T}$$

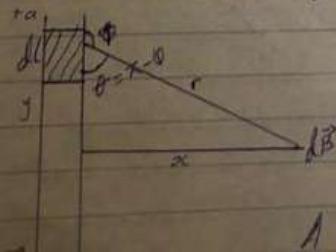
$$f = \frac{gB}{2\pi m}$$

5a. Biot - Savart law is an equation describing the magnetic field generated by a constant electric current. It relates the magnetic field to the magnitude, direction, length and proximity of the electric current. It states that the magnetic intensity at any point due to a steady current in an infinitely long straight wire is directly proportional to the current and inversely proportional to the distance from point to wire.

b. Observations from the Biot - Savart experiment led to the mathematical expression:

$$\delta B = \frac{\mu_0 \times I \cdot \delta l \cdot \hat{r}}{4\pi r^2}$$

Known as Biot - Savart law, where δB = magnetic field, δl = length of wire, I = Current, r = distance from wire to magnetic field and μ_0 = Permeability of free space Constant ($4\pi \times 10^{-7} \text{ Tm/A}$)



A section of a straight current-carrying conductor.

Applying the Biot-Savart law, we find the magnitude of the field $d\vec{B}$ to be

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

but $r^2 = x^2 + y^2$ from Pythagoras' theorem
and $\sin \theta = \sin(\pi - \theta) = \frac{y}{\sqrt{x^2 + y^2}} = \frac{y}{(x^2 + y^2)^{1/2}}$
 $\therefore B = 1$

The magnitude then becomes:

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

But $dl = dy$

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

Using special integrals:

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

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

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

When a is larger than x
 $(x^2 + a^2)^{1/2} \approx a$ as $a \rightarrow \infty$

$\therefore B = \frac{\mu_0 I}{2\pi x}$ where x = radius of a circle

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