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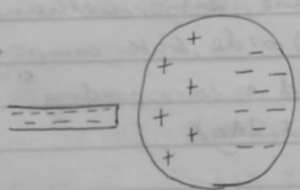
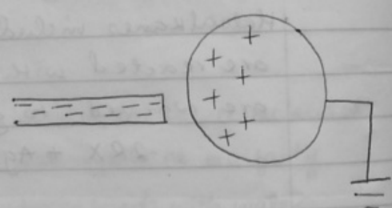
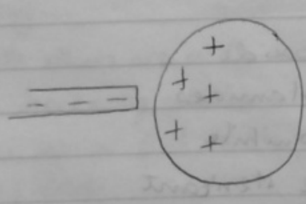
100 LEVEL

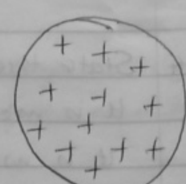
PRODUCTION OF CHARGES BY INDUCTION

This is the process by which objects obtain charges without contact. If a negatively charged rod is brought near a neutral insulated conducting sphere, the repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere. The electrons on the side closest to the rod move away, to the side farthest from the rod. The result is that the side closest to the negatively charged rubber rod is dominated by positive charges. A grounded conducting wire is then connected to the sphere and most of its electrons move into the earth. The wire is removed, leaving the sphere with an excess of positive charges. Lastly, the negatively charged rubber rod is removed leaving the sphere with uniformly distributed positive charges.


Step 1


Step 2


Step 3


The Positively Charged Sphere

1b Let the two charges be : q_1 and q_2

Sum of the charges $(q_1 + q_2) = 5.0 \times 10^{-5}$ C

Repelling force (F) = 1.0N

Distance (r) = 2.0m ; $r^2 = 4.0$m

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

$1.0N = \frac{9 \times 10^9 Nm^2C^{-2} \times q_1q_2}{4.0m}$

$4.0Nm = 9 \times 10^9 Nm^2C^{-2} \times q_1q_2$

$q_1q_2 = \frac{4.0Nm}{9 \times 10^9 Nm^2C^{-2}} = 4.44 \times 10^{-10} C^2$

Recall :

$x^2 -$ (sum of roots) $x +$ (products of roots) = 0

where; product of roots = q_1q_2 ; sum of roots = $q_1 + q_2 = 5.0 \times 10^{-5}$ C

$x^2 - (5.0 \times 10^{-5} C)x + (4.44 \times 10^{-10} C^2) = 0$

$x^2 - 3.887 \times 10^{-5} Cx + 1.113 \times 10^{-5} Cx + 4.44 \times 10^{-10} C^2 = 0$

$x(x - 3.887 \times 10^{-5} C) + 1.113 \times 10^{-5} C (x + 3.989 \times 10^{-5} C) = 0$

But 3.887×10^{-5} C and 3.989×10^{-5} C are approx. equal

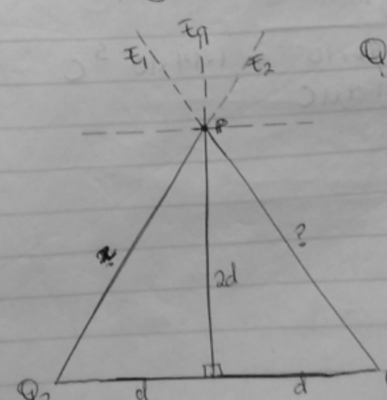
∴ Using 3.887×10^{-5} C

The roots are : 3.89×10^{-5} C and 1.110×10^{-5} C

where the roots of the equations is the charges.

∴ The charges are $+3.89 \times 10^{-5}$ C and 1.11×10^{-5} C

1c



$Q_1 = Q_2 = 8\mu C$; Electric field at P = 0

To find 'x' using pythagoras'

$x = \sqrt{2d^2 + d^2}$

$x = \sqrt{1^2 + 0.5^2}$

$x = \sqrt{1 + 0.25} = \sqrt{1.25}$

∴ $x = 1.12$m

$\sin\theta = {}^{2d}/_{1.12}$; $\theta = 63.43°$

$\cos\theta = {}^{d}/_{1.12}$; $\theta = 26.56°$

$E = \frac{kq}{r^2}$

$Q_1 = Q_2$ Note: $E_1 = E_2$

$E_1 = E_2 = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-6} C}{1.12^2 m^2} = 5.74\times10^4 NC^{-1}$

$\therefore E_1 = E_2 = 5.74\times10^4 NC^{-1}$

$Eq = \frac{9\times10^9 Nm^2C^{-2} \times q}{1^2} = 9\times10^9 q NC^{-1}$ $\therefore Eq = 9\times10^9 q \; NC^{-1}$

Forces	Angles	X-component	Y component
$5.74\times10^4 NC^{-1}$	$63.43°$	$5.74\times10^4 \cos 63.43 = +2.57\times10^4$	$5.74\times10^4 \sin 63.43 = 5.13\times10^4$
$5.74\times10^4 NC^{-1}$	$63.43°$	$5.74\times10^4 \cos 63.43 = -2.57\times10^4$	$5.74\times10^4 \sin 63.43 = 5.13\times10^4$
$9\times10^9 q \; NC^{-1}$	$90°$	$9\times10^9 q \cos 90° = 0$	$9\times10^9 q \sin 90° = 9.0\times10^9 q$
		$\Sigma x = 0 NC$	$\Sigma y = 1.026\times10^5 NC^{-1} + 9.0\times10^9 q$

$Eq = \sqrt{\Sigma x^2 + \Sigma y^2}$

$= \sqrt{(0)^2 + [(1.026\times10^5)^2 + (9.0\times10^9 q)^2]}$

$= \sqrt{1.053\times10^{10} + (9.0\times10^9 q)^2}$

But $Eq = 0$

$\therefore 0 = \sqrt{1.053\times10^{10} + (9.0\times10^9 q)^2}$

$0 = 1.053\times10^{10} + (9.0\times10^9 q)^2$

$(9.0\times10^9 q)^2 = 1.053\times10^{10}$

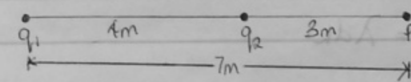
$\therefore q^2 = \frac{1.053\times10^{10}}{9.0\times10^9} = 1.2996\times10^{-10}$

$\therefore q = \sqrt{1.2996\times10^{-10}} = 1.14\times10^{-5} C$

$\therefore q = 11.4 \mu C$

2a <u>Electric field</u> is the region of space in which an electric charge will experience an electric force while <u>electric field intensity</u> also known as electric field strength is defined as the force per unit charge; it is the magnitude of electric field.

b) $q_1 = 8nC$ $q_2 = 12nC$



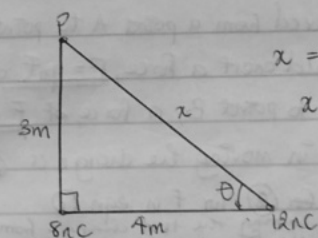
$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-9} C}{7^2} = 1.469 NC^{-1}$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 Nm^2C^{-2} \times 12\times10^{-9} C}{3^2} = 12 NC^{-1}$

$E_{net} = E_1 + E_2 = 1.469 NC^{-1} + 12 NC^{-1} = 13.469 NC^{-1}$

$\therefore E_{net} \simeq 13.5 NC^{-1}$

bii



$x = \sqrt{3^2 + 4^2}$

$x = \sqrt{9 + 16} = \sqrt{25} m$

$\therefore x = 5m$

$\theta = \sin^{-1}(3/5) = 36.9°$

$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 Nm^2C^{-2} \times 8\times10^{-9} C}{3^2} = 8NC^{-1}$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 Nm^2C^{-2} \times 12\times10^{-9} C}{5^2} = 4.32 NC^{-1}$

Vector	Angle	X-Component	Y component
$8NC^{-1}$	$90°$	$8NC^{-1} \cos 90 = 0NC^{-1}$	$8 \sin 90° = 8NC^{-1}$
$4.32NC^{-1}$	$36.9°$	$4.32 \cos 36.9 = 3.45NC^{-1}$	$4.32 \sin 36.9 = 2.60NC^{-1}$
		$\Sigma x = 3.45NC^{-1}$	$\Sigma y = 10.60NC^{-1}$

$\Sigma net = \sqrt{\Sigma Fx^2 + \Sigma Fy^2}$

$\Sigma net = \sqrt{3.45^2 + 10.60^2} = \sqrt{124.2625}$

$\Sigma net = 11.147 NC^{-1} \simeq 11.5 NC^{-1}$

3a Volume Charge Density

$$\rho = \frac{dQ}{dV} \longrightarrow dQ = \rho dV$$

Surface Charge Density

$$\sigma = \frac{dQ}{dA} \longrightarrow dQ = \sigma dA$$

Linear Charge Density

$$\lambda = \frac{dQ}{dL} \longrightarrow dQ = \lambda dL$$

3b ELECTRIC POTENTIAL DIFFERENCE

The electric potential difference between two points in an electric field is the workdone per unit charge against electrical forces when a charge is transported from one point to the other. It is a scalar quantity and measured in volts (v) or Joules per coloumb (J/C). In an electric field, supposed a test charge "q_0" is moved from a point A to point B along an arbitrary path. The electric field would exert a force, $F = q_0E$ on the charge. For "q_0" to move from a point A to point B, a force, ~~of~~ $F = -q_0E$ has to be exerted on it. The workdone in moving the charge is $dW = F \cdot dL$ — ①

Recall: $F = -q_0E$ — — ② substituting ~~for~~ ② for F in eqn ①

$dW = -q_0E \cdot dL$ ∴ Total workdone of moving the test charge from A to B ~~electrical potential difference~~ :

$$W(A \longrightarrow B)_{Ag} = -q_0\int_A^B E\,dL \text{ — — } ④$$

From the definition of Electrical Potential Difference

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

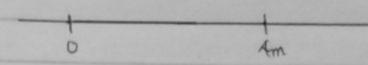
Substitute equation ④ in ⑤

$$V_B - V_A = -\cancel{q_0}\int_A^B E\,dL \text{ — — } ⑥$$

$$\Delta U = \frac{-W(A \longrightarrow B)E}{q_0} = \frac{W(A \longrightarrow B)_{Ag}}{E}$$

$$\therefore V_B - V_A = \frac{\Delta U}{q_0} = \frac{U_B - U_A}{q_0}$$

Diagram 1



c $Q_1 = 10\mu C$

$Q_2 = -2\mu C$

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

when $V = 0$; $0 = 9\times10^9 Nm^2C^{-2}\left(\frac{10\times10^{-6}}{r^1} + \frac{-2\times10^{-6}}{r^2}\right)$

$$\frac{0}{9\times10^9 Nm^2C^{-2}} = \left(\frac{10\times10^{-6}}{r^1} + \frac{-2\times10^{-6}}{r^2}\right) ; \frac{10\times10^{-6}}{r_1} = \frac{2\times10^{-6}}{r^2}$$

$$2r_1 = 10r_2 ; r_1 = 5r_2$$

Recall the diagram above ;

The position along the x-axis where V=0 is 5m from $Q_1 = 10\mu C$ and 1m from $Q_2 = -2\mu C$

4 Magnetic Flux refers to the number of magnetic lines of force passing through a given closed surface which is the magnetic field. ~~surface~~ It is what generates the field around a magnetic material. Its S.I unit is Weber (Wb)

b.) $m = 9.11\times10^{-31}kg$, $r = 1.4\times10^{-7}m$, $\theta = 90°$, $B = 3.5\times10^{1}T$, $V = 3\times10^{8}ms^{-1}$

$$F = qVB\sin\theta = \frac{mv^2}{r}$$

$$q = \frac{mv^2}{VBr\sin\theta} = \frac{9.11\times10^{-31}kg \times \cancel{3\times10^8 ms^{-1}} \times 3\times10^8 ms^{-1}}{\cancel{3\times10^8 ms^{-1}} \times 3.5\times10^{-1}T \times 1.4\times10^{-7}m \times \sin 90}$$

$$q = \frac{2.733\times10^{-22}kgms^{-1}}{4.9\times10^{-8}} = 5.578\times10^{-15}\ C$$

$$\omega = \frac{qB}{m_e} = \frac{5.578\times10^{-15}C \times 3.5\times10^{-1}T}{9.11\times10^{-31}kg} = 2.14\times10^{15}rad/s$$

$$\therefore \omega = 2.14\times10^{15}rad/s$$

c) Electrons exhibit uniform circular motion. The acceleration thus, is centripetal

d) acceleration v^2/r [$F_B = qVB = mv^2/r$]. The angular speed is $\omega = v/r$. Substituting adequately, the angular speed (also cyclotron frequency) is 2.14×10^{15} rad/s. The electron circulates at this angular speed in the type of accelerator called a cyclotron.