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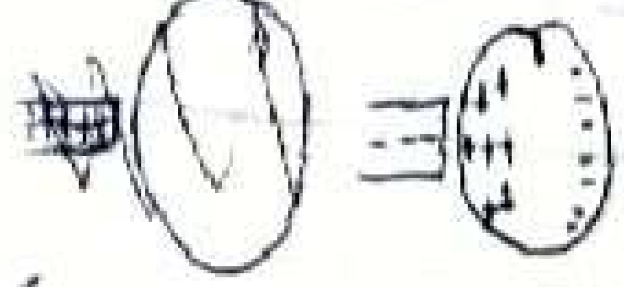
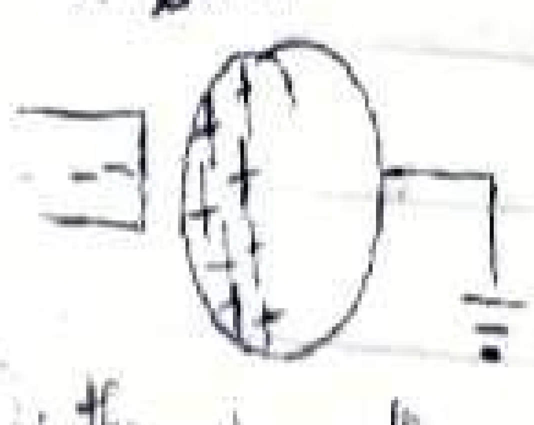
CTION A

rging by induction

ectron charges obtained on an object without touching is
called electrostatic induction
Consider a negatively charged rubber rod brought near a
neutral (uncharged) conducting sphere that is insulated so
that no conducting path to ground is shown below. The
repulsive force between the electrons on the rod and those in
the sphere cause redistribution of charges so electrons move to
the side farthest from the rod.



The region of the sphere nearest the negatively charged rod
has an excess of positive charge because of migration away
from the location. If the grounded conducting wire is then
connected to the sphere, some of the electrons leave and travel
to the earth



If the wire is then removed conducting sphere is left with
excess positive charge

Finally, when the rubber is removed from the vicinity of the
sphere the induced positive charges remain ungrounded and
becomes uniformly distributed over the surface of the sp[here]

1b $K = 9 \times 10^9$

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

$F = 1N$

$d = 2m$

Calculate the charge on each sphere

Recall that

$K = 9 \times 10^9$

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

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

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

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

In quadratic from.

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

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

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

1c $Q_1 = Q_2 = 8uC$

$d = 0.5$

determine Q if electric field at point p is zero.

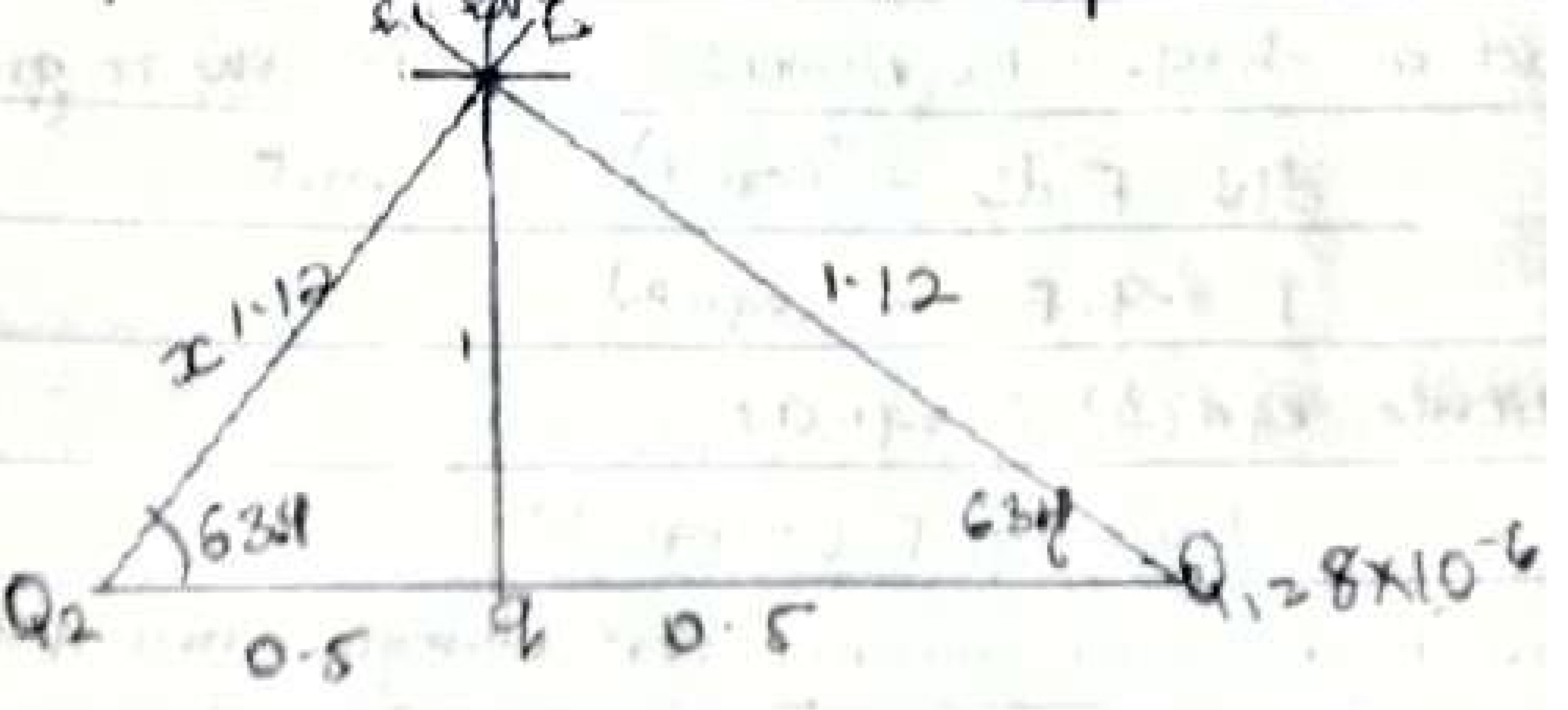
$\theta =$

$\tan \theta = \frac{opp}{adj}$

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

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

$\theta = 63.4$



$$E_1 = \frac{K q_1'}{r_1^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.79592$$

$$E_2 = \frac{KQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.123} = 5739.79592$$

$$Eq = \frac{Kq}{r_3^2} = \frac{9\times10^9 \times q}{1} = 9\times10^9 q$$

Vector	angle	x-comp	y-comp
		$E_1 \times \cos\theta$	
$E_1 = 5739.79592$	63.4°	$= -2570.045785$	5132.262839
$E_2 = 5739.79592$	63.4°	2570.045785	5132.262839
$Eq = 9\times10^9 q$	90°	$Eq\cos\theta = 0$	$9\times10^9 q$
		$Ex = 0$	$Ey = 10264.52568$

$$\text{Magnitude} = \sqrt{(Ex)^2 + (Ey^2)}$$

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

Since $E = 0$

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

Make q the subject of formulae

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

$$q = 1.1405\times10^{-6}$$

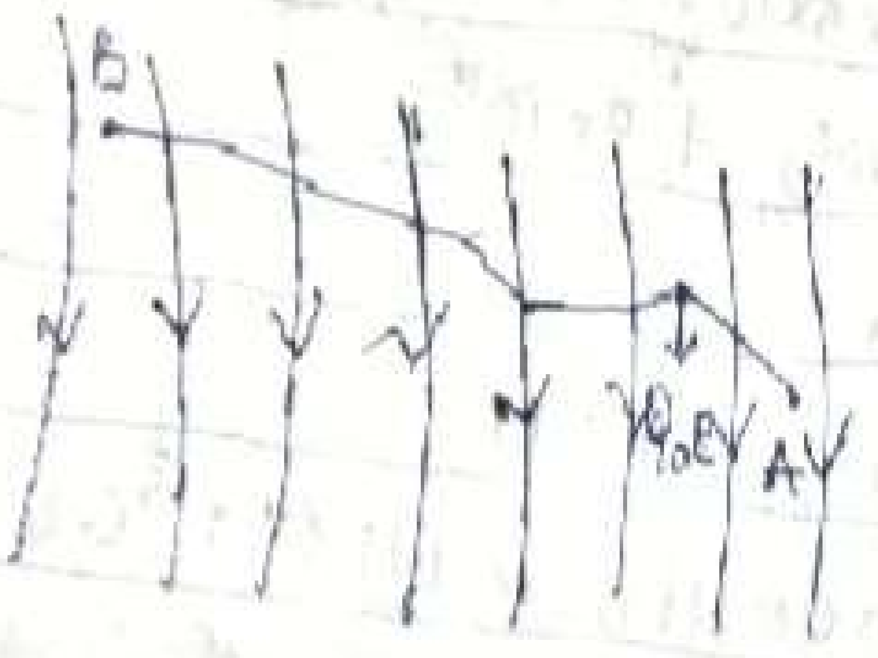
$$= 11.4\mu C.$$

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

(ii) Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

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

3b) Electric potential difference: The electric potential difference between two points in an electric field can be defined as work done per unit charge against electrical forces when a charge is transported from one point to another. It is a scalar quantity. It's unit is either Volts(V) or Joules per ~~col~~ coulomb (J/C)



In the diagram above, if a test charge (q_0) is moved from point A to B along an arbitrary path inside electric field E. E then exerts a force $F = q_0E$ on the charge in the above diagram. To move the test charge from A to B at const velocity, $F = -q_0E$ must act on charge. The elemental work done dW is given as

$$dW = F \cdot dL - (\text{equ } 1)$$ but

$$F = -q_0 E - (\text{equ } 2)$$

Substitute equ (2) in equ (1)

$$dW = -q_0 E dL - (\text{equ } 3)$$

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

$$W(A \rightarrow B)_{ag} = -q_0 \int_A^B E dL - (\text{equ } 4)$$

From electric potential difference $= V_B - V_A = \frac{W(A \rightarrow B)_{ag}}{q_0} - (\text{equ } 5)$

Substitute equ 4 in 5 $= V_B - V_A = -\int_{A}^{B} E dL - (\text{equ } 6)$

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 ϕ. Mathematically given as $\phi = B \cdot dA$

4b $m = 9 \times 10^{-31}$ kg , $B = 3.5 \times 10^{-1}$ weber/meter²

$r = 1.4 \times 10^{-7}$m , cyclotron frequency = angular speed

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

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

$$w = 62222222222.222222 T^{-1}$$

4c We are given the following parameters in the question

i Mass (ii) Radius (iii) Magnetic field

Angular speed = $\frac{v}{r} = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}} = 62222222222.22222$

Therefore cyclotron frequency $= 62222222222.22222 T^{-1}$ having a unit of $\frac{1}{T}$ which is equal to the unit frequency dimensionally.

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

Mathematically represented as

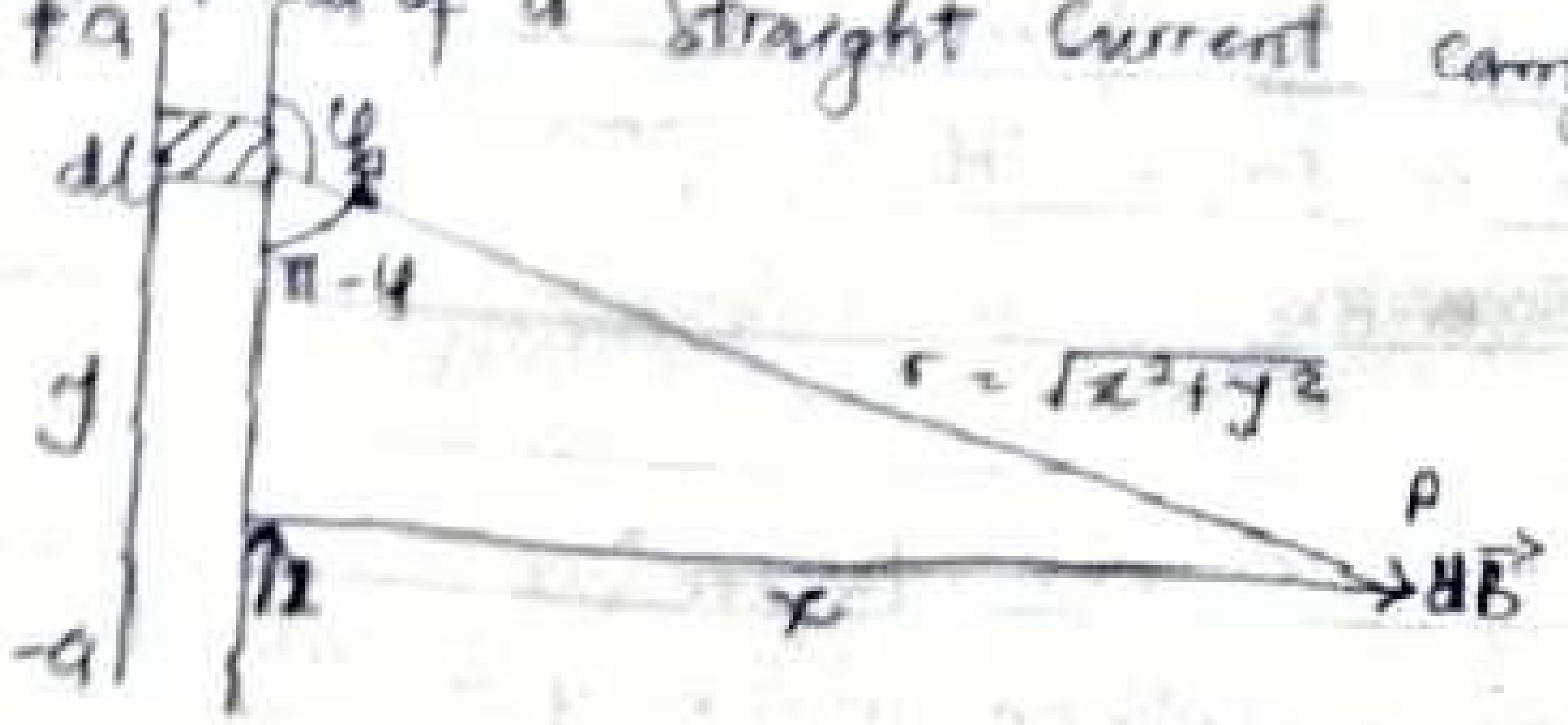
$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{I \, d\vec{l} \times r}{r^2}$$

where μ is a constant called permeability of free space

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

The unit of B is weber/metre².

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 field dB

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

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

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

From the diagram, $r^2 = x^2 - y^2$ (pythagoras theorem)

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

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

Substitute (ii) into (i) we have!

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

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

Recalling $dl = dy$

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

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

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 (iii) then becomes

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

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

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

When the length of 2a is very great in comparison to distance x from point P, we consider it infinitely long. That is when a is larger than x,

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

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

In physical situation, we have axial symmetry about the y-axis. Thus, at all points of the circle of radius r, around the conductor, Magnitude of B is

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{--- (*)}$$

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