2/6/24

Sunday

Biot - savart law XII physics - 2024

unit → 3

5 mark

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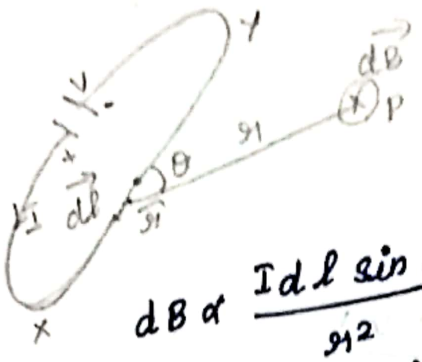

$$dB \propto \frac{I\,dl\,\sin\theta}{r^2}$$

$$dB = K\,\frac{I\,dl\,\sin\theta}{r^2}$$

$K = \frac{\mu_0}{4\pi}$ $\mu_0 \to$ permaelitity of free space

$\mu_0 \to 4\pi \times 10^{-7}\,Hm^{-1}$

$$dB = \frac{\mu_0}{4\pi}\,\frac{I\,dl\,\sin\theta}{r^2}$$ H - Henry

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

$\theta = 90^\circ$

$$\vec{dB} = \frac{\mu_0}{4\pi}\,\frac{I\,dl\,\sin 90^\circ}{r^2}\,\hat{r}$$ $\sin 90^\circ = 1$

$$\vec{dB} = \frac{\mu_0}{4\pi}\,\frac{I\,dl\,(1)}{r^2}\,\hat{r}$$

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

net magnetic field

$$\vec{B} = \int \vec{dB}$$

$$\vec{B} = \int \frac{\mu_0}{4\pi}\,\frac{I\,dl}{r^2}\,\hat{r}$$ $\frac{\mu_0 I}{4\pi}$ = constant

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

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Special case

1) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2} \hat{r}$ $\theta = 0°$

$\theta = 0°$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta(0°)}{r^2} \hat{r}$ $\sin(0°) = 0$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl\,(0)}{r^2} \hat{r}$ $\theta = 90°$

$d\vec{B} = \frac{\mu_0}{4\pi} (0) \hat{r}$

$d\vec{B} = 0$

ii) case

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2} \hat{r}$

$\theta = 90°$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl \sin(90°)}{r^2} \hat{r}$ $\sin(90°) = 1$

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

$F \propto q$

$F \propto Idl$

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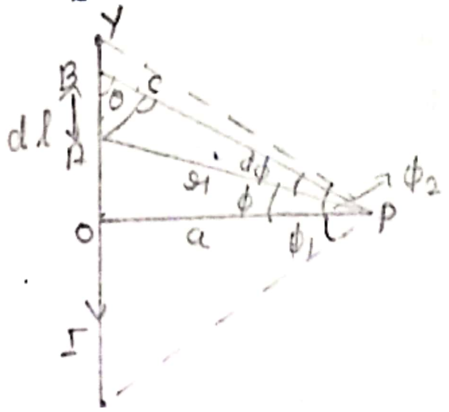
Book Back

2) L/A (2/5 mark)

2) Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor Biot - savart law



YY' → Infinitely long straight conductor

I → steady current

a → distance

dl → small line element

$AB = dl$

θ → Angle

r → distance

$OP = a$

$AP = r$

using a Biot - savart law

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2} \hat{r}$$

i) $\Delta ABC \rightarrow \sin\theta$

ii) $\Delta APC \rightarrow \sin\theta$

iii) $\Delta OPA \rightarrow \cos\theta$

i) ΔABC

$$\sin\theta = \frac{AC}{AB}$$

$AB \sin\theta = AC$

$AB = dl$

$dl \sin\theta = AC$

ii) ΔAPC

$$\sin\theta = \frac{AC}{AP}$$

$$\sin\theta = \frac{AC}{AP}$$

$\theta = d\phi$

$$\sin(d\phi) = \frac{AC}{AP} \qquad \sin d\phi = d\phi$$

$AP = r$

$AP \sin(d\phi) = AC$

$r\, d\phi = AC$

$AC = dl \sin\theta$

$$r\,d\phi = dl\sin\theta$$

$$dl\sin\theta = r\,d\phi$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,\cancel{r}\,d\phi}{r^2}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\phi}{r}\hat{r}$$

iv) ΔOPA

$$\cos\theta = \frac{OP}{AP} \qquad \theta=\phi$$

$$\cos\phi = \frac{OP}{AP} \qquad OP=a$$

$$AP=r$$

$$\cos\phi = \frac{a}{r}$$

$$r = \frac{a}{\cos\phi}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\phi}{r}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\phi}{\frac{a}{\cos\phi}}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\phi}{a}\cos\phi\,\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{a}\cos\phi\,d\phi\,\hat{r}$$

$$d\vec{B} = \frac{\mu_0 I}{4\pi a}\cos\phi\,d\phi\,\hat{r}$$

Total magnetic field

$$\vec{B} = \int_{-\phi_1}^{\phi_2} d\vec{B}$$

$$\vec{B} = \int_{\phi_1}^{\phi_2} \vec{dB}$$

$$\vec{B} = \int_{\phi_1}^{\phi_2} \frac{\mu_0 I}{4\pi a} \cos\phi \, d\phi \, \hat{n}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \int_{\phi_1}^{\phi_2} \cos\phi \, d\phi$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[\sin\phi\right]_{\phi_1}^{\phi_2} \qquad \int \cos\phi \, d\phi = \sin\phi$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[\sin\phi_2 - (-\sin\phi_1)\right]$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[\sin\phi_2 + \sin\phi_1\right]$$

$$\phi_2 = \phi_1 = 90^\circ$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[\sin(90) + \sin 90^\circ\right]$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[1+1\right] \qquad \sin 90^\circ = 1$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} \hat{n} \left[2\right]$$

$$\vec{B} = \frac{\mu_0 I}{2\pi a} \hat{n}$$

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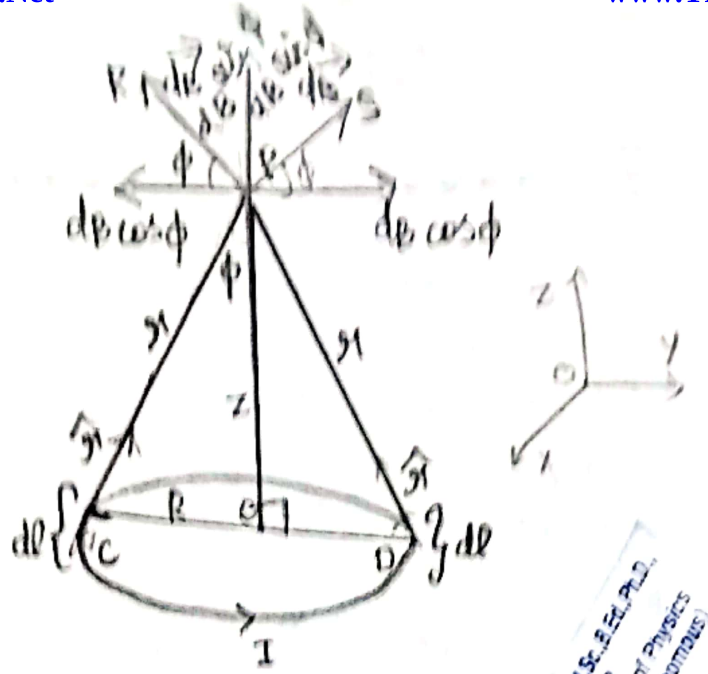
3) LA 3|5 mark

magnetic field produced along the axis of the current carrying circular coil



I → current

R → Radius

circular coil

z = distance

O → centre of coil

each coil length → dl

dB cos φ → y direction

dB sin φ → x direction

Horizontal component direction

vertical component direction

using Biot savart law

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

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

$\theta = 90°$

$$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin(90°)}{r^2}$$

$$dB = \frac{\mu_0}{4\pi} \frac{I dl (1)}{r^2}$$

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

net magnetic field

$$\vec{B} = \int d\vec{B}$$

$$\vec{B} = \int dB \sin\phi \,\hat{k}$$

$$\vec{B} = \int \frac{\mu_0}{4\pi} \frac{I\,dl}{r^2} \sin\phi \,\hat{k}$$

$$\vec{B} = \int \frac{\mu_0 I}{4\pi} \frac{dl}{r^2} \sin\phi \,\hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{dl}{r^2} \sin\phi \,\hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{1}{r^2} \sin\phi \,\hat{k}\, dl$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \,\hat{k} \int dl$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \,\hat{k} \int_0^{2\pi R} dl$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \,\hat{k} \,[l]_0^{2\pi R} \qquad \int dl = l$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \cdot \hat{k} \,[2\pi R - 0]$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{r^2} \sin\phi \cdot \hat{k} = [2\pi R]$$

$$r^2 = R^2 + z^2$$

$$\sin\phi = \frac{R}{\sqrt{R^2+z^2}}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{1}{R^2+z^2} \frac{R}{\sqrt{R^2+z^2}} \cdot \hat{k} \,[2\pi R]$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{R}{(R^2+z^2)\sqrt{R^2+z^2}} (2\pi R) \cdot \hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{R}{(R^2+z^2)(R^2+z^2)^{1/2}} \cdot (2\pi R) \cdot \hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{R}{(R^2+z^2)^{3/2}} (2\pi R) \cdot \hat{k}$$

$$\vec{B} = \frac{4 \mu_0 I}{2} \frac{R(R)}{(R^2+z^2)^{3/2}} \cdot \hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{2} \frac{R^2}{(R^2+z^2)^{3/2}} \cdot \hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{2} \frac{R^2}{(R^2)^{3/2}} \hat{k}$$

$z=0$

$$\vec{B} = \frac{\mu_0 I}{2} \frac{R^2}{R^3}$$

$$\vec{B} = \frac{\mu_0 I}{2} \frac{1}{R} \cdot k$$

$$\vec{B} = \frac{\mu_0 I}{2R}$$

number of turns

$$\vec{B} = \frac{\mu_0 N I}{2R} \cdot \hat{k}$$

3/6/24 Monday

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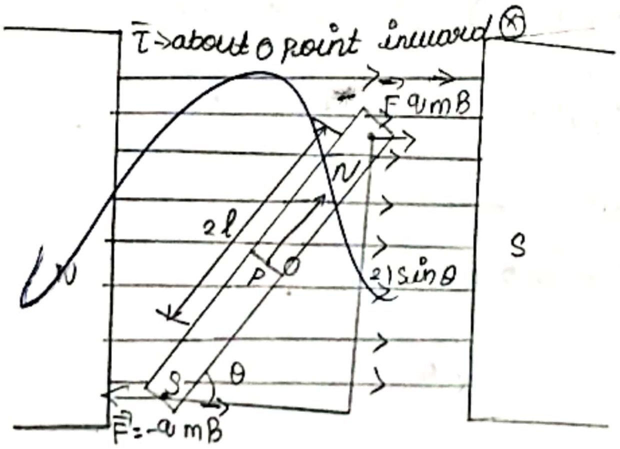
L/A 4th 5 mark

4) compute the torque experienced by a magnetic needle in a uniform magnetic field



Bar magnet

magnet length l

$S \Rightarrow$ south pole

$N \Rightarrow$ North pole

$B \Rightarrow$ uniform magnetic field

$q_m \Rightarrow$ magnetic pole strength

$q_m B \Rightarrow$ acting opposite direction

net magnet is zero

North pole

$$\vec{F}_N = q_m \vec{B}$$

south pole (opposite direction)

$$\vec{F}_S = -q_m \vec{B}$$

net Force acting dipole

$$\vec{F} = \vec{F}_N + \vec{F}_S$$

$$\vec{F}_{net} = q_m \vec{B} + (-q_m \vec{B})$$

$$\vec{F}_{net} = q_m B - q_m B$$

$$\vec{F}_{net} = 0$$

The net magnet is zero

Torque

$$\vec{\tau} = (\vec{ON} \times \vec{F}_N) + (\vec{OS} \times \vec{F}_S)$$

$$\vec{\tau} = (\vec{ON} \times q_m \vec{B}) + (\vec{OS} \times (-q_m \vec{B}))$$

$$|\vec{\tau}| = |\vec{ON}|\,|q_m \vec{B}| + |\vec{OS}| \times |-q_m \vec{B}|$$

$$ON = l \quad OS = l$$

$$\tau = l\, q_m B \sin\theta + l\, q_m B \sin\theta$$

$$\tau = (l + l)\, q_m B \sin\theta$$

$\tau = 2l\, q_m B \sin\theta$

$\tau = P_m B \sin\theta$

$\vec{\tau} = \vec{P_m} \times \vec{B}$

5 mark
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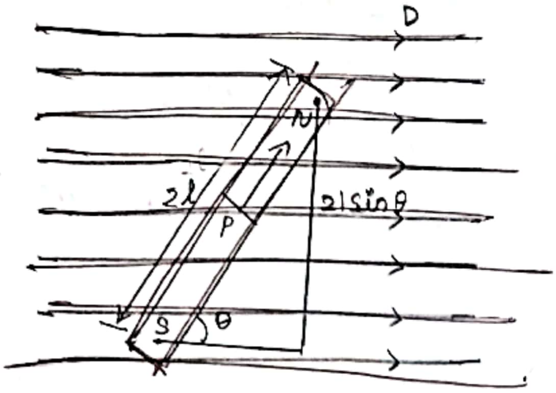
Potential energy of a bar magnet in a uniform magnetic field



$dw = |\tau_{ext}|\, d\theta$

$dw = P_m B \sin\theta\, d\theta$

Total workdone

$w = \int_{\theta'}^{\theta} dw$

$w = \int_{\theta'}^{\theta} P_m B \sin\theta\, d\theta$

$w = P_m B \int_{\theta'}^{\theta} \sin\theta\, d\theta$

$\int \sin\theta\, d\theta = -\cos\theta$

$w = P_m B \left[-\cos\theta\right]_{\theta'}^{\theta}$

$w = -P_m B \left[\cos\theta\right]_{\theta'}^{\theta}$

$w = -P_m B \left[\cos\theta - \cos\theta'\right]$

$w = -P_m B \left[\cos\theta - \cos 90\right]$ $\theta = 90^\circ$

$\cos 90 = 0$

$w = -P_m B \left[\cos\theta - 0\right]$

$W = -P_m B \cos\theta$

$\vec{W} = -\vec{P_m} \cdot \vec{B}$

$W = U$

$U = -\vec{P_m} \cdot \vec{B}$

$U = -P_m B \cos\theta$

i) $\theta = 0°$ special case

$U = -P_m B \cos(0)$ $\qquad \cos(0) = 1$

$U = -P_m B(1)$

$U = -P_m B$ $\qquad$ minimum

$U_{parallel} = -P_m B$

$$\boxed{U_{parallel} = U_{minimum} = -P_m B}$$

ii) $\theta = 180°$

$U = -P_m B \cos(180°)$

$U = -P_m B(-1)$

$U = P_m B$ $\qquad$ maximum

$U_{anti\ parallel} = P_m B$

$$\boxed{U_{anti\ parallel} = U_{maximum} = P_m B}$$

Pg: 140 Example 3.7

i) $U = -P_m B \cos\theta$

$U_{parallel} = U_{minimum} = -P_m B \cos(0°)$

$= -P_m B \qquad \cos(0) = 1$

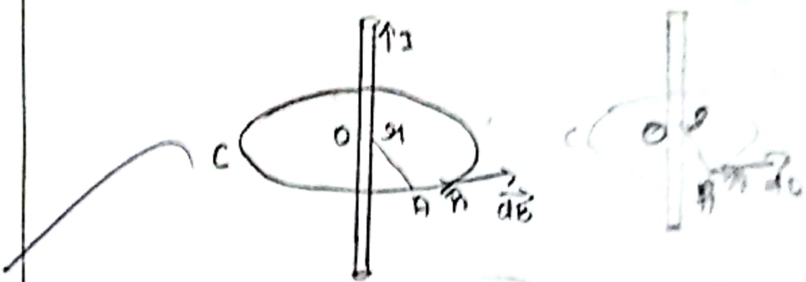
$U_{anti\ parallel} = U_{minimum} = -P_m B \cos\theta(180)$

$= -P_m B(-1)$

$= P_m B$

7) B/B L/A 7 Qu.

7) Find the magnetic field due to a long straight conductor using Ampere's circuital law



I → current

cylindrical shape

symmentorical about axis

circular shape

distance r

using Ampere circuital law

straight conductor

Infinite length

$\vec{B}$ magnetic field

circuital law formula

$$\oint_C \vec{B}\cdot\vec{dl} = \mu_0 I$$

using Ampere's circuital law

$$\oint_C \vec{B}\,\vec{dl} = \mu_0 I$$

$$B\oint_C dl = \mu_0 I$$

$$B\int_0^{2\pi r} dl = \mu_0 I$$

$$B[l]_0^{2\pi r} = \mu_0 I$$

$$B(2\pi r - 0) = \mu_0 I$$

$$B(2\pi r) = \mu_0 I$$

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

$$\vec{B} = \frac{\mu_0 I}{2\pi r} \cdot \hat{n}$$

pg:163 Example 3.15

$I = 1A$

$r = 1m$

$B = ?$

Earth magnetic field $B \sim 10^{-5} T$ compared?

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

$\mu_0 = 4\pi \times 10^{-7} \, Hm^{-1}$

$$B = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 1}$$

T - Tesla

$$B = 2 \times 10^{-7} T$$

So, $B_{straightwire}$ is one hundred times smaller than B_{Earth}.

63/[illegible]/24