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COVID-19 HOLIDAY ASSIGNMENT.
SECTION A

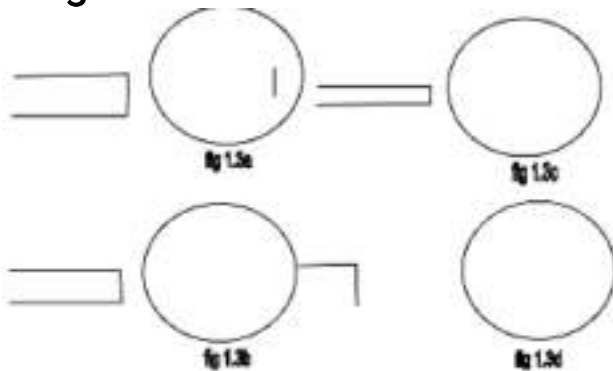
1a. Charging by Induction:

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. 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, some of the protons 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 negative charge.

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

Diagram



1B

$1b \quad Q_1 + Q_2 = 5 \times 10^{-8} C$
 $F = 1 N$
 $d = 2m$

Recall that
 $k = 9 \times 10^9$
 $F = k \frac{Q_1 Q_2}{r^2}$

$1 = \frac{9 \times 10^9 \times (Q_1 \times (5 \times 10^{-8} - Q_1))}{2^2}$

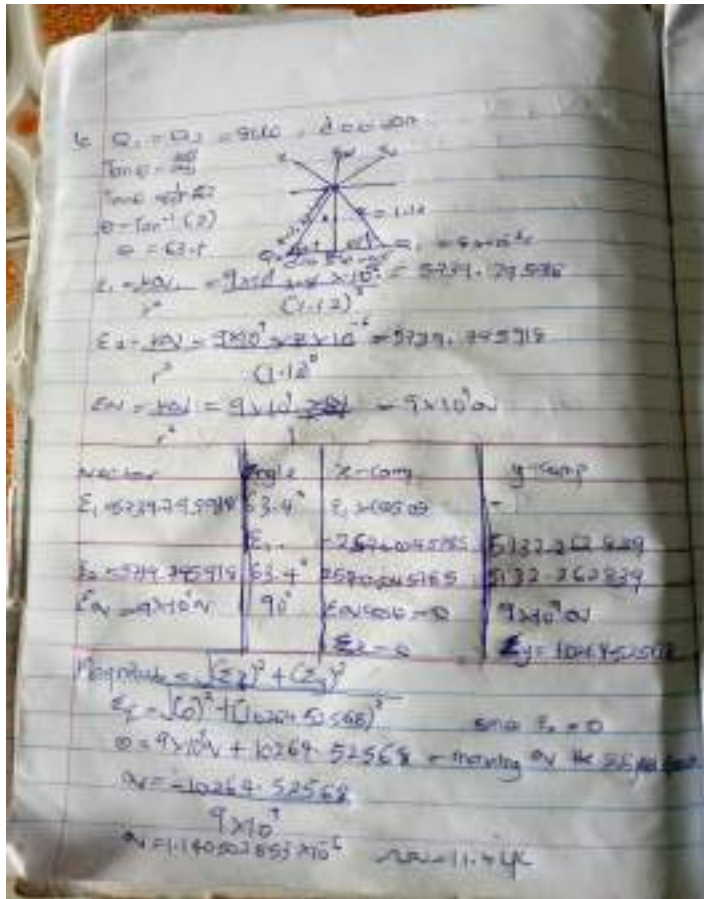
$4 = 9 \times 10^9 \times 5 \times 10^{-16} Q_1 - 9 \times 10^9 Q_1^2$
 $4 = 4.5 \times 10^{-6} Q_1 - 9 \times 10^9 Q_1^2$

It is a quadratic eq
 $9 \times 10^9 Q_1^2 - 4.5 \times 10^{-6} Q_1 + 4 = 0$

$Q_1 = \frac{0.0000111 \pm \dots}{2}$
 $\approx Q_1 = 1.11 \times 10^{-5} C$

$Q_2 = 0.0000389 \dots$
 $\approx Q_2 = 3.89 \times 10^{-5} C$

1C



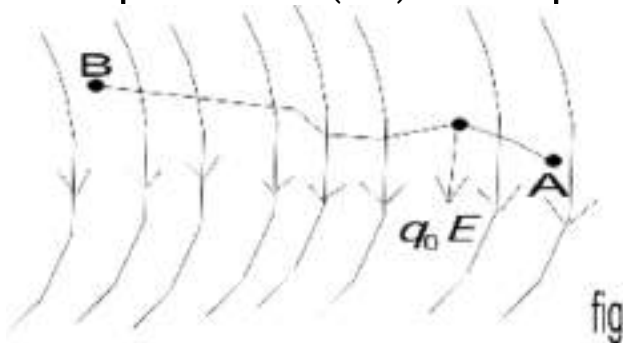
3a. Volume charge density, $=dQ/dV = \rho$

Surface charge density, $=dQ/dA = \sigma$

Linear charge density, $=dQ/dL = \lambda$

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 (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. 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 work done dW is given as:

$$dW=F \cdot dL \quad (1)$$

$$\text{But } F=-q_0E \quad (2)$$

Substituting equation (2) in (1) yields

$$dW=-q_0E \cdot dL \quad (3)$$

$$W=-q_0 \int E \cdot dL \quad \dots \quad (3)$$

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

$$W_{(AB)} = -q_0 \int_A^B E \cdot dL \quad \dots \dots \dots (4)$$

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

$$V_B - V_A = W_{(AB)} / q_0 \quad \dots \dots \dots (5)$$

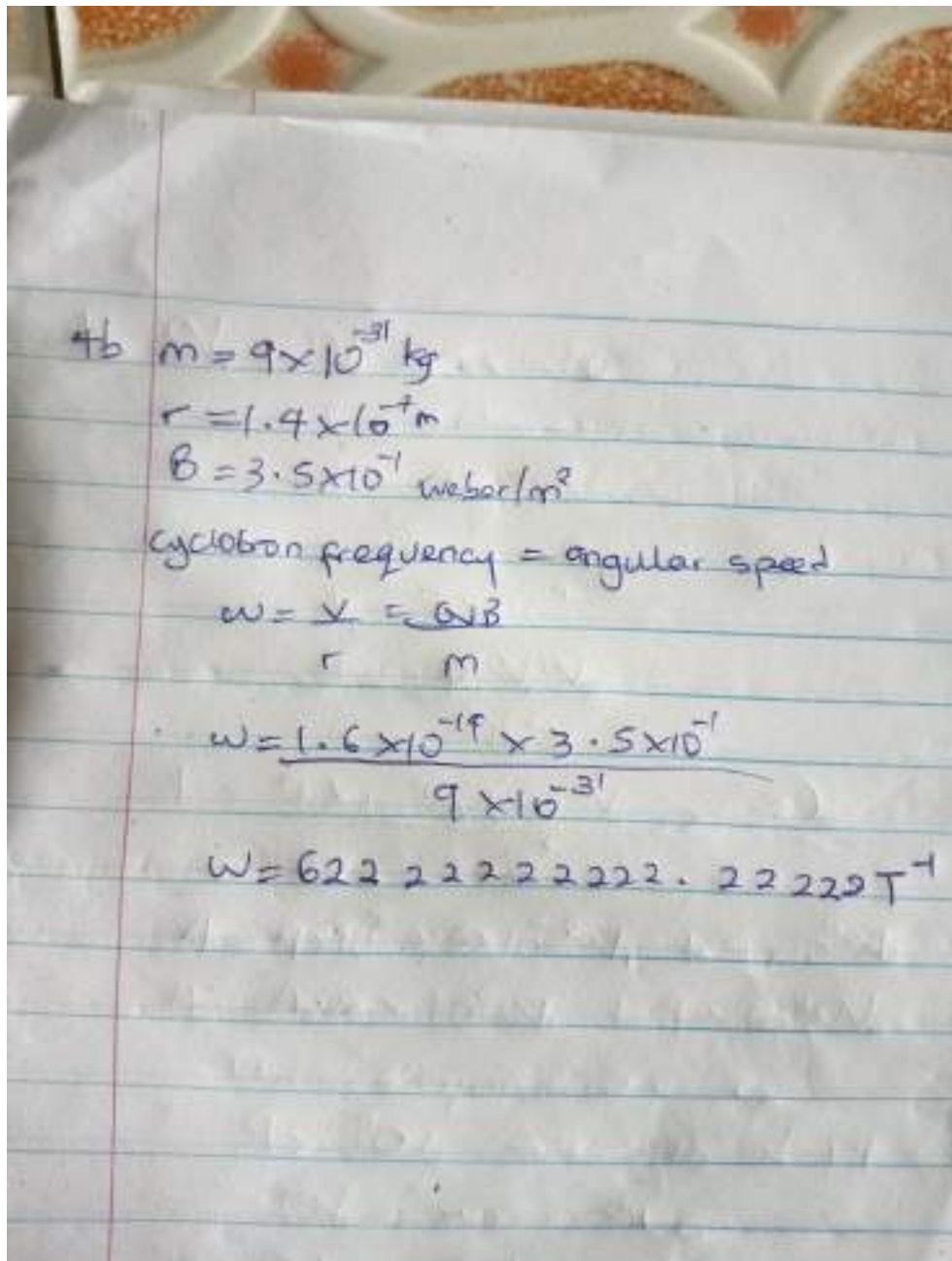
Putting equation (4) in (5) yields

$$V_B - V_A = - \int_A^B E \cdot dL \quad \dots \dots \dots (6)$$

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 the symbol Φ . mathematically given as $\Phi = \int B \cdot dA$

4b.



4c. In the question we were given parameters such as

i. mass of the electron = $9.11 \times 10^{-31} \text{ kg}$

ii. A radius of $1.4 \times 10^{-7} \text{ m}$

iii. magnetic field of $3.5 \times 10^{-1} \text{ weber/meter square}$

and you are asked to find the cyclotron frequency which is equal

or the same thing as angular speed. it is called cyclotron frequency because it is a frequency of an accelerator called cyclotron.

Recall that angular speed is given as $\omega = vr = qBm$

Substituting we have $\omega = vr = qBm$

$$= 1.6 \times 10^{-19} \times 3.5 \times 10^{-10}$$

$$9.11 \times 10^{-31}$$

$$qBm = 1.6 \times 10^{-19} \times 3.5 \times 10^{-10} \times 9.11 \times 10^{-31}$$

$$= 62222222222.22222 \text{ T}$$

SO since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $= 62222222222.22222$, having a unit as $1/T$ which is equal to the unit of frequency dimensionally.

5b. Magnetic Field of a Straight Current Carrying Conductor

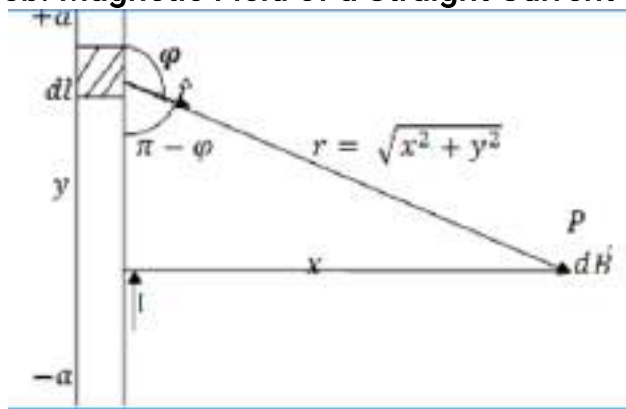


Fig 1: A section of a Straight Current Carrying Conductor

Applying the Biot-Savart law, we find the magnitude of the field dB

$$dB = \frac{\mu_0 I dl \sin \theta}{4\pi r^2}$$

$$\sin \theta = \sin \phi$$

$$\therefore B = \frac{\mu_0 I a \sin \phi}{2\pi r^2}$$

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

$$B = \frac{\mu_0 I a}{4\pi r^3} \sin(\theta) \quad (*)$$

$$\text{But } \sin\theta = \frac{y}{r} = \frac{y}{\sqrt{x^2 + y^2}} \quad (**)$$

Substituting (**) into (*), we have

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

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Recall $dl = dy$

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

$$B = \frac{\mu_0 I a}{4\pi} \frac{1}{\sqrt{x^2 + y^2}} \quad (***)$$

Using special integrals:

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

Equation (***) therefore becomes

$$B = \frac{\mu_0 I a}{4\pi} \frac{1}{\sqrt{x^2 + y^2}}$$

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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 ,

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

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

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

$$B = \frac{\mu_0 I}{2\pi r} \quad (#)$$

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