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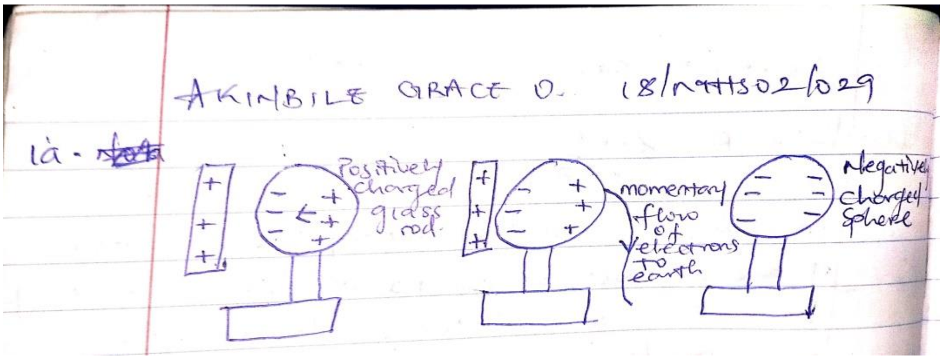
MATRIC NUMBER: 18/MHS02/029

DEPARTMENT: NURSING, 200LVL (C.O)

COURSE: PHY 102 (PHYSICS)

<u>ANSWERS</u>

1a)



A neutral conducting sphere is at rest on top an insulating stand. A positively charged tube is brought near (without touching) to the neutral sphere. The presence of the positively charged tube forces electron movement from right to left side of the sphere. This movement of electrons is merely a reaction to the presence of positive charge. Once touched by the ground, the electron leaves the sphere. When the tube is moved away, there is an overall negative charge left on the sphere.

1b)

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1b. Let the values of the individual charges be q_1 and q_2

The condition on the combined charge of the sphere is given as;

$q_1 + q_2 = 5.0 \times 10^{-5} C$ --- (1)

Both charges are positive because their sum is positive and they repel each other, thus; $|q_1| = q_1$ and $|q_2| = q_2$.

Using $F = \frac{k q_1 q_2}{r^2} = 1.0N$

$q_1 q_2 = (1.0N) \frac{r^2}{k}$

$= (1.0N)(2.0m)^2 \times 8.99 \times 10^9 N/m^2/C^2$

$q_1 q_2 = 4.449 \times 10^{-10} C^2$ --- (2)

From eqn (1)

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

Substituting for q_2 in eqn (2)

$q_1(5.0 \times 10^{-5} - q_1) = 4.449 \times 10^{-10}$

$5.0 \times 10^{-5} q_1 - q_1^2 = 4.449 \times 10^{-10}$

$q_1^2 - (5.0 \times 10^{-5}) q_1 + 4.449 \times 10^{-10} = 0$

Using quadratic formular

$q_1 = \frac{-(-5.0 \times 10^{-5}) \pm \sqrt{(5 \times 10^{-5})^2 - 4(4.449 \times 10^{-10})}}{2}$

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1b contd $q_1 = \frac{5\times10^{-5} \pm \sqrt{2.684\times10^{-5}}}{2}$

$q_1 = 3.842 \times 10^{-5}C$

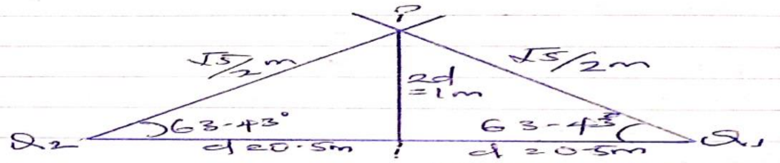
Substituting for q_1 in eqn ②

$q_2 = 5.0 \times 10^{-5} - 3.842 \times 10^{-5}$

$q_2 = 1.16 \times 10^{-5}C$

Hence, the charge on each sphere are $3.842 \times 10^{-5}C$ and $1.16 \times 10^{-5}C$.

1c



$Q_1 = Q_2 = 8\mu C$

$d = 0.5m$

$E = \frac{Kq_1}{r^2}$

$E = \frac{(9\times10^9)(8\times10^{-6})}{(\sqrt{5}/2)^2}$

$= \frac{72000\times4}{5} = 57600 = 5.76\times10^4$

Using pythagoras theorem

$hyp^2 = opp^2 + adj^2$

$= 1^2_m + 0.5^2_m$

$hyp = \sqrt{5/4}$

$= \sqrt{5}/2m$

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1c. contd Angle, SOH, $\sin\theta = \frac{opp}{hyp} = \frac{1}{\sqrt{5}/2} = 0.8944$

$\theta = \sin^{-1}(0.8944) = 63.43°$

$\rightarrow E_{1x} = 5.76\times10^4\cos 63.43$

$= 25763.95$

$\rightarrow E_{1y} = 5.76\times10^4 \sin 63.43$

$= 51516.78$

$\rightarrow E_{2x} = -25763.95, \quad E_{2y} = 51516.78$

$\vec{E_x} = 25763.95 + (-25763.95) = 0$

$\vec{E_y} = E_{1y} + E_{2y} + E_{qP}$

$0 = 51516.78 + 51516.78 + E_{qP}$

$0 = 1.03034\times10^5 + E_{qP}$

$E_{qP} = -1.03034\times10^5$

$E = Kq_1/r^2$

$-1.03034\times10^5 = \frac{9\times10^9\times q_P}{1^2}$

$-1.03034\times10^5 = 9\times10^9 q_P$

$q_P = \frac{-1.03034\times10^5}{9\times10^9} = -1.1448\times10^{-5}$

$q_P = -1.1\times10^{-5}$

$q_P = -11\times10^{-6}$

$\therefore q_P = -11\mu C$

3)

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3a i.) Volume charge density, $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

ii.) Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

iii.) Linear charge density, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \Rightarrow dE = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2} \quad --- (1)$$

Using the superposition principle, the total electric field, E is the vector sum (integral) of these infinitesimal contributions—

$$E = \frac{1}{4\pi\varepsilon_0}\int\frac{dQ}{r^2} \quad --- (2)$$

where r is the distance from dQ to point P.

3b The potential difference between two points is one volt if the work done in taking one coulomb of positive charge from one point to the other is one joule. Mathematically,

$$W = qV \text{ or } V = \frac{W}{q}.$$

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3b The electric potential difference between two points in an electric field can be defined as the work per unit charge against electrical forces when a charge is transported from one point to the other. It is measured in volt (V) or Joules per coulomb (J/C) and is a scalar quantity.

Suppose a test charge, q_0 is moved from point A to point B along an arbitrary path inside an electric field E. The electric field exerts a force, $F = q_0E$ on the charge. To move the charge from A to B at a constant velocity, an external force of $F = -q_0E$ must act on the charge. Therefore, elemental work done, dW is given as;

$$dW = F.dl \quad --- (1)$$

but $F = -q_0E \quad --- (2)$

Substituting eqn (2) in (1) yields;

$$dW = -q_0E\,dl \quad --- (3)$$

Then total work done is

$$W(A \rightarrow B)_{Ag} = -q_0\int_A^B E\,dl \quad --- (4)$$

From the definition of potential difference, it follows that

$$V_B - V_A = \frac{W(A \rightarrow B)_{Ag}}{q_0} \quad --- (5)$$

Putting eqn (4) in (5) yields;

$$V_B - V_A = -\int_A^B E\,dl \quad --- (6)$$

3c)

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3c

$Q_1 \xleftarrow{\quad r \quad} \xrightarrow{} \overset{V}{} \xleftarrow{\quad 4-r \quad} Q_2 \; 4m$

$E = \frac{KQ_1}{r}$

$E_1 = \frac{(9\times10^9)(10\times10^{-6})}{r} = \frac{90,000}{r}$

$E_2 = \frac{KQ_2}{r} = \frac{(9\times10^9)(-2\times10^{-6})}{4-r} = -\frac{18000}{4-r}$

$E_{net} = E_1 + E_2$

$= \frac{90,000}{r} + \left(\frac{-18,000}{4-r}\right)$

$E,\ \frac{4-r(90,000) + r(-18,000)}{(4-r)r} = V$

$\frac{360,000 - 90,000r - 18,000r}{(4-r)r} = V$

$360000 - 90,000r - 18,000r = V(4-r)r$

$V = 360,000 - 108,000r$

$0 = 360{,}000 - 108,000r$

$\Rightarrow 108,000r = 360,000$

$r = \frac{360,000}{108,000} = 3.33m$

$\therefore V = 0$ at $r = 3.33m$

4a) Magnetic flux is defined as the number of magnetic field lines passing through a given closed surface (It gives the measurement of the total magnetic field that passes through a given area). Its S.I unit is weber (Wb).

Magnetic flux= magnetic field *area*angle btw the planar area and magnetic flux

4b)

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4b $m = 9\times10^{-31}kg$

$r = 1.4\times10^{-7}m$

$B = 3.5\times10^{-1}wb/m^2$

Cyclotron frequency = angular speed

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

$w = \frac{1.6\times10^{-19}\times3.5\times10^{-4}}{9\times10^{-31}}$

$w = 622.2T^{-1}$

4c. ~~Since~~ Since the cyclotron frequency is equal to angular speed, the cyclotron frequency is equal to 622.22T having a unit of 1/T which is equal to the unit of frequency.

5a) The 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 points. It tells the magnetic field toward the magnitude, length, direction as well as the closeness of the electric current.

5b)

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5b **Magnetic field of a straight current-carrying conductor:-**

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

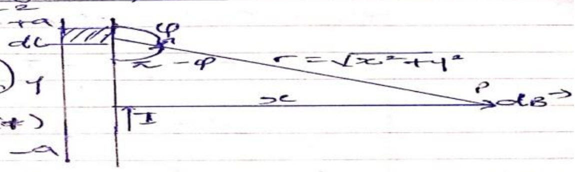
$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a}\frac{dl\sin\varphi}{r^2}$$

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

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

from the diagram;

$r^2 = x^2 + y^2$ (using pythagoras theorem)



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

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

By substituting (2) into (1), we have;

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

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

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5b. cont'd Recall $dl = dy$

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

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

Using special integrals;

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

Eqn. (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 x from point P, it is considered infinitely long i.e when a is much larger than x,

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

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No 5b cont'd:- $B = \frac{\mu_0 I}{2\pi x}$

In physics, axial symmetry is about the y-axis. Thus, at all points in a circle of radius, r, around the conductor, the magnitude of B is;

$$B = \frac{\mu_0 I}{2\pi r} \quad --- (5)$$

Eqn (5) defines the magnitude of the magnetic field of flux density B near a long, straight current carrying conductor.