6·07·2021

Ch-4

Application of Ampere's law to find the magnetic field of solenoid and toroid.

Home Assignment:

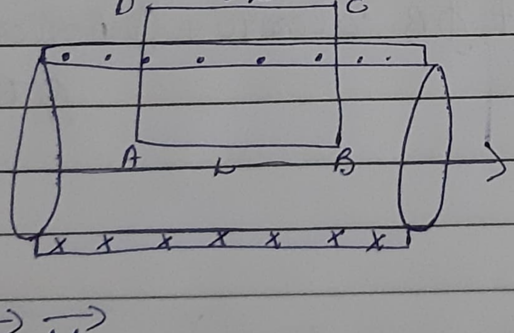
Q 1: State Ampere's circuital law. Show through an example, how this law enables an easy evaluation of the magnetic field inside a very long solenoid having n turns per unit length carrying a current I.

Ans 1. Ampere's circuital law states that "The line integral of the resultant magnetic field along a closed plane curve is equal to μ_0 time the total current crossing the area bounded by the closed curve provided the electric field inside the loop remains constant".

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

Example

Total no. of turns in AB = nL



$$\oint_{ABCD} \vec{B} \cdot \vec{dl}$$

$$= \oint_A^B \vec{B} \cdot dl + \oint_B^C \vec{B} \cdot \vec{dl} + \oint_C^D \vec{B} \cdot \vec{dl} + \oint_D^A \vec{B} \cdot \vec{dl}$$

$$= BL + 0 + 0 + 0$$

$$= BL$$

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

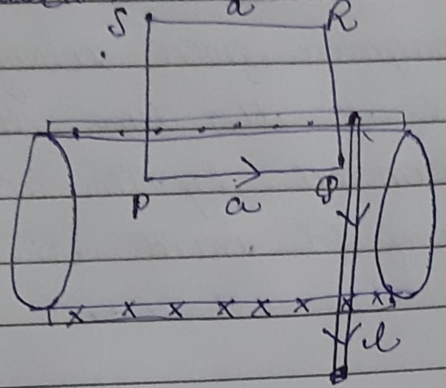
$$\Rightarrow BL = \mu_0 n L I$$

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

Q2 Answer the following:

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

Ans a)



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

$$\oint \vec{B} \cdot \vec{dl} = \oint_{PQ} \vec{B} \cdot \vec{dl} + \oint_{QR} \vec{B} \cdot \vec{dl} + \oint_{RS} \vec{B} \cdot \vec{dl} + \oint_{SP} \vec{B} \cdot \vec{dl}$$

$$= \oint B \cdot dl \cos 0^\circ + \oint B \cdot dl \cos 90^\circ + \oint B \cdot dl \cos 0^\circ + \oint B \cdot dl \cos 90^\circ$$

$$= B \cdot a$$

$$\mu_0 I_0 = \mu_0 n a I$$

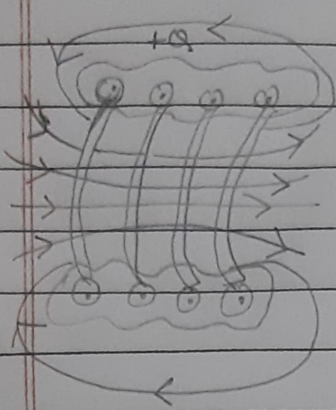
$$\therefore \boxed{B = \mu_0 n I}$$

($n \rightarrow$ no. of turns per unit length
$I \rightarrow$ current
$a \rightarrow$ length of the path)

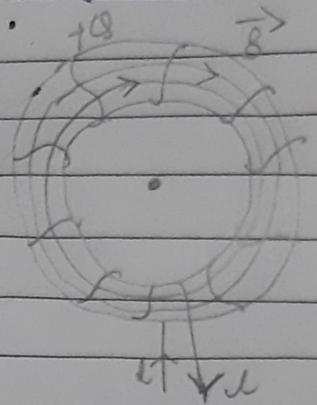
→

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: b) Solenoid



Toroid



→ Magnetic field is created outside

→ Magnetic field is created within

→ It has a uniform magnetic field inside

→ It does not have a uniform magnetic field inside it.

c) How is the magnetic field inside a given solenoid made stronger?

Ans c) The magnetic field inside a given solenoid is made stronger → by increasing the number of turns of the solenoid

→ by increasing the current passing through the solenoid.

→ by inserting an iron core inside it.

→

Q3. A solenoid coil of 300 turns/m is carrying a current of 5A. The length of the solenoid is 0.5 m and has a radius of 1cm. Find the magnitude of the magnetic field inside the solenoid.

Ans 3. $n = 300$

$I = 5A$

$l = 0.5m$

$r = 1cm$

$$B = \mu_0 n I$$
$$= 4\pi \times 10^{-7} \times 300 \times 5$$
$$= 6000 \times 10^{-7} \times \pi$$
$$= 6\pi \times 10^{-4}$$
$$= 18.84 \times 10^{-4} \ T$$

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

Ans 4. $B = \mu_0 n I$

$$2.52 \times 10^{-3} = 4\pi \times 10^{-7} \times 500 \times I$$

$$\Rightarrow I = \frac{2.52 \times 10^{-3} \times 0.5}{4\pi \times 10^{-7} \times 500}$$

$$= \frac{252 \times 10^{7} \times 7 \times 0.5}{4 \times 22 \times 10^{3} \times 100 \times 500}$$

$22 \times 5 = 110$

$$= 2.0 A$$