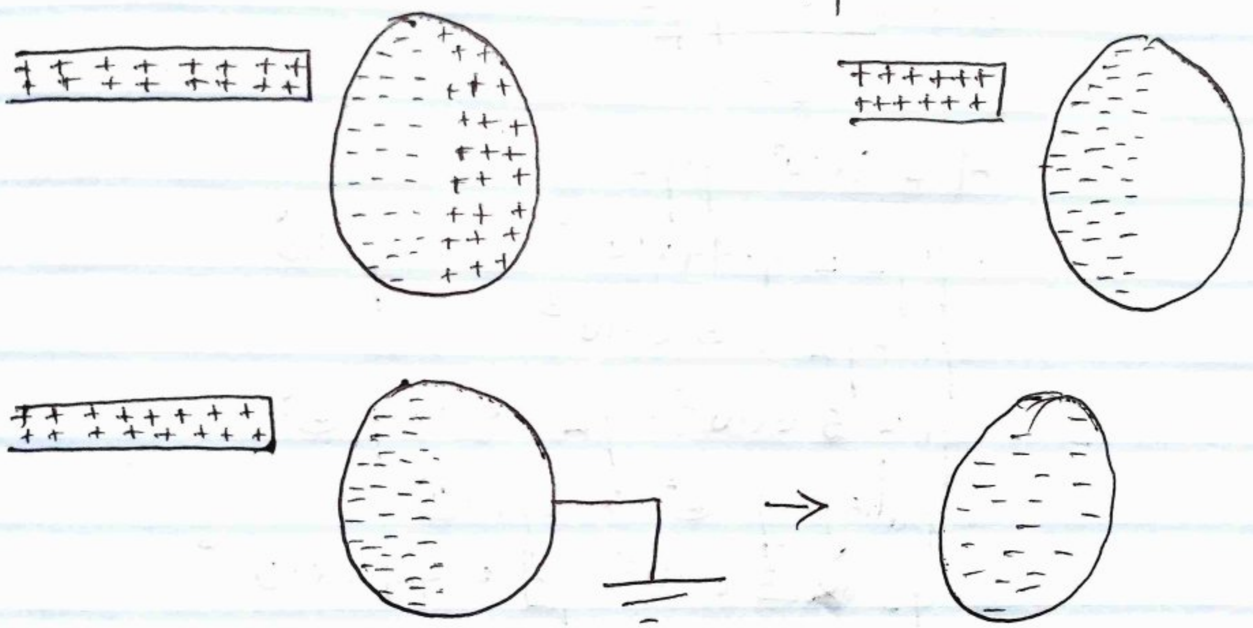
BADMUS TOLUWANI AMINAT MBBS
19/MHS01/116

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



Electric charges can be obtained on an object without touching it by a process called electrical Induction as shown above.

1b Each of 2 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 10N when the spheres are 2.0m apart, calculate the charge on each sphere.

1b Solution

$f = 1.0N$, $r = 2.0m$, $Q = 5.0\times10^{-5}$ $\therefore q_1 + q_2 = Q = 5.0\times10^{-5}$

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

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

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

$\therefore q_1q_2 = 4.44\times10^{-10}$ ... eqn 1

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

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

$\therefore$ puting eqn 2 in eqn 1

$$q_2 \times [5.0\times10^{-5} - q_2] = 4.44\times10^{-10}$$

$$5.0\times10^{-5} q_2 - q_2^2 = 4.44\times10^{-10}$$

$$-q_2^2 + 5.0\times10^{-5} q_2 - 4.44\times10^{-10} = 0$$

$q_2 = 3.845\times10^{-5}C$ or $q_1 = 5.0\times10^{-5} - 1.155\times10^{-5}$

$= 1.155\times10^{-5}C$ $\qquad = 3.845\times10^{-5}C$

$\therefore q_2 = 3.845\times10^{-5}C$ and $q_1 = 1.155\times10^{-5}C$

1c Three charges were positioned as shown in the figure below. If $Q_1 = Q_2 = 8\mu C$ and $d = 0.5m$, determine the electric field at $P = 0$

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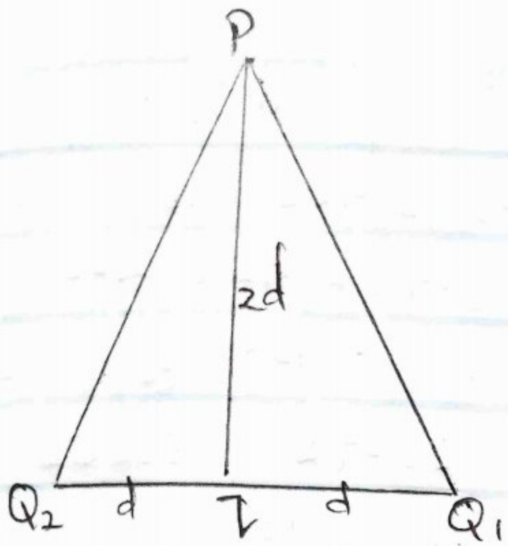
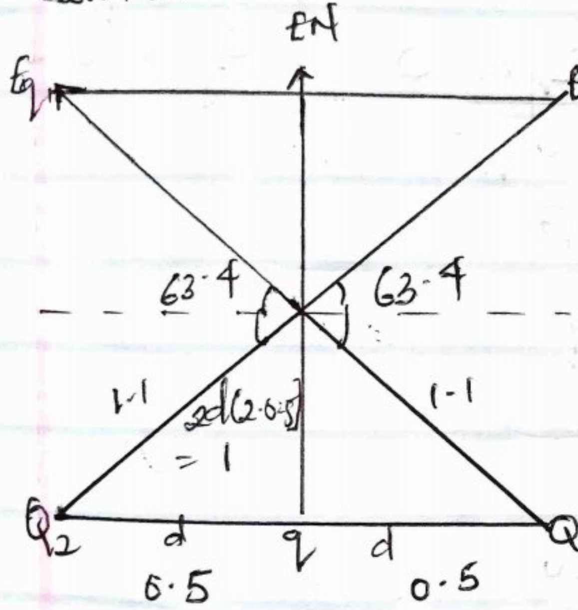
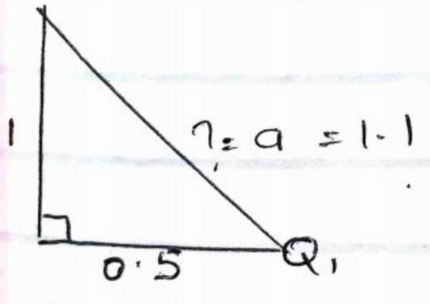


Solution



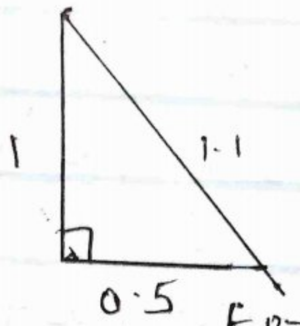


Using Pythagoras theorem

$a^2 = 1^2 + 0.5^2$

$a^2 = 1 + 0.25$

$a^2 = 1.25$, $a = \sqrt{1.25}$ $\therefore a = 1.1$



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

$\theta = 63.4$

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

$E_{q_1} = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2}$

$E_{q_1} = 59504\,N/C$

$E_{q_2} = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{1.1^2}$

$E_{q_2} = 59504\,N/C$

$E_q = \frac{kq}{r} = \frac{9\times10^9 \times q}{1^2} = 9\times10^9 q\,N/C$

$\therefore E_{q_1} = 59504$

$E_{q_2} = 59504$

$E_q = 9\times10^9 q$

Vector	Angle	X component	Y component
$f_{q_1} = 59504$	$63.4°$	$-59504 \cos 63.4 = -26643$	$59504 \sin 63.4 = 53205$
$f_{q_2} = 59504$	$63.4°$	$59504 \cos 63.4 = 26643$	$59504 \sin 63.4 = 53205$
$f_q = 9\times10^9 q$	$90°$	$9\times10^9 q \cos 90 = 0$	$9\times10^9 q \sin 90 = 9\times10^9 q$

$\Sigma f_x = 0$ $\Sigma f_y = 106410 + 9\times10^9 q$

$$\Sigma p = \sqrt{0^2 + (106410 + 9\times10^9 q)^2}$$

$$\Sigma p = \sqrt{(106410 + 9\times10^9 q)^2}$$

$$\Sigma p = 106410 + 9\times10^9 q$$

at $\Sigma p = 0$

$$106410 + 9\times10^9 q = 0$$

$$\frac{\cancel{9\times10^9} q}{\cancel{9\times10^9}} = \frac{-106410}{9\times10^9}$$

$$q = -1.18\times10^{-5} C$$

$$q \simeq 12 \mu C$$

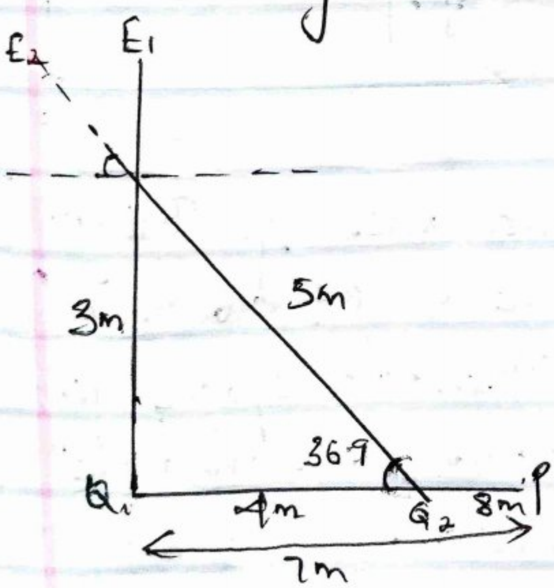
2a Distinguish between the terms :- Electric field and Electric field intensity.

Electric field :- It 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.

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 point Q on the y axis at $y = 3m$ due to the charges



$\tan\theta = 3/4$

$\theta = \tan^{-1} 0.75 \therefore \theta = 36.9°$

$E_p = EQ_1 + EQ_2$

(i) $EQ_1 = \frac{kQ}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2} = 1.469 N/C$

$EQ_2 = \frac{kQ}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-5}}{3^2} = 12 N/C$

$E_{Pnet} = 1.469 + 12 = 13.5 N/C$

(ii) $E_{net}\,Q = \vec{E_1} + \vec{E_2}$

$E_1 = \frac{kQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2} = 8 N/C$

$E_2 = \frac{kQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{5^2} = 4.32 N/C$

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°	$= 4.32\cos 36.9 = -3.45$	$4.32\sin 36.9 = 2.59$
		$E_{fx} = -3.45$	$E_{fy} = 10.59$

$$E_{net}\,Q = \sqrt{(-3.45)^2 + (10.59)^2}$$

$$= 11.14N/C$$

4a Magnetic flux is defined as the strength of the magnetic field represented by lines of forces. It is represented by the symbol Φ

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 of $3.5 \times 10^{-}$ Weber/meter square perpendicular to the speed with which electron moves. find the cyclotron frequency of the moving electron.

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4b Solution

$M = 9.11 \times 10^{-31}$ kg , $r = 1.4 \times 10^{-7}$ m , $B = 3.5 \times 10^{-1}$ weber/m^2

$\theta = 90°$, $w = ?$, $q = -1.60 \times 10^{-19}$ C

$$w = \frac{qB}{M_e}$$

$$W = \frac{-1.60 \times 10^{-19} \times 3.5 \times 10^{-1}}{9.11 \times 10^{-31}} = -6.15 \times 10^{10} \text{ rad/sec}$$

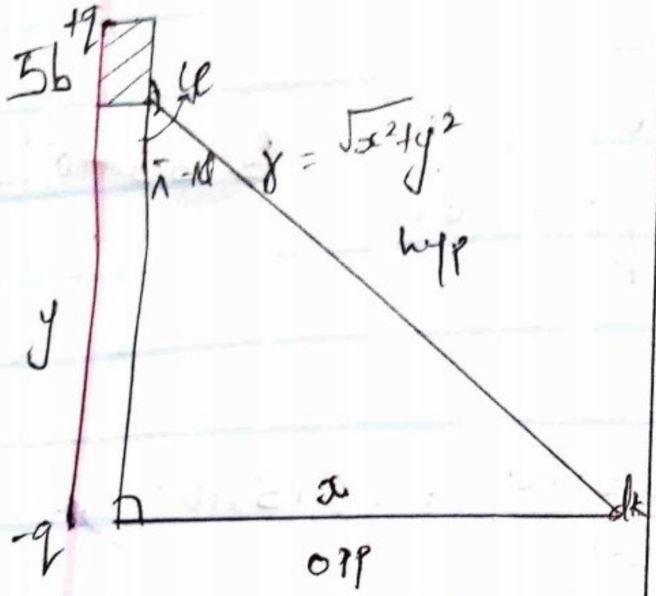
4c Discuss your answer in the above :-

Since our cyclotron frequency is negative ; -6.15×10^{10} rad/sec. It means that the charge particle electron circulate in a negative or opposite direction at the angular frequency.

5a State the biot-Savart law

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 forms.

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



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

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

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

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

from the diagram, $r^2 = x^2+y^2$

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

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

Substituting eqn 2 into 1 we have

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

Using law of indices

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

recall $dl = dy$

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

Using special integrals

$$\int \frac{dy}{(x^2+y^2)^{3/4}} = \frac{1}{x^2} \frac{y}{(x^2+y^2)^{1/2}}$$

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 from point p, we consider it ~~~~ infinitely long. That is, when a is much larger than x.

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

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

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

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