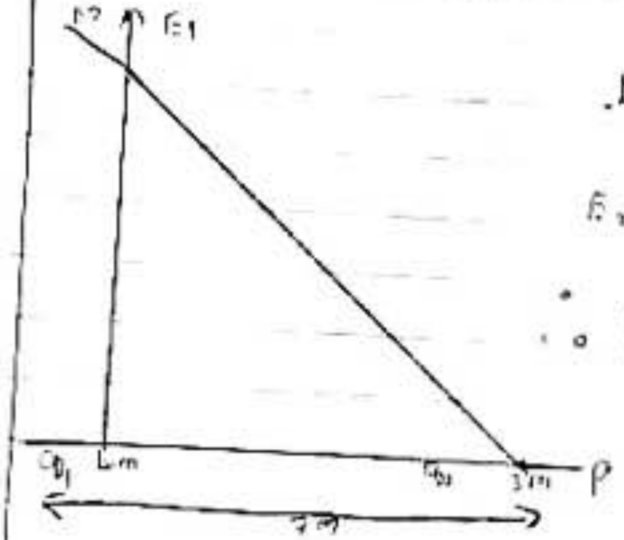
Name: [illegible]
Dept: [illegible]
Matric: [illegible]
Course code: [illegible]

Assignment

1. Distinguish between the terms: electric field and electric field intensity.
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.

2. A positive charge $Q_1 = 8nC$ at the origin.
A second positive charge $Q_2 = 12nC$ on the x-axis at x = 4m.
i. The net electric field at a point P on the x-axis at x = 6m.
ii. The electric field at a point Q on the y-axis at y = 3m.

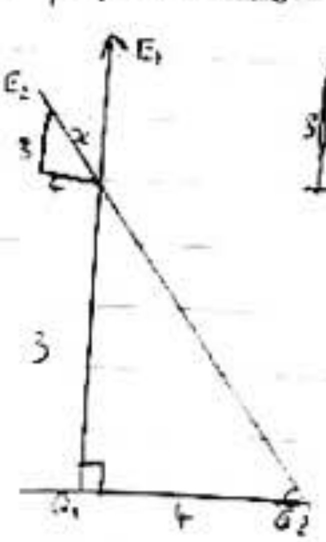


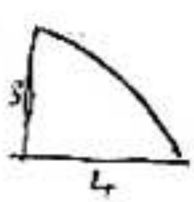
$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{6^2}$ [illegible]

$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{2^2}$ [illegible]

$\therefore E_{net} = \vec{E}_1 + E_2$
$= (\ldots + \ldots)$ N/C $= \ldots$ N/C

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





$C^2 = 4^2 + 6^2$
$C^2 = 4^2 + 3^2$
$C^2 = 16 + 9$
$C^2 = \sqrt{25}$
$C = 5$

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

$= 8N/C$

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

$= 4.32 N/C$

Vector	angle	x-comp	y-comp
$E_1 = 8N/C$	90°	0 N/C	

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10°	N/C	[illegible]
[illegible]	56.3°	1.45 N/C	8 N/C
			5.4 N/C

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

$$= 11.12\,N/C = 11.13\,N/C$$

2) Formulation of identities of charges

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

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

iii) Linear charge density. $\tau = \frac{dQ}{dt} \longrightarrow dQ = \tau\, dt$

3a) Explain with appropriate equations the electrical potential difference

Electrical potential difference ~~is a difference~~ between two points in electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to another.

Electrical potential due to a single point charge

$$V_B - V_A = \frac{Q}{4\pi\epsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

where V = Electrical potential

r_B = is the distance of Q to point B.

r_A = is the distance of Q to point A.

Q = is the point charge

Due to several point charge

$$V = \sum_{i=1,2}^{n} V_i = \frac{1}{4\pi\epsilon_0}\sum_{i=1,2}^{n}\frac{Q_i}{r_i}$$

where Q_i is the value of the ith charge and r_i is the distance of this charge from point P.

(b) $Q_1 = 10\,NC$

$Q_2 = 2\,NC$

$x = 0$

$x = Lm$ Position along the x-axis when $x = 0$

$$V_P = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right) \quad \text{Recall } \frac{1}{4\pi\epsilon_0} = 9\times10^9 = k$$

$$V_P = k\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right)$$

$$V_P = 9\times10^9\left(\frac{10\times10^{-6}}{L+x} + \frac{-2\times10^{-6}}{x}\right)$$

$$0 = 9\times10^9\left(\frac{10\times10^{-6}}{4+x} + \frac{-2\times10^{-6}}{x}\right)$$

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

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

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

$8 \times 10^{-6} = 8 \times 10^{-6} x$

$x = \frac{8 \times 10^{-6}}{8 \times 10^{-6}}$

$x = 1$

$\therefore$ Position along the x-axis is 1m

where $V = 0$

$V = k\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right)$

$0 = \left(\frac{10 \times 10^{-6}}{4-x} + \frac{-2 \times 10^{-6}}{x}\right)$

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

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

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

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

$8 \times 10^{-6} = 12 \times 10^{-6} x$

$x = \frac{8 \times 10^{-6}}{12 \times 10^{-6}}$

$x = 0.67$

Position of $V = 0$ is 0.67m

Section B

4a) This is defined as the strength of magnetic field represented by lines of force It is usually represented by the symbol ϕ

4b) An electron (mass) = 9.11×10^{-31} kg $Q = 1.6 \times 10^{-19}$ ---- constant.

Radius = 1.4×10^{-7}m

Magnetic field = 3.5×10^{-1}

$M_e = 9.11 \times 10^{-31}$ kg

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

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

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

$FB = qVB = \frac{M_e V_1}{r}$

$\frac{m_e v}{r}$ ... qBr

$v = \frac{qBr}{m_e} = \frac{1.6\times10^{-19}\times3.5\times10^{-1}\times1.4\times10^{-7}}{9.11\times10^{-31}}$

$v = \frac{7.84\times10^{-27}}{9.11\times10^{-31}} = 8.61\times10^{-3}\,m/s$

$W = \frac{v}{r} = \frac{qBr}{rm_e} = \frac{1.6\times10^{-19}\times3.5\times10^{-1}}{9.11\times10^{-31}}$

$W = 6.14\times10^{10}\,e^{-1}$

(4) In 4b, we were given parameters; mass of electron $= 9.11\times10^{-31}$ kg, radius $= 1.4\times10^{-7}$ m, $B = 3.5\times10^{-5}$, Cyclotron freq. 1.6×10^{9} and we were asked to find cyclotron frequency which is known as angular speed. It is called cyclotron frequency because it has a frequency called cyclotron.

Recall W = angular speed

$w = \frac{qB}{m_e}$ Since cyclotron frequency = angular speed

The cyclotron frequency $= 6.14\times10^{10}\,e^{-1}$ having a unit of $1/T$ which is the unit of frequency dimensionally.

(5) 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 square of radius (r^2). Mathematically

$$\vec{dB} = \frac{\mu_0 I}{4\pi}\frac{\vec{dl}\times\hat{r}}{r^2}$$

where μ_0 (permeability of free space) $= 4\pi\times10^{-7}$ T.m/A; r = radius, $\vec{dB}$ = magnetic field, I = steady current, dl = length of wire, unit is w/A^2

Magnetic field of a straight current carrying conductor

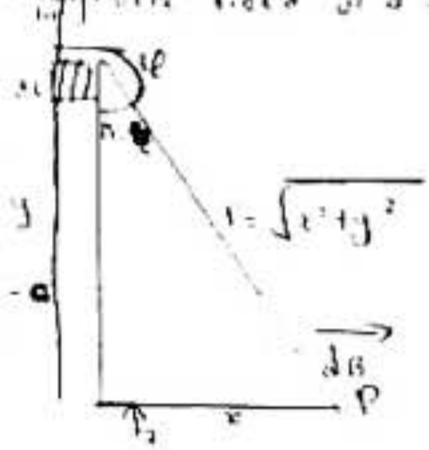


Illustration of a straight current carrying conductor

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

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

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

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

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

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

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

Substituting (ii) into (i), 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 $dl = dy$

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

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

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 (iv) therefore becomes

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

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

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

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

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