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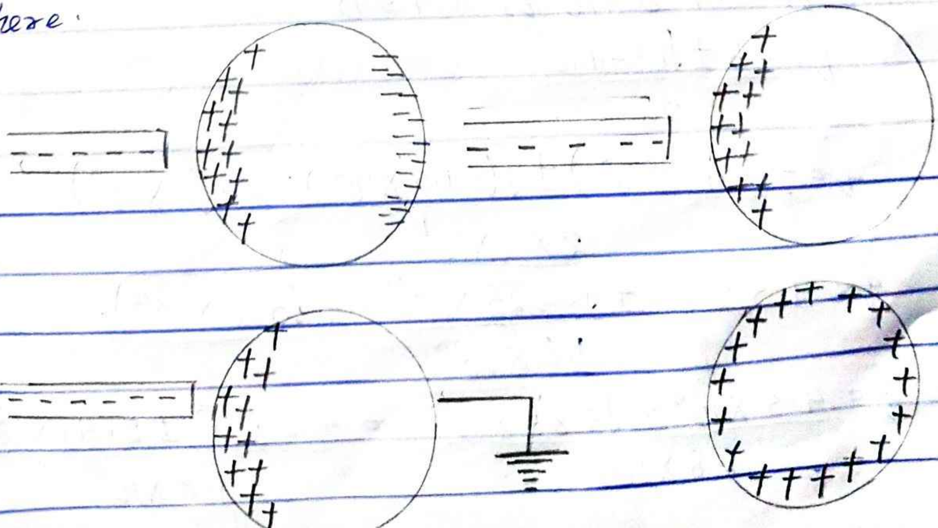
PHARMACOLOGY
MEDICINE & HEALTH SCIENCES
PHY 102 (ASSIGNMENT)
19/MHS07/002

SECTION A

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

Electric Charges can be obtained on an object without touching it by a process called Electrostatic Induction. A negatively charged ~~sphere~~ rubber rod bought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to the ground. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on 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, some of the electrons leave the sphere and travel to the earth. If the wire to the ground is removed, the conducting sphere is ~~left~~ left with an excess of induced positive charge.

Finally, when the rubber rod is removed from the vicinity of the sphere, the induced positive charge remains on the ungrounded sphere & becomes uniformly distributed over the surface of the sphere.



1b Each of two 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 1.0N. When the spheres are 2.0 m apart, & Calculate the charge on each sphere.

$K = 9 \times 10^{9}\ Nm^2/C^2$

Given,

$F = 1.0N$

$D = 2.0m$

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

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

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

From coulomb's law,

$$F = \frac{Kq_1q_2}{r^2}$$

$$1.0 = \frac{9\times10^{9}(5\times10^{-5} - q_2)q_2}{(2)^2}$$

$$1.0 = \frac{9\times10^{9}(5.0\times10^{-5}q_2 - q_2^2)}{4}$$

~~$1.0 = 9\times10^9$~~ $1.0 = \frac{4.5\times10^{5}q_2 - 9\times10^{9}q_2^2}{4}$

$4.5\times10^{5}q_2 - 9\times10^{9}q_2^2 = 4$

$9\times10^{9}q_2^2 - 4.5\times10^{5}q_2 + 4 = 0$

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

$$q = \frac{-(-4.5\times10^{5}) \pm \sqrt{(-4.5\times10^{5})^2 - 4(9\times10^{9})}}{2\times9\times10^{9}}$$

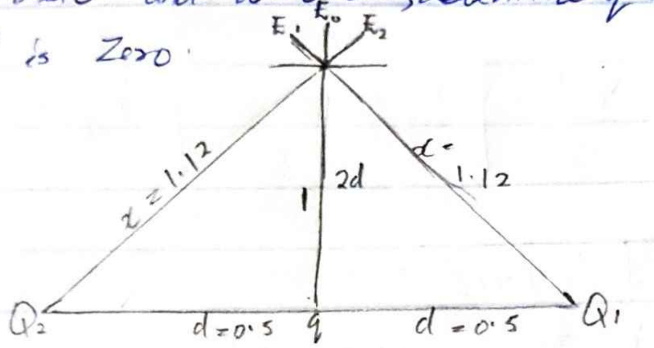
$$q = \frac{4.5\times10^{5} \pm \sqrt{2.025\times10^{11} - 4(3.6\times10^{10})}}{1.8\times10^{10}}$$

$$q = \frac{4.5\times10^{5} \pm \sqrt{5.85\times10^{10}}}{1.8\times10^{10}} = \frac{4.5\times10^{5} \pm 2.41\times10^{5}}{1.8\times10^{10}}$$

$q_1 = \frac{4.5\times10^5 + 2.41\times10^5}{1.8\times10^{10}}$ or $q_2 = \frac{4.5\times10^5 - 2.41\times10^5}{1.8\times10^{10}}$

$q_1 = 3.8\times10^{-5}$ C   $q_2 = 1.1\times10^{-5}$ 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 $q$ if the electric field at P is zero.




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

$\sqrt{x^2} = \sqrt{1.25}$

$x = 1.12$

$E_1 = \frac{Kq_1}{r_1^2}$

$= \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2}$

~~$= 9\times10^9 \times$~~ $= 57397.959$

$E_2 = \frac{Kq_2}{r_2^2}$

$= \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2}$

$= 57397.959$

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

~~$= 1$~~

$E_q = \frac{Kq}{r^2}$

$= \frac{9\times10^9 \times q}{1}$

$= 1$

| Vector | Angle | x-component | y-component |
| --- | --- | --- | --- |
| $E_1 = 57397.959$ | $63.4°$ | $E_{1x} \cos\theta$ $= 25700.45$ | $E_{1y} \sin\theta$ $= 51322.62$ |
| $E_2 = 57397.959$ | $63.4°$ | $E_{2x} \cos\theta$ $= 25700.45$ | $E_{2y} \sin\theta$ $= 51322.62$ |
| $E_q = 9\times10^9 q$ | $90°$ | $E_{qx} \cos\theta$ $E_x = 0$ | $E_{qy} \sin\theta$ $= 10264.52568$ |

$$\text{Magnitude} = \sqrt{(E_x)^2 + (E_y)^2}$$

$$E_q = \sqrt{(0)^2 + (10264.52568)^2}$$

since $E_q = 0 \therefore 0 = 9\times10^9 q + 10264.52568$

Making $q$ the subject of the formula

$$q = \frac{10264.52568}{9\times10^9}$$

$$q = 1.140502853\times10^{-6}$$

$$\simeq 11.4 \mu C$$

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

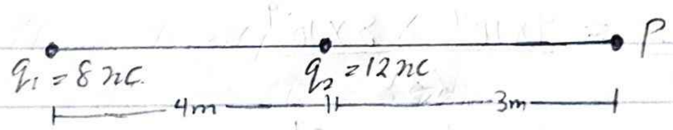
Electric Field is a region of space in which an electric charge will experience an electric force. while Electric Field Intensity (E) can be defined as the force per unit charge. Mathematically, $E = \frac{F(N)}{q_0 (C)}$. It is measured in Newton per coulomb (N/C). The direction of the electric field intensity E at a point in space is the same as the direction of the force a positive test charge would experience if it were placed at that point.

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 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.

i




$E = E_1 + E_2$

$E_1 = \frac{kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{(7)^2}$

$= \frac{9 \times 8 \times 10^{9-9}}{49}$

$= 1.469 \ N/C$

$E_2 = \frac{kq^2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{(3)^2}$

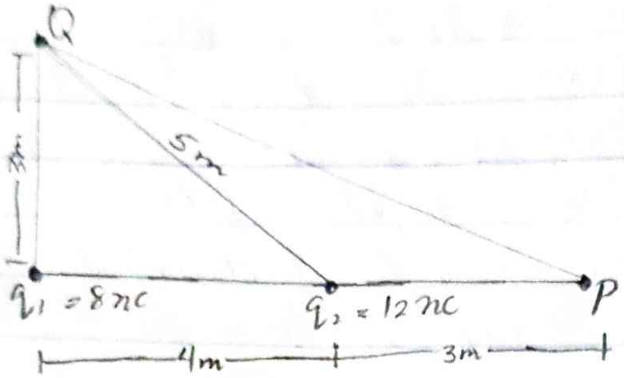
$= 12.0 \ N/C$

$E = 1.469 + 12$

$= 13.469$

$\simeq 13.5\ N/c$

ii




Using ~~phy~~ pythagoras theorem,

$Hyp^2 = 3^2 + 4^2$

$Hyp^2 = 9 + 16$

$Hyp^2 = \sqrt{25}$

$Hyp = 5$

$E = E_1 + E_2$

$E_1 = \frac{kq_1}{r_1^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{(3)^2}$

$= \frac{9 \times 10^9 \times 8 \times 10^{-9}}{9}$

$= 8.0\ N/c$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{(5)^2}$

$= \frac{9 \times 10^9 \times 12 \times 10^{-9}}{25}$

$= 4.32\ N/c$

| Vector | Angle | X-component | Y-component |
|---|---|---|---|
| $E_1 = 8.0\ N/c$ | $90^\circ$ | $8.0 \cos 90$ $= 0$ | $8.0 \sin 90$ $= 8.0$ |
| $E_2 = 4.32\ N/c$ | $36.9^\circ$ | $4.32 \cos 36.9$ $= 3.45$ | $4.32 \sin$ ~~36.9~~ $36.9$ $= 2.59$ |

$E_x = (8.0 \cos 90) + (9.32 \cos 36.9)$

$E_x = 3.45$

~~$E_y = (9.32 \cos 36.9) + (8.0$~~

$E_y = (9.32 \sin 36.9) + (8.0 \sin 90)$

$E_y = 10.59$

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

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

$E = 11.2$ N/C

SECTION B

5a State the Biot-Savart Law.

Biot-savart Law states that "the magnetic field is directly proportional to the product permeability of free space ($\mu$), the current ($I$), the radius and inversely proportional to square of radius ($r^2$). It can be represented mathematically by

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

Where $\mu_0$ is a constant called Permeability of free space

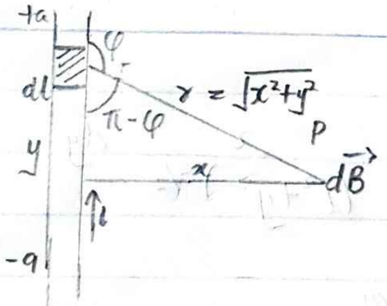
$$\mu_0 = 4\pi \times 10^{-7} \ T.m/A$$

The unit of B is weber/metre square.

5b Using the Biot-Stavart Law, Show that the magnitude of the magnetic field of a straight current-carrying conductor is given as

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

Magnetic Field of a Straight Current Carrying Conductor




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

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

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

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

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

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

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

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 $dl = dy$

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

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

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 conductor is very great in comparison to its distance x from point P, we consider its infinitely long. i.e 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

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

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

4a What is Magnetic Flux

- Magnetic Flux is defined as the strength of magnetic field represented by lines of force. It is usually represented by the symbol $\Phi$.

Mathematically:

$$\Phi = \vec{B} \cdot d\vec{A}$$

$$\Phi = \int \vec{B} \cdot d\vec{A}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$= BA\cos\theta$$

4b An electron with rest of mass 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 $3.5 \times 10^{-1}$ webber/meter square, perpendicular to the speed with which electron moves. Find the cyclotron frequency of the moving electron.

$$F_B = qVB = \frac{mv^2}{r}$$

$$m_p V = qBr$$

$$V = qBr$$

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

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

Given,

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

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

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

Cyclotron Frequency = Angular Speed

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

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

$= 6.15 \times 10^{10}$ T or $6.2\ T^{-1}$

4c Discuss your answer in 4b above.

In the question we were given paraniters such as;

mass of the electron = $9.11 \times 10^{-31}$ Kg

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

Magnetic field of $3.5 \times 10^{-1}$ webter / meter square.

There we go on to find the cyclotron frequency which is also equal or the same thing as angular speed. It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron

Recall,

Angular Speed : $\omega = \frac{v}{r} = \frac{qB}{m}$

Then we substitue in the figures giving the answer $6.15 \times 10^{10}$ T or $6.2\ T^{-1}$.