Date 06/07/21

Chapter-4

Moving Charges & Magnetism

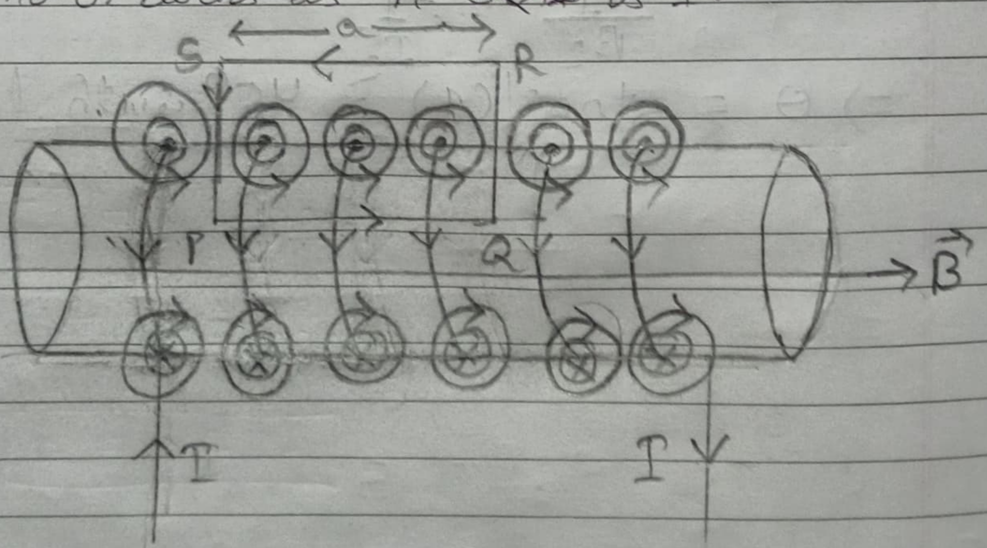
Home Assignment -2

Q1. State Ampere's Circuital law. Show through an example, how this law enables an easy evaluation of the magnetic ~~current~~ field inside a very long solenoid having n turns per unit length carrying a current I.

Ans- Ampere's Circuital law states that the line integral $\oint \vec{B} \cdot \vec{dl}$ for a closed curve is equal to μ_0 times the net current I threading in through the area bounded by the curve.

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

Now,
Lets consider a straight solenoid, where the current passing through the length of the wire with no. of turns as n ~~is~~ is I.



Here,
In this solenoid, the magnetic field only exists at the centre of the solenoid ~~at it is~~ uniformly and at its ends it becomes half.
Outside the solenoid, the magnetic field doesn't exists.

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Here,
As we know that taking one turn of the current flow, the vertical component gets canceled out and the magnetic field exists only for the horizontal component.
So, the same happens for all the turns within the solenoid so, the magnetic field exists only at the horizontal side of solenoid.
Outside the solenoid the magnetic field value is zero.
Now,
Considering an rectangular Ampere loop on the solenoid as PQRS.
Taking the length of PQ = RS = a.
We have to use the Ampere circuit law,
Now,
According to Ampere Circuital law,

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 I_0$$

So, for
L.H.S

$$\oint \vec{B}\cdot\vec{dl} = \oint_P^Q \vec{B}\cdot\vec{dl} + \oint_Q^R \vec{B}\cdot\vec{dl} + \oint_R^S \vec{B}\cdot\vec{dl} + \oint_S^P \vec{B}\cdot\vec{dl}$$

$$= \oint_P^Q B\,dl\cos 0^\circ + \oint_Q^R B\,dl\cos 90^\circ + \oint_R^S B\,dl\cos 0^\circ + \oint_S^P B\,dl\cos 90^\circ$$

$$= \oint_P^Q B\,dl + 0 + \oint_R^S 0\times dl + 0$$

$$= B\cdot\oint_P^Q dl$$

$$= B\cdot a$$

$$\Rightarrow \oint \vec{B}\cdot\vec{dl} = Ba$$

~~R.H.S~~

~~$\oint \mu_0 I_0$~~

Now,

Here, I_0 is the current flowing through the number of ~~po~~ turns per unit length a.

As, here,

$$n = \frac{N}{l} \quad \text{(Number of turns per unit length.)}$$

$$\Rightarrow N = nl \quad \text{(Total number of turns)}$$

Now,

Total current throughout the solenoid

$$I_{net} = NI$$
$$= nlI.$$

Lets consider the length of wire to be l.

So,

For length 'l' current is nlI

For length 'a' current is naI

So, here

$$I_0 = naI.$$

R.H.S

$$\mu_0 I_0 = \mu_0 naI.$$

So, As,

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$
$$\Rightarrow Ba = \mu_0 naI$$
$$\Rightarrow \boxed{B = \mu_0 nI}$$

Here, the magnetic field is evaluated just by no. of turns of flow of current through the solenoid.

So, it can be easily evaluated by taking no. of turns per unit length and current flowing through the solenoid.

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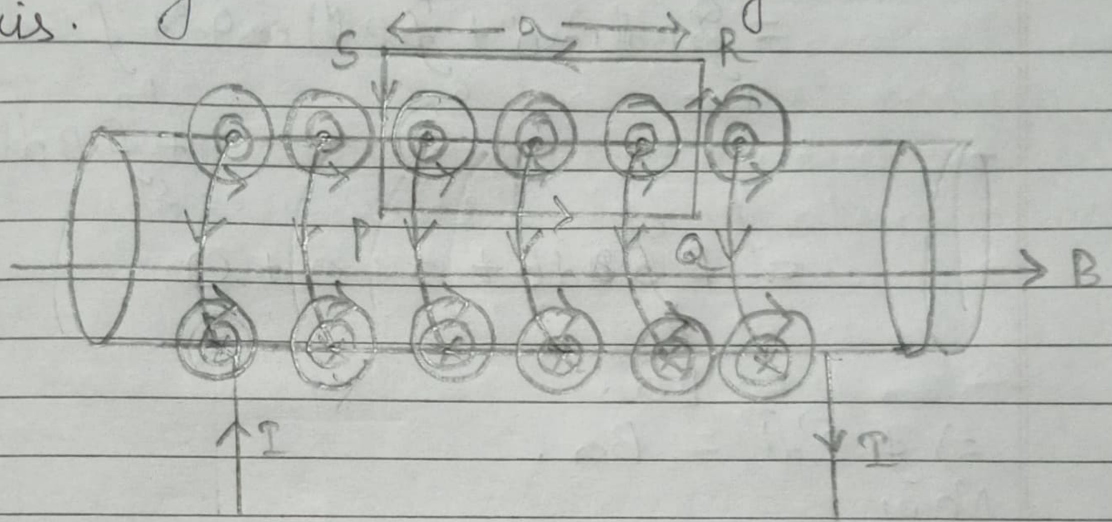
Q.2 Answer the following

a) Using Ampere's circuital law, obtain the expression for the magnetic field due to a long solenoid on its axis.

Ans-



Here,

The Current flowing through each turn = I

Magnetic field only exist at the horizontal axis of the solenoid and not outside the solenoid

Because,

By taking one turn, the vertical components of the magnetic field gets cancelled out and the horizontal component only comes as a result.

Now,

Lets consider the length of solenoid to be l.

Consider,

~~An amper. The curr~~ An amperian loop PQRS of length of side PQ = RS = a.

Now,

Current flowing with length a = I_0.

So,

According to Ampere Circuital law,

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

So,

Lets Consider,

L.H.S

$$\oint \vec{B}\cdot\vec{dl} = \oint_P^Q \vec{B}\cdot\vec{dl} + \oint_Q^R \vec{B}\cdot\vec{dl} + \oint_R^S \vec{B}\cdot\vec{dl} + \oint_S^P \vec{B}\cdot\vec{dl}$$

$$= \oint_P^Q B\,dl\cos 0^\circ + \oint_Q^R B\,dl\cos 90^\circ + \oint_R^S B\,dl\cos 0^\circ + \oint_S^P B\,dl\cos 90^\circ$$

$$= B\oint_P^Q dl + 0 + 0 + 0$$

$$= Ba.$$

$$\Rightarrow \oint \vec{B}\cdot\vec{dl} = Ba.$$

Now,

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

$n \rightarrow$ Number of turns per unit length.

$N \rightarrow$ Total No. of turns.

$N = nl$.

$\therefore$ Total current $= NI = nlI$.

So, here,

Current through length 'l' $= nlI$

Current through length 'a' $= naI$

$\Rightarrow I_0 = naI$.

R.H.S

$\mu_0 I_0 = \mu_0 naI$.

So, Here,

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 I_0$$

$$\Rightarrow Ba = \mu_0 naI$$

$$\Rightarrow \boxed{B = \mu_0 nI}$$

$\therefore$ The expression for magnetic field is.

$$B = \mu_0 nI.$$

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Q.B) In what respect, is a toroid different from a Solenoid? Draw and compare the pattern of the magnetic field lines in the two cases.

Ans- In a toroid, the magnetic field exists only in the tubular area bounded ~~boun~~ by the coil. and it does not exist in the area outside and inside the toroid.

Whereas,

In Solenoid, the magnetic ~~field~~ field exists only inside the solenoid and it uniform at the centre but it gets half towards the ends and it doesn't exist outside the solenoid.

Now,

Diagram for Solenoid:-

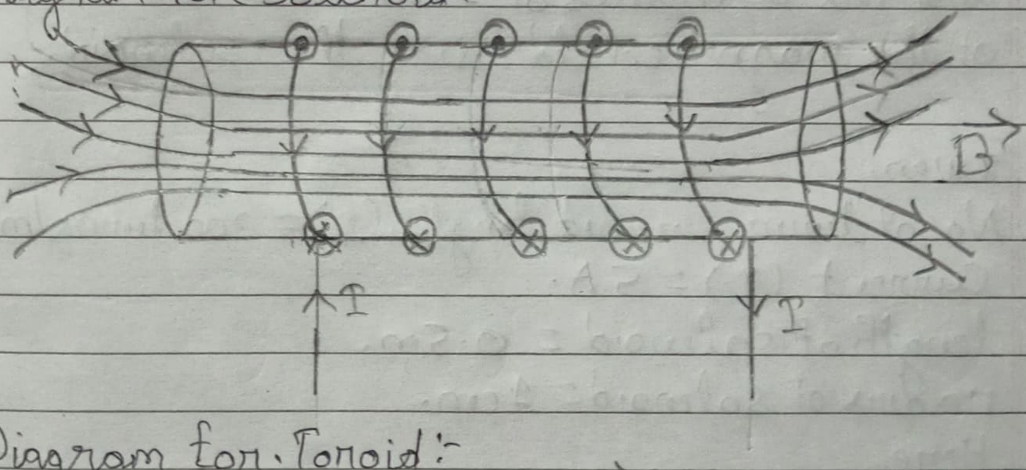
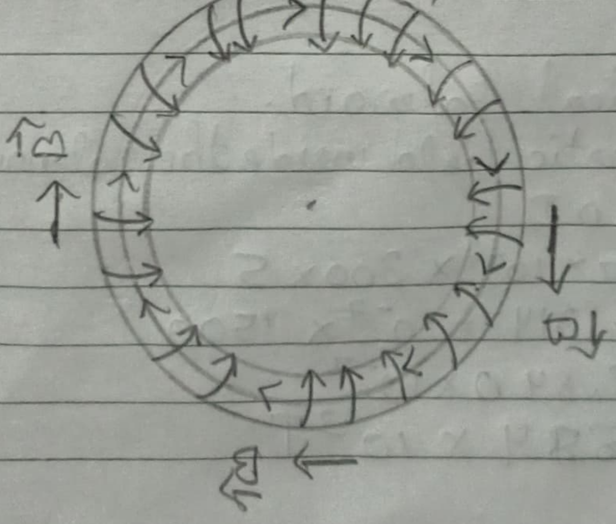


Diagram for Toroid:-



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c) How magnetic field inside a given solenoid made strong.

Ans- The magnetic field inside a give solenoid is made strong. by-
→ Increasing the number of turns per unit length through which current flows.
→ Increasing the current flowing through each turn of the coil.
→ Using laminated coil of soft iron

Q.3. A solenoid coil of 300 turns/m is carrying a current 5A. The length of the solenoid is 0.5m and has a radius of 1 cm. Find the magnitude of the magnetic field inside the solenoid.

Ans- Given,
No. of turns per unit length (n) = 300 turns/m.
Current (I) = 5 A.
length of solenoid = 0.5m.
radius of solenoid = 1 cm.
Here,
length > radius. i.e; 0.5m > 0.01 m.
So,
It is an ideal solenoid.
∴ The magnetic field inside the solenoid is.

$B = \mu_0 n I$
$= 4\pi \times 10^{-7} \times 300 \times 5$
$= 4 \times (3.14) \times 10^{-7} \times 1500$
$= 18,840 \times 10^{-7}$
$= 1.884 \times 10^{-3}$ T

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Q4. A 0.5m long solenoid has 500 turns and has a flux density of 2.52×10^{-3} T at the centre. Find the current in the solenoid. Given. $\mu_0 = 4\pi \times 10^{-7}\ H m^{-1}$

Ans- Given,
Flux density (B) = 2.52×10^{-3} T
length of solenoid = 0.5m.
No. of turns of coil (N) = 500 turns.
∴ No. of turns per unit length.

$$n = \frac{N}{l} = \frac{500}{0.5} = 1000 \text{ turns.}$$

Now,
The current in the solenoid will be.

$$B = \mu_0 n I$$

$$\Rightarrow I = \frac{B}{\mu_0 n}$$

$$= \frac{2.52 \times 10^{-3}}{4\pi \times 10^{-7} \times 1000}$$

$$= \frac{2.52 \times 10^{-3}}{4 \times (3.14) \times 10^{-4}}$$

$$= \frac{0.63}{3.14} \times 10$$

$$= \frac{6.3}{3.14} = 2.0 \text{ A.}$$