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PHY 102 ASSIGNMENT.

SECTION A

QUESTION 2

a) An electric field is a region of space in which an electric charge will experience an electric force. While, the electric field strength or electric field intensity, E can be defined as the force per unit charge. Mathematically, it is given as $E = \frac{F(N)}{q_o(C)}$ which is measured in Newton per coloumb (N/C)

b) $Q_1 = 8\mu C$, $Q_2 = 12\mu C$, $x = 4m$, $K = 9\times10^9$.

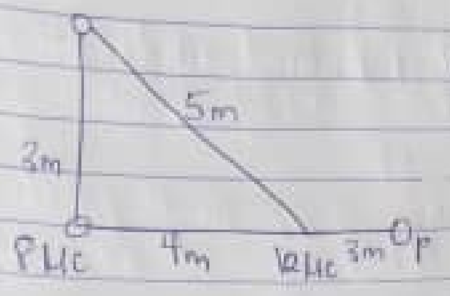
i) $x = 7m$.

$$E_{1P} = \frac{Kq_1P}{r^2} = \frac{9\times10^9 \times (8\times10^{-9})}{7^2} = 1.469N/C.$$

$$E_{2P} = \frac{Kq_2P}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{3^2} = 12N/C.$$

$$E_{net} = 12 + 1.469$$
$$= 13.469 N/C$$
$$= 13.5 N/C.$$

ii)



By Pythagoras
hyp = 5m
$\cos\theta = \frac{4}{5}$
$\theta = 36.87°$

$E_{1q} = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2} = 8 N/C$

$E_{2q} = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{5^2} = 4.32 N/C$

Vector	Angle	x-component	y-component
$E_{1q} = 8 N/C$	$90°$	$8 \cos 90 = 0$	$8 \sin 90 = 8$
$E_{2q} = 4.32 N/C$	$36.87°$	$4.32 \cos 36.87° = 3.46$	$4.32 \sin 36.87° = 2.59$
		$\Sigma = 3.46 N/C$	$\Sigma = 10.59 N/C$

$E_{net} = \sqrt{(3.46)^2 + (10.59)^2}$
$E_{net} = 11.14 N/C$

QUESTION 3

a) i) volume charge density, $\rho = \frac{dQ}{dv} \rightarrow dQ = \rho dv$

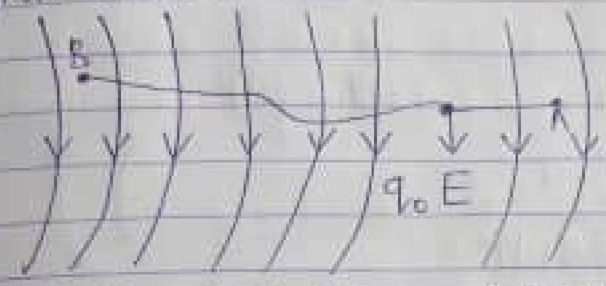
ii) Surface charge density, $\sigma = \frac{dQ}{dv} \rightarrow dQ = \sigma dA$

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

b) Electric Potential difference

The electric potential difference between two points in an electric field can be defined as the work done 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). Electric potential difference is a scalar quantity.

Suppose a test charge, q_0 is moved from point A ~~a~~ to point B along an arbitrary path inside an electric field, E. The electric field exerts a force ~~$F = q_0E$~~ $F = q_0E$ on the charge as shown in the diagram below.



To move the test charge from A to B at constant velocity, an external force of $F = -q_0E$ ~~must~~ act on the charge. Then, the elemental workdone dW is given as:

$$dw = F \cdot dL \quad ---(1)$$

But

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

Substituting (2) in (1) gives

$$dW = -q_0 E dL \quad ---(3).$$

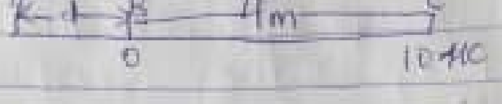
Therefore, total work done in moving the test charge from A to B is:

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

from the definition of potential difference, we can say that
$V_B - V_A = \frac{Wd(A \to B)Ag}{q_0}$ ... (5)

Putting 4 in 5
$V_B - V_A = -\int_A^B E\,dL$

c) $Q_1 = 10\,\mu C$
$Q_2 = -2\,\mu C$



The point is d because the net force, $B = 0$.
Electric field intensity $= \frac{q}{4\pi\varepsilon_0 r^2}$
$= \frac{-2\times10^{-9}}{4\pi\varepsilon_0(d)^2} = 0$

and also
$\frac{10\times10^{-9}}{4\pi\varepsilon_0(4+d)^2} = 0$

Equating both sides
$\frac{2\times10^{-9}C}{4\pi\varepsilon_0(d)^2} = \frac{10\times10^{-9}C}{4\pi\varepsilon_0(4+d)^2}$

$\frac{2}{d^2} = \frac{10}{(4+d)^2}$

$2(4+d)^2 = 10d^2$

$2(4+d)(4+d) = 10d^2$

$2(16+4d+4d+d^2) = 10d^2$

$32+8d+8d+2d^2 = 10d^2$

$32+16d+2d^2 = 10d^2$

$32+16d+2d^2-10d^2 = 0$

$32+16d-8d^2 = 0$

$8d^2 - 16d - 32 = 0$

$d^2 - 2d - 4 = 0$

Using almighty formula

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

$$d = \frac{-(-2) \pm \sqrt{(-2)^2 - 4(1)(-4)}}{2(1)}$$

~~$d = 1 \pm 4.4721$~~

~~$d =$~~

$d = 1 \pm 4.4721$

$d = 5.5$ or $-3.5m$

The point on x-axis is $5.5m$ or $-3.5m$

SECTION B

QUESTION 4

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

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

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

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

$q = 1.6 \times 10^{-19} C$

$$V = \frac{qBr}{m}$$

$$= \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1} \times 1.4 \times 10^{-7}}{9.11 \times 10^{-31}}$$

$V = 8.61 \times 10^{3} m/s$

∴ Angular speed / cyclotron frequency

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

$$= \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times10^{-31}}$$

$$= 6.15\times10^{10} \text{ rads}$$

c) The charge particle circulates at the angular frequency or angular speed of 6.15×10^{10} rads in the type of accelerator called cyclotron. Therefore, angular speed can also be seen as the cyclotron frequency.

QUESTION 5.

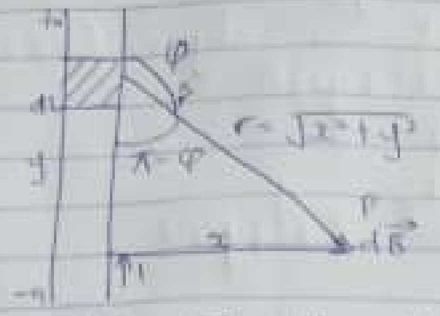
a) The Biot-Savart law is an equation describing the magnetic field generated by a constant electric current. It is given as

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

where μ_0 is a constant called permeability of free space.

$\mu_0 = 4\pi \times10^{-7}$ T.m/A.

1)



A section of a straight current carrying conductor

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

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

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

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

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

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

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

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 it infinitely long. That is, when a is much larger than x,

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

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

At all points in a circle of radius r, around the conductor,

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