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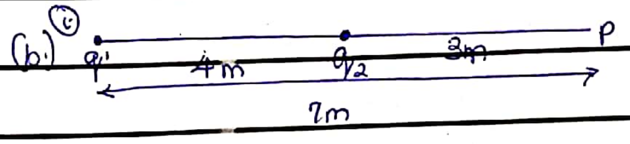
PHY 102 Assignment.

2) (a) Electric field is the region of space in which an electric charge will experience an electric force while electric field intensity also known as electric field strength is defined as the force per unit charge, it is magnitude of the electric field.

(b) (i)



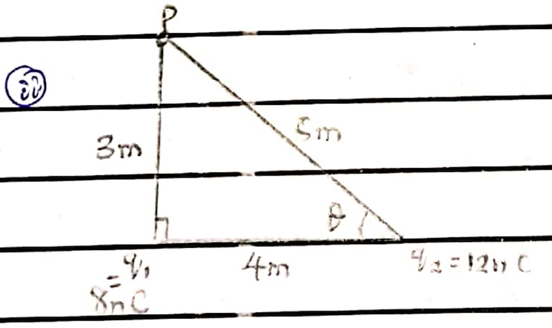
$q_1 = 8nC$ $q_2 = 12nC$

$$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.469 N/C$$

$$E_2 = \frac{kq_2^2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12 N/C$$

$$E_{net} = E_1 + E_2 = (1.469N/C + 12N/C) = 13.469N/C = 13.5N/C$$

(ii)



$$|pq_2| = \sqrt{3^2+4^2} = \sqrt{25} = 5m$$

$$\sin\theta = 3/5$$

$$\theta = \sin^{-1}(3/5) = 36.9^\circ$$

$$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8 N/C$$ $$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9\times12\times10^{-9}}{5^2} = 4.32 N/C$$

Vector	Angle	x-component	y-component
$E_1 = 8N/C$	$90^\circ C$	$E_{1x} = 8\cos 90^\circ = 0N/C$	$E_{1y} = 8\sin 90^\circ = 8N/C$
$E_2 = 4.32N/C$	36.9°	$E_{2x} = 4.32\cos 36.9^\circ = 3.45N/C$	$E_{2y} = 4.32\sin 36.9^\circ = 2.60N/C$
		$\Sigma E_x = 3.45 N/C$	$\Sigma E_y = 10.60N/C$

$$E_{net} = \sqrt{\Sigma E_x^2 + \Sigma E_y^2} = \sqrt{3.45^2 + 10.6^2} = \sqrt{124.2625}$$

$$= 11.147 \simeq 11.15N/C$$

3.(a) i) Volume charge density, $\rho = {dQ}/{dv} \rightarrow dQ = \rho dv$

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

iii) Linear charge density, $\lambda = {dQ}/{dl} \rightarrow dQ = \lambda dL$

b) The electric potential difference between two points in an electric field can be defined as the work per unit charge against electric forces when a charge is transported from one point to the other. It is a scalar quantity and is measured in volts (V) or Joules per Coulomb (J/C). In an electric field, suppose a test charge, q_o is moved from a point A to point B along an arbitrary path the electric field exerts a force $F = q_0 E$ on the charge. For the test charge to move from A to B, an external force $F = -q_0 E$ acts on the charge. The work done in moving this charge is given as $dW = F \cdot dL$ ①

But, $F = -q_0 E$ — ② substituting eqn ② in ①; $dW = -q_0 E dL$ — ③

∴ The total work done in moving test charge from A to B is:

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

From the definition of electric potential difference; $V_B - V_A = \frac{W(A \rightarrow B)_{Ag}}{q_0}$ — ⑤

Substituting eqn ④ into eqn ⑤

$$V_B - V_A = -\int_A^B E dL \quad — ⑥$$

$\Delta U = \frac{-W(A \rightarrow B) \cdot E}{q_0} = \frac{W(A \rightarrow B)_{Ag}}{E}$ ∴ $V_B - V_A = \frac{\Delta U}{q_0} = \frac{U_B - U_A}{q_0}$ [Hence we can defined p.d as ~~the potential~~ energy per unit charge]

c) $Q_1 = 10\mu C$ at 0, $Q_2 = 2\mu C$ at 4m

$Q_1 = 10\mu C$ $Q_2 = -2\mu C$

$V = \frac{1}{4\pi\epsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$

when $V = 0$; $0 = 9 \times 10^9 \left[\frac{10 \times 10^{-6}}{r_1} - \frac{2 \times 10^{-6}}{r_2}\right]$; $\frac{0}{9 \times 10^9} = \frac{10 \times 10^{-6}}{r_1} - \frac{2 \times 10^{-6}}{r_2}$; $\frac{10 \times 10^{-6}}{r_1} = \frac{2 \times 10^{-6}}{r_2}$

$2r_1 = 10r_2$ ∴ $r_1 = 5r_2$

Referring to the diagram above, the position along the x-axis where $V = 0$ is 5m from $Q_1 = 10\mu C$ and 1m from $Q_2 = -2\mu C$

4)(a) Magnetic flux refers to the number of magnetic lines of force passing through a given closed surface which is the magnetic field. It is what generates the field around a magnetic material. The S.I unit is Weber (Wb).

b) $F = qVB\sin\theta = \frac{mv^2}{r}$ $\qquad m = 9.11\times10^{-31}\,kg,\ r = 1.4\times10^{-7}\,m$

$\theta = 90^\circ,\ B = 3.5\times10^{-1}\,T,\ v = 3\times10^{8}\,ms^{-1}$

$$q\times3\times10^{8}\times3.5\times10^{-1}\times\sin90^\circ = \frac{9.11\times10^{-31}\times(3\times10^{8})^2}{1.4\times10^{-7}}$$

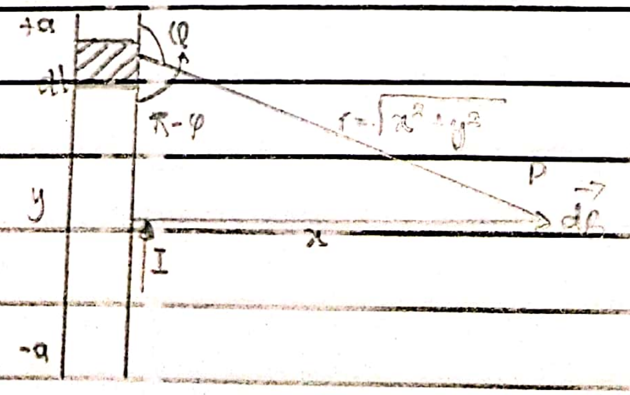
$$q = \frac{9.11\times10^{-31}\times\cancel{3\times10^{8}}\times3\times10^{8}}{\cancel{3\times10^{8}}\times3.5\times10^{-1}\times\sin90^\circ\times1.4\times10^{-7}} = \frac{2.733\times10^{-22}}{4.9\times10^{-8}} = 5.578\times10^{-15}\,C$$

$$\omega = \frac{qB}{m_e} = \frac{5.578\times10^{-15}\times3.5\times10^{-1}}{9.11\times10^{-31}} = \frac{1.952\times10^{-15}}{9.11\times10^{-31}} = 2.14\times10^{15}\,rad/s$$

c) The motion of the electron is a uniform circular motion, so the acceleration will be the centripetal acceleration V^2/r $\left[FB = qVB = \frac{mv^2}{r}\right]$. The angular speed of the electron will be $\omega = V/r$ so if you carry out the necessary substitution, 2.14×10^{15} rad/s will be the angular speed also known as cyclotron frequency of the electron because the electron circulates at this angular speed in the type of accelerator called cyclotron.

5) (a) 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 is stated as; $\vec{dB} = \frac{\mu_0 I\,\vec{dl}\times\hat{r}}{4\pi r^2}$, where μ_0 is permeability of free space $[\mu_0 = 4\pi\times10^{-7}\,T\cdot m/A]$

(b.)



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

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

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

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

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

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

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

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

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

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

Using eqn ③; $B = \frac{\mu_0 I x}{4\pi}\left[\frac{y}{x^2(x^2+y^2)^{1/2}}\right]_{-a}^{a}$; $B = \frac{\mu_0 I x}{4\pi}\left[\frac{2a}{x^2(x^2+a^2)^{1/2}}\right]$

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

When the length $2a$ of the conductor is very great in comparison to its distance x from point P, it is said to be infinitely long.

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

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