MADUBOM OLUCHI PRECIOUS
MEDICAL LABORATORY SCIENCE
19/MHS06/020

SECTION A

Electric field and electric field intensity

Electric field	Electric field intensity
⇒ It is a region of space in which any electric charge will experience an electric force	It is the force per unit charge

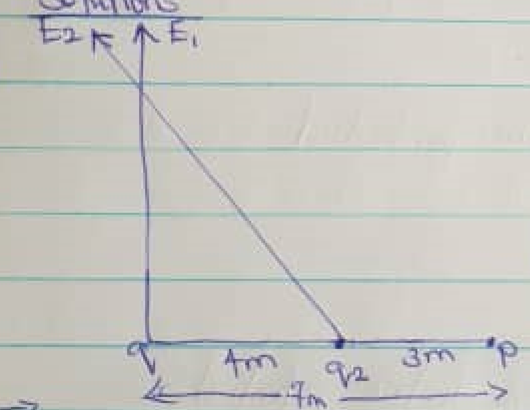
2 $q_1 = 8nC$ at origin. $q_2 = 12nC$ on x axis at $\lambda = 4m$

i) net electric field at point p on the axis at $x = 7m$

ii) electric field at a point Q on the y axis at $y = 3m$ due to the charges.

Solutions

i)



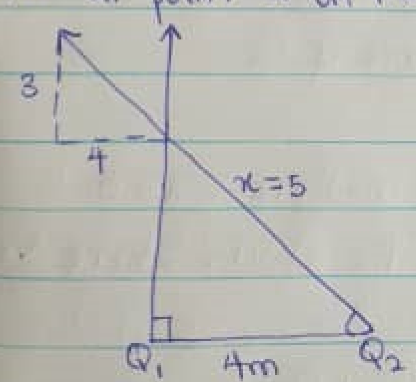
$E_1 = \frac{KQ_1}{r_2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2}$

$= 1.469 N/c \approx 1.5N/c$

$E_2 = \frac{KQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{7^2} = 12N/c$

$E_{net} = \vec{E_1} + \vec{E_2} = 12 + 1.5 = 13.5N/c$

ii) $\vec{E}$ at point Q on the y axis at $y = 3m$ due to charge



$c^2 = a^2 + b^2$

$c^2 = 4^2 + 3^2 = 5$

$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = 8N/c$

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32N/c$

Vector	Angle	x-comp	y-comp
$E_1 = 8N/C$	90°	$0 N/C$	$8N/C$
$E_2 = 4.32N/C$	36.87°	$-3.45N/C$	$2.59N/C$
		$\Sigma f_x = -3.45N/C$	$\Sigma f_y = 10.59N/C$

$$E_{net} = \sqrt{\Sigma f_x^2 + \Sigma f_y^2}$$
$$E_{net} = 11.12N/C$$

3) Formulation of identities of charge

i) Volume charge density $\rho = dQ/dv = dQ = \rho dv$

ii) Surface charge density $\sigma = dQ/dA = dQ = \sigma dA$

iii) Inner charge density $\lambda = dQ/dk = dQ = \lambda dk$

b) electric potential difference equation

- due to a single point charge

$$V_B - V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

where Q = point charge v = electric pontential

r_B = distance of Q to point B

r_A = distance of Q to point A

- due to several point charges

$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

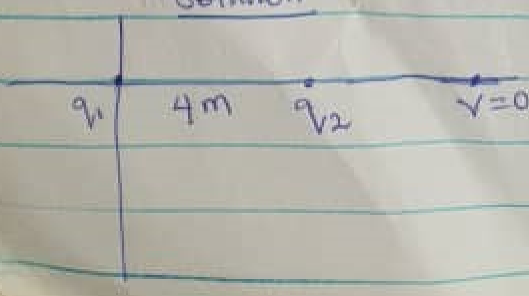
where v = electric potential

Q = point charge

r = distance of Q

3c) Point charge $Q_1 = 10\mu C$ $Q_2 = -2\mu C$ along x-axis $x = 0$ $x = 4m$ respectively. find the position along the x-axis where $v = 0$

Solution



$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

$\Rightarrow$ Recall $\frac{1}{4\pi\varepsilon_0} = k = 9\times10^9$

$$V_p = k\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

$$V_p = 9\times10^{9} \times \left[\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right]$$

$$\cancel{V_p} = 0 = 9\times10^{9} \times \left[\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right]$$

$$0 = \frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x} = \frac{10\times10^{-6}}{4+x} = \frac{2\times10^{-6}}{x}$$

$$10\times10^{-6}x = (4+x)(2\times10^{-6})$$

$$10\times10^{-6}x = 8\times10^{-6} + 2\times10^{-6}x$$

$$8\times10^{-6} = 10\times10^{-6}x - 2\times10^{-6}x$$

$$8\times10^{-6} = 8\times10^{-6}x$$

$$x = \frac{8\times10^{-6}}{8\times10^{-6}} = 1$$

∴ position along the x-axis is 1m

where $V = 0$

$$V = k\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$$

$$0 = \left[\frac{10\times10^{-6}}{4-x} + \frac{-2\times10^{-6}}{x}\right]$$

$$\frac{2\times10^{-6}}{x} = \frac{10\times10^{-6}}{4-x}$$

$$(4-x)(2\times10^{-6}) = 10\times10^{-6}x$$

$$8\times10^{-6} - 2\times10^{-6}x = 10\times10^{-6}x$$

$$8\times10^{-6} = 10\times10^{-6}x + 2\times10^{-6}x$$

$$8\times10^{-6} = 12\times10^{-6}x$$

$$x = \frac{8\times10^{-6}}{12\times10^{-6}} = 0.67m$$

∴ Position of $V=0$ is $0.67m$

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SECTION B

4a) Magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is denoted as ϕ.

$$\phi = B \cdot dA$$

b) $m_e = 9.11 \times 10^{-31}$ kg, $r = 1.4 \times 10^{-7}$ m, $B = 3.5 \times 10^{-1}$ w/m^2

cyclotron frequency = angular speed $q = 1.6 \times 10^{-19}$

$$F_B = qvB = \frac{m_e v^2}{r}$$

$$m_e v = qBr$$

$$v = \frac{qBr}{m_e} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1} \times 1.4 \times 10^{-7}}{9.11 \times 10^{-31}} = 8.61 \times 10^{-3} \text{ m/s}$$

$$\omega = \frac{v}{r} = \frac{qB}{m_e} = \frac{1.6 \times 10^{-19} \times 3 \times 5 \times 10^{-1}}{9.11 \times 10^{-31}} = 6.14 \times 10^{10} s^{-1}$$

4c) In 4b we were given parameters, mass of electron $= 9.11 \times 10^{-31}$ kg, radius $= 1.4 \times 10^{-7}$ m, $B = 3.5 \times 10^{-1}$ w/m^2

We were asked to find the cyclotron frequency which is the same thing as angular speed. It is called cyclotron frequency because it is a frequency of an accelerator called cyclotron.

Recall ω = angular speed; $\omega = \frac{qB}{m_e}$ since cyclotron frequency = angular speed

The

The cyclotron frequency $= 6.14 \times 10^{-10} s^{-1}$ having a unit of $\frac{1}{T}$ which is the unit of frequency dimensionally.

5a) Bio-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to the square of radius.

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

5b)

$t a^{2}$

dL

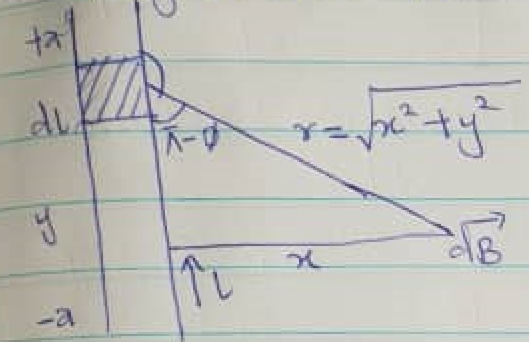
y

$-a$

Ap

th-

5b) Magnetic field of a straight current carrying conductor



A section of a straight current carrying conductor.

Applying Bio-savart law, we find the magnitude of the field ($\vec{dB}$) from the diagram

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

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

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

from the diagram $r^2 = x^2 + y^2$

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

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

substitute (ii) into (i)

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

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

$dl = dy$; $B = \dfrac{\mu_0 I x}{4\pi} \displaystyle\int_{-a}^{a} \frac{1}{(x^2+y^2)^{3/2}} dy$ ---(iii)

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

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

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