PINNICK ITSE ORITSETSERUNDEDE
CHEMICAL ENGINEERING
19/ENG01/013

PHY 102 Assignment

Question 1

a Consider a positively charged rubber rod brought near a neutral (uncharged) Conducting sphere that is insulated So that their is no conducting path to ground as shown below. The repulsive force between the electrons in the rod and those in 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 [fig a]. The region of the Sphere nearest to 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 b], Some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed [fig c], 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 d], the induced negative charge remains on the Ungrounded Sphere and becomes Uniformly distributed over the surface of the sphere.

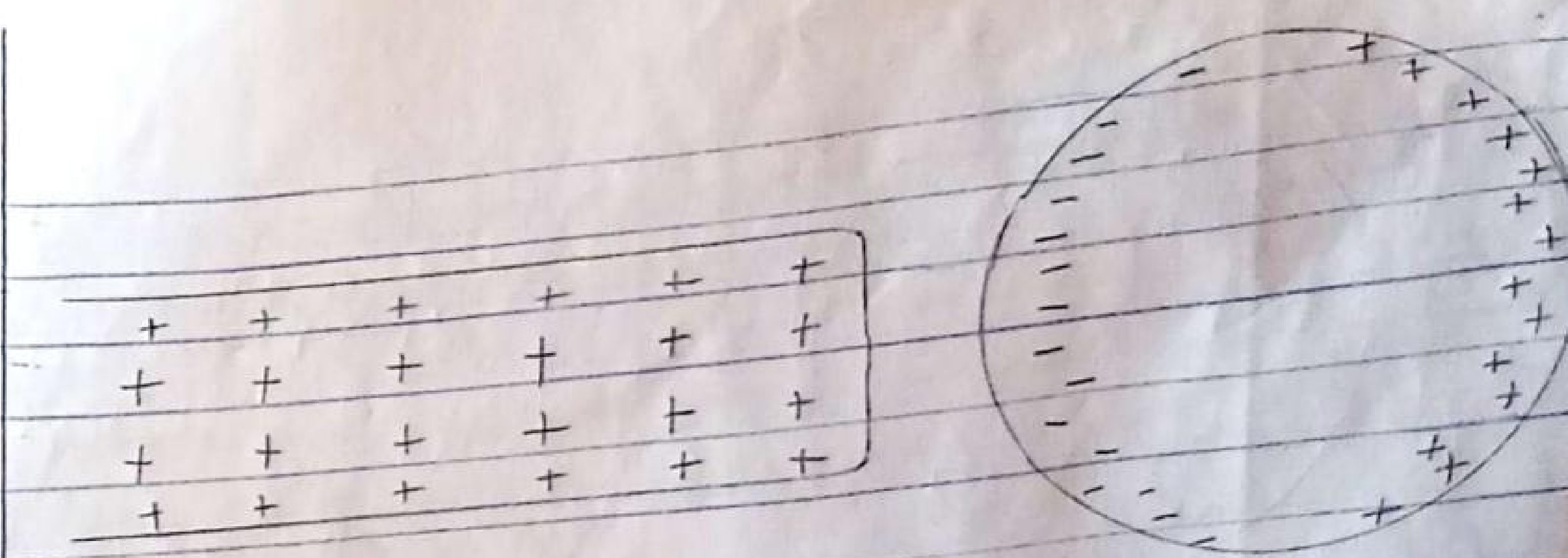


fig a

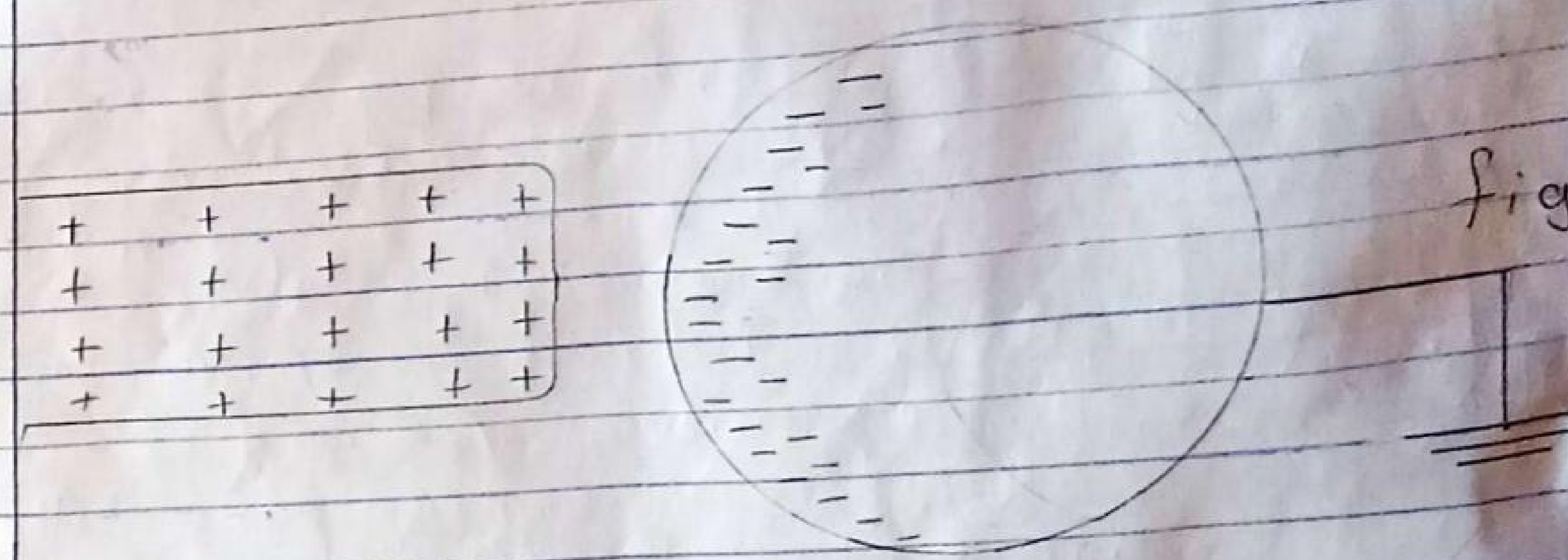
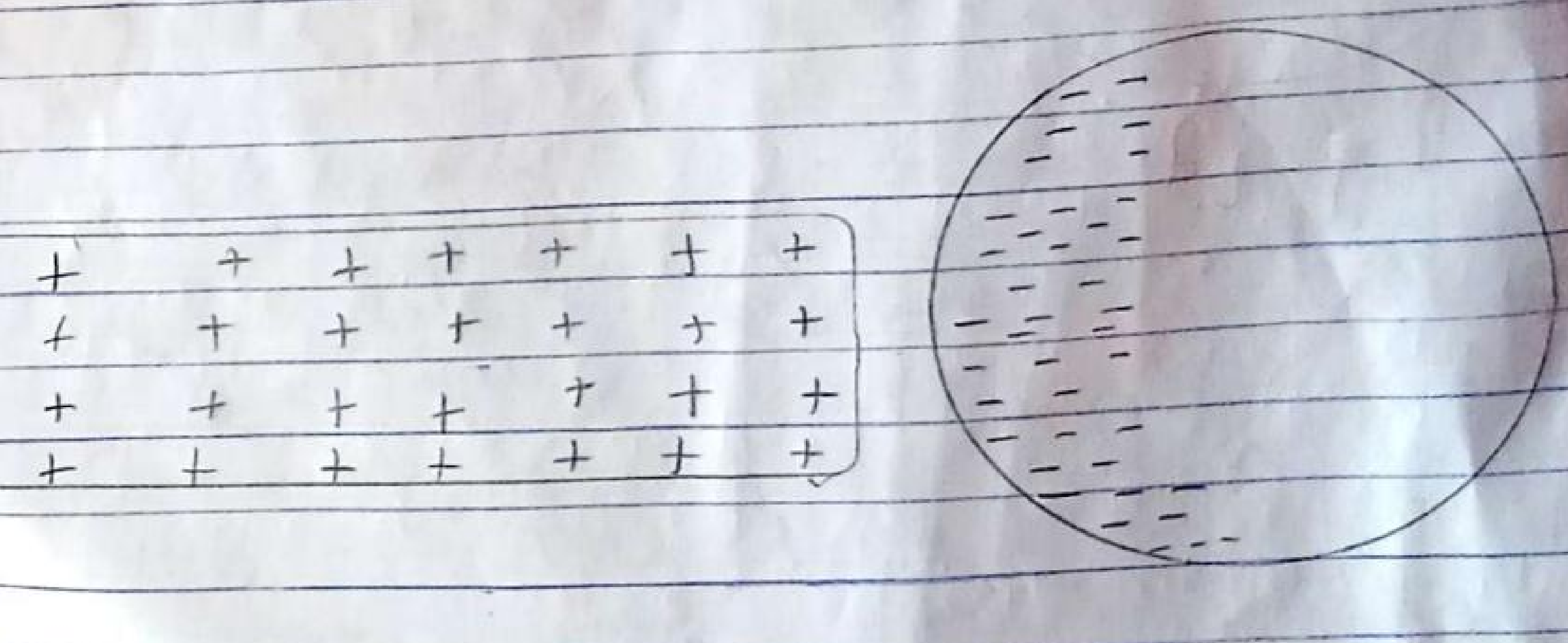
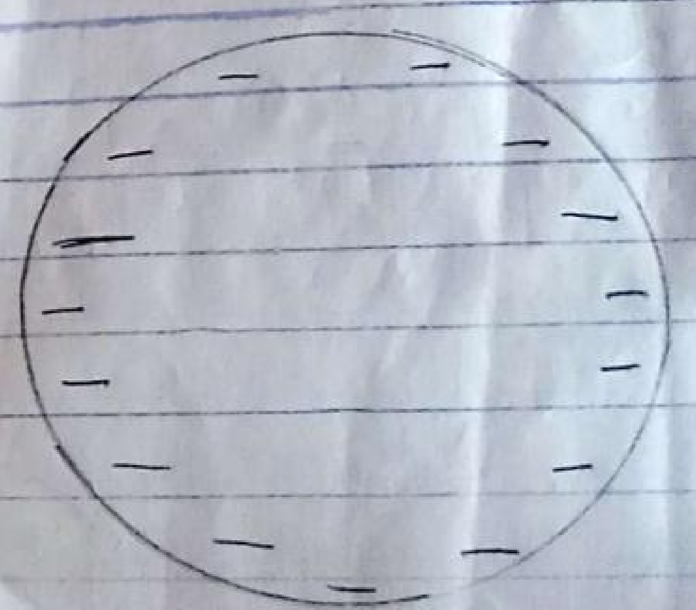


fig b



fig



fig

1b $F = \frac{k q_1 q_2}{r^2}$

Where

$F = 1.0N$

$k = 9\times10^9 Nm^2/C^2$

$r = 2.0m$

$q_1 + q_2 = 5.0\times10^{-5}C$

$q_1 = 5.0\times10^{-5} - q_2$

$$1.0 = \frac{9\times10^9 \times (5.0\times10^{-5} - q_2) \times q_2}{2^2}$$

$$4 = 4.5\times10^5 q_2 - 9\times10^9 q_2^2$$

$$9\times10^9 q_2^2 - 4.5\times10^5 q_2 + 4 = 0$$

$$q_2 = 1.16\times10^{-5}$$

$\therefore q_1 = (5.0\times10^{-5}) - (1.16\times10^{-5})$

$q_1 = 3.84\times10^{-5}$

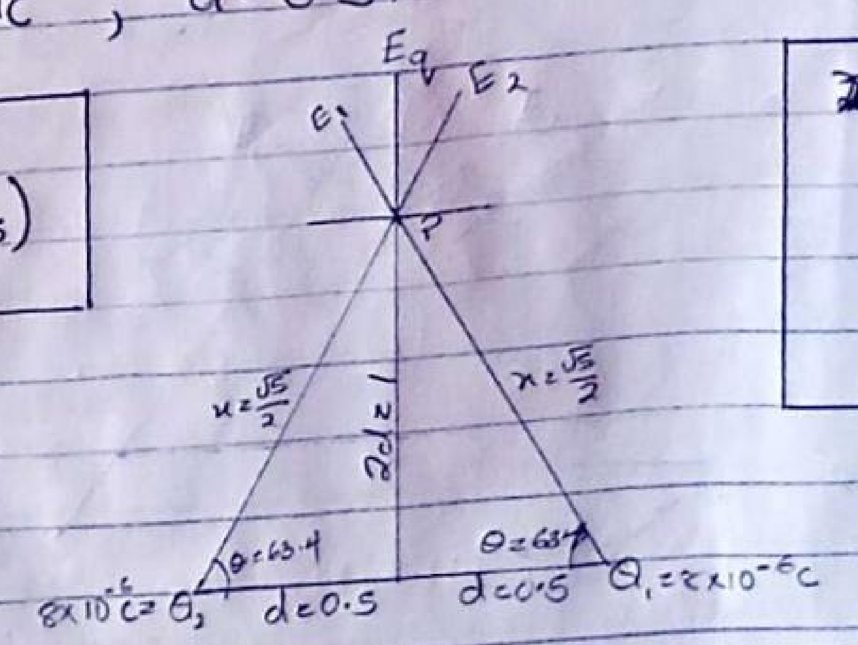
$\therefore q_1 = 3.84\times10^{-5}$ & $q_2 = 1.16\times10^{-5}$

1c $Q_1 = Q_2 = 8\mu C$; $d = 0.5m$

$\tan\theta = 1/0.5$

$\theta = \tan^{-1}(1/0.5)$

$\theta = 63.4$



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

$x = \sqrt{1 + 0.25}$

$x = \sqrt{1.25}$

$x = \frac{\sqrt5}{2}$

$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(\sqrt5/2)^2} = 57600$$

Since $E_1 = E_2$; $E_2 = 57600$

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

Vector	angle	x-Component $(E\cos\theta)$	y-Component $(E\sin\theta)$
$E_1 = 57600$	63.4	-25790.92	51503.28
$E_2 = 57600$	63.4	25790.92	51503.28
$E_q = 9\times10^9 q$	90°	0	$9\times10^9 q$
		$\Sigma x = 0$	$E_y = 9\times10^9 q + 103006.56$

$$E = \sqrt{Ex^2 + Ey^2}$$

$E = 0$

$$\therefore \quad 0 = \sqrt{0^2 + (9\times10^9 q + 103006.56)^2}$$

$$0^2 = 0^2 + (9\times10^9 q + 103006.56)^2$$

$$0 = 8.1\times10^{19} q^2 + 1.06\times10^9$$

$$-8.1\times10^{19} q^2 = 1.06\times10^9$$

$$-q^2 = \frac{1.06\times10^9}{8.1\times10^{19}}$$

$$-q^2 = +1.31\times10^{-10}$$

$$-q = \sqrt{+1.31\times10^{-10}}$$

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

$$\therefore \underline{\underline{q \simeq -11.4\,\mu C}}$$

3a - <u>Volume charge dencity:</u>

$$\rho = \frac{dQ}{dV} \rightarrow dQ = \rho\, dV$$

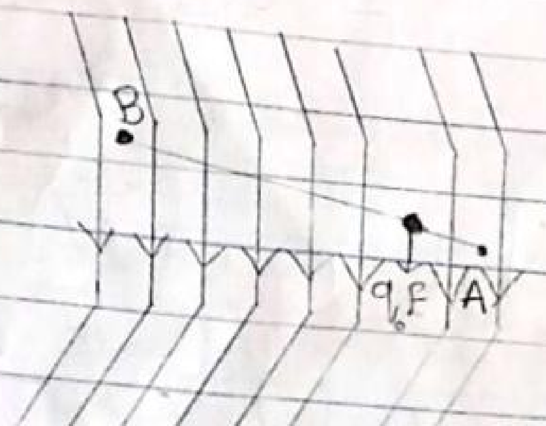
- <u>Surface charge dencity:</u>

$$\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma\, dA$$

- <u>Linear charge dencity:</u>

$$\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda\, dL$$

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 colomb (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 as shown in the diagram. 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:

$$dW = F.dL \quad - - - (1)$$

But $F = -q_0E \quad - - - (2)$

Substituting equ (2) in (1) yields

$$dW = -q_0E\,dl \quad - - - (3)$$

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

$$W(A \to B)_{Ag} = -q_0\int_A^B E\,dl \quad - - - (4)$$

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

$$V_B - V_A = \frac{W(A \to B)_{Ag}}{q_0} \quad - - - (5)$$

Putting equ (4) in (5) yields

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

4a Magnetic Flux through a surface is the surface integral of the normal component of the magnetic field flux density 'B' passing through that surface.

4b

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

(i) $r = 1.4 \times 10^{-7} m$; $B = 3.5 \times 10^{-1}$ Weber/meter
$m = 9.11 \times 10^{-31}$; $q = -1.60 \times 10^{-19}$

$$\omega = \frac{qB}{m} = \frac{(-1.60 \times 10^{-19})(3.5 \times 10^{-1})}{9.11 \times 10^{-31}}$$

$$\omega = -6.147 \times 10^{10} \text{ rad/s}$$

4c In 4b we were told to find the cyclotron frequency of the moving electron. I used the formulae for angular speed - $\omega = \frac{qB}{m}$ because

angular speed could also be known as cyclotron frequency because the charge particle circulates at this angular frequency or angular speed in the type of accelerator called cyclotron.

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5a The Biot-Savart Law states that it is a mathematical expression which illustrates the magnetic field produced by a stable electric current in the particular electromagnetism of physics. It tells the magnetic field towards the magnitude, length, direction, as well as closeness of the electric current.

5b $$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin\varphi}{r^2}$$

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

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

Where $r^2 = x^2 + y^2$

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

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

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

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

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

Recall $dl = dy$

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

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

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

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

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

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

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

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