-:(Applied Physics):-

Semester # 01:-

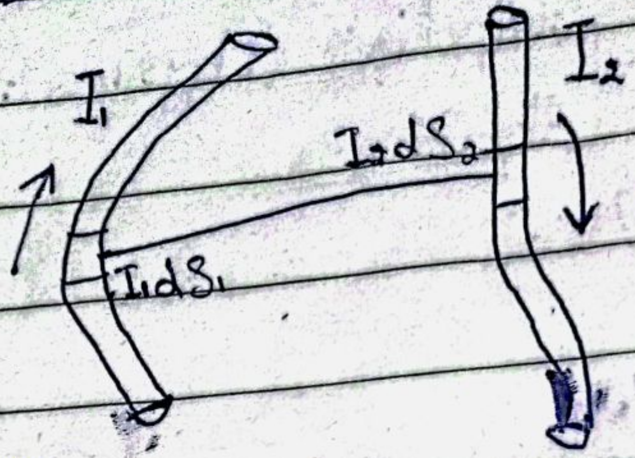
Ch # 09:-

QNo 1:-
State and explain Biot-Savart law?

Answer:-
Biot-Savart law:-
The magnitude of magnetic field at a point due to current distribution is directly proportional to amount of current and length of conductor.
And Inversely proportional to the square of distance b/w point and current distribution.

The magnetic field is generated around a conductor when currents flows through it.

Diagram:-



Explanation:-

Now consider two conductors through which current I_1 and I_2 flows in opposite direction.

Divide the first wire into differential element dS_1 and the define for each element a length vector $\vec{dS_1}$ that has magnitude dS_1 and direction is the direction of current in dS_1.

In this way, differential current length element of first wire is $I_1 \vec{dS_1}$.

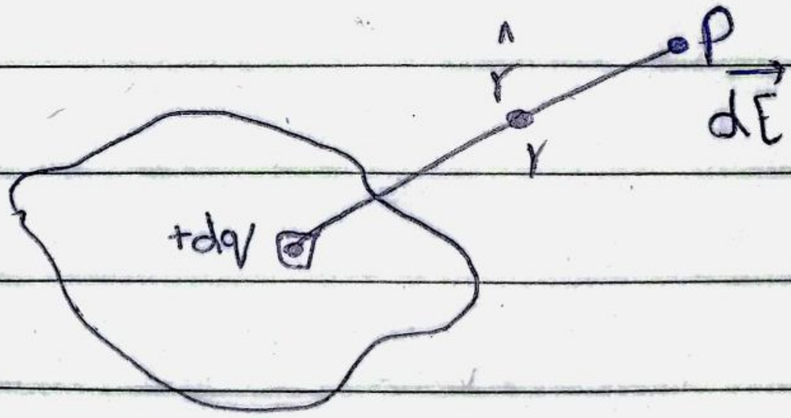
Similarly differential current length element of second wire is $I_2 d\vec{S}_2$.

The magnetic force $d\vec{F}_{12}$ exerted on current element $I_2 d\vec{S}_2$ which is placed in magnetic field $\vec{B}_1$ ~~of~~ is:

$$dF_{12} = I_2 (d\vec{S}_2 \times \vec{B}_1)$$

Similarly The dF_{21} placed in $\vec{B}_2$ is:

$$dF_{21} = I_1 (d\vec{S}_1 \times B_2)$$

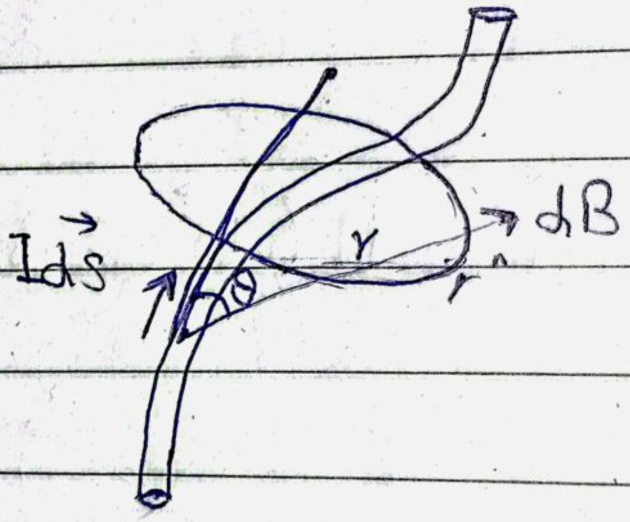


Now Take a point P having distance 'r' from charge dq of some charge distribution. The electric field $\vec{dE}$ is given as:

$$\boxed{d\vec{E} = \frac{K\,dq}{r^2} \times \hat{r}}$$

Similarly, take a point P having distance r from current element $I d\vec{S}$ of some current distribution.

The magnetic field $d\vec{B}$ is given as:



$$d\vec{B} = \frac{K\, I d\vec{S}}{r^2} \times \hat{r}$$

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

Q.No2:-

By using Biot-Savart law, determine the magnetic field at a point having distance R away from the long straight current carrying wire?

Ans:-

"The magnetic field is generated when current flows through a straight conductor."

Consider a long straight wire to infinite length through which current I flows.

Take a point P having perpendicular distance R from wire. Φ

By using Biot-Savart law:

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dS \sin\theta}{r^2} \quad \text{--- (i)}$$

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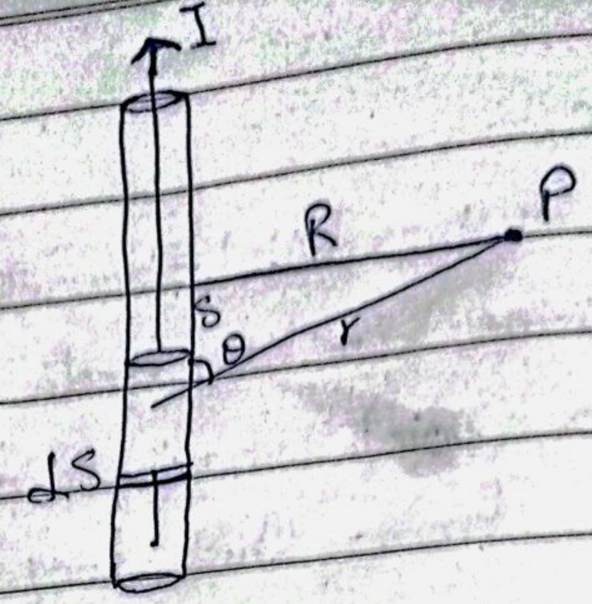


By Phategerous Theorem:

$$r^2 = R^2 + S^2$$

and $\sin\theta = \dfrac{R}{r} = \dfrac{R}{\sqrt{R^2+S^2}}$

Put in (i)

$$dB = \frac{\mu_0}{4\pi}\left(\frac{I\,dS}{R^2+S^2}\right)\left(\frac{R}{\sqrt{R^2+S^2}}\right)$$

$$dB = \frac{\mu_0 IR}{4\pi}\;\frac{dS}{(R^2+S^2)^{3/2}}$$

The net magnetic field is

$$B = \int_{-\infty}^{+\infty} dB = \int_{-\infty}^{+\infty} 2dB = \int_{-\infty}^{+\infty} 2dB$$

$$B = 2\int_{-\infty}^{\infty} dB$$

$$B = \cancel{2}\int_{-\infty}^{\infty} \frac{\mu_0 IR}{\cancel{4}\pi}\;\frac{dS}{(R^2+S^2)^{3/2}}$$

Put $S = R\cot\theta$ then $dS = -R\,\mathrm{cosec}^2\theta\, d\theta$

when $S = 0$

$0 = R\cot\theta$

$\cot\theta = 0$

$\dfrac{\cos\theta}{\sin\theta} = 0$

$\cos\theta = 0$

$\theta = \cos^{-1}(0)$

$\boxed{\theta = 90^\circ}$

when $S = \infty$

~~$\infty = \cot\theta R$~~

~~$\cot\theta = \infty$~~

$\infty = \cot\theta R$

$\dfrac{\infty}{R} = \cot\theta$

$\dfrac{R}{\infty} = \tan\theta$

$\tan\theta = 0$

$\dfrac{\sin\theta}{\cos\theta} = 0$

$\sin\theta = 0$

$\theta = \sin^{-1}(0)$

$\boxed{\theta = 0^\circ}$

$$B = \frac{\mu_0 I R}{2\pi} \int_0^{90} \frac{-R\,\mathrm{cosec}^2\theta\, d\theta}{(R^2 + R^2\cot^2\theta)^{3/2}}$$

$$B = \frac{\mu_0 I R}{2\pi} \int_0^{90} \frac{-R\,\mathrm{cosec}^2\theta\, d\theta}{(R^2)^{3/2}(1+\cot^2\theta)^{3/2}}$$

$$B = \frac{\mu_0 I R}{2\pi R^3} \int_0^{90} \frac{-R\,\mathrm{cosec}^2\theta\, d\theta}{(\mathrm{cosec}^2\theta)^{3/2}}$$

$$B = \frac{\mu_0 I}{2\pi R^{\cancel{2}}} \int_{0}^{90°} \frac{-\cancel{R}\, \operatorname{cosec}^2\theta}{\operatorname{cosec}^3\theta}\, d\theta$$

$$B = \frac{-\mu_0 I}{2\pi R} \int_{0}^{90°} \frac{1}{\operatorname{cosec}\theta}\, d\theta$$

$$B = \frac{-\mu_0 I}{2\pi R} \int_{0}^{90°} \sin\theta \, d\theta$$

$$B = \frac{-\mu_0 I}{2\pi R} \left| \cos\theta \right|_{0}^{90°}$$

$$B = \frac{-\mu_0 I}{2\pi R} \left(\cos(90°) - \cos(0°) \right)$$

$$B = \frac{-\mu_0 I}{2\pi R} (0-1)$$

$$\boxed{B = \frac{\mu_0 I}{2\pi R}}$$

This is the magnitude of magnetic field at a point P having perpendicular distance R from current carrying straight conductor.

-:(Physics):-

Semester 01:-

Ch # 09:-

QNo4:-

Two long parallel wires carrying currents I_1 and I_2 are seperated by a distance d. Find magnitude of magnetic force experienced by each wire.

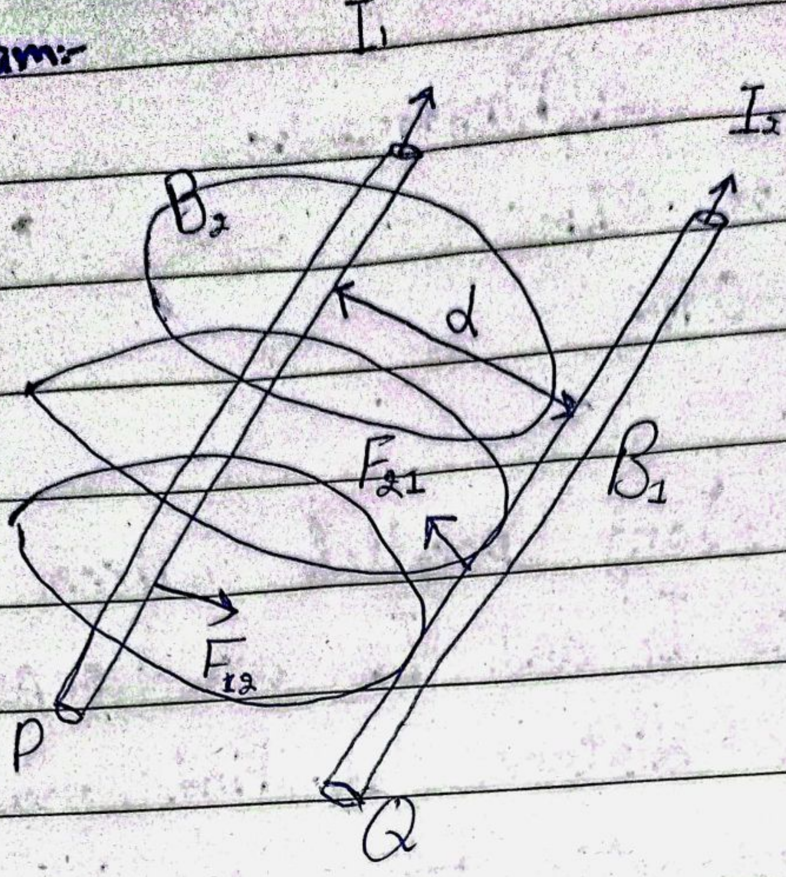
Alternatively, show that parallel currents attracts and anti-parallel currents repel each other?

Answer:-

(i) Parallel Current Attract:-

The parallel current flowing through conductors attract each other. Consider two parallel conductors P and Q each of length L having seperation d.

Diagram:-



The magnitude of magnetic field B_1 where Q is placed is given by Biot-Savart law.

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

The magnetic force experienced by conductor Q having current I_2 is:

$$F_{21} = I_2 L B_1$$

$$F_{21} = I_2 L \frac{\mu_0 I_1}{2\pi d} \quad \text{(i)}$$

This is magnitude of magnetic force which is acting on conductor Q.

Similarly, The magnetic field B_2 where conductor P is placed is given by Biot-Savart law:

$$B_2 = \frac{\mu_0 I_2}{2\pi d}$$

The magnetic force experienced by conductor P having current I_1 is :

$$F_{12} = I_1 L B_2$$

$$F_{12} = I_1 L \frac{\mu_0 I_2}{2\pi d} \quad \text{--- (ii)}$$

Compairing eq (i) and eq (ii)

$$\boxed{F_{12} = F_{21}}$$

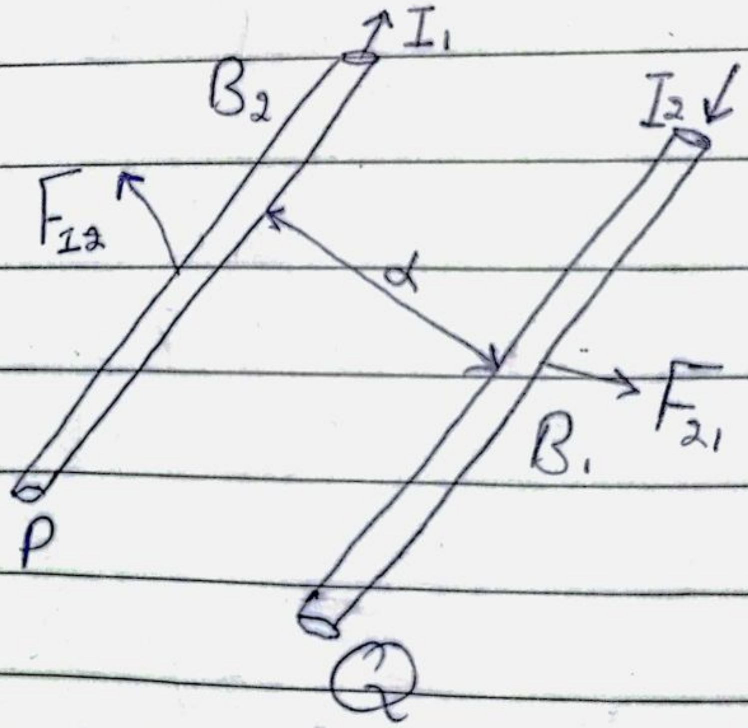
It shows that F_{12} and F_{21} are equal in magnitude but towards each other and their point of application is not same.

(ii) Anti-Parallel current Repels:-

The anti-parallel currents flowing through conductors repel each other.

Consider two parallel conductors P and Q each of length L having seperation d. ~~The current~~

Diagram:-



The magnitude of magnetic field B_1 where conductor Q is placed given by Biot-Savart law.

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

The magnetic force experienced by conductor Q having current I_2 is:

$$F_{21} = I_2 L B_1$$

$$F_{21} = I_2 L \frac{\mu_0 I_1}{2\pi d} \quad \text{—— (i)}$$

This is magnitude of magnetic force which is acting on conductor Q.

Similarly, the magnitude of magnetic field B_2 where the conductor P is placed is given by Biot-Savart law:

$$B_2 = \frac{\mu_0 I_2}{2\pi d}$$

The magnetic force experienced by conductor P carryind current I_1 is:

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$$F_{12} = I_1 L B_2$$

$$F_{12} = I_1 L \frac{\mu_0 I_2}{2\pi d} \quad \text{—— (ii)}$$

Compairing eq (i) and (ii)

$$\boxed{F_{12} = F_{21}}$$

It shows that F_{21} and F_{12} are equal in magnitude but acting away from each other.

-: (Applied Physics) :-

Semester 01:-

Ch # 09:-

Qno5:-

State and explain Ampere law, write its integral and differential form?

Answer:-

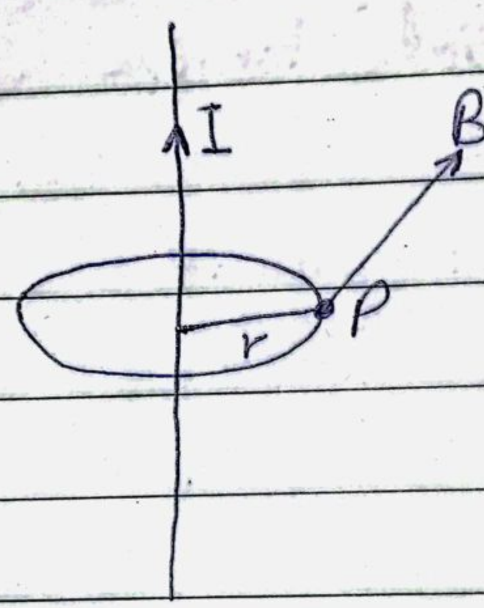
Ampere's law:-

The Ampere's law state that, a magnetic field is generated around a conductor when current flows through it.

The magnitude of generated magnetic field at a point is directly proportional to amount of ~~work~~ current and inversely proportional to the distance between point and straight current carrying conductor.

The direction of magnetic field is given by the Right hand Rule.

Diagram:-



Consider a straight conductor through which current I flows.

The magnetic field B is generated around it.

The magnitude of magnetic field B depends upon current I and distance r between conductor and point P.

$$B \propto \frac{I}{r}$$

$$B = \frac{\mu_0}{2\pi}\left(\frac{I}{r}\right)$$

where $\frac{\mu_0}{2\pi}$ is constant

μ_0 is called permeability of free space. Its value is $4\pi \times 10^{-7}$ where $2\pi r$ is the length of path denoted by l.

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

$$Bl = \mu_0 I$$

$$Bl\cos 0^\circ = \mu_0 I$$

$$\vec{B}\cdot\vec{l} = \mu_0 I$$

Take a small length element dr.

$$\oint \vec{B}\cdot d\vec{r} = \mu_0 I$$

$$\boxed{\oint B\,dr\cos\theta = \mu_0 I}$$

Integral Form

$$\oint \vec{B} \cdot \vec{dr} = \mu_0 I$$

The value of current in terms of current density is:

$$I = \int \vec{J} \cdot \vec{da}$$

So,

$$\boxed{\oint \vec{B} \cdot \vec{dr} = \mu_0 \int \vec{J} \cdot \vec{da}} \quad \text{(i)}$$

This is called integral form of Ampere's laws

Differential form:-

$$\oint \vec{B} \cdot \vec{dr} = \mu_0 \int \vec{J} \cdot \vec{da}$$

By stoke's law:

$$\oint \vec{B} \cdot \vec{dr} = \int (\vec{\nabla} \times \vec{B}) \cdot \vec{da}$$

Put in above eq.

$$\int (\vec{\nabla} \times \vec{B}) \cdot \vec{da} = \mu_0 \int \vec{J} \cdot \vec{da}$$

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$$\int (\vec{\nabla} \times \vec{B} - \mu_0 \vec{J}) . \vec{da} = 0$$

$$\vec{\nabla} \times \vec{B} - \mu_0 \vec{J} = 0$$

$$\boxed{\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}}$$

This is called differential form of Ampere law.

QNo6:-

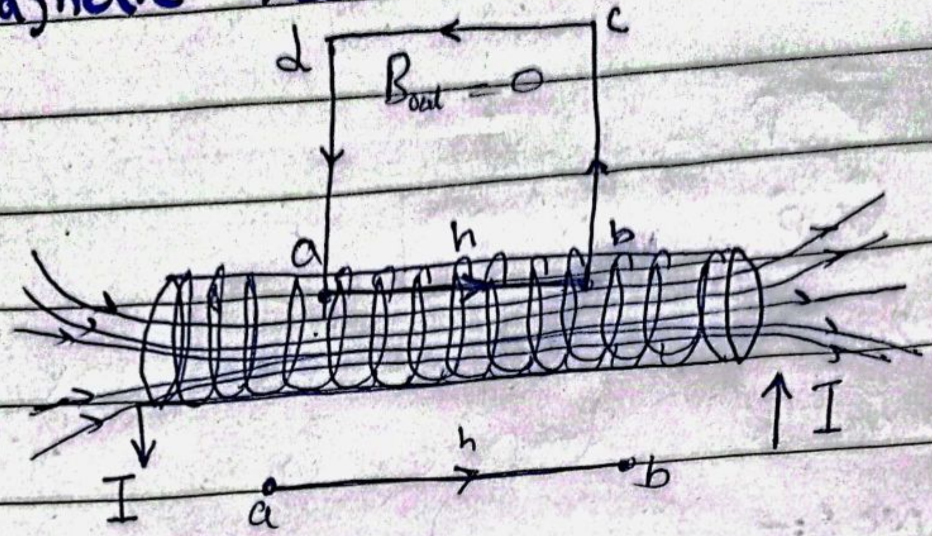
Apply Ampere's law to calculate magnetic field within and outside a current carrying solenoid?

Ans:-

A long tightly wound cylinderical conducting wire is called Solenoid.

The magnetic field is generated when current flows through windings of solenoid.

(i) Magnetic field inside solenoid:-



Consider a solenoid having N turns and length l. The current I. froms through each turn of solenoid.

$$n = \frac{N}{l}$$

The magnetic field outside the solenoid is zero.
Take a loop in the shape of rectangle to calculate magnetic field inside the solenoid.

By Ampere law:

$$\oint \vec{B} \cdot \vec{dr} = \mu_o I$$

$$\int_a^b \vec{B} \cdot \vec{dr} + \int_b^c \vec{B} \cdot \vec{dr} + \int_c^d \vec{B} \cdot \vec{dr} + \int_d^a \vec{B} \cdot \vec{dr} = \mu_o I$$

$$\int_a^b Bdr\cos 0 + \int_b^c Bdr\cos 90° + \int_c^d Bdr\cos 180° + \int_d^a Bdr\cos 90° = \mu_o I$$

$$\int_a^b Bdr(1) + 0 + 0 + 0 = \mu_o I$$

$$\int_a^b B \cdot dr = \mu_o I$$

The length of loop from a to b is h

So

$$hB = \mu_o I \quad \text{——— (i)}$$

Unit length has turn = n

h length has turn = nh

One turn has current = I_o

nh turn has current = nhI_o

$$I = nhI_o \quad \text{——— (ii)}$$

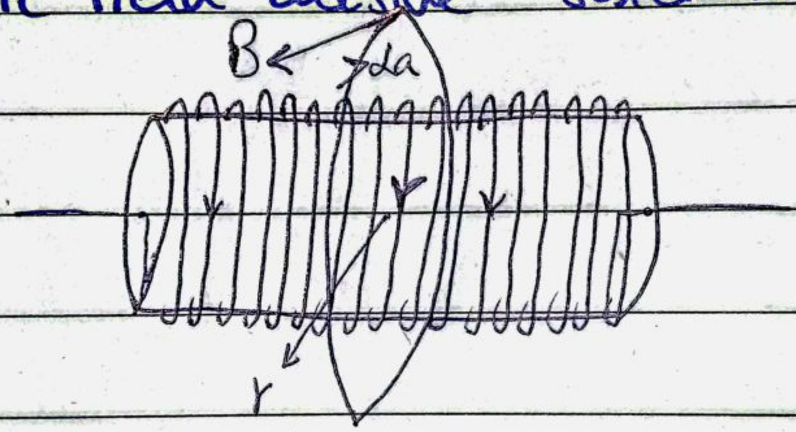
Put in (i)

$$BK = \mu_0 nKI_0$$

$$\boxed{B = \mu_0 n I_0}$$

This is the magnitude of magnetic field inside the solenoid. The direction of magnetic field is given by right hand rule.

(ii) Magnetic field outside solenoid:-



Consider a solenoid having n terms per unit length. The current I_0 flow through each turn of solenoid.

Imagine a Amperion loop having radius r. The magnetic field lines will be tangential.

By Ampere's law:

$$\oint \vec{B}\cdot d\vec{r} = \mu_o I$$

$$\oint B_t\, dr \cos 0^\circ = \mu_o I_o$$

$$B_t \oint dr = \mu_o I_o$$

$$B_t (2\pi r) = \mu_o I_o$$

$$B_t = \frac{\mu_o I_o}{2\pi r} \quad \text{——— (i)}$$

This is magnetic field outside the solenoid.

we Know that

$$B = \mu_o n I_o \quad \text{——— (ii)}$$

Divide eq (i) by eq (ii)

$$\frac{B_t}{B} = \left(\frac{\cancel{\mu_o}\,\cancel{I_o}}{2\pi r}\right)\left(\frac{1}{\cancel{\mu_o} n \cancel{I_o}}\right)$$

$$\frac{B_t}{B} = \frac{1}{2\pi r n}$$

$$\boxed{B_t = \frac{B}{2\pi r n}}$$

It shows B_t smaller than B because $2\pi r n$ is very large factor. That is why the magnetic field outside the solenoid is weaker than inside.

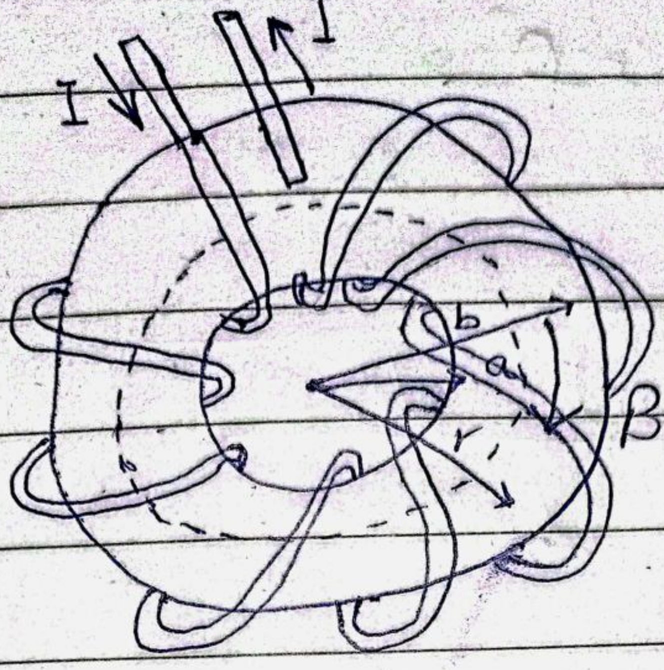
Q No 7:-

Apply Ampere's law to calculate magnetic field at the interior points of a current carrying toroid?

Ans:-

The solenoid bend into circle shape is called Toroid. A strong magnetic field is generated when current flows through windings of solenoid. These magnetic field lines are along the axis of the solenoid.

Magnetic field due to toroid:-



Consider a toroid having N turns and each turn carries current I_o, The total current is:

$$I = NI_o$$

To calculate magnetic field, B at a point P inside Toroid, imagine an Amperion loop of radius r.

The magnetic field B and small length element dr are along tangent direction so make zero angle.

By Ampere's law:

$$\oint \vec{B}\cdot\vec{dr} = \mu_0 I$$

$$\oint B\,dr\cos 0^\circ = \mu_0 N I_0$$

$$B\oint dr = \mu_0 N I_0$$

$$B(2\pi r) = \mu_0 N I_0$$

$$\boxed{B = \frac{\mu_0 N I_0}{2\pi r}}$$

This is magnitude of magnetic field inside toroid. It depends upon turn of toroid and radius r.
The direction of magnetic field within toroid is given by Right hand Rule.

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