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a) Electric field is a region of space in which an electric charge will experience an electric force. While electric field intensity is the force per unit charge.

b.

P_2 P_1

$q_1 = 8nC$ 3 7

$q_2 = 12nC$

i. $E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = \frac{72}{49} = 1.47N/C$

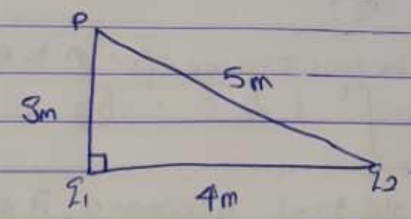
$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9 \times 12\times10^{-9}}{(7-4)^2} = \frac{108}{9} = 12N/C$

$E_{net} = E_1 + E_2 = 1.47 + 12$

$E_{net} = 13.47$

$E_{net} \simeq 13.5N/C$

ii.



$|Pq_2| = \sqrt{3^2+4^2} = \sqrt{25} = 5m$

$\sin x = 3/5$, $x = \sin^{-1}(3/5) = 36.9°$

$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9\times8\times10^{-9}}{3^2} = \frac{72}{9} = 8N/C$

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9\times12\times10^{-9}}{5^2} = \frac{108}{25} = 4.32N/C$

Vector	Angle	x - Component	y - component
$E_1 = 8N/C$	$90°$	$E_1x = 8\cos 90 = 0$	$E_1y = 8\sin 90 = 8$
$E_2 = 4.32N/C$	$36.9°$	$E_2x = 4.32\cos 36.9 = 3.46$	$E_2y = 4.32\sin 36.9 = 2.59$
		$\Sigma E_x = 3.46N/C$	$\Sigma E_y = 10.59N/C$

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

$E = \sqrt{(3.46)^2 + (10.59)^2}$

$E = \sqrt{11.9716 + 112.1481}$

$E = \sqrt{124.1197}$

$E = 11.14 \, N/C$

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

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

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

b) To move the test charge from A to B at constant velocity, an external force of $F = -q_0 E$ must act on the charge

$\therefore$ Work done $dW = F \cdot dl \quad \ldots (1)$

But $F = -q_0 E \quad \ldots (2)$

Put (2) in (1)

$dW = -q_0 E dl \quad \ldots (3)$

Total work done in moving the test charge from A to B is

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

From the definition of electric potential difference, it follows

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

Put (4) into (5)

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

c $Q_1 = 1$

$Q_2 = -$

When

$0 =$

$\frac{0}{9\times10^9}$

$\frac{2\times}{r}$

When

Rec

The

$V =$

4 Mag

field

b $m =$

$r =$

B

9 $Q_1 = 10\times10^{-6}C$

$Q_2 = -2\times10^{-6}C$

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

When $V = 0$

$$0 = 9\times10^9 \times \left[\frac{10\times10^{-6}}{r_1} - \frac{2\times10^{-6}}{r_2}\right]$$

$$\frac{0}{9\times10^9} = \frac{10\times10^{-6}}{r_1} - \frac{2\times10^{-6}}{r_2}$$

$$\frac{2\times10^{-6}}{r_2} = \frac{10\times10^{-6}}{r_1}$$

$$2\times10^{-6}r_1 = 10\times10^{-6}r_2$$

$$2r_1 = 10r_2$$

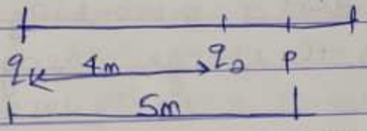
$$r_1 = 5r_2$$

When $r_2 = 1m$, $r_1 = 5m$

$r_2 = 2m$, $r_1 = 10m$

$r_2 = 3m$, $r_1 = 15m$

Recall the distance from q_1 to q_2 is 4m



Therefore 5m to the origin on the axis where $V = 0$. That is the position [5m]

9a Magnetic flux is defined as the strength of the magnetic field which can be represented by the lines of force

b $m = 9.11\times10^{-31}kg$ $\quad$ $w = ?$

$r = 1.4\times10^{-7}m$ $\quad$ $q = 1.6\times10^{-19}$

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

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

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

$w = \frac{5.6\times10^{-20}}{9.11\times10^{-31}}$

$w = \frac{5.6\times10^{-20--31}}{9.11} = \frac{5.6\times10^{11}}{9.11}$

$w = 6.1471\times10^{10}$

$w \simeq 6.15\times10^{10}\,rad/s$

c) In (b) above we were given parameters such as mass, radius and magnetic field. And we were asked to find the cyclotron frequency which is equal to the angular speed. It is called cyclotron frequency because the charge particle circulates at the angular frequency.

5a) Biot-Savart law states that the magnetic field is directly proportional to the product of permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to the square of radius (r^2). Mathematically, $dB = \frac{\mu_0 dl I r}{4\pi r^2}$

b) To 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 $x^2 + y^2 = r^2$ pythagoras theorem.

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

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

Put (2) into (1)

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

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

Recall $dl = dy$

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

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

Using special integrals:

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

Equ (3) therefore becomes

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

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

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

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

In physical situation, we have axial symmetry about the y-axis. Therefore $B = \frac{\mu_0 I}{2\pi r}$