APHL

19/MHS01/397

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PHY 102 COVID-19 HOLIDAY ASSIGNMENT

1a Electrostatic induction is the process by which electric charges can be obtained on an object without touching it.

How to charge a sphere negatively by induction

Consider a positively charged rubber rob brought near a neutral sphere as shown below. The repulsive force between the protons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some protons move to the side of the sphere farthest away from the rod (Fig 1.1a). The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from this location.

A grounded conducting wire is then connected to the sphere as shown in Fig 1.1b. Some of the protons leave the sphere and travel to the earth. The wire is then removed in Fig 1.1c and the conducting sphere is left with an excess of induced negative charged

Finally, The rubber rod is 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 (Fig 1.1d)

Fig 1.1a

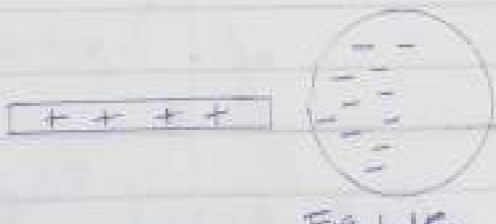

Fig 1.1c

Fig 1.1b

Fig 1.1d

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1b Let the charges on each of the two sphere be $q_1$ and $q_2$

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

$q_1 = 5.0 \times 10^{-5} - q_2$

$F = 1.0N$, $r = 2.0m$.

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

$1 = \frac{8.9 \times 10^9 \times (5.0 \times 10^{-5} - q_2) q_2}{2^2}$

$\frac{4}{8.9 \times 10^9} = \frac{\cancel{8.9 \times 10^9} \times 5 \times 10^{-5} q_2 - q_2^2}{\cancel{8.9 \times 10^9}}$

$4.45 \times 10^{-10} = 5 \times 10^{-5} q_2 - q_2^2$

$q_2^2 - 5 \times 10^{-5} q_2 + 4.45 \times 10^{-10} = 0.$

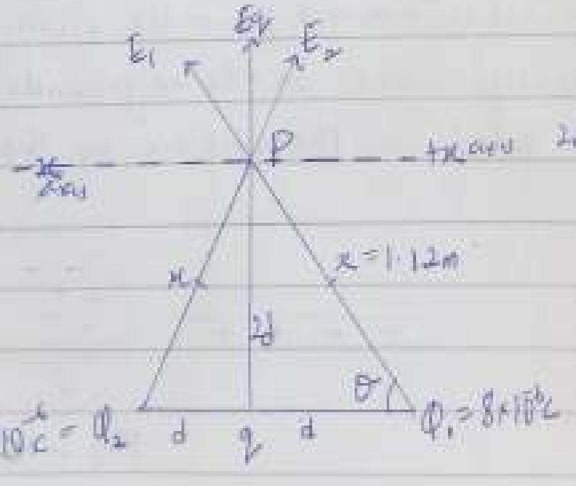
$q_2 = 3.89 \times 10^{-5} C$

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

$q_1 = 5.0 \times 10^{-5} - 3.89 \times 10^{-5}$

$q_1 = 1.11 \times 10^{-5} C.$

1c.





Using Pythagoras theorem,

$x^2 = (2d)^2 + (d)^2$

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

$x^2 = 1.25$

$x = \sqrt{1.25} = 1.12m$

$\tan\theta = \frac{1}{0.5}$  $\theta = \tan^{-1}(2)$

$\theta = 63.43°$

$E_1 = \frac{k q_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-6}}{(1.12)^2} = 57397.95918 N/C$

$E_2 = \frac{k q_2}{r^2} = \frac{9 \times 10^9 \times (8 \times 10^{-6})}{(1.12)^2} = 57397.95918 N/C$

$E_q = \frac{k q}{r^2} = \frac{9 \times 10^9 \times q}{(1)^2} = 9 \times 10^9 q N/C$

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| VECTOR | ANGLE | X-COMPONENT | Y-COMPONENT |
| --- | --- | --- | --- |
| $E_1 = 57397.95918$ | $63.43°$ | $E_{1x} = -57397.95918 \cos 63.43$ <br> $= -25673.58$ N/C | $E_{1y} = 57397.95918 \sin 63.43$ <br> $= 51336.0781$ |
| $E_2 = 57397.95918$ | $63.43°$ | $E_{2x} = 57397.95918 \cos 63.43°$ <br> $= 25673.58$ N/C | $E_{2y} = 57397.95918 \sin 63.43$ <br> $= 51336.0781$ |
| $E_q = 9\times10^9 q$ | $90°$ | $E_{qx} = 9\times10^9 \cos 90°$ <br> $= 0$ N/C <br> $\Sigma E_x = 0$ N/C | $E_{qy} = 9\times10^9 \sin 90°$ <br> $= 9\times10^9 q$ <br> $\Sigma y = (102672.1562 + 9\times10^9 q)$ N/C |

The magnitude of resultant electric field $E_p$ at point P is

$$E_p = \sqrt{(\Sigma E_x)^2 + (\Sigma E_y)^2}$$

$$= \sqrt{0^2 + (102672.1562 + 9.0\times10^9 q)^2}$$

$$E_p = 102672.1562 + 9.0\times10^9 q$$

The charge at $P = 0$

$$0 = 102672.1562 + 9.0\times10^9 q$$

$$\frac{9.0\times10^9 q}{9.0\times10^9} = \frac{-102672.1562}{9\times10^9}$$

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

$$q = -11\times10^{-6} C$$

$$\therefore q = -11 \mu C$$

| 2(a) Electric Field | Electric Field intensity |
| --- | --- |
| It is a region of space where an electric charge experiences an electric force. | This is defined as the force per unit charge. Its SI unit is N/C. |

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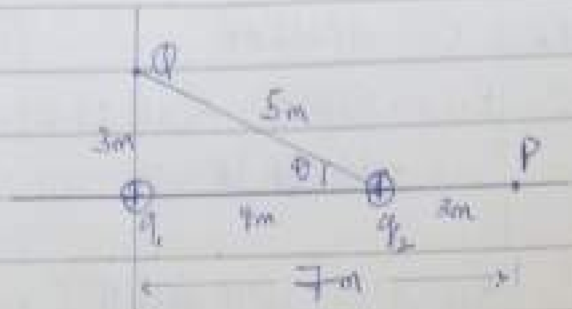
2(b)




$q_1 = +8nC$

$q_2 = +12nC$

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

$\therefore \theta = 36.87°$

(i) $E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{(7)^2} = \frac{72}{49} = 1.469\ N/C \simeq 1.47\ N/C$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{(3)^2} = 12\ N/C$

The net Electric Field at a point P on the x-axis $= E_1 + E_2$

$= 12 + 1.47$

$= 13.47\ N/C$

$\therefore E_{net} = 13.5\ N/C.$

(ii) For point Q, $E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8\ N/C.$

$r_2 = 5m$ (Pythagorean triple).

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\ N/C$

| VECTOR | ANGLE | X - COMPONENT | Y - COMPONENT |
|---|---|---|---|
| $E_1 = 8$ | 90° | $8\cos 90° = 0\ N/C$ | $8\sin 90° = 8\ N/C$ |
| $E_2 = 4.32$ | 36.87° | $4.32\cos 36.87° = 3.46\ N/C$ | $4.32\sin 36.87° = 2.592\ N/C$ |
| | | $\Sigma E_x = 3.46$ | $\Sigma E_y = 10.592$ |

The magnitude of the resultant electric field E at point Q is

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

$= \sqrt{(3.46)^2 + (10.592)^2}$

$= \sqrt{11.9716 + 112.1905}$

$= \sqrt{124.162064}$

$E_{net} = 11.14\ N/C$

4 (a) What is Magnetic flux?

Answer.

Magnetic flux (Magnetic lines of force) is the imaginary line along which a free north pole would tend to follow if placed in a magnetic field. It represents the direction and strength of the magnetic field at any point.

(b) $m = 9.11 \times 10^{-31}$ kg , $B = 3.5 \times 10^{-1}$ Weber/meter square

$r = 1.4 \times 10^{-7}$ m   Cyclotron Frequency = ?

Recall that angular speed, $w = \frac{v}{r} = \frac{qB}{m}$

$$w = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}}$$

$$= 0.61470911 \times 10^{11}$$

$$w = 6.1470911 \times 10^{10} T^{-1}$$

Note: Cyclotron frequency = angular speed

∴ The cyclotron frequency of the moving electron is,

$$w = 6.1470911 \times 10^{10} T^{-1}$$

(c) The cyclotron frequency is equal to $6.1470911 \times 10^{10} T^{-1}$, having a unit as $1/T$ which is equal to the unit of frequency dimensionally.

5 (a) Biot-Savart law states that the magnetic field $dB$ at a particular point due to small element $dL$ of a conductor carrying a current is directly proportional to the product of permeability of free space ($\mu_0$), the current ($I$), the change in length, the radius and inversely proportional to square of radius ($r^2$). It can be represented in Mathematical form as

$$dB = \frac{\mu_0 I dL \times \hat{r}}{r^2}$$

where; $\mu_0$ is a constant called permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} T.\frac{m}{A} \text{ or } 4\pi \times 10^{-7} Hm^{-1}$$

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$I$ = current

$r$ = radius

(b)

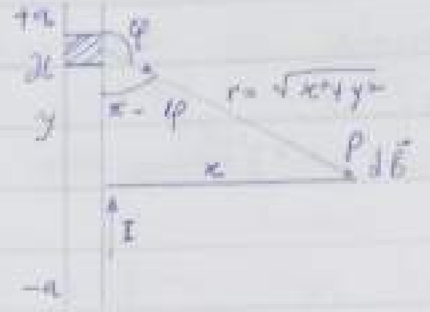


Fig 1.1e: A section of a Straight current carrying Conductor.

Applying the Biot-Savart law, we find the magnitute of the field dB

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

$$\sin(\pi-\varphi) = \sin \cancel{\theta}\varphi$$

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

From the diagram above, $r^2 = x^2+y^2$ (Pythagoras theorem)

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

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

Substituting (ii) into (i), 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 $dl = dy$

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

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

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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 (iii) will 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,

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

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

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

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{- - - - (iv)}$$

Equation (iv) defines the magnitude of the magnetic field of a straight current-carrying conductor.