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DEPT: Nursing science
MAT NO: 19/MHS02/096
COURSE CODE: PHY 102

COVID-19 HOLIDAY ASSIGNMENT

SECTION A

1a) Charging by Induction: Electric charges can be obtained on an object without touching it, by a Process called electrostatic induction.
Consider a Positively 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 Protons in the rod and those in the sphere Causes a redistribution of charges on the sphere so that some Protons move to the side of the sphere farthest away from the rod in fig 1.3a. The region of the sphere nearest the Positively charged rod has an excess of negative charge because of the migration of Protons away from this location. If a grounded conducting wire is then Connected to the sphere, as in fig 1.3b, some of the Protons 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 negative charge.

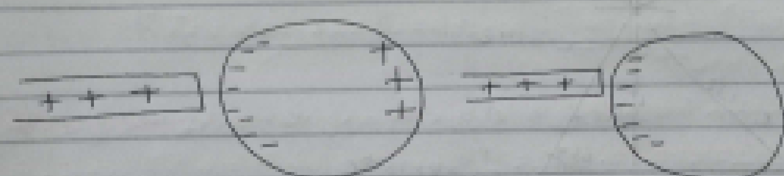


fig 1.3a

fig 1.3c

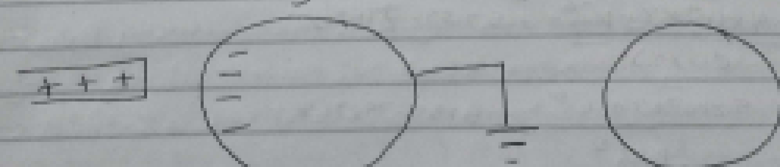


fig 1.3b

fig 1.3d

b) $K = 9 \times 10^9$
$q_1 + q_2 = 5 \times 10^{-5}$ C
$F = 1N$
$d = 2m$

Calculate the charge on each sphere?

Recall that

$k = 9 \times 10^9$

$F = \frac{kq_1q_2}{r^2}$

$1 = \frac{9 \times 10^9 \times (q_1q_2\ 5 \times 10^{-5})}{2^2}$

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

$4 = 4.5 \times 10^5 q_1^2 + 9 \times 10^9 q_2$

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

$q_1 = 0.000011c$

$q_2 = 0.0000038c$

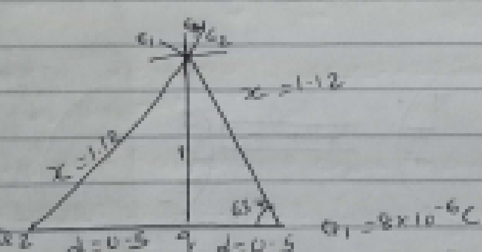
$= q_1 = 1.11 \times 10^{-5}\ c$

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

C $Q_1 = Q_2 = 8uc$

$d = 0.5m$

determine Q if electric field at a point P is zero



$E_1 = \frac{kq_1}{r_2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.795918$

$E_2 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.12^2} = 5739.795918$

$E_q = \frac{kq}{r^2} = \frac{9 \times 10^9 \times q}{1} = 9 \times 10^9 q$

$\tan\theta = \frac{opp}{adj} = \frac{1}{0.5}$ $\theta = \tan^{-1}(2)$

$\theta = 0.6349$

Vector	angle	x - Comp	y - Comp
$E_1 = 5737.795918$	$63.4°$	$E_1 \times \cos\theta$ -2570.045786	5132.262839
$E_2 = 5739.795918$	$63.4°$	2570.045785	5132.262839
$E_q = 9 \times 10^9 q$	$90°$	$E_q \cos\theta = 0$ $E_x = 0$	$9 \times 10^9 q$ $E_y = 10264.52568$

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

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

since $E = 0$

$0 = 9 \times 10^9 q + 10264.52568$

making q subject of formula

$q = \frac{-10264.5268}{9 \times 10^9}$

$q = 1.140502853 \times 10^{-6}$

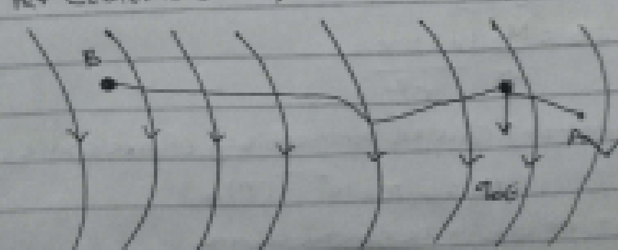
$= q = 11.4 \mu c$

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

ii) Surface charge density, $\sigma = \frac{dQ}{dA}$ and $Q = \sigma dA$

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

3b) Electric Potential difference between two points in an electric field can b[e]
defined as the work done per unit charge against electrical forces whe[n]
a charge is transported from one point to the other. It is measured in [volts]
(v) or Joules per Coulomb (J/c). Electric Potential difference is a scala[r]
quantity.



SECTION B

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 $\phi = B \cdot dA$

4b) $m = 9 \times 10^{-31} kg$, $r = 1.4 \times 10^{-7} m$, $B = 3.5 \times 10^{-1}$ weber/meter^2

Cyclotron Frequency = angular speed

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

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

$$w = 622.2 T^{-1}$$

c) 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^{-1} weber/meter square

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

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

$$\frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = 62222222222.222222 T^{-1}$$

so since Cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $62222222222.222222 T^{-1}$, having a unit as $1/T$ which is equal to the unit of frequency dimensionally.

5) Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free 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

$$dB = \frac{\mu_0}{4\pi} \frac{I \, dl \times r}{r^2}$$

where μ_0 is a constant called permeability of free space.

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

The unit of B is weber/metre square

5b) Magnetic Field of a Straight Current Carrying Conductor

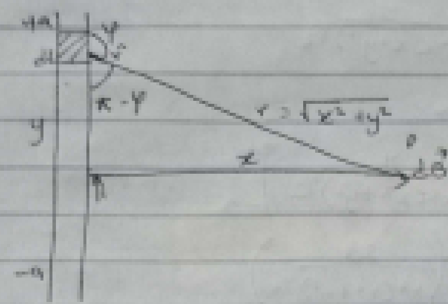


Fig: A section of a straight carrying conductor.

Applying the Biot-savart law,

magnitude of the field dB

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

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

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

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

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

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

Substituting eqn 2 into eqn 1 we have

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

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

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

Recall $dl = dy$

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

Using special Integrals:

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

Equation (3) therefore becomes

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

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

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

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

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

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

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