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COLLEGE: MHS

DEPARTMENT: NURSING SCIENCE

COURSE CODE: PHY102

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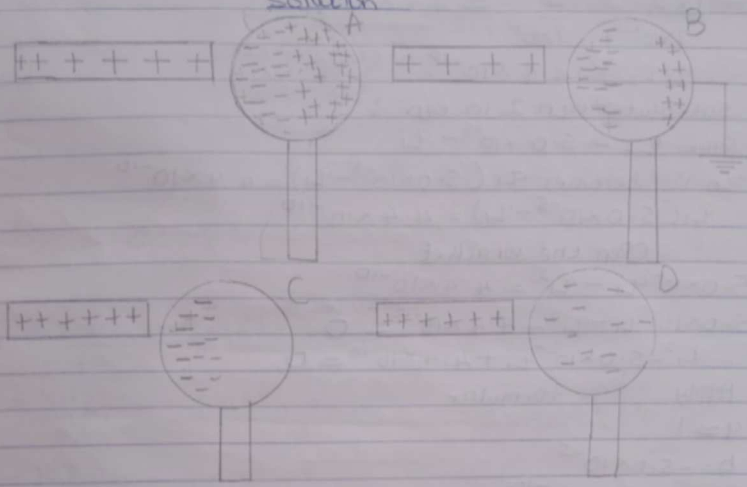
1a) Explain with the aid of diagram how you can produce a negatively charged sphere by method of Induction

Solution



1b) 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

$f = 1.0N$

$r = 2.0M$

$k = 9.0\times10^{9}Nm^{2}C^{2}$

$q_1 + q_2 = 5.0\times10^{-5}$ ----- eqn 1

$q_2 = 5.0\times10^{-5} - q_1$ ----- eqn 2

Recall that:

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

make q_1q_2 subject of formular

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$q_1q_2 = \frac{fr^2}{k}$

$= \frac{1\times 2^2}{9\times10^9} = \frac{4}{9\times10^9} = 4.4\times10^{-10}$

$\therefore q_1q_2 = 4.4\times10^{-10}$ ...... eqn (3)

Substitute eqn 2 in eqn 3

Since $q_2 = 5.0\times10^{-5} - q_1$

eqn (3) becomes $q_1(5.0\times10^{-5} - q_1) = 4.4\times10^{-10}$

$q_1(5.0\times10^{-5} - q_1) = 4.4\times10^{-10}$

Open the bracket

$5.0\times10^{-5}q_1 - q_1^2 = 4.4\times10^{-10}$

$5.0\times10^{-5}q_1 - q_1^2 - 4.4\times10^{-10} = 0$

$\therefore q_1^2 - 5.0\times10^{-5}q_1 + 4.4\times10^{-10} = 0$

Apply formular

$a = 1$

$b = -5.0\times10^{-5}$

$c = 4.4\times10^{-10}$

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

$\frac{-(-5.0\times10^{-5}) \pm \sqrt{(-5.0\times10^{-5}) - 4\times1\times4.4\times10^{-10}}}{2\times1}$

$= \frac{5.0\times10^{-5} \pm 2.7\times10^{-5}}{2}$

$\therefore q_1 = \frac{5.0\times10^{-5} + 2.7\times10^{-5}}{2}$ OR $\frac{5.0\times10^{-5} - 2.7\times10^{-5}}{2}$

$\therefore q_1 = 3.85\times10^{-5}C$ OR $1.15\times10^{-5}C$

To get q_2 Sub in eqn (2) $= q_2 = 5.0\times10^{-5} - q_1$

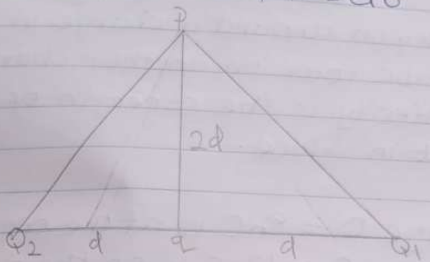
when $q_1 = 3.85\times10^{-5}C$

$q_2 = 5.0\times10^{-5}C - 3.85\times10^{-5}C = 1.15\times10^{-5}C$

when $q_1 = 1.15\times10^{-5}$

$q_2 = 5.0\times10^{-5}C - 1.15\times10^{-5} = 3.85\times10^{-5}C$

1c) Three charges were positioned as shown in the figure below $Q_1 = Q_2 = 8\mu C$ and $d = 0.5m$, determine q if the electric field at P is zero



Solution

$$E_1 = \frac{Kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2} = 5.9\times10^4$$

$$E_2 = \frac{Kq_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2} = 5.9\times10^4$$

$$E_q = \frac{Kq}{r^2} = \frac{9\times10^9 \times q}{1^2} = 9\times10^9 q$$

Vector	Angle	X-comp	Y-comp
$E_1 = 5.9\times10^4$	$63.4°$	$E_{1x} = E_1 \cos\theta$ $= 5.9\times10^4 \times \cos 63.4$ $= -2.6\times10^4$	$E_{1y} = E_1 \sin\theta$ $= 5.9\times10^4 \times \sin 63.4$ $= 5.3\times10^4$
$E_2 = 5.9\times10^4$	$63.4°$	$E_{2x} = E_2 \cos\theta$ $= 5.9\times10^4 \times \cos 63.4$ $E_{2x} = 2.6\times10^4$	$E_{2y} = E_2 \sin\theta$ $= 5.9\times10^4 \times \sin 63.4$ $= 5.3\times10^4$
$E_q = 9\times10^9 q$	$90°$	$E_{qx} = E_q \cos\theta$ $= 9\times10^9 q \times \cos 90$ $= 0$	$E_{qy} = E_q \sin\theta$ $= 9\times10^9 q \times \sin 90$ $= 9\times10^9 q$
		$\lvert E_x \rvert = 0$	$\lvert E_y \rvert = 1.0\times10^5 + 9\times10^9 q$

$$|E| = \sqrt{(E_x)^2 + (E_y)^2} = \sqrt{(0^2) + (1.0\times10^5)^2 + (9\times10^9 q)^2}$$

$$|E| = \sqrt{(1.0\times10^5)^2} + \sqrt{(9\times10^9 q)^2}$$

$\therefore |E| = 1.0\times10^5 + 9\times10^9 q$ where $|E| = 0$

$$0 = 1.0\times10^5 + 9\times10^9 q$$

$$9\times10^9 q = -1.0\times10^5, \quad q = -1.1\times10^{-5} C$$

2a) Distinguish between the terms electric field and electric field Intensity.

Solution

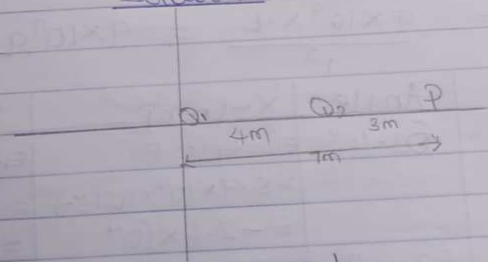
Electric field is a region around a charge in which it exerts electrostatic force on another charges while Electric field Intesity is the strength of electric field field at any Point in Space.

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 at point P on the x axis at $x = 7m$

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

Solution

2bi)



$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.47 n/c$$

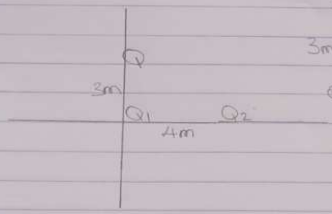
$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12 n/c$$

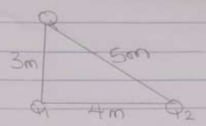
Vector	Angle	x-axis	Y-axis
$E_1 = 1.47$	$0°$	$E_{1x} = E_1 \cos\theta$ $= 1.47 \times \cos 0$ $= 1.47$	$E_{1y} = E_1 \sin\theta$ $= 1.47 \times \sin 0 = 0$
$E_2 = 12$	$0°$	$E_{2x} = E_2 \cos\theta$ $= 12 \times \cos 0 = 12$	$E_{2y} = E_2 \sin\theta$ $= 12 \times \sin 0 = 0$
		$13.47 = 13.5$	0

$$|E| = \sqrt{(E_x)^2 + (E_y)^2}$$

$$|E| = \sqrt{13.5^2} \quad E = 13.5 n/C$$

2bi)





$$E_1 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8n/c$$

$$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32n/c$$

Vector	Angle	x-comp	Y-comp
$E_1 = 8n/c$	90°	$E_{1x} = E_1 \cos\theta$	$E_{1Y} = E_1 \sin\theta$
		$E_{1x} = 8 \times \cos 90$	$E_{1Y} = 8 \times \sin 90$
		$= 0$	$E_{1Y} = 8$
$E_2 = 4.32n/c$	36.87	$E_{2x} = E_2 \cos\theta$	$E_{2y} = E_2 \sin\theta$
		$E_{2x} = 4.32 \times \cos 36.87$	$E_{2y} = 4.32 \times \sin 36.87$
		$E_{2x} = -3.45$	$E_{2y} = 2.6$
		$\lvert E_x\rvert = -3.45$	$\lvert E_y\rvert = 10.6$

$$|E| = \sqrt{(-3.45)^2 + (10.6)^2} = 11.15 \ \Omega \ 11.2n/c$$

SECTION B

4a) What is Magnetic flux?

Solution

Magnetic flux is defined as the strength of a magnetic field which can be represented by line of forces. It is represented by the symbol Φ. Mathematically $\Phi = B \cdot dA$

4b) An electron with a rest mass of 9.11×10^{-31} kg moves in a circular orbit of radius 1.4×10^{-7}m in a uniform magnetic field 3.5×10^{-1} web/meter square, perpendicular to the speed with which electron moves. Find cyclotron frequency of the moving electron.

Solution

$m = 9.11 \times 10^{-31}$ kg

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

$B = 3.5 \times 10^{-1}$ weber/meter^2

Cyclotron frequency $(\omega) = \frac{V}{r} = \frac{qB}{m}$

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

$$\omega = 6.147 \times 10^{10} \text{ rad/s}$$

4c) Discuss your answer in 4b above

Solution

Cyclotron frequency = Angular Speed = $\frac{V}{r}$ $\frac{\text{(Velocity)}}{\text{(Radius)}}$

from the equation $F_B = qVB = \frac{mV^2}{r}$ we have $r = \frac{mV}{qB}$

making $\frac{V}{r}$ subject of formular we have $\frac{V}{R} = \frac{qB}{m}$

therefore, Cyclotron frequency $(\omega) = \frac{qB}{m}$

$q = 1.6 \times 10^{-19}$ C, $B = 3.5 \times 10^{-1}$ web/meter^2, $m = 9.11 \times 10^{-31}$ kg

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 9.11 \times 10^{-31}}{3.5 \times 10^{-1}} = 6.147 \times 10^{10} \text{ rad/s}$$

5a) State the Biot-Savart Law.

Solution

Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space(μ), the current (I), the change in length, the radius and inversely proportional to the square of radius (r^2). It can be represented mathematically by:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, \vec{dl} \times \hat{r}}{r^2}$$

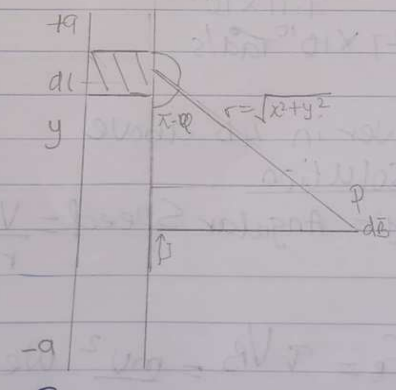
Where μ_0 is a constant called permeability of free space

$$\mu_0 = 4\pi \times 10^{-7}\ T.m/A$$

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

Solution

Magnetic field of a straight current carrying conductor



Applying the Biot-Savart law, we find the magnitude of the field $\vec{dB}$

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

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

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

from diagram, $r^2 = x^2 + y^2$ (Pythagoras theorem)

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

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

Substituting $(**)$ into $(*)$, 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 $dl = dy$

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

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

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

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

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

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

When the length $2a$ of the conductors 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,

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

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