

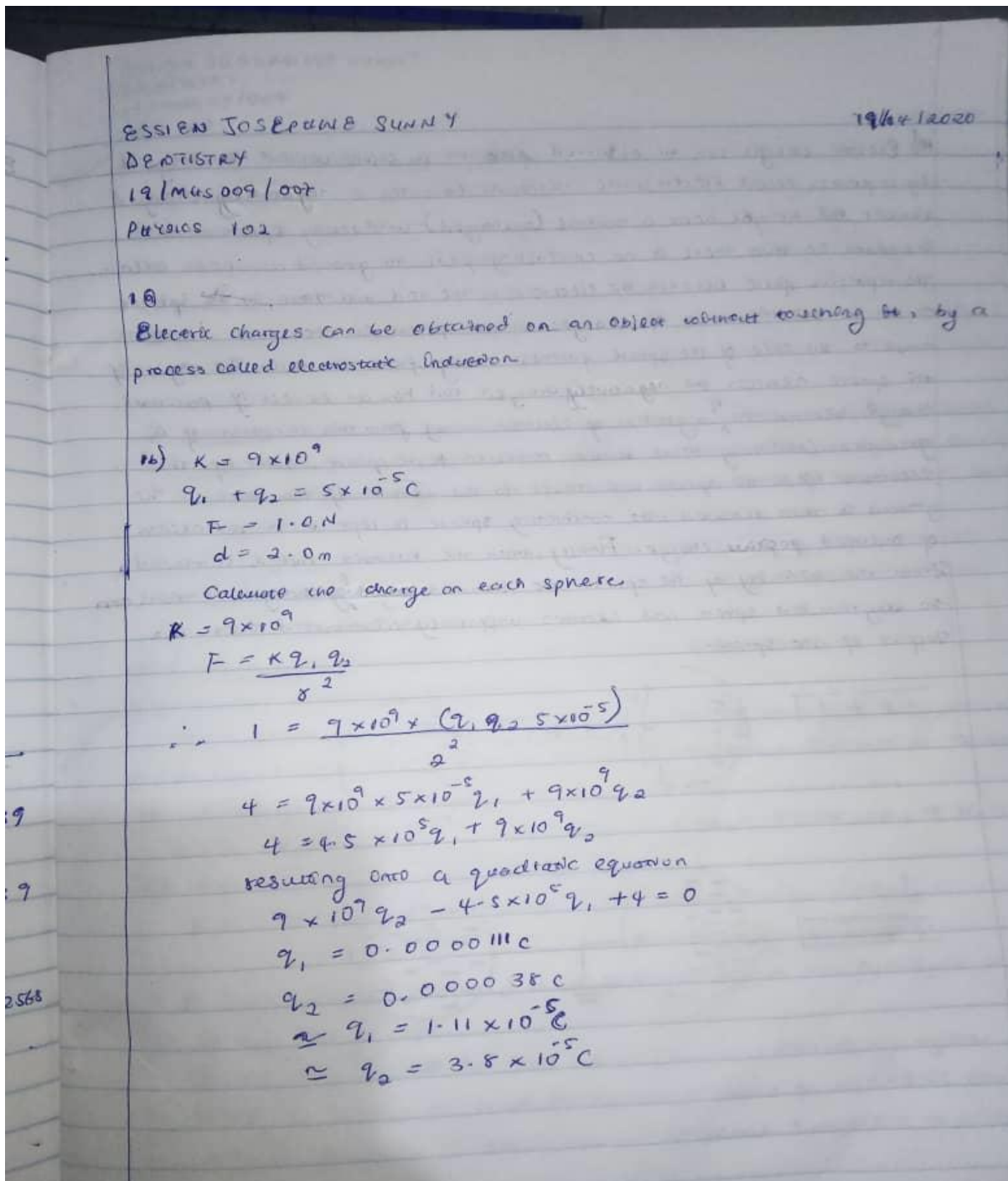
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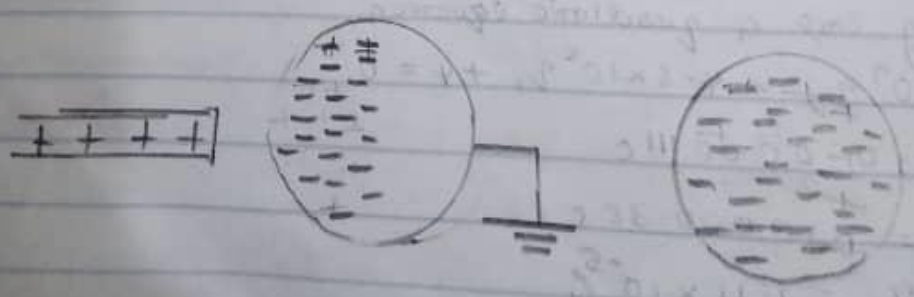
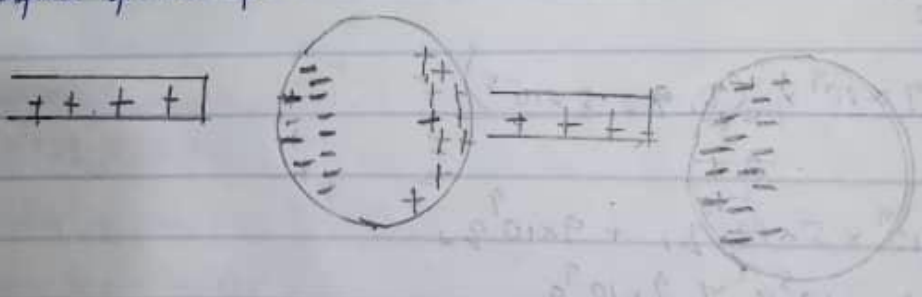
COURSE CODE: PHY 102

MATRIC NO.: 19/MHS09/007

COVID-19 Holiday Assignment



10) Electric charges can be obtained ~~from~~ 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 electrons in the rod and those on the sphere 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 positively charged rod has an excess of positive charge because the migration of electrons away from this location. If a grounded conducting wire is then connected to the sphere, some of the electrons leave the sphere and travel to the earth. If the wire to the 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 negative charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.



⑩  $Q_1 = Q_2 = 8 \mu\text{C}$

$d = 0.5 \text{ m}$

determine  $\vec{E}$  of electric field at a point  $P$  at  $30^\circ$

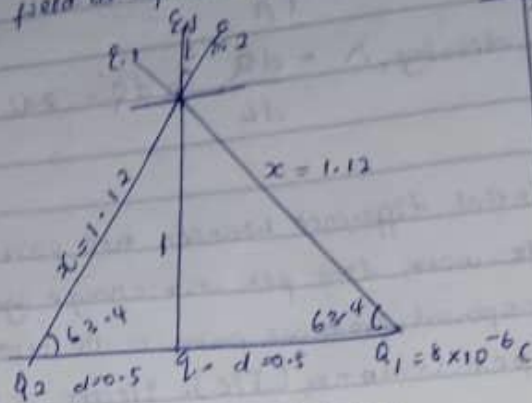
$\theta =$

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

$\tan \theta = \frac{1}{0.5} = 2$

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

$= 63.4^\circ$



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

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

$$= 1.12$$

$E_1 = \frac{kQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 5739.795918$

$E_2 = \frac{kQ_2}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.12^2} = 5739.795918$

$E_4 = \frac{kq}{r^2} = \frac{9 \times 10^9 \times q}{1} = 9 \times 10^9 q$

Vector	angle	x-comp.	y-comp.
$E_1 = 5739.795918$	$63.4^\circ$	$E_1 \cos \theta$	$E_1 \sin \theta$
$E_2 = 5739.795918$	$63.4^\circ$	$-2570.045785$	$5132.262839$
$E_4 = 9 \times 10^9 q$	$90^\circ$	$E_4 \cos 90 = 0$	$9 \times 10^9 q$
		$E_x = 0$	$E_y = 10264.52568$

magn. net field =  $\sqrt{(E_x)^2 + (E_y)^2}$

$E_4 = \sqrt{(0)^2 + (10264.52568)^2}$

Since  $E_x = 0$

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

making  $q$  subject of formula

$q = \frac{-10264.52568}{9 \times 10^9} = -1.140502853 \times 10^{-6}$

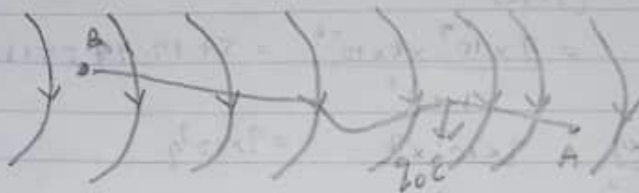
$\approx q = -11.44 \mu\text{C}$

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

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

Linear charge density,  $\lambda = \frac{dQ}{dL}$  'n'  $dQ = \lambda dL$

3b) 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 one point A to point B along an arbitrary path inside an electric field  $E$ . The electric field  $E$  exerts a force  $F = q_0 E$  on the charge. To move the test charge from A to B at constant velocity, an external force of  $F = -q_0 E$  must act on the charge.

Therefore, the elemental work done  $dW$  is given as:

$$dW = F \cdot dl \quad \text{--- (1)}$$

But  $F = -q_0 E$  --- (2)

Substituting equation (2) in (1) yields

$$dW = -q_0 E dl \quad \text{--- (3)}$$

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

$$W(A \rightarrow B)_{Aq} = -q_0 \int_A^B E dl \quad \text{--- (4)}$$

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

$$V_B - V_A = \frac{W(A \rightarrow B)_{Aq}}{q_0} \quad \text{--- (5)}$$

Putting equation (4) in (5) yields  $V_B - V_A = - \int_A^B E dl$  --- (6)

## SECTION B

49) 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  $\Phi$ .  
mathematically given as  $\Phi = B \cdot dA$

$$40) m = 9 \times 10^{-31} \text{ Kg}$$

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

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

Cyclotron frequency = angular speed

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

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

$$\omega = 62.22222222222222 \text{ T}^{-1}$$

40) 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  $3.5 \times 10^{-1} \text{ weber/meter}^2$

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 ~~an~~ a frequency of an accelerator called cyclotron.

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

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

$$= 62.22222222222222 \text{ T}^{-1}$$

So since cyclotron frequency is equal to angular speed, the cyclotron frequency is equal to  $62.22222222222222 \text{ T}^{-1}$ , having a unit as ~~per~~  $1/\text{T}$  which is equal to the unit of frequency dimensionally.

5(a) Biot-Savart law states that the magnetic field  $B$  is directly proportional to the product permeability of free space ( $\mu_0$ ), 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

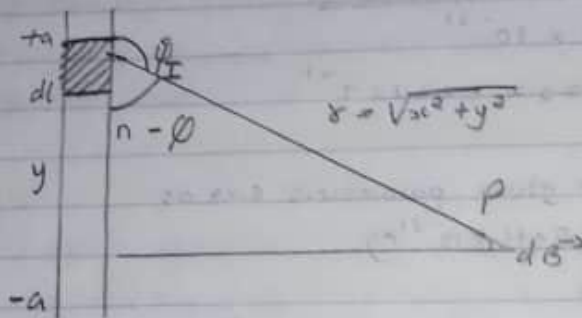
$$d\vec{B} = \frac{\mu_0 I d\vec{l} \times \hat{r}}{4\pi r^2} \quad \text{--- (1)}$$

where  $\mu_0$  is a constant called permeability of free space.

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

The unit is weber / meter square

5(b)



A section of a Straight Current Carrying Conductor

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

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

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

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

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

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

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

Substituting (\*\*) into (\*) we have

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

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

Recall  $dl = dy$

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

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

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 (\*\*\*) therefore 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  $2a$  of the conductor is very great in comparison to the 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 on 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 or flux density  $B$  near a long, straight current carrying conductor