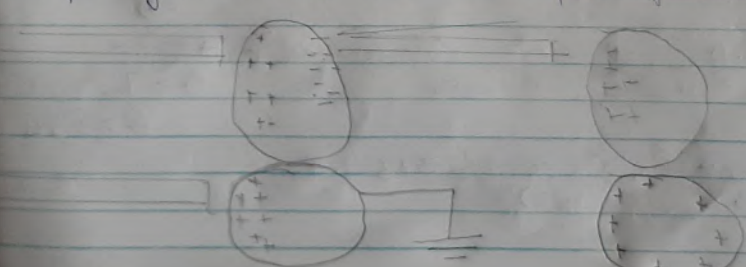
Name: Afletor Josemawa Ehimona 19/SCI01/016
PHY 102

Section A

1) Charging by induction

Electric Charges can be obtained on an Object without touching it by a process called electrostatic induction. Consider a negatively Charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no Conducting path to ground as show below. The repulsive force between the electrons in the rod, & those in the sphere Causes a redistribution of Charges on the sphere farthest away from the rod. The region of the sphere nearest the negatively Charged has an excess of positive Charge because of the migration of electrons away from this location. If a grounded Conducting wire is then Connected to the Sphere as in (fig 1.3b) 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 the Conducting sphere is left with an excess of induced Positive Charge. Finally, when the rubber rod is removed from the vicinity of the Sphere the inducing Positive Charge remains on the ungrounded sphere & becomes uniformly distributed over the Surface of the Sphere



19/SCIO1/016 PHY 102 MID SEMESTER ASSIGNMENT

1b) $k = 9 \times 10^9$

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

$F = 1N$

$d = 2m$

Charge on each sphere = ?

$F = \frac{kq_1 \cdot q_2}{r^2}$

$1 = \frac{9 \times 10^9 \times (q_1 \cdot q_2 = 5 \times 10^{-5})}{2^2}$

$4 = 9 \times 10^9 \times 5 \times 10^{-5} q_1 + 9 \times 10^9 q_2$

$4 = 4.5 \times 10^5 q_1 + 9 \times 10^9 q_2$

Quadratic equation

$9 \times 10^9 q_2 - 4.5 \times 10^5 q_1 + 4 = 0$

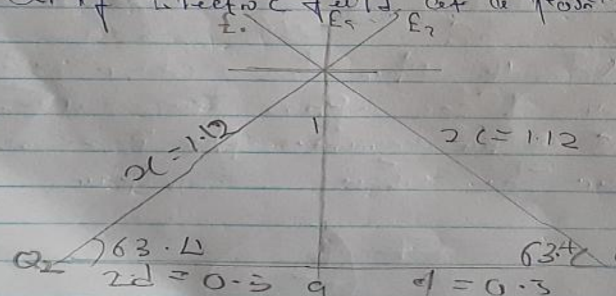
$q_1 = 0.0000111C \simeq 1.11 \times 10^{-5} C$

$q_2 = 0.000038C \simeq 3.8 \times 10^{-5} C$

c) $Q_1 = Q_2 = 8 \mu C$

$d = 0.5m$

Q1 if Electric field at a Point P is zero




$x^2 = 1^2 + 0.5$

$\sqrt{x^2} = \sqrt{1.25}$

$x = \sqrt{1.25}$

$x = 1.12$

$\tan\theta = \frac{Opp}{Adj}$

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

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

$\theta = 63.4$

$E = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 57397.9598$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 57397.95918$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{1} = 9\times10^9 q$

| Vector | Angle | X-Component | Y-Component |
|---|---|---|---|
| $E_1 = 57397.95918$ | $63.4°$ | $E_1 \cos\theta =$ 2570.046785 | $E_1 \sin\theta =$ 5132.262839 |
| $E_2 = 57397.95918$ | $63.4°$ | 2570.045785 | 5132.262839 |
| $E_q = 9\times10^9 q$ | $90°$ | $E_q \cos\theta = 0$<br>$E_x = 0$ | $9\times10^9 q$<br>$E_y = 10264.52568$ |

Magnitude $= \sqrt{(E_x)^2 + (E_y)^2}$

$E_q = \sqrt{(0)^2 + (10264.52568)^2}$

Since $E_q = 0$

$0 = 9\times10^9 q + 10264.52568$

Making q subject of formula

$q = \frac{-10264.52568}{9\times10^9}$

$q = -1.140502853\times10^{-16}$

$q = 11.4\mu C$

2c) Volume Charge density $= \frac{dQ}{dV}$ $\Rightarrow dQ = \rho\, dV$

Surface Charge density $\sigma = \frac{dQ}{dA}$ $\Rightarrow dQ = \sigma\, dA$

Linear Charge density $= \frac{dQ}{dL}$ $\Rightarrow dQ = \lambda\, dL$

Electric Potential difference

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 charged is transported from one point to another. It is measured in Volt (V) or Joules per Coloumb (J/C). It is a scalar quantity

Elemental work done $dW$ is given

$$dW = F\,dl \quad \text{--- (1)}$$

But $F = -q_0 E$ --- (2)

Substituting equation (2) in (1) $= dW = -q_0 E\,dl$ --- (3)

Total work done in moving the test charge from A to B is

$$W(A'nB)_{Ag} = -q_0 \int_A^B E\,dl \quad \text{--- (4)}$$

From the definition of electric potential difference it follows that:

$$V_B - V_A = \frac{W(A'nB)_{Ag}}{q_0} \quad \text{--- (5)}$$

putting eqn (4) in (5) yields $V_B - V_A = -\int_A^B E\,dl$ --- 6

Section B

a) Magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol $\phi$ Mathematically given as $\phi = B \cdot dA$

b) $m = 9 \times 10^{-31}$ kg

$r = 1.14 \times 10^{-}$

$B = 3.3 \times 10^{-1}$ weber/meter$^2$

Cyclotron frequency = angular speed

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

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$$\omega = 6.22 \times 10^{10} \, s^{-1}$$

19/SCIO1/016 PHY 102 MID SEMESTER ASSIGNMENT

4c mass of electron $= 9.4 \times 10^{-31}$ kg
radius $= 1.4 \times 10^{-7}$m
magnetic field $= 3.5 \times 10^{-1}$ Weber/metre
Cyclotron frequency can be called angular speed
Recall that angular speed $\omega = \frac{V}{r} = \frac{qB}{m}$

Substituting we have $\omega = \frac{V}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$
$= 6.22 \times 10^{10}\ T^{-1}$

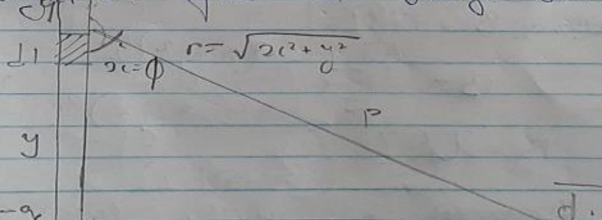
So Cyclotron frequency $= 6.22 \times 10^{10}\ T^{-1}$, the unit is equal to unit of frequency dimensionally

5.) Biot-Savart law states that the magnetic field is directly proportional to the product of permeability of free space ($\mu$) the current (I), the change in length, the radius is inversely proportional to the square of radius ($r^2$). It can be represented mathematically by

$dB = \frac{\mu_0 I dl \times r}{4\pi r^2}$ where $\mu$ is a constant called permeability of free space
$\mu = 4\pi \times 10^{-7}$ T.m/A

Unit of B is Weber/meter square

5b) 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 dB

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

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

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

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

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

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

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

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

Recall $dl = dy$

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

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

Using special integrals: $\int \frac{dy}{(x^2+y^2)^{3/2}} = \frac{1}{x^2} \cdot \frac{y}{(x^2+y^2)^{1/2}}$

Equation (3) becomes $B = \frac{\mu_0 I x}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$

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

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

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 B, when a is much larger than x, $(x^2+a^2)^{1/2} \approx a$

then $x$, $(x^2+a^2)^{1/2} \simeq a$, as $a \longrightarrow \infty$

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

In a physical situation, we have axial symmetry about the y-axis. Thus at all points in a circle of radius r around the conductor the magnitude of B is ! $B = \frac{\mu_0 I}{2\pi r}$

(magnitude of the magnetic field of flux density B near a long straight current carrying conductor).