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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 (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.

Finally, when the rubber rod is removed from the vicinity of the sphere (fig 1.3d), the induced negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

Diagram:

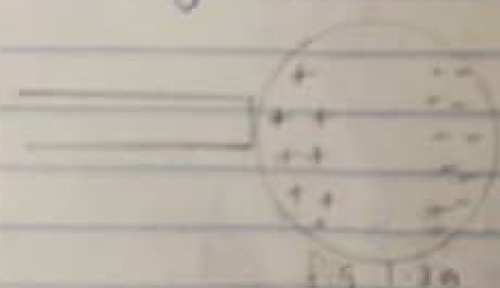


fig 1.3a

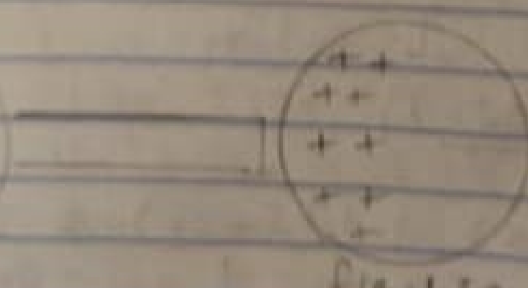


fig 1.3c

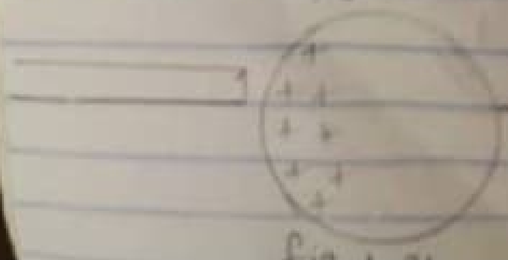


fig 1.3b

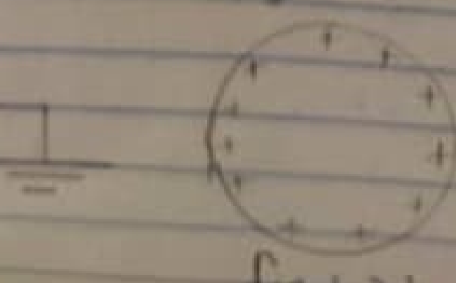


fig 1.3d

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

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

$F = 1N$

$d = 2m$

Charge on each sphere = ?

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

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

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

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

Quadratic equation

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

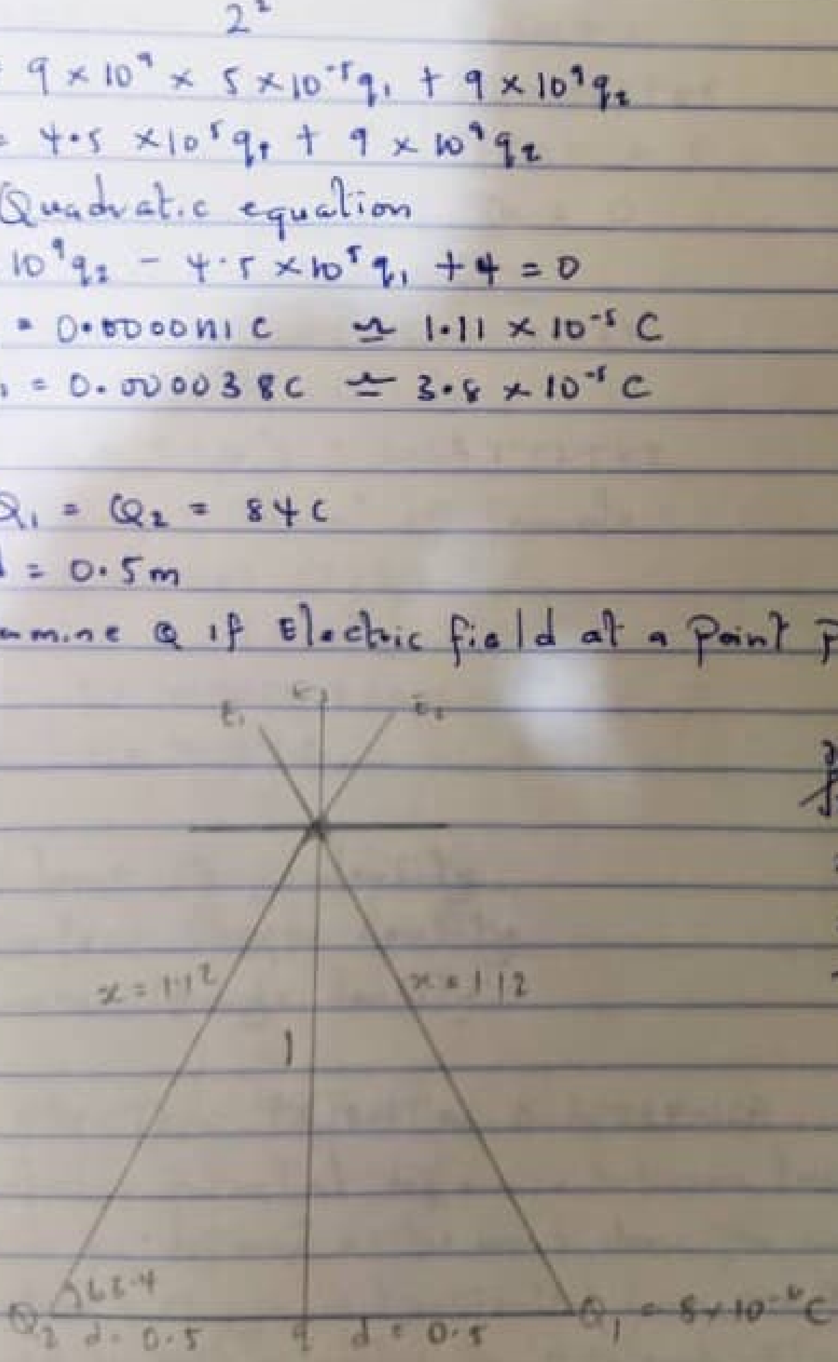
$q_1 = 0.000011\,C \simeq 1.11 \times 10^{-5}\,C$

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

1c). $Q_1 = Q_2 = 84\,C$

$d = 0.5m$

determine Q if Electric field at a Point P is zero



$x^2 = 1^2 + 0.5^2$

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

$x = \sqrt{1.25}$

$x = 1.12$

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

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

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

$\theta = 63.4$

$$E_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 57397.9598$$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.795918$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{1 \cancel{(1.12)^2}} = 9\times10^9 q$

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°	$E_2 \cos\theta =$ 2570.046785	$E_2 \sin\theta =$ 5132.262839
$E_q = 9\times10^9 q$	90°	$E_q \cos\theta = 0$	$E_q \sin\theta = 9\times10^9 q$
		$E_x = 0$	$E_y = 10264.52568$

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

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

$q = 1.140502853 \times 10^{-16}$

$q = 11.4 \mu C$

3a) Volume Charge density

ii) Surface Charge density

iii) Linear Charge density

3b) 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 forces when a charge is transported from one point to the other. It is measured in Volt or Joules per Coulomb. Electric potential difference is a scalar quantity.

Consider the diagram above, Suppose a test charge is moved from point to point along an arbitrary path inside an electric field. The electric field exerts a force on the charge shown in fig 3.1. To move the test charge from to at constant velocity, an external force of must act on the charge. Therefore, The elemental work done is given as:

$$dW = f \cdot dL \quad ---- \text{(1)}$$

But $F = -q_0 L \quad .... \text{(2)}$

Substituting equation (2) in (1) $= dW = -q_0 E dL \quad ---- \text{(3)}$

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

$$W(A' \cap B)_{Ag} = -q_0 \int_A^B \bar{E} dL \quad ---- \text{(4)}$$

from the definition of electric potential difference, it follows that:

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

Putting equation (4) in (5) yields $V_B - V_A = \int_A^B \bar{E} dL \quad —— \text{(6)}$

~~4a~~

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

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

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

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

4c) Mass of electron $= 9.11 \times 10^{-31}$ kg

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

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

Cyclotron frequency. Can be called Angular Speed

Recall, That Angular Speed $\omega = \frac{V}{r} = \frac{qB}{m}$

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

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

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 permeability of free space (μ), the current (I) the change in length, the radius and inversely proportional to the square of radius (r^2). It can be represented mathematically by:

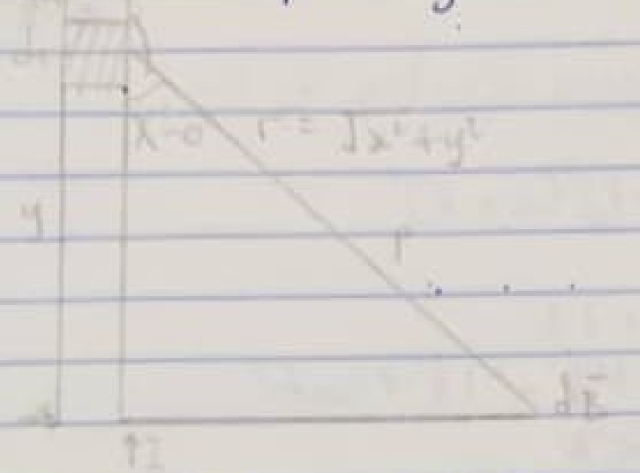
$dB = \frac{\mu_0 I dl \times r}{4\pi r^2}$, where μ_0 is a constant called permeability of free space

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

Unit of B is weber/metre square

5b) Magnetic field of a straight current carrying conductor

fig 1: A section of a straight current carrying conductor Applying the Biot-Savart law, we find magnitude of the field



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

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

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

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

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

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

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

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

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

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

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

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

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

When the length 2a of the conductor is very great in comparison to the 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 $a \to \infty$