$(x^2 + a^2)^{3/2} = x^3$ as $a \to 0$

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

$\therefore B = \dfrac{\mu_0 I}{2\pi r}$.

Soln

$M = 9.11 \times 10^{-31} kg$ $r = 1.4 \times 10^{-4} m$

$B = 3.5 \times 10^{-1}$ weber/m^2, $\theta = 90°$

$w = ?$, $q = -1.60 \times 10^{-19} c$

$$w = \frac{qB}{M_e} = -\frac{1.60 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$W = -6.15 \times 10^{10} \text{ rads}^{-1}$$

4c Discuss your answer in the above

Soln

Since the cyclotron frequency is negative $(-6.15 \times 10^{10} \text{ rads}^{-1})$, it means that the charge particle electron circulates in a negative or opposite direction at this angular frequency.

5a State the Biot-Savart law

Ans

The Biot-Savart law is an equation that describes the magnetic field created by a current carrying wire and allows you to calculate its strength at various points.

b Using the Biot-savart law, show that the magnitude of the magnetic field of a straight current-carrying conductor is given as

$$B = \frac{\mu_0 I}{2\pi r}.$$

Soln

Applying the Biot-Savart law we have the magnitude of the field $d\vec{B}$

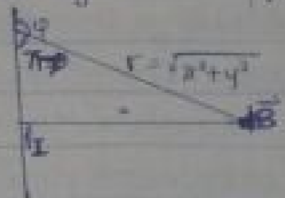
$$\vec{B} = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin\theta}{r^2}$$

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

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

From the diagram below

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



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

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

Substitute equ ** in equ *

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

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

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

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

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

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

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

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

$x^2 + a^2$

$\therefore B$

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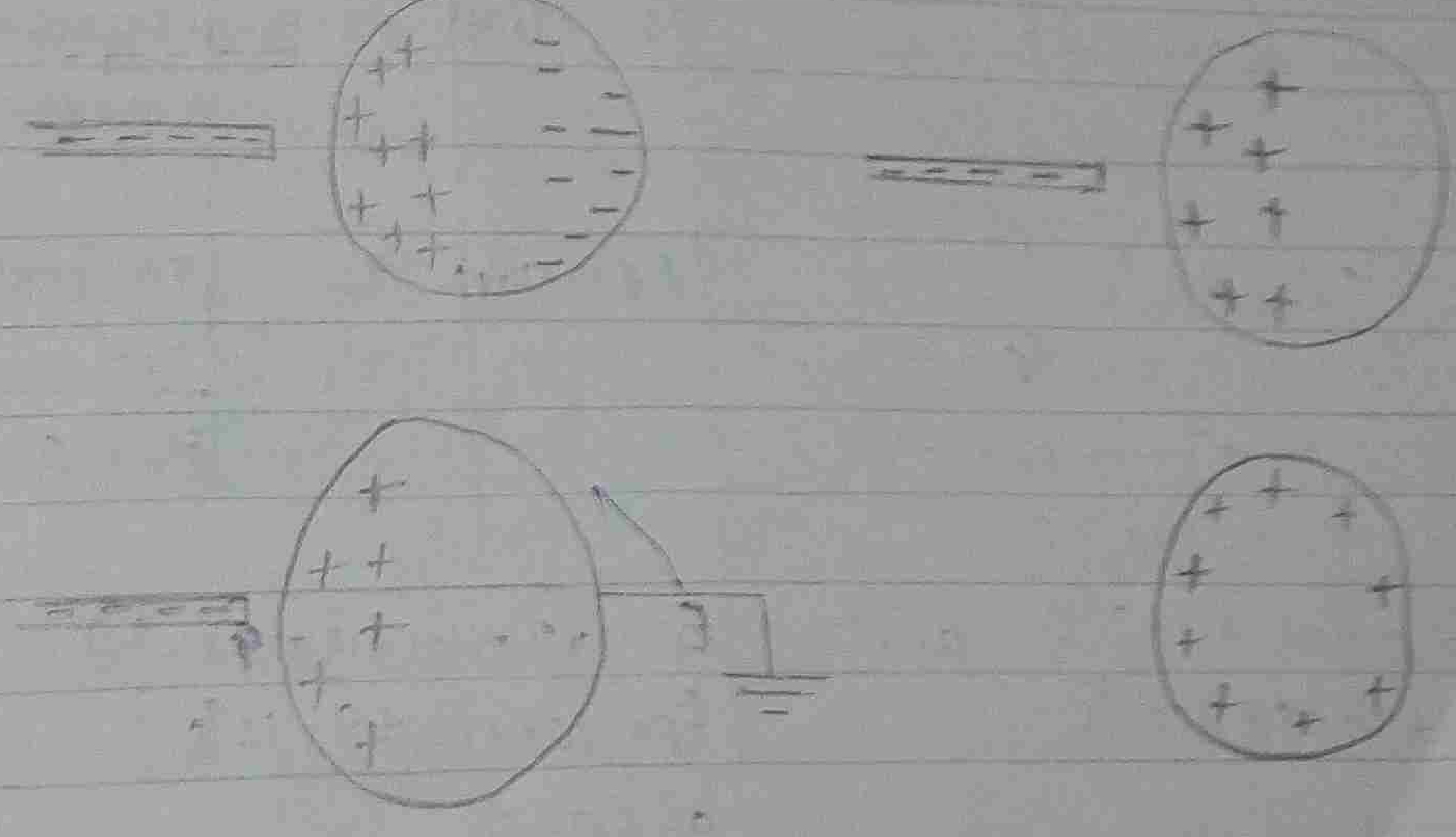
1a Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction

Soln

a A negatively charged rubber rod is brought near a neutral conducting sphere that is insulated. 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



b Each of two small spheres is charged positively, the combined charge being 5.0×10^{-5}C. If each sphere is repelled from the other by a force of 1.0N when the spheres are 2.0m apart, calculate the charge on each sphere.

Soln

$q_1 + q_2 = 5.0\times10^{-5}C$, $F = 1.0N$, $r = 2.0m$

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

$$1 = \frac{9\times10^9 \times q_1q_2}{2^2}$$

$$4 = 9\times10^9 q_1q_2$$

$$\frac{4}{9\times10^9} = q_1q_2$$

$q_1 q_2 = 4.44 \times 10^{-10}$ --- (i)

$q_1 + q_2 = 5.0 \times 10^{-5}$ --- (ii)

From equ(ii) $q_1 = 5.0 \times 10^{-5} - q_2$

Substitute the value of q_1 in equ(i)

$(5.0 \times 10^{-5} - q_2) q_2 = 4.44 \times 10^{-10}$

$5.0 \times 10^{-5} q_2 - q_2^2 = 4.44 \times 10^{-10}$

$5.0 \times 10^{-5} q_2 - q_2^2 - 4.44 \times 10^{-10} = 0$

$q_2^2 - 5.0 \times 10^{-5} q_2 + 4.44 \times 10^{-10} = 0$

$q_2 = 3.845 \times 10^{-5} C$ or $q_2 = 1.155 \times 10^{-5} C$

Substitute the values of q_2 in equ(ii)

$q_1 + 3.845 \times 10^{-5} = 5.0 \times 10^{-5}$

$q_1 = 5.0 \times 10^{-5} - 3.845 \times 10^{-5}$

$= 1.155 \times 10^{-5} C$

OR $q_1 + 1.155 \times 10^{-5} C = 5.0 \times 10^{-5}$

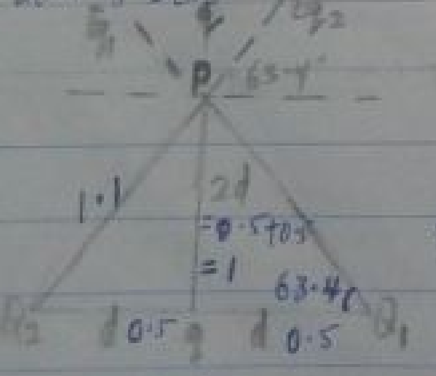
$q_1 = 5.0 \times 10^{-5} C - 1.155 \times 10^{-5} C$

$= 3.845 \times 10^{-5} C$

$\therefore q_1 = 3.845 \times 10^{-5} C$ and

$q_2 = 1.155 \times 10^{-5} C$.

c. Three charges were positioned as shown in the figure below. If $Q_1 = Q_2 = 8 \mu C$ and $d = 0.5 m$, determine q if the electric field at P is zero.



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

$\tan\theta = 2$

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

$\theta = 63.4$

$8 \mu C = 8 \times 10^{-6} C$

$E_p = \vec{Eq_1} + Eq_2 + Eq$

$Eq_1 = \frac{kq_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.1^2} = 59504 N/C$

$Eq_2 = \frac{kQ_2}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{1.1^2} = 59504 N/C$

$Eq = \frac{kq}{r^2} = \frac{9 \times 10^9 \times q}{1^2} = 9 \times 10^9 q \ N/C$

Vector	Angle	X-Component	Y-Component
$Eq_1 = 59504$	63.4°	$-59504 \cos 63.4$ $= -26643 N/C$	$59504 \sin 63.4$ $= 53206$
$Eq_2 = 59504$	63.4	$-59504 \cos 63.4$ $= -26643 N/C$	$59504 \sin 63.4$ $= 53206$
$Eq = 9 \times 10^9 q$	90	$9 \times 10^9 q \cos 90$ $= 0$	$9 \times 10^9 q \sin 90$ $= 9 \times 10^9 q$
		$\Sigma F_x = 0$	$\Sigma F_y = 106412 + 9 \times 10^9 q$

$E_p = \sqrt{0^2 + (106412 + 9 \times 10^9 q)^2}$

$E_p = 106412 + 9 \times 10^9 q$

at $E_p = 0$

$106412 + 9 \times 10^9 q = 0$

$\frac{9 \times 10^9 q}{9 \times 10^9} = \frac{-106412}{9 \times 10^9}$

$q = -1.18 \times 10^{-5} C$

$\therefore q = -12 \mu C$

3a) Distinguish between the electric field intensity and electric field.

Ans

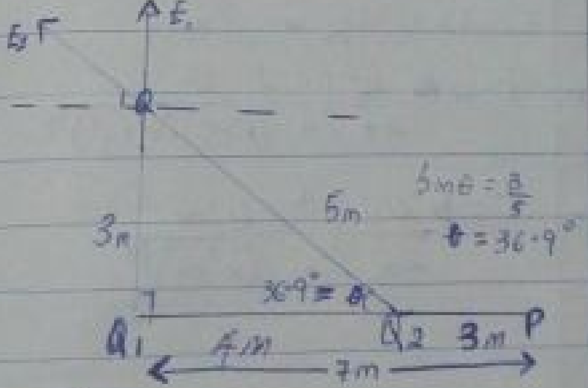
An electric field is a region of space in which an electric charge will experience an electric force while Electric field intensity is the force per unit charge.

b) A positive charge $Q_1 = 8nC$ is at the origin, and a second positive charge $Q_2 = 12nC$ is on the x-axis at $x = 4m$. Find (i) the net electric field at a point P on the x axis at $x = 7m$ &

(ii) the electric field at a point Q on the y axis at $y = 3m$ due to the charges

Soln

i



$E_p = E_{q_1} + E_{q_2}$

$$E_{q_1} = \frac{kq}{r^2} = \frac{9\times10^{9} \times 8\times10^{-9}}{7^2} = 1.469N/C$$

$$E_{q_2} = \frac{kq_2}{r^2} = \frac{9\times10^{9} \times 12\times10^{-9}}{3^2} = 12N/C$$

$$E_{Pnet} = 1.469 + 12.000$$

$$= 13.469 \approx 13.5N/C$$

ii) $E_{net_Q} = \vec{E}_1 + \vec{E}_2$

$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^{9}\times8\times10^{-9}}{3^2} = 8N/C$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^{9}\times12\times10^{-9}}{5^2} = 4.32N/C$$

Vector	Angle	x Component	y Component
$E_1 = 8N/C$	90°	$8\cos 90 = 0$	$8\sin 90 = 8$
$E_2 = 4.32N/C$	36.9	$-4.32\cos 36.9 = -3.45$	$4.32\sin 36.9 = 2.59$
		$\Sigma f_x = -3.45$	$\Sigma f_y = 10.59$

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

$$= 11.14N/C$$

4a) What is Magnetic flux?

Magnetic flux is defined as the strength of the magnetic field represented by lines of force. It is represented by the symbol Φ

4b) An electron with a rest mass of $9.11\times10^{-31}kg$ moves in a circular orbit of radius $1.4\times10^{-5}m$ in a uniform magnetic field of 3.5×10^{-5} weber/meter square, perpendicular to the speed with which electron moves. Find the cyclotron frequency of moving electron.