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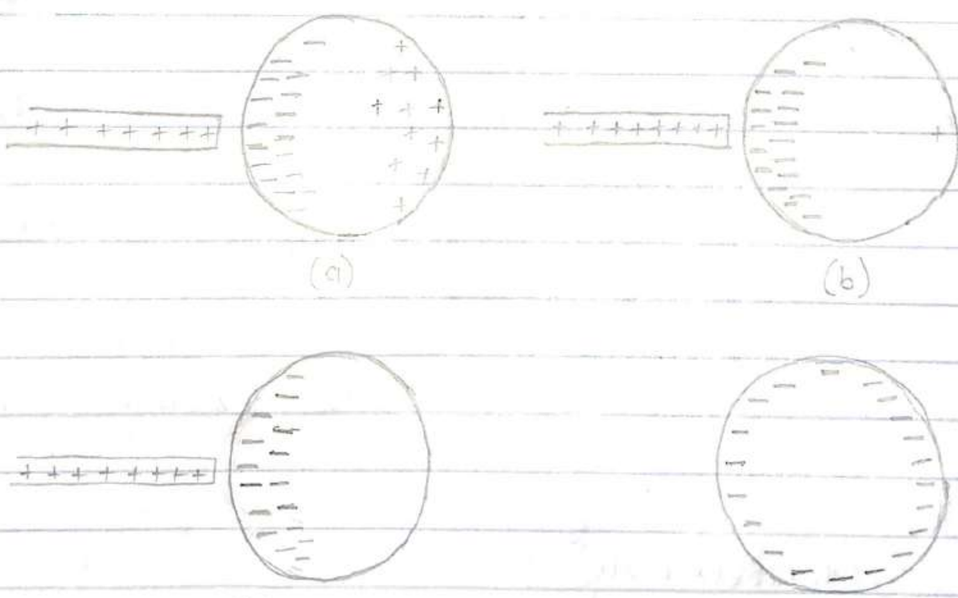
COURSE CODE: PHY 102
~~DATE~~ TOPIC. COVID-19 HOLIDAY ASSIGNMENT

1a ~~Charg~~ Consider a positively charged ~~sphere~~ rubber rod brought near a neutral (uncharged) conducting sphere. The repulsive ~~charge~~ force between the positive charge (protons) in the rod and those in the sphere causes redistribution of charges in the sphere so that the 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 electrons because of the migration of positive charges away from this location. This process is polarization. A grounded conducting wire is then connected to the sphere. ~~and Electrons are~~ attracted Electrons from the ground ~~on~~ are attracted to the positive charge in the sphere and enter it through the ~~a~~ conducting wire. If the ground conducting wire 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.



(a) (b) (c) (d)

1 b $Q_1 + Q_2 = 5 \times 10^{-5} C$ $r = 2.0m$ $F = 1N$ $k = 9 \times 10^9 \ Nm^2/C^2$ $q_1 = ?$ $q_2 = ?$

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

From Coulomb's Law:

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

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

$1 = \frac{9 \times 10^9 q_1 (5 \times 10^{-5} - q_1)}{4}$

$4 = 9 \times 10^9 q_1 (5 \times 10^{-5} - q_1)$

$4 = 4.5 \times 10^5 q_1 - 9 \times 10^9 q_1^2$

$(9 \times 10^9) q_1^2 - (4.5 \times 10^5) q_1 - 4 = 0$

Using quadratic formula:

$q_1 = \frac{-(-4.5 \times 10^5) + \sqrt{(-4.5 \times 10^5)^2 - 4(9 \times 10^9)(4)}}{2(9 \times 10^9)}$

=

OR

$q_1 = \frac{-(-4.5 \times 10^5) - \sqrt{(-4.5 \times 10^5)^2 - 4(9 \times 10^9)(4)}}{2(9 \times 10^9)}$

$q_1 = 3.84 \times 10^{-5} C$ or $q_1 = 1.16 \times 10^{-5} C$

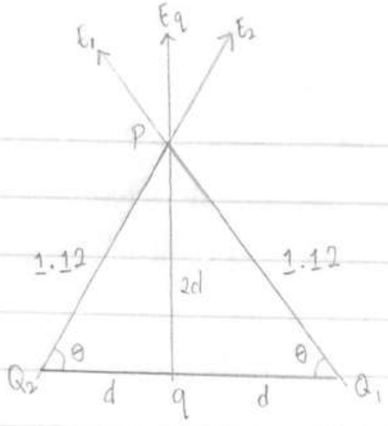
When $q_1 = 3.84 \times 10^{-5} C$, $q_2 = (5 \times 10^{-5}) - (3.84 \times 10^{-5})$

$q_2 = 1.16 \times 10^{-5} C$

When $q_1 = 1.16 \times 10^{-5} C$, $q_2 = (5 \times 10^{-5}) - (1.16 \times 10^{-5})$

$= 3.84 \times 10^{-5} C$

$\therefore q_1 = 3.84 \times 10^{-5} C$ and $q_2 = 1.16 \times 10^{-5} C$ or vice versa.



1c $Q_1 = Q_2 = 8\mu C = 8\times10^{-6}\,C$

$d = 0.5m$

$2d = 1m$

$\tan\theta = 1/0.5$

$\theta = \tan^{-1}(1/0.5) = 63.4°$

$E_1 = \dfrac{KQ_1}{r_1^2} = \dfrac{9\times10^9 \times 8\times10^{-6}}{1.12^2} = 57397.95918\,N/C$

Since $q_1 = q_2$ and $r_1 = r_2$, $E_1 = E_2 = 57397.95918\,N/C$

$E_q = \dfrac{Kq}{r_q^2} = \dfrac{9\times10^9 \times q}{1^2} = 9\times10^9 q\ N/C$

Vector	Angle	X-Component	Y-Component
$E_1 = 57397.95918\,N/C$	63.4°	$E_{1x} = -57397.95918\cos 63.4$ $= -25700.45785\,N/C$	$E_{1y} = 57397.95918\sin 63.4$ $= 51322.62839\,N/C$
$E_2 = 57397.95918\,N/C$	63.4°	$E_{2x} = 57397.95918\cos 63.4$ $= 25700.45785\,N/C$	$E_{2y} = 57397.95918\sin 63.4$ $= 51322.62839\,N/C$
$E_q = 9\times10^9 q$	90°	$E_{qx} = 9\times10^9 q\cos 90$ $= 0\,N/C$	$E_{qy} = 9\times10^9 q\sin 90$ $= 9\times10^9 q\ N/C$
		$\Sigma E_x = 0\,N/C$	$\Sigma E_y = (102645.2568 + 9\times10^9 q)\,N/C$

$E = \sqrt{\Sigma E_x^2 + \Sigma E_y^2} = \sqrt{0^2 + (102645.2568 + 9\times10^9 q)^2}$

$= 0 + (102645.2568 + 9\times10^9 q)$

$E = 102645.2568 + 9\times10^9 q$

Since the electric field at P is 0, $E = 0$

$0 = 102645.2568 \times 9\times10^9 q$

$\dfrac{-9\times10^9 q}{-9\times10^9} = \dfrac{102645.2568}{-9\times10^9}$

$q = -1.14\times10^{-5}\,C$

$= -11.4\times10^{-6}\,C$

$q = -11.4\mu C$

$q \simeq -11\mu C$

1c ~~$\theta = 102645.2568 \div 9\times10^9 q$~~ $Eq = \frac{kq}{r^2}$

$q = \frac{Eq\, r^2}{k} = \frac{102645.2568 \times 1^2}{9\times10^9}$

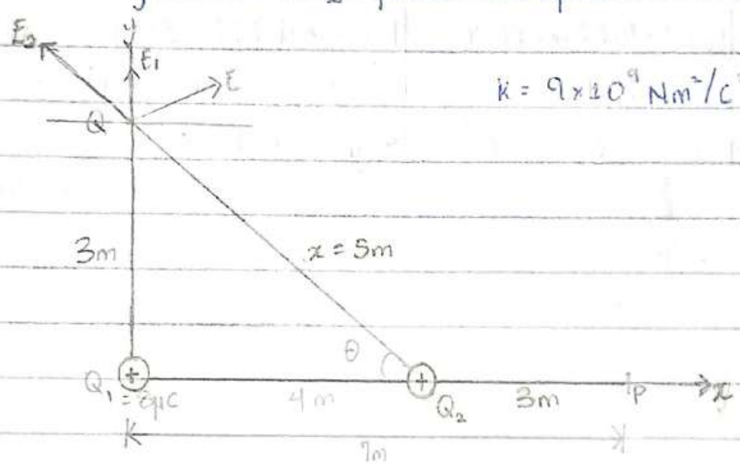
$q = 1.14 \times 10^{-5}\, C$

$= 11.4 \times 10^{-6}\, C$

$q = 11.4\mu C$

2a Electric field is a region in space in which an electric charge will ~~exert~~ experience an electric force while electric field intensity is the strength of an electric field at any point in space.

b



$k = 9\times10^9\, Nm^2/C^2$ $Q_1 = 8nC = 8\times10^{-9}C$ $Q_2 = 12nC = 12\times10^{-9}C$

$3^2 + 4^2 = x^2$

$9 + 16 = x^2$

$x^2 = 25$

$x = 5m$

$\tan\theta = \frac{3}{4}$

$\theta = \tan^{-1}(3/4)$

$= 36.9°$

i $E_1 = \frac{kQ_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = \frac{72}{49} = 1.47\, N/C$

$E_2 = \frac{kQ_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = \frac{108}{9} = 12\, N/C$

$E_{net} = E_1 + E_2$

$= 1.47 + 12$

$E_{net} = 13.47\, N/C$

$\simeq 13.5\, N/C$

2bii $\mathcal{E}_1 = \frac{KQ_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = \frac{72}{9} = 8 N/C$

$\mathcal{E}_2 = \frac{KQ_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = \frac{108}{25} = 4.32 N/C$

Vector	Angle	X - Component	Y - Component
$E_1 = 8N/C$	$90°$	$E_{1x} = 8\cos 90°$ $= 0 N/C$	$E_{1y} = 8\sin 90°$ $= 8N/C$
$E_2 = 4.32N/C$	$36.9°$	$E_{2x} = -4.32\cos 36.9$ $= -3.45N/C$	$E_{2y} = 4.32\sin 36.9$ $= 2.59 N/C$
		$\Sigma E_x = -3.45 N/C$	$\Sigma E_y = 10.59 N/C$

$E = \sqrt{\Sigma E_x^2 + \Sigma E_y^2}$

$E = \sqrt{(-3.45)^2 + 10.59^2}$

$E = \sqrt{11.9025 + 112.1481}$

$E = \sqrt{124.0506}$

$E = 11.14 N/C$

4

Section B

4a Magnetic flux is defined as the strength of a magnetic field represented by lines of force.

b $m = 9.11\times10^{-31}$ kg $r = 1.4\times10^{-7}$ m $B = 3.5\times10^{-1}$ Weber/m^2 $q = -1.6\times10^{-19}$ C

$\omega = \frac{qB}{m} = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times10^{-31}}$

$\omega = 6.15\times10^{10}$ rad/s

c In the question, we were asked to look for cyclotron frequency. Cyclotron frequency is another name for angular speed. Angular speed is often called cyclotron frequency because the charge particle circulates at this angular frequency

4c or angular speed in a type of acceleration called cyclotron. Angular speed is usually given as (v/r) which is the ratio of the speed of a particle to its radius. It can also be written as (qB/m) where q is the charge of the particle, B is the magnetic flux density or magnetic field and m is the mass of the particle.

With all the parameters given in question 4b, $\omega = qB/m$ was the appropriate formula to use.

5a Biot-Savart Law states that the magnitude of a magnetic field is directly proportional to the current, magnitude of the length element, and the unit vector $\hat{r}$ that points from $d\vec{l}$ to P and inversely proportional to the square of the distance, r from $d\vec{l}$ to point P.

Mathematically, the Biot-Savart law states that at any point P, the magnetic field $d\vec{B}$ due to a length element $d\vec{l}$ of a current-carrying wire is given by:

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

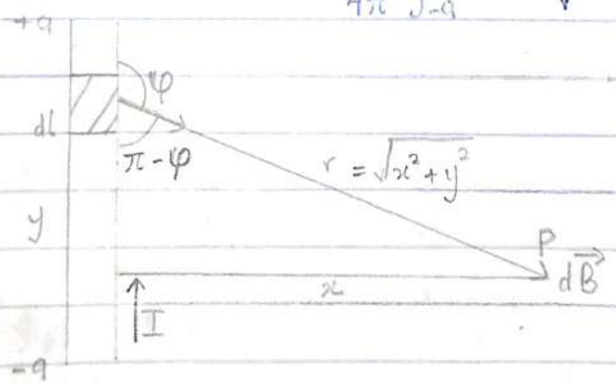
where μ_0 is a constant called permeability of free space.

b Applying the Biot-Savart law, we find the magnitude of the field $d\vec{B}$ of the diagram below:

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

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

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



5b From the diagram, $r^2 = x^2 + y^2$ (Pythagoras' theorem)

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

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

Substituting (ii) into (i)

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

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

Recall $dl = dy$

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

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

Using special integrals:

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

Eqn (iii) therefore becomes:

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

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

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

5b When 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,

$$(x^2 + a^2)^{1/2} \cong a, \quad \text{as} \quad a \longrightarrow \infty$$

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

In a physical situation, we have axial ~~symetry~~ symmetry about the y-axis Thus, at all points in a circle of radius r, around the conductor, the magnitude of B is:

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

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