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DEPARTMENT: MEDICAL LABORATORY SCIENCE (MLS)
MAT NO: 19/MHS06/006
Course Code: PHY 102

SECTION B

4a Magnetic flux is defined as the strength of the magnetic field which can be represented by lines of forces. It is represented by the symbol Φ. Mathematically given as $\Phi = B \cdot dA$.

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

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

$B = 3.5 \times 10^{-1}$ weber/meter^2

cyclotron frequency = angular speed.

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

$$\omega = \frac{qB}{m} = \frac{1.6 \times 10^{-19} \times 3.5 \times 10^{-1}}{9 \times 10^{-31}}$$

$\omega = 62222222222.22222 T s^{-1}$

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c) In 4(b) above, we were given parameters to find the cyclotron frequency of a moving electron. We have mass of the electron = 9.11×10^{-31} kg

Radius = 1.4×10^{-7} m

magnetic field = 3.5×10^{-1} weber.

Cyclotron frequency is the same thing as angular speed. It is known as cyclotron frequency because it is a frequency of an accelerator called CYCLOTRON.

Substituting the given values, we have:

$$\frac{qB}{m} = \frac{1.6 \times 10^{-10} \times 3.5 \times 10^{-10}}{9.11 \times 10^{-31}}$$

$= 62222222222.22222 T^{-1}$

So since cyclotron frequency is equal to angular speed the cyclotron frequency is equal to $62222222222.22222 T^{-1}$, having a unit as (T^{-1}) which is equal to the unit of frequency dimensionally

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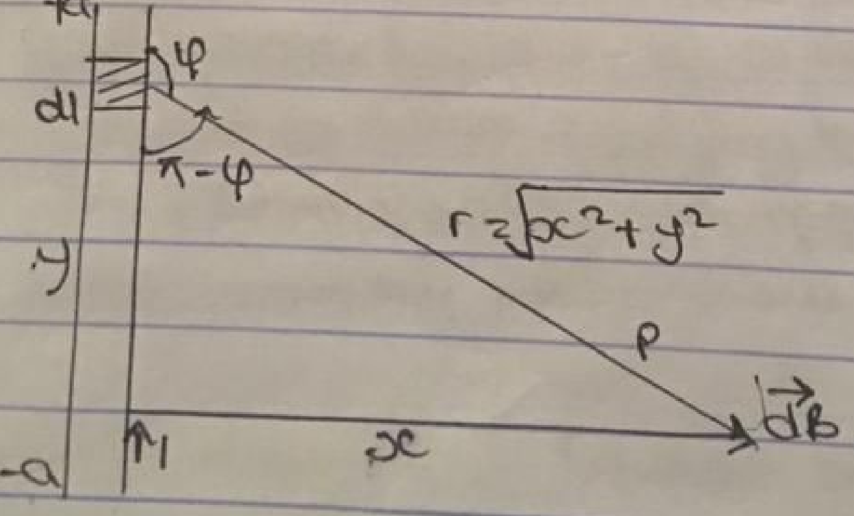
5a Biot-Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to square of radius (r²). It can be represented mathematically by

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

Where μ_0 is a constant called permeability of free space. $\mu_0 = 4\pi \times 10^{-7} T \frac{m}{A}$

The unit of B is weber/metre square

5b Magnetic field of a straight current carrying conductor.



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So continued

Fig 1: A section of a straight current carrying conductor applying the Biot-Savart law, we find the magnitude of the field dB

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

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

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

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

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

But $\sin(\pi - \varphi) = \frac{x}{\sqrt{x^2+y^2}} = \frac{x}{(x^2+y^2)^{\sqrt{2}}}$ ..... (ii)

substituting eqn (ii) into (i) we have

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

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

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5b continued

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;

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

Equation (iii) 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.

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5b continued

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

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

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, the magnitude of B is

$$B = \frac{\mu_0 I}{2\pi r} \quad \text{---- (*)}$$

Equation (*) defines the magnitude of the magnetic field of flux density B near a long, straight current carrying conductor.

SECTION A

3a(i) Volume charge density; $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

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

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

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3b 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 volts (V) or joules per coulomb (J/C). Electric potential difference is a scalar quantity.

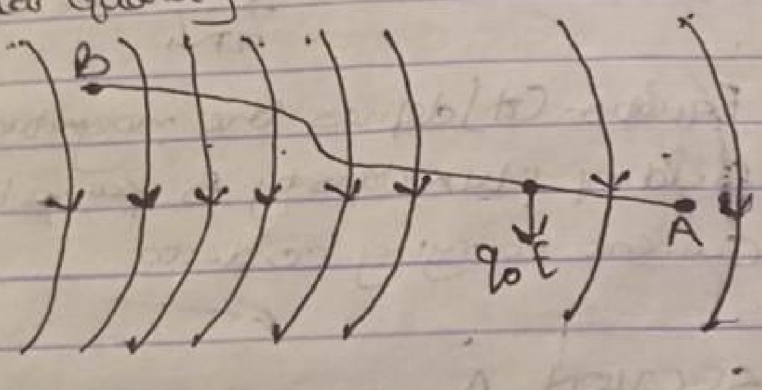

fig 4-1

Consider the diagram above, suppose a test charge q_0 is moved from point A to point B along an arbitrary path inside an electric field E. The electric field E exerts a force $F = q_0E$ on the charge as shown in fig 4-1. To move the test charge from A to B at constant velocity, an external force of $F = -q_0E$ must act on the charge. Therefore, the elemental work done dW

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is given as: $dW = F \cdot dl$ —— (1)

But, $F = -q_0 E$ —— (2)

Substituting equation (2) in (1) yields

$dW = -q_0 E dl$ ---- (3)

$\Rightarrow W = -q_0 E dl$ --- (3)

The total work done in moving the test charge from A to B is $W(A \rightarrow B)_{Ag} = -q_0 \int_A^B E dl$ --- (4).

From the definition of electric potential difference, it follows that:

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

putting equation (4) in (5) yields

$V_B - V_A = -\int_A^B E dl$ ---- (6)

1a Charging by induction:

Electric charges can be obtained on an object without touching it, by a process called electrostatic induction. Consider a positively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to

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1a continued.

ground as shown below. The repulsive force betw the protons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some protons move to the side of the sphere farthest away from the rod (fig 13a). The region of the sphere nearest the positively charged rod has an access of negative charge because of the migration of protons away from this location. If a grounded conducting wire to then connected to the sphere, as in (fig 13b), some of the protons leave the sphere and travel to the earth. If the wire to ground is then removed fig (13c). The conducting sphere is left with an excess of induced negative charge. Finally, when the rubber is removed from the vicinity of the sphere fig (13d), the induced, negatively charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere

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Diagram:

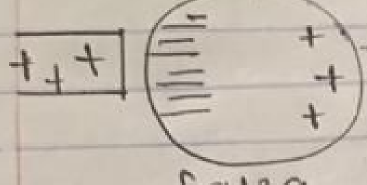

fig 13a

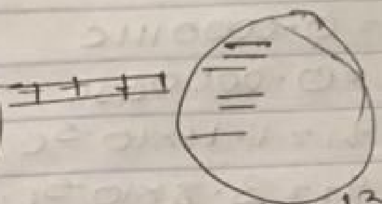

fig 13c

fig 13b

fig 13d

1b $K=9\times10^9$, $q_1+q_2=5\times10^{-5}C$, $F=1N$, $d=2m$

calculate the charge on each sphere?

Recall that? $K=9\times10^9$

$$F=\frac{kq_1q_2}{r^2}$$

$$1=\frac{9\times10^9\times(q_1q_2 5\times10^{-5})}{2^2}$$

$$4=9\times10^9\times5\times10^{-5}q_1+9\times10^9q_2$$

$$4=4.5\times10^5q_2+9\times10^9q_2$$

It is a quadratic equation.

$$9\times10^9q_2-4.5\times10^5q_1+4=0$$

1c

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$9\times10^9 q_2$

$q_1 = 0.0000111C$

$q_2 = 0.000038C$

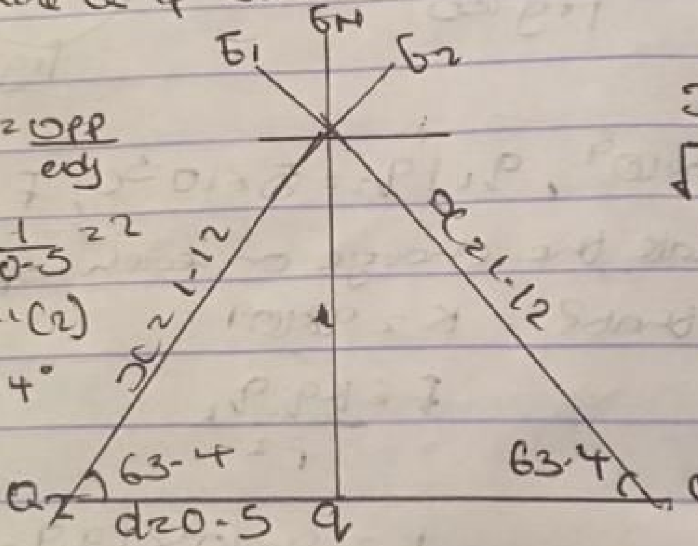
$\therefore q_1 = 1.11\times10^{-5}C$

$\therefore q_2 = 3.8\times10^{-5}C.$

1C $Q_1 = Q_2 = 8\mu C$

$d = 0.5m$

determine Q if electric Field at a point P is zero



$Tan\theta = \frac{opp}{adj}$

$Tan\theta = \frac{1}{0.5} = 2$

$\theta = Tan^{-1}(2)$

$\theta = 63.4°$

$x^2 = 1^2 + 0.5^2$

$\sqrt{x^2} = \sqrt{1.25}$

$x = \sqrt{1.25}$

$x = 1.12$

$$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.795918$$

$$E_2 = \frac{kq_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5739.795918$$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{1} = ~~5739~~ \cdot 9\times10^9 q$

Vector	angle	x-comp	y-comp
$E_1 = 5739.795918$	$63.4°$	$E_1 \times \cos\theta$	
		-2570.045785	5132.262835
$E_2 = 5739.795918$	$63.4°$	2570.045785	5132.262895
$E_q = 9\times10^9 q$	$90°$	$E_q\cos\theta = 0$	$9\times10^9 q$
		$\Sigma x = 0$	Σy^2
			10264.5256

magnitude $= \sqrt{(\Sigma x)^2 + (\Sigma y)^2}$

$E_q = \sqrt{(0)^2 + (10264.52568)^2}$

since $E_q = 0$

$0 = 9\times10^9 q + 10264.52568$

making q subject of formulae

$q = \frac{-10264.52568}{9\times10^9}$

$q = 1.140502853\times10^{-16}$

$\therefore q = 11.4 \mu C$ ..