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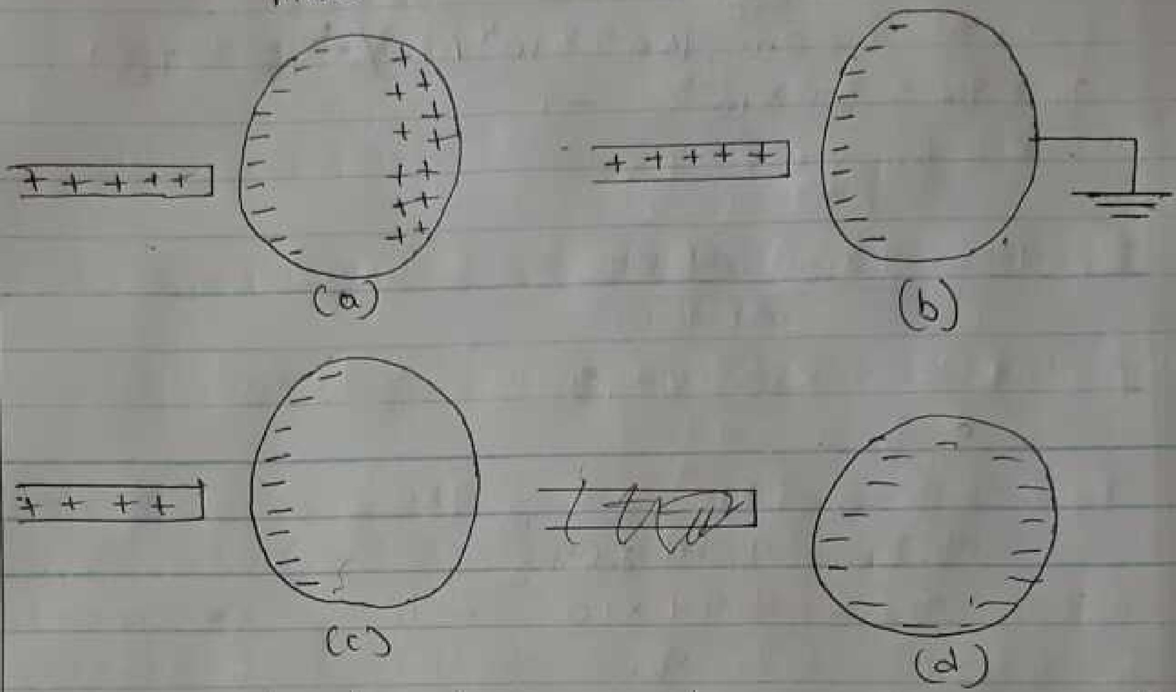
Department: Medicine and Surgery
Course: PHY102

Assignment

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

Answer



A positively charged rubber rod is brought near a neutral conducting sphere that is insulated so that there is no conducting path to the ground. 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. The region of the sphere nearest to the positively charged rod has an excess of negative charge because of 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 ground is then removed, the conducting sphere is left with an excess of induced negative charge. When the rod is then 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.

1b) Each of two small spheres is charged positively, the combined charge being $5.0 \times 10^{-5} C$. 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

$F = 1.0N$, $r = 2m$, $k = 9 \times 10^9 Nm^2/C^2$, $q_1 = ?$, $q_2 = ?$.

$q_1 + q_2 = 5.0 \times 10^{-5} C$ — i

$$F = \frac{kq_1 q_2}{r^2}$$

$$1 = \frac{9 \times 10^9 \times q_1 \times q_2}{2^2}$$

$$4 = 9 \times 10^9 \times q_1 q_2$$

$$q_1 q_2 = \frac{4}{9 \times 10^9}$$

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

$$q_2 = \frac{4.44 \times 10^{-10}}{q_1} \quad \text{— ii}$$

Put ii in i

$$q_1 + \frac{4.44 \times 10^{-10}}{q_1} = 5.0 \times 10^{-5}$$ multiply through by q_1

$$q_1^2 + 4.44 \times 10^{-10} = 5.0 \times 10^{-5} q_1$$

$$\underset{a}{q_1^2} - \underset{b}{5.0 \times 10^{-5} q} + \underset{c}{4.44 \times 10^{-10}} = 0$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-(-5.0 \times 10^{-5}) \pm \sqrt{(-5.0 \times 10^{-5})^2 - 4 \times 1 \times 4.44 \times 10^{-10}}}{2}$$

$$= \frac{5.0 \times 10^{-5} \pm \sqrt{7.24 \times 10^{-10}}}{2}$$

$$= \frac{5.0 \times 10^{-5} \pm 2.691 \times 10^{-5}}{2}$$

$= \dfrac{5.0\times10^{-5} + 2.691\times10^{-5}}{2}$ or $\dfrac{5.0\times10^{-5} - 2.691\times10^{-5}}{2}$

$= \dfrac{7.691\times10^{-5}}{2}$ or $\dfrac{2.309\times10^{-5}}{2}$

$\therefore q_1 = 3.84\times10^{-5}$ or 1.15×10^{-5}

$q_2 = \dfrac{4.44\times10^{-10}}{q_1}$

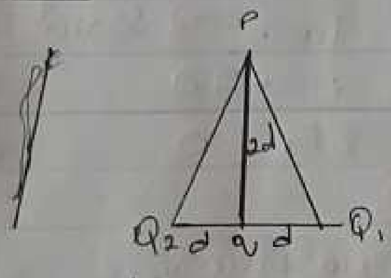
when $q_1 = 3.84\times10^{-5}$, $q_2 = \dfrac{4.44\times10^{-10}}{3.84\times10^{-5}} = 1.15\times10^{-5}$

when $q_1 = 1.15\times10^{-5}$; $q_2 = \dfrac{4.44\times10^{-10}}{1.15\times10^{-5}} = 3.84\times10^{-5}$

since $q_1 = q_2$ $\therefore$ q_1 & $q_2 = 3.84\times10^{-5}C$ or $1.15\times10^{-5}C$.

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

Soln

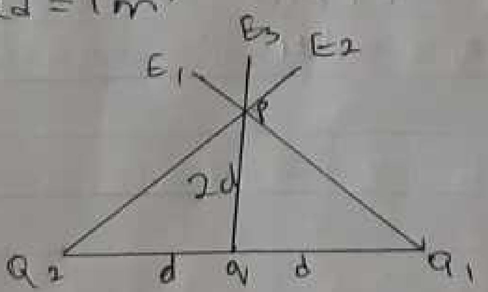


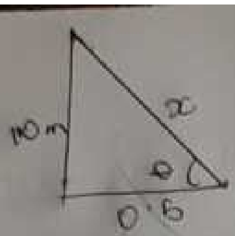
$Q_1 = 8\mu C = 8.0\times10^{-6}C$

$Q_2 = 8\mu C = 8.0\times10^{-6}C$

$d = 0.5m$, $2d = 1m$

E at $P = 0$





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

$x^2 = 1 + 0.25$

$x^2 = 1.25$

$x = 1.1180$

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

$\theta = \tan^{-1}\left(\frac{1}{0.5}\right) = 63.43$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8.0\times10^{-6}}{(1.1180)^2} = 5.76\times10^4$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 8.0\times10^{-6}}{(1.1180)^2} = 5.76\times10^4$

$E_3 = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{1^2} = 9\times10^9 q$

Vector	Angle	x- Component	y = component
$E_1 = 5.76\times10^4$	63.43°	$F\cos\theta = 2.58\times10^4$	$F\sin\theta = 5.15\times10^4$
$E_2 = 5.76\times10^4$	63.43°	$F\cos\theta = -2.58\times10^4$	$F\sin\theta = 5.15\times10^4$
$E_3 = 9\times10^9 q$	90°	$F\cos\theta = 0$	$F\sin\theta = 9\times10^9 q$
		$\Sigma E_x = 0$	$\Sigma E_y = 1.03\times10^5 + 9\times10^9 q$

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

$0 = \sqrt{0 + (1.03\times10^5 + 9\times10^9 q)^2}$

$0 = 1.03\times10^5 + 9\times10^9 q$

$9\times10^9 q = -1.03\times10^5$

$q = -1.1\times10^{-5}$

$q = -11\mu C$

2a Distinguish between the terms electric field and electric field intensity

Answer

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

b.) A positive charge $Q_1 = 8\mu C$ is at the origin, a second positive charge $Q_2 = 12\mu C$ is on the x-axis at $x = 4m$. Find:

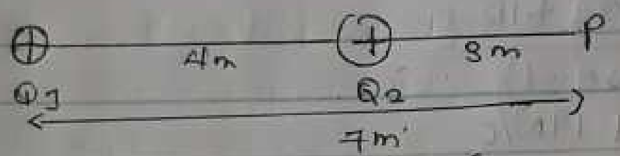
Find (i) The net electric field at a point P on the x-axis at $x = 7m$

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

Solt

$Q_1 = 8\mu C = 8.0 \times 10^{-9}$, $Q_2 = 12\mu C = 1.2 \times 10^{-8}$, $k = 9 \times 10^9 Nm^2/C^2$.

a.)



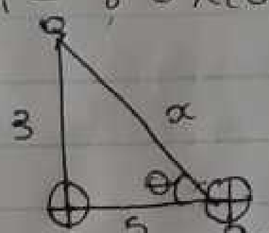
$$E_1 = \frac{kQ_1}{r^2} = \frac{(9 \times 10^9) \times 8.0 \times 10^{-9}}{7^2} = 1.46 N/C.$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{(9 \times 10^9) \times 1.2 \times 10^{-8}}{3^2} = 12 N/C$$

$$E = E_1 + E_2 = 1.46 + 12.0 = 13.46 \simeq 13.5 N/C$$

$$E = 13.5 N/C.$$

b.) $Q_1 = 8.0 \times 10^{-9} C$, $Q_2 = 1.2 \times 10^{-8} C$



$$x^2 = 3^2 + 5^2$$

$$x^2 = 9 + 16$$

$$x^2 = 25$$

$$x = 5$$

$\sin\theta = \frac{3}{5}$

$\theta = \sin^{-1}\left(\frac{3}{5}\right) = 36.87^\circ$

$E_1 = \frac{kQ_1}{r^2} = \frac{(9\times10^{9})\times 8.0\times10^{-9}}{3^2} = 8 N/C.$

$E_2 = \frac{kQ_2}{r^2} = \frac{(9\times10^{9})\times 1.2\times10^{-8}}{5^2} = 4.32 N/C$

Vector	Angle	x-component	y-component
$E_1 = 8$	90	$8\times\cos 90 = 0$	$8\times\sin 90 = 8$
$E_2 = 4.32$	36.87	$4.32\times\cos 36.87 = 3.456$	$4.32\times\sin 36.87 = 2.5920$
		$\Sigma E_x = 3.456$	$\Sigma E_y = 10.592$

$E_{net} = \sqrt{E_x^2 + E_y^2}$

$= \sqrt{(3.456)^2 + (10.592)^2}$

$= \sqrt{11.94 + 112.19}$

$= \sqrt{124.13}$

$E_{net} = 11.14 N/C$

3a. State the formulation of the following identities of charges

i. Volume charge density.

ii. Surface charge density.

iii. Linear charge density

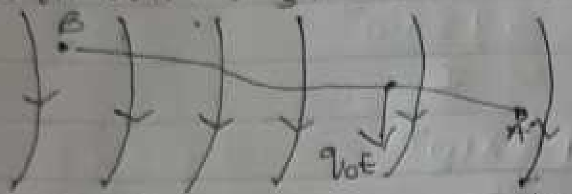
Soln.

i. Volume charge density, $\rho = \frac{dQ}{dV}$

ii. Surface charge density, $\sigma = \frac{dQ}{dA}$.

iii. Linear charge density, $\lambda = \frac{dQ}{dL}$

3b) Explain with appropriate equations, the electric potential difference
Electric potential difference between 2 points in an electric field can ~~per unit charge~~ be defined as the work done per unit charge against electrical forces when a charge is transported from one point to another. It is measured in Volt (v). It 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 fig 3.1. 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: $dW = F.dL \cdots (1)$

But; $F = -q_0E \cdots (2)$

substitutiting eqn 2 in 1

$$dW = -q_0EdL \; -- (3).$$

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

$$W(A \rightarrow B)_{Ag} = -q_0 \int_A^B EdL \cdots (4)$$

From the definition of electric potential difference,

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

Putting eqn 4 in 5:

$$V_B - V_A = -\int_A^B EdL.$$

c) Two point charges $Q_1 = 10\mu C$ and $Q_2 = -2\mu C$ are arranged along the x-axis at $x = 0$ and $x = 4m$ respectively, Find the position along the x-axis where $V = 0$.

Soln

$$Q_1 = 10\mu C = 1.0 \times 10^{-5} C$$

$$Q_2 = -2\mu C = -2.0 \times 10^{-6} C.$$

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

$r_1 = 4m$, $r_2 = x$

$$V = 9\times10^{9} \times \left[\frac{1.0\times10^{-5}}{4+x} + \frac{-2.0\times10^{-6}}{x}\right]$$

$$0 = \frac{9\times10^{4}}{4+x} - \frac{1.8\times10^{4}}{x}$$

$$\frac{9\times10^{4}}{4+x} \times \frac{1.8\times10^{4}}{x}$$

$$9\times10^{4}x = 7.2\times10^{4} + 1.8\times10^{4}x$$

$$9\times10^{4}x - 1.8\times10^{4} = 7.2\times10^{4}$$

$$7.2\times10^{4}x = 7.2\times10^{4}$$

$$x = 1m$$

The point along the x-axis where $V=0$ is positioned at.

$$4+x = 4+1 = 5m.$$

5a State the Biot-Savart law

Answer

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

5b Using the Biot-Savart law, show that the magnitude of the magnetic field of a straight current-carrying conductor is given as $B = \frac{\mu_0 I}{2\pi r}$

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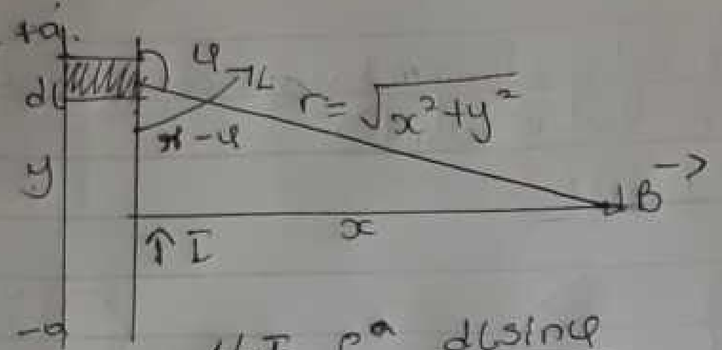

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dL \sin\varphi}{r^2}$$

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

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

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

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

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

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

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

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

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

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

when a is much larger than x $\therefore$ $(x^2+a^2)^{1/2} \simeq a$ as $a \to \infty$

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