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19/MHS 01/300
Medicine and Surgery
Phy 102
Instruction: Answer 4 Questions in All - 2 in section A and 2 in section B

No. 2

a) Electric field is a region of space in which an electric charge will experience an electric force.

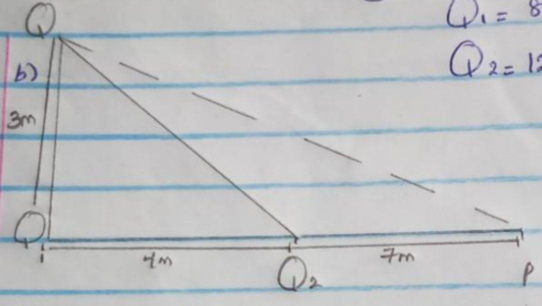
While

Electric field intensity at any point is the strength of an electric field. It is the force per unit positive charge.

$Q_1 = 8nC = 8 \times 10^{-9} C$

$Q_2 = 12nC = 12 \times 10^{-9} C$

b)



Recall that: $E = \frac{Kq}{r^2}$

$\therefore E_1 = \frac{(8.99 \times 10^9) \times (8 \times 10^{-9})}{(7.0)^2} = 1.47 N/C$

$\therefore E_2 = \frac{(8.99 \times 10^9) \times (12 \times 10^{-9})}{(3.0)^2} = 11.9 N/C \simeq 12 N/C$

Vector	Angle	X - comp	Y - comp
$E_1 = 1.47 N/C$	$0°$	$E_{1x} = 1.47 \cos 0°$ $E_{1,x} = 1.47 N/C$	$E_{1,y} = 1.47 \sin 0$ $= 0 N/C$
$E_2 = 12 N/C$	$0°$	$E_{2,x} = 12 \cos 0°$ $E_{2,x} = \underline{12 N/C}$	$E_{2,y} = 12 \sin 0$ $E_y = \underline{0 N/C}$
		$x = \underline{13.47 N/C}$	$y = \underline{0 N/C}$

$E_{net} = \sqrt{(E_x)^2 + (E_y)^2}$

$= \sqrt{(13.47)^2 + (0)^2}$

$= \sqrt{181.4409}$

$E_{net} = 13.47N$

ii $E_1 = \frac{KQ}{r^2} = \frac{(8.99 \times 10^9) \times (8 \times 10^{-9})}{3^2} = 7.99 N/C$

$E_2 = \frac{KQ}{r^2} = \frac{(8.99 \times 10^9) \times (12 \times 10^{-9})}{5^2} = 4.32 N/C$

Vector	Angle	x-Comp	y-Comp
$E_1 = 7.99 N/C$	$90°$	$E_1 = 7.99 \cos 90$ $= 0$	$E_1 = 7.99 \sin 90$
$E_2 = 4.32 N/C$	$36.86°$	$E_2 = 4.32 \cos 36.86$ $E_2 = \underline{3.45 N/C}$	$E_2 = 4.32 \sin 36.86$ $= \underline{2.59}$

$E_x = \underline{3.45 N/C}$ E_y $\underline{10.58}$

$E_{net} = \sqrt{E_x^2 + E_y^2}$

$= \sqrt{(3.45)^2 + (10.58)^2}$

$= \sqrt{11.9 + 111.93}$

$= 11.12 N/C$

No. 3

a)

(i) Volume Charge density.

$\rho = \frac{dQ}{dv} \Rightarrow dQ = \rho dv$

Where: ρ = Volume Charge density

V = Volume

Q = Electric charge

(ii) Surface Charge density

$\sigma = \frac{dQ}{dA} = dQ = \sigma dA$

Where: σ = Surface Charge

A = Area ; Q = electric charge

(iii) Linear Charge density.

$\lambda = \frac{dQ}{dL} = dQ = \lambda dL$

Where; λ = Linear Charge

L = Length.

b) Electric Potential difference is defined as the work done per unit Charge against electrical forces when a charge is transported from one point to the other.

Mathematically, it can be expressed as:

$V = \frac{W}{q}$

Where: W = Workdone

q = Charge

Element workdone dw is given as:

$dw = f \cdot dL$ - - - (i)

But: $f = -q_0E$ - - - (ii)

∴ Substituting equ ii in i gives:

$dw = -q_0 E dL$ - - - (iii)

$$W(A\to B)Ag = -q_0\int_A^B E\,dl \quad ---(iv)$$

$$\Rightarrow V_B - V_A = \frac{W(A\to B)Ag}{q_0} \quad ---(v)$$

$\therefore$ Putting equ iv into v yields

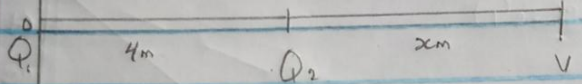
$$V_B - V_A = -\int_A^B E\,dl$$

c) $Q_1 = 10\,\mu c = 10\times10^{-6}c$

$Q_2 = -2\,\mu c = -2\times10^{-6}c$

Recall that: $V_P = K\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$

Position (i) When V is to the right of Q_2



$$V_P = K\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

$$\Rightarrow 0 = 8.99\times10^{+9}\left(\frac{10}{x} + \frac{(-2)}{x-4}\right)$$

$$\Rightarrow 0 = \frac{(10)(8.99\times10^{9})}{x} - \frac{(2)(8.99\times10^{9})}{x-4}$$

$$\Rightarrow \frac{8.99\times10^{10}}{x} = \frac{1.798\times10^{10}}{x-4}$$

$$\Rightarrow 8.99\times10^{10}(x-4) = 1.798\times10^{10}x$$

$$\Rightarrow 8.99\times10^{10}x - 3.596\times10^{11} = 1.798\times10^{10}x$$

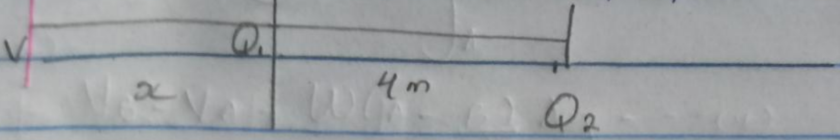
$$\Rightarrow -3.596\times10^{11} = 1.798\times10^{10}x - 8.99\times10^{10}x$$

$$\Rightarrow -3.596\times10^{11} = -7.192\times10^{10}x$$

$$\Rightarrow x = \frac{-3.596\times10^{11}}{-7.192\times10^{10}}$$

$x = 5m$

Position (2) when V is to the left of Q_1



$$0 = 8.99 \times 10^9 \left(\frac{10}{x} - \frac{2}{(x+4)} \right)$$

$$\Rightarrow 0 = \frac{8.99 \times 10^{10}}{x} - \frac{1.798 \times 10^{10}}{x+4}$$

$$\Rightarrow \frac{8.99 \times 10^{10}}{x} = \frac{1.798 \times 10^{10}}{x+4}$$

$$\Rightarrow 8.99 \times 10^{10}(x+4) = 1.798 \times 10^{10} x$$

$$\Rightarrow 8.99 \times 10^{10} x + 3.596 \times 10^{11} = 1.798 \times 10^{10} x$$

$$\Rightarrow 8.99 \times 10^{10} x - 1.798 \times 10^{10} x = -3.596 \times 10^{11}$$

$$= 7.192 \times 10^{10} x = -3.596 \times 10^{11}$$

$$x = \frac{-3.596 \times 10^{11}}{7.192 \times 10^{10}}$$

$$x = -5m$$

Section B

No. 4

a)

Magnetic flux is defined as the strength of magnetic field represented by lines of force. It is usually represented by the symbol ϕ.

b) Mass $= 9.11 \times 10^{-3}$ kg

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

Magnetic field $= 3.5 \times 10^{-1}$ W/m^2

Cyclotron frequency = ???

Recall that:

Cyclotron frequency = Angular speed (ω)

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

$$\omega = \frac{(1.6 \times 10^{-19}) \times (3.5 \times 10^{-1})}{9.11 \times 10^{-31}} = 6.14709 \times 10^{10} \text{ rad/sec}$$

c) From the question in 4b, we were provided some parameters,

Mass of the electron $= 9.11 \times 10^{-31}$ kg

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

Magnetic field $= 3.5 \times 10^{-1}$ W/m^2

We were asked to find the value of the cyclotron frequency of the moving electron. We recall that cyclotron frequency is equal to angular speed (ω).

$$\text{Angular speed } (\omega) = \frac{v}{r} = \frac{qB}{m}$$

$\therefore$ Inputing the given parameters yield:

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

$$\omega = 6.14709 \times 10^{10} \text{ rad/sec}$$

Since Cyclotron frequency = Angular speed. It implies that the value gotten for cyclotron frequency will posses the unit of angular speed which is rad/sec

No. 5

a) Biot Savart's law is based on some set of observations for the magnetic field $d\vec{B}$ at a point P associated with a length element $d\vec{l}$ of a wire carrying a steady current I. It relates the magnetic field to the magnitude, direction, length and proximity of the electric current.

Mathematically, it can be expressed as:

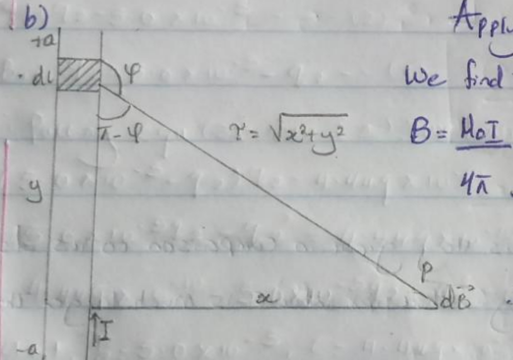
$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$$

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

$$B = \frac{\mu_0}{4\pi} \int \frac{I dl \sin\theta}{r^2}$$

Where: μ_0 = Permitivity of free space.

b)



Applying the Biot-Savart law,

We find the magnitude of the feild $d\vec{B}$

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

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

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

from the diagram, $r^2 = x^2 + y^2$ (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 $\sin(\pi - \varphi) = \dfrac{x}{\sqrt{x^2+y^2}} = \dfrac{x}{(x^2+y^2)^{1/2}}$ - - - - (2)

$\therefore$ Substituting (2) into (1); yields

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

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

Recall $dl = dy$

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

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

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

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

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

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

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 larger than x,:

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

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

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

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

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