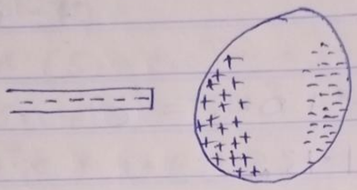
UKANNA NNEOMA GEM
19/MHS01/415
PHY 102
COVID-19 HOLIDAY ASSIGNMENT.

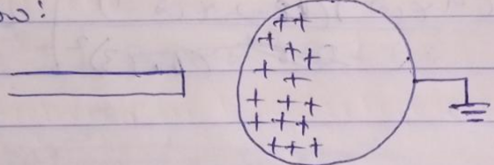
1) Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction.

Soln

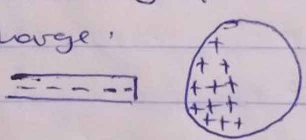
Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to the ground as shown below.



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 the ground is then removed as shown below, the conducting sphere is left with 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 become uniformly distributed over the surface of the sphere

b| Each of 2 small spheres is charged positively, the combined charge being $5.0\times10^{-5}$ C. If each spheres is repelled from the other ~~charged positively~~ by a force of 1.0N when the spheres are 2.0m apart, calculate the charge on each sphere.

sol

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

$F = \frac{kq_1q_2}{r^2} = \quad 1.0 = \frac{9\times10^9 q_1 q_2}{2^2}$

$4 = 9\times10^9 \times (5\times10^{-5} - q)q_2$

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

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

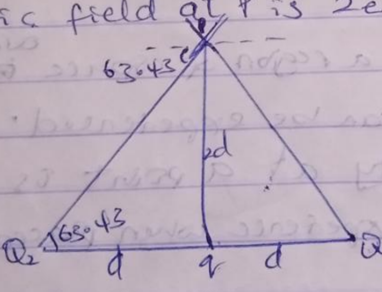
Using, $\frac{-b \pm \sqrt{b^2-4ac}}{2a}$

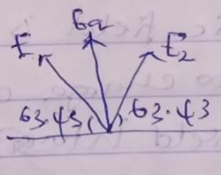
$\frac{4.5\times10^5 \pm \sqrt{2.025\times10^{11} - 1.44\times10^{11}}}{1.8\times10^{10}}$

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

$q_1 = 3.84\times10^{-5} \qquad q_2 = 1.15\times10^{-5}$

c| Three charges were positioned as shown 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.




sol $\sqrt{2d^2+d^2} = d\sqrt{5} \qquad \tan\theta = 2\cancel{d}/\cancel{d}$

$\tan^{-1}(2) = 63.43°$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9\times(8\times10^{-6})}{(d\sqrt{5})^2}$

$= \frac{9\times10^9\times(8\times10^{-6})}{(\sqrt{5}/2)^2} = 57600$ N/C

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$$E_2 = \frac{KQ_2}{r_2} = \frac{9\times10^{9}\times(8\times10^{-6})}{(d\sqrt{5})^2} = 57600\ N/C.$$

$$E_q = \frac{Kq}{r^2} = \frac{9\times10^{9}\times q}{(2d)^2} = \frac{9\times10^{9}q}{1^2} = 9\times10^{9}q\ N/C.$$

| Vector | $\theta$ | x-Component | y-Component |
|---|---|---|---|
| $E_1 = 57600\,N/C$ | $63.43^\circ$ | $57600\cos 63.43 = -25764$ | $57600\sin 63.43 = +51516.8$ |
| $E_2 = 57600\,N/C$ | $63.43^\circ$ | $57600\cos 63.43 = +25764$ | $57600\sin 63.43 = +51516.8$ |
| $E_q = 9\times10^{9}q\,N/C$ | $90^\circ$ | $9\times10^{9}q\cos 90 = 0$ | $9\times10^{9}q\sin 90 = 9\times10^{9}q$ |
| | | $E_{fx} = 0$ | $E_{fy} = 103033.6 + 9\times10^{9}q$ |

$$E_{net} = \sqrt{E_{fx}^2 + E_{fy}^2}$$

but $E_{net}$ at point $P = 0$.

$$0 = \sqrt{0^2 + (103033.6 + 9\times10^{9}q)^2}$$

$$0 = 103033.6 + 9\times10^{9}q$$

$$q = \frac{-103033.6}{9\times10^{9}}$$

$$q = -1.14481778\times10^{-5}$$

$$q = -11.4\times10^{-6}$$

$$q = -11.4\,\mu C$$

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

An electric field is a region of space over which the force due to charge can be experienced. While,

Electric field Intensity at a point is the force that a unit charge will experience when placed at that point.

2b A positive charge $Q_1 = 8\,nC$ is at the origin and a second positive charge $Q_2 = 12\,nC$ 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 a point Q on the y axis at $y = 3m$ due to the charges.

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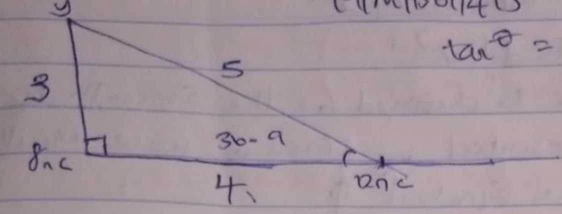
$\tan^{\theta} = 36.9^{\circ}$




for P

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

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

Then for Q

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

$E(q_2 \text{ to } Q) = \dfrac{Kq}{r^2} = \dfrac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\ N/C.$

for Q

| vector | Angle | x-component | y-component |
| --- | --- | --- | --- |
| $E_1 = 8$ N/C | $90^\circ$ | $8\cos 90 = 0$ | $8 \sin 90 = +8$ |
| $E_2 = 4.32$ N/C | $36.9^\circ$ | $4.32 \cos 36.9 = -3.45$ | $4.32 \sin 36.9 = +2.59$ |
| | | $E_{px} = -3.45$ N/C | $E_{py} = 10.59$ N/C |
| for P | | | |
| $E_1 = 1.469$ N/C | $90^\circ$ | $1.469 \cos 90 = 0$ | $1.469 \sin 90 = +1.47$ |
| $E_2 = 12$ N/C | $36.9^\circ$ | $12 \cos 36.9 = -9.6$ | $12 \sin 36.9 = +7.21$ |
| | | $E_{px} = -9.6$ N/C | $E_{py} = 8.68$ N/C |

i) $E_{net} = \sqrt{E_{px}^2 + E_{py}^2}$

$= \sqrt{(-3.45)^2 + (10.59)^2}$

$= \sqrt{124.0506}$

$= 11.14\ N/C$

The net electric field at point Q $= 11.14\ N/C$

ii) $= \sqrt{(-9.6)^2 + (8.68)^2}$

$= \sqrt{167.5024}$

$= 12.94\ N/C$

The electric field at point P $= 12.94\ N/C.$

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4a What is Magnetic flux?.

Magnetic flux is defined as the strength of a magnetic field represented by lines of force usually represented by the symbol $\phi$

4b An electron with a rest of $9.11 \times 10^{31}$ kg moves in a circular orbit of radius $1.4 \times 10^{-7}$ m in a uniform magnetic field of $3.5 \times 10^{-1}$ weber/meter square, perpendicular to the speed with which electron moves. find the cyclotron frequency of the moving electron. $M_e = 9.11 \times 10^{-31}$ $r = 1.4 \times 10^{-7}$ m

$\theta = 90$ Cyclotron frequency = Angular speed = $\omega$

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

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

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

$\therefore \omega = 6.15 \times 10^{10}$ rad/s.

4c An electron of mass $9.11 \times 10^{31}$ kg and charge $1.6 \times 10^{-9}$ C in motion in a magnetic field of $3.5 \times 10^{-1}$ Tesla perpendicular with the field will have an angular frequency of $6.15 \times 10^{10}$ radius.

5a State the Biot-Savart Law.

i The vector $\vec{dB}$ is perpendicular to $\vec{dl}$ (which points in the direction of the current) and to the unit vector $\hat{r}$ directed from $\vec{dl}$ toward P.

ii The magnitude of $\vec{dB}$ is inversely proportional to $r^2$: where r is the distance from $\vec{dl}$ to P.

iii The magnitude of $\vec{dB}$ is proportional to the current I and to the magnitude of the length element $\vec{dl}$

iv The magnitude of $\vec{dB}$ is proportional to $\theta$, where $\theta$ is the angle between $\hat{r}$ and dl.

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

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

Sol

Applying the biot-savart law, we find the magnitude of the field

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

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

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

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

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

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

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

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 3 therefore becomes

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

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

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

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 longer than x,

$(x^2+a^2)^{1/2} \simeq a$ 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 on a circle of radius r, around the conductor, the magnitude of B is:

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

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