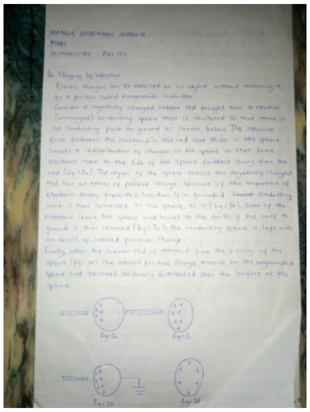
Ibanga Utibeabasi Godwin

19/MHS01/184



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MBBS
19/MHS01/184 Phy 102

2a. Charging by induction

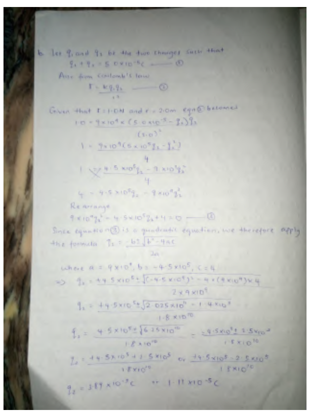
Electric charges can be obtained on an object without touching it, by a process called electrostatic induction.

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 shown below. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some electrons move to the side of the sphere farthest away from the rod (fig 1.3a). The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded ~~[illegible]~~ 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 (fig 1.3c), 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 (fig 1.3d), the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

fig 1.3a   fig 1.3c

fig 1.3b   fig 1.3d



b. Let q_1 and q_2 be the two charges such that

$q_1 + q_2 = 5.0 \times 10^{-5} C$ ——— (1)

Also from Coulomb's law

$F = \frac{kq_1q_2}{r^2}$ ——— (2)

Given that $F = 1.0N$ and $r = 2.0m$ eqn (2) becomes

$1.0 = \frac{9\times10^9 \times (5.0\times10^{-5} - q_2)q_2}{(2.0)^2}$

$1 = \frac{9\times10^9(5\times10^{-5}q_2 - q_2^2)}{4}$

$1 = \frac{4.5\times10^5 q_2 - 9\times10^9 q_2^2}{4}$

$4 = 4.5\times10^5 q_2 - 9\times10^9 q_2^2$

Rearrange

$9\times10^9 q_2^2 - 4.5\times10^5 q_2 + 4 = 0$ ——— (3)

Since equation (3) is a quadratic equation, we therefore apply the formula $q_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

where $a = 9\times10^9$, $b = -4.5\times10^5$, $c = 4$

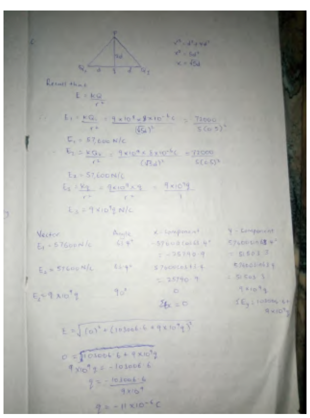
$\Rightarrow q_2 = \frac{+4.5\times10^5 \pm \sqrt{(-4.5\times10^5)^2 - 4\times(9\times10^9)\times4}}{2\times9\times10^9}$

$q_2 = \frac{+4.5\times10^5 \pm \sqrt{2.025\times10^{11} - 1.4\times10^{11}}}{1.8\times10^{10}}$

$q_2 = \frac{4.5\times10^5 \pm \sqrt{6.25\times10^{10}}}{1.8\times10^{10}} = \frac{4.5\times10^5 \pm 2.5\times10^5}{1.8\times10^{10}}$

$q_2 = \frac{+4.5\times10^5 + 2.5\times10^5}{1.8\times10^{10}}$ or $\frac{+4.5\times10^5 - 2.5\times10^5}{1.8\times10^{10}}$

$q_2 = 3.89\times10^{-5}C$ or $1.11\times10^{-5}C$



c.

$x^2 = d^2 + 4d^2$

$x^2 = 5d^2$

$x = \sqrt{5}d$

Recall that

$E = \frac{kQ}{r^2}$

[illegible]

Vector	Angle	x-component	y-component
[illegible]	[illegible]	[illegible]	[illegible]
$E_3 = 9\times10^9 q$	90°	0	$9\times10^9 q$

$\Sigma E_x = 0$

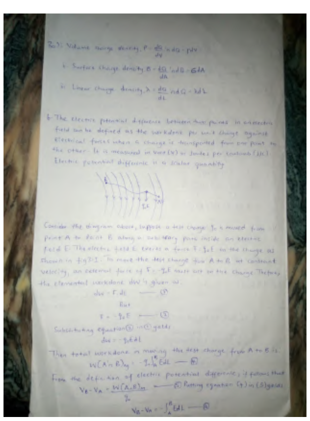
$E = \sqrt{(0)^2 + (103006.6 + 9\times10^9 q)^2}$

$0 = \sqrt{103006.6 + 9\times10^9 q}$

$9\times10^9 q = -103006.6$

$q = -\frac{103006.6}{9\times10^9}$

$q = -11\times10^{-6}C$



3a) i. Volume charge density, $\rho = \frac{dQ}{dV}$, $dQ = \rho dV$

ii. Surface charge density $\sigma = \frac{dQ}{dA}$, $dQ = \sigma dA$

iii. Linear charge density, $\lambda = \frac{dQ}{dL}$, $dQ = \lambda dL$

b. The electric potential difference between two points in an electric field can be defined as the workdone per unit charge against electrical forces 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.

Consider the diagram above, suppose a test charge q_0 is moved from point A to point B along an arbitrary path inside an electric field E. The electric field E exerts a force $F = q_0E$ on the charge as shown in fig 3.1. To move the test charge from A to B at constant velocity, an external force of $F = -q_0E$ must act on the charge. Therefore, the elemental workdone dW is given as:

$dW = F.dL$ ——— (1)

But

$F = -q_0E$ ——— (2)

Substituting equation (2) in (1) yields

$dW = -q_0EdL$

Then total workdone in moving the test charge from A to B is:

$W(A \to B)_{ag} = -q_0\int_A^B EdL$ ——— (4)

From the definition of electric potential difference, it follows that

$V_B - V_A = \frac{W(A \to B)_{ag}}{q_0}$ ——— (5) Putting equation (4) in (5) yields

$V_B - V_A = -\int_A^B EdL$ ——— (6)

4a. 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 Φ. Mathematically given as

$$\Phi = B \cdot dA$$

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

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

$B = 3.5 \times 10^{-1}$ weber/meter²

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

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

$$w = 62222222222.22 s^{-1}$$

c. We were given parameters like

mass of electron $= 9.11 \times 10^{-31} kg$

radius of $1.4 \times 10^{-7} m$

Magnetic field of 3.5×10^{-1} weber/meter²

Recall that angular speed is given as $w = \frac{v}{r} = \frac{qB}{m}$

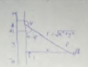
Substituting we have $w = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$

$= 61471212222.22 s^{-1}$

Since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $= 61471212222.22 T^{-1}$, having a unit as 1/T which is equal to the unit of frequency dimensionally

5a. Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ_0), the current (I), the change in length, the radius and inversely proportional to square of radius (r^2).

b. Magnetic field of a straight current carrying conductor



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

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

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

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

From diagram $r^2 = x^2 + y^2$ Pythagoras theorem

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

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

Substituting (**) into (*) 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 $dl = dy$

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

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 (***) therefore becomes

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

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

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

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

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

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

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