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Matric No. ; 19/MHS01/013
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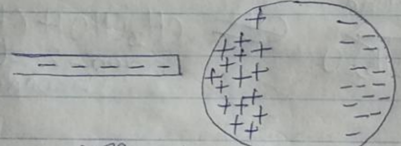
Course; Phy 102

COVID-19 HOLIDAY ASSIGNMENT.

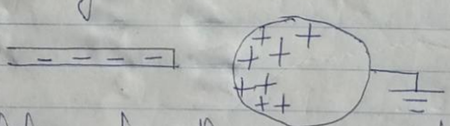
1a) Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction

Answer

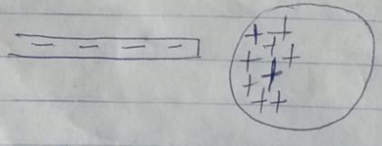
Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to ground ~~as shown below~~. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some electrons move to the side of the sphere farthest away from the rod



The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded conducting wire is then connected to the sphere as shown below

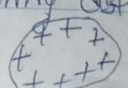


Some of the electrons leave the sphere and travel to the earth. If the wire to ground is then removed as shown below, the conducting sphere is left with an excess of induced positive charge.



Finally, when the rubber rod is removed from the vicinity of the sphere as shown below, the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere

i.e



$$1 = \frac{9\times10^9 \times q_1 \times [5.0\times10^{-5} - q_1]}{2^2}$$

$$4 = 9\times10^9 \times [5.0\times10^{-5} q_1 - q_1^2]$$

$$4 = 4.5\times10^5 q_1 - 9\times10^9 q_1^2$$

$$1 = \frac{9\times10^9 \times q_1 \times [(5\times10^{-5}) - q_1]}{}$$

(16) 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.

Solution

$$F = \frac{Kq_1q_2}{r^2} = \frac{9\times10^9 \times q_1 \times [(5.0\times10^{-5}) - q_1]}{2^2} = 1$$

$$4 = 9\times10^9 \times q_1 \times [(5.0\times10^{-5}) - q_1]$$

$$4 = 9\times10^9 q_1 [(5\times10^{-5}) - q_1]$$

$$4 = 4.5\times10^5 q_1 - 9\times10^9 q_1^2$$

$$9\times10^9 q_1^2 - 4.5\times10^5 q_1 + 4 = 0$$

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

$$\frac{4.5\times10^5 \pm \sqrt{2.025\times10^{11} - 1.44\times10^{11}}}{1.8\times10^{10}}$$

$$\frac{4.5\times10^5 \pm 241867.7324}{1.8\times10^{10}} = 3.84\times10^{-5} \text{ or } 1.15\times10^{-5}$$

(2a) Distinguish between the terms: electric field & electric field intensity.

Answer

An electric field is a region of space in which an electric charge will experience an electric force.

While

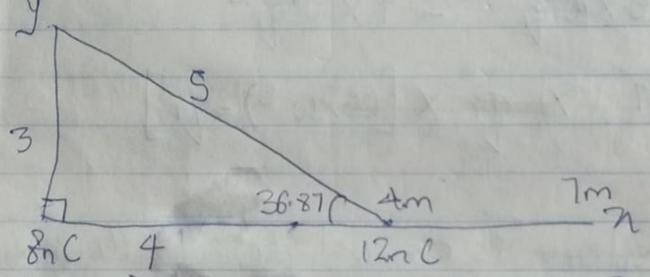
Electric field intensity can be defined as the force per unit charge.

(2b) 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 axis at $x = 7m$

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

Solution



$$\mathcal{E}(q_1 \text{ to } P) = \frac{kq}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.469\,N/C$$

$$\mathcal{E}(q_2 \text{ to } P) = \frac{kq}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12\,N/C$$

$$\mathcal{E} = 12 + 1.469 = 13.5\,N/C$$

Then for Q

$$\mathcal{E}(q_1 \text{ to } Q) = \frac{kq}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8\,N/C$$

$$\mathcal{E}(q_2 \text{ to } Q) = \frac{kq}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\,N/C$$

		X component	Y component
8	90°	$8\cos 90 = 0$	$8\sin 90 = 8$
11.32	36.87°	3.46	2.59
		3.46	10.59

$$\sqrt{(0.59)^2+(3.46)^2}$$

$$= 11.14 N/C$$

$$\tan\theta = \frac{y}{x}$$

$$\tan\theta = \frac{11.14}{13.5}$$

$$\theta = \tan^{-1}\left[\frac{11.14}{13.5}\right]$$

$$\theta \cong 39.53^{\circ}$$

(4a) Magnetic flux is the measure of the strength of a magnetic field in a given area.

(4b) Mass of 9.11×10^{-31} kg, Radius $= 1.4 \times 10^{-7}$ m, magnetic field $= 3.5 \times 10^{-1}$ weber/m^2

Cyclotron frequency = Angular speed $= \omega$

Recall, $r = \frac{mv}{qB}$ and $\omega = \frac{v}{r}$

$$\omega = v \div \left[\frac{mv}{qB}\right]$$

$$\omega = \cancel{v} \times \frac{qB}{m\cancel{v}}$$

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

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

$$\omega = 6.14 \times 10^{10}\ rad/s.$$

(5a) Biot-Savart law is based on the following observations for the magnetic field $d\vec{B}$ at a point P associated with a length element $d\vec{l}$ of a wire carrying a steady current I.

(56) Using Biot-Savart law, show that the magnitude of the magnetic field of a straight current carrying conductor is given as:

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

Solution

Applying the Biot-savart law, we find the magnitude of the field as

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

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

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

From Pythagoras theorem: $r^2 = x^2 + y^2$

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

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

Substituting (2) into (1), 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 $dl = dy$

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

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

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

Equation (3) therefore becomes

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

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

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

When the 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,

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

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

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

$$B = \frac{\mu_0 I}{2\pi r} \quad \ldots (\#)$$

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