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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 negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting part required on the ground as shown below. The repulsive force between the electrons in the rod and those in the sphere across causes a 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 this location. If a grounded conducting wire is the connected to the sphere, as in, 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.

(fig 1.3d) the induced positive charge remains. on the ungrounded sphere an
becomes uniformly distributed over the surface of the sphere

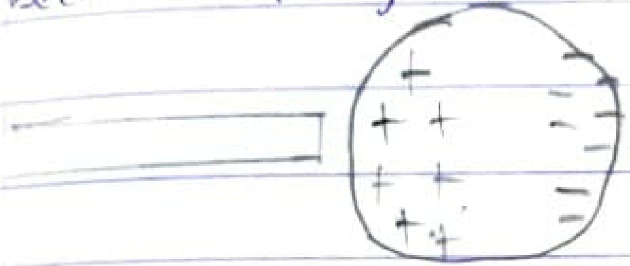


fig 1.3a

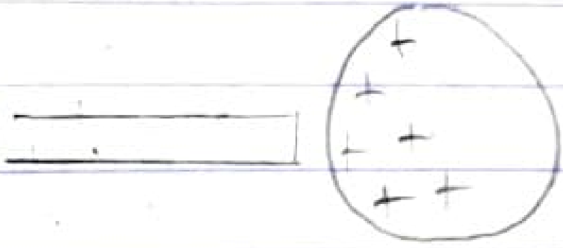


fig 1.3c

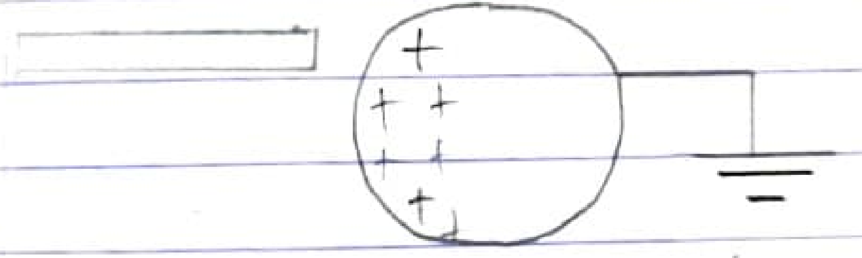


fig 1.3b

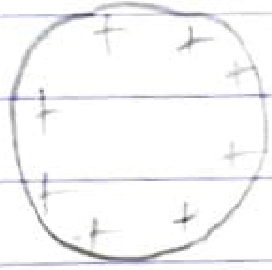


fig 1.3d

16, $K = 9 \times 10^9$

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

$F = 1N$

$d = 2m$

Charge on each sphere = ?

$$F = \frac{Kq_1q_2}{r^2}$$

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

$4 = 9\times10^9 \times 5\times10^{-5} q_1 + 9\times10\ q_2$

$4 = 4.5\times10^5 q_1 + 9\times10^9 q_2$

Quadratic equation

$9\times10^9 q_2 - 4.5\times10^5 q_1 + 4 = 0$

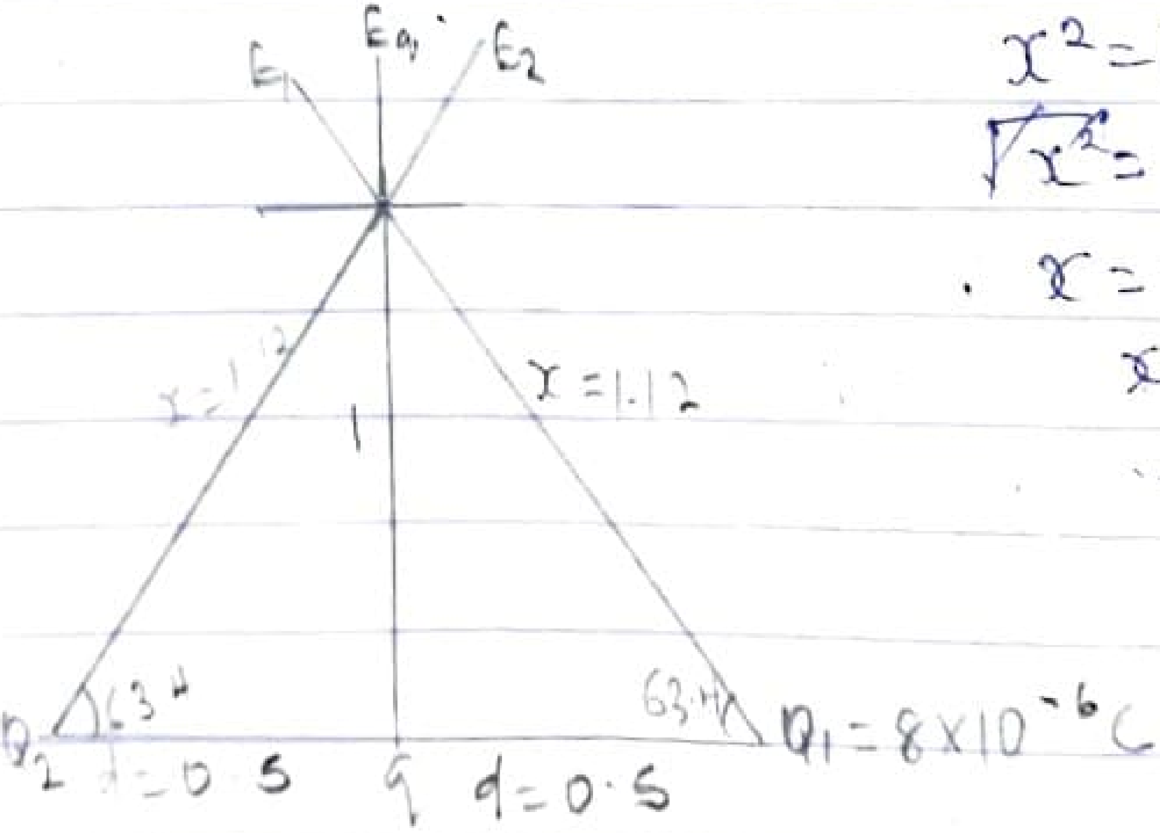
$q_1 = 0.0000111C \simeq 1.11\times10^{-5}C$

$q_2 = 0.000038C \simeq 3.8\times10^{-5}C$

$Q_1 = Q_2 = 8\mu C$

$d = 0.5m$

Q/ if Electric field at a point P is zero.



$x^2 = 1^2 +$

$\sqrt{x^2} = \sqrt{1.}$

$x = \sqrt{1.}$

$x = 1$

Tan

T

$E_1 = \frac{Kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 57397.9598$

$$E_2 = \frac{Kq_2}{r^2} = \frac{9\times10^9\times8\times10^{-6}}{(1.12)^2} = 57397.95918$$

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

Vector	Angle	X-component	Y_componen
$E_1 = 57397.95918$	63.4°	$E_1\cos\theta =$ 2570.046785	$E_1\sin\theta =$ 5132.26283
$E_2 = 57397.95918$	63.4°	2570.045785	5132.26283
$E_q = 9\times10^9 q$	90°	$E_q\cos\theta = 0$	$9\times10^9 q$
		$E_x = 0$	$E_y = 1024.52568$

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

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

Since $E_q = 0$

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

Making q subject of formula

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

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

$$q = 11.4\,\mu C$$

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

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

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

3b, Electric potential difference

The Electric potential difference between two points i
field can be defined as the workdone per unit cha
electrical forces when a charge is transported from o
another. It is measured in Volt (v) or Joules per co
It is a scaler quantity.

Elemental work done dW is given as

$$dW = F \cdot dL \quad -- ①$$

But $F = -q_0 E$ -- ②

substituting equation ② in ① $= dW = -q_0 E dL$ -

Total work done in moving the test charge from A to

$$W(A\text{'n } B)_{ag} = -q_0 \int_A^B E\,dL \quad -- ④$$

from the definition of electric potential difference, it fo

$_A = \frac{W(A' \cap B)Ag}{q_0}$ ⋯ ⑤

ing equation ④ in ⑤ yields $V_B - V_A = -\int_A^B E\,dL$ ⋯ ⑥

SECTION B

gnetic flux is defined as the strength of the magnetic field ch can be represented by line of forces. It is represented by symbol Φ. Mathematically given as $\Phi B \cdot dA$

$= 9 \times 10^{-31}\,Kg$

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

$= 3.5 \times 10^{-1}$ weber/meter^2

Cyclotron frequency = angular speed

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

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

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

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

radius = $f{\cdot}4 \times 10^{-7}$ m

magnetic field = 3.5×10^{-1} weber/meter^2.

cyclotron frequency can be called Angular speed

Recall that Angular speed $\omega = \frac{v}{r} = \frac{qB}{m}$

Substituting we have, ~~$\frac{qB}{m} = 1.6 \times 10^{-19} \times 3.5$~~ $\omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.}{9.11 \times 10^{-3}}$

$= 6.22 \times 10^{10}$ T

So cyclotron frequency $= 6.22 \times 10^{10}$ T^{-1}, the unit is e

of frequency dimensionally.

5. Biot-Savart law states that the magnetic field is dire
to the product permeability of free space (μ), the curr
change in length, the radius and inversely proportional to
of radius (r^2). It can be represented mathematically

$$dB = \frac{\mu_0 I dl \times r}{4\pi r^2}$$ where μ_0 is a constance

Permeability of

$\mu = 4\pi \times 10^{-7}$ T.$\frac{m}{A}$

Unit of B is weber/metre square.

5b, Magnetic Field of a straight current carrying condu

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

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

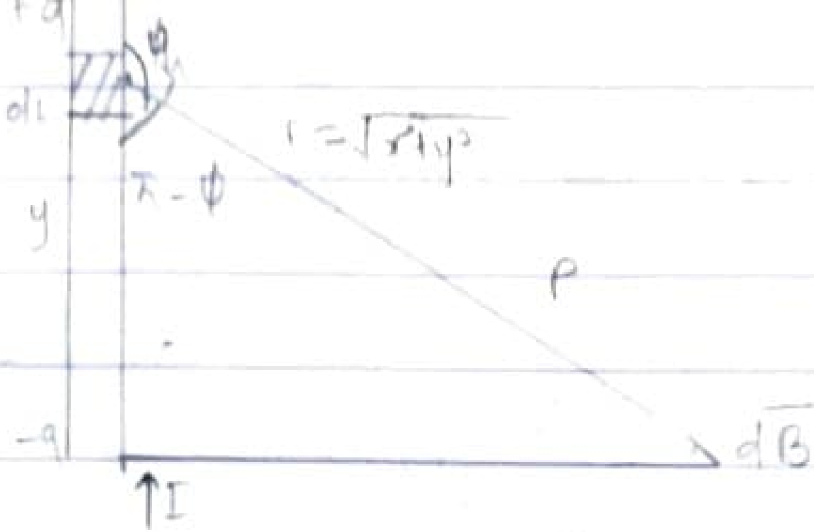
$$B = \frac{\mu_0 I x}{4\pi} \left(\frac{2a}{x^2(x^2+a^2)^{1/2}} \right)$$

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

When the length $2a$ of the conductor is very great in compari
to its distance x from point P, we consider it infinitely long. That B,
when a is much larger than x, $(x^2+a^2)^{1/2} \simeq a$, as $a \rightarrow$

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

- In a physical situation, we have axial symmetry about the y-axis Th
at all points in a circle of radius r, around the conductor, the magnitu
of B is: $B = \dfrac{\mu_0 I}{2\pi r}$ --- # (magnitude of the magnetic fi
of flux density B near a lo
Straight current carrying conduc



A section of a straight current carrying conductor

Applying the Biot-savart law, we find the magnitude of the field d

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

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

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

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

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

$$B = \mu_0 I \int^{a} dl \quad x$$