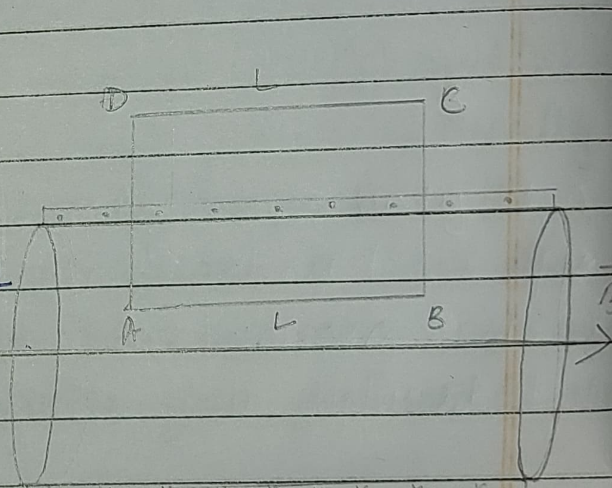
Home Assignment:

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.

A- According to Ampere's circuital law, the line integral of magnetic field induction along a closed curve is equal to total current passing through the surface enclosed in the closed curve times the permeability of the medium.

$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_{in}$

Example:



Total no. of turns in AB = nL

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

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

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

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

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

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

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

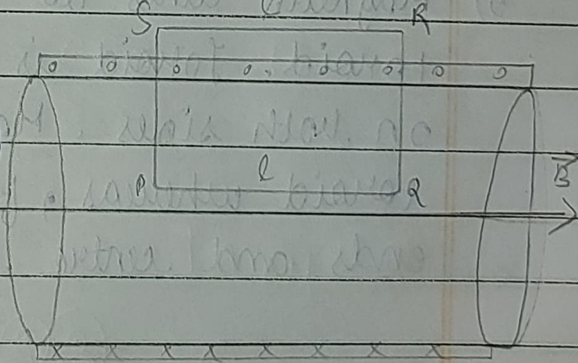
2 Answer the following:

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

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.

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

A - Consider a symmetrical long solenoid having number of turns per unit length equal to n.



Let I be the current flowing in the solenoid, then by right hand rule, the magnetic field is parallel to the axis of the solenoid.

Consider a closed path PQRS.

$$\oint_{PQRS} \vec{B}\cdot d\vec{l} = \oint_{P}^{Q} \vec{B}\cdot d\vec{l} + \oint_{Q}^{R} \vec{B}\cdot d\vec{l} + \oint_{R}^{S} \vec{B}\cdot d\vec{l} + \oint_{S}^{P} \vec{B}\cdot d\vec{l}$$

$$= Bl + 0 + 0 + 0 = Bl$$

$$\oint_{PQRS} \vec{B}\cdot d\vec{l} = Bl$$

Now, using amperes law,

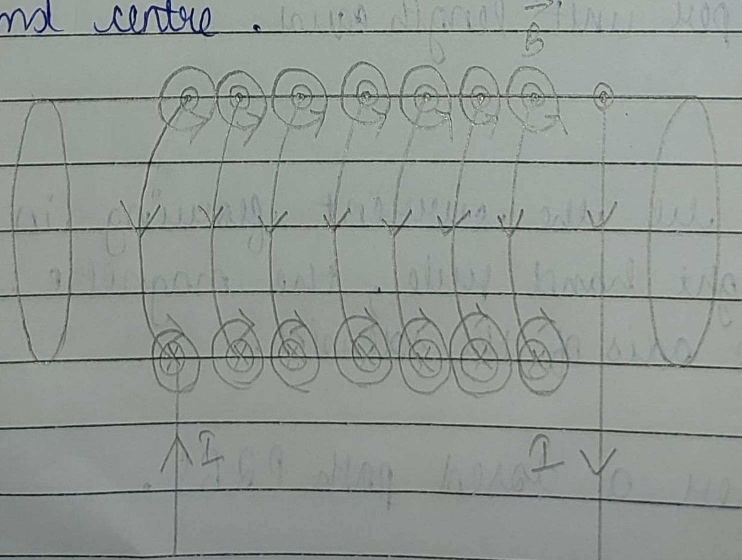
$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$$

This implies,

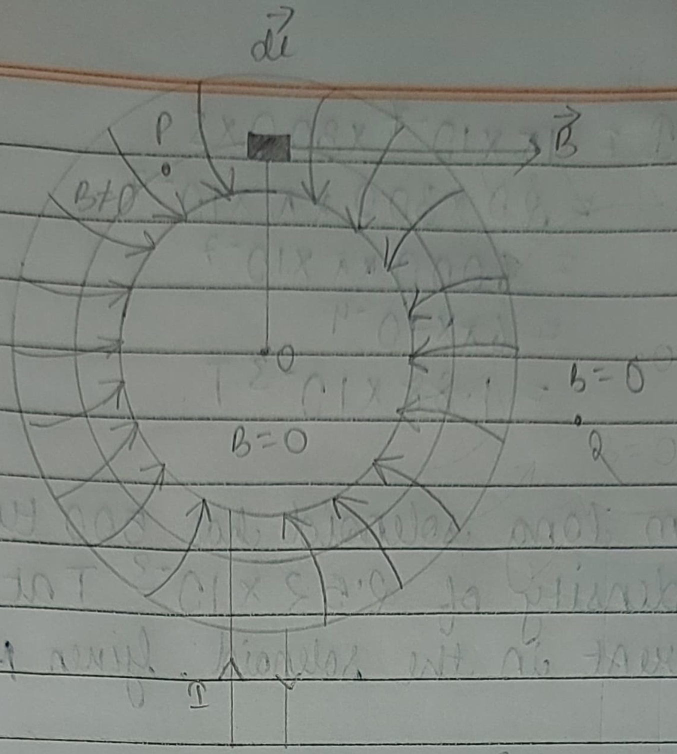
$$Bl = \mu_0 (nlI)$$

$$\Rightarrow B = \mu_0 n I$$

b) Magnetic lines do not exist outside the body of a toroid. Toroid is closed and solenoid is open on both sides. Magnetic field is uniform inside a toroid whereas, for a solenoid it is different at two ends and centre.



SOLENOID



TOROID

c The magnetic field is made strong by :

i passing large current and

ii using laminated coil of soft iron.

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

A- $n = 300$

$I = 5A$

$l = 0.5m$

$r = 0.01m$

$\frac{l}{r} = \frac{0.5}{0.01} = 50 \Rightarrow l >> r$

Date

$B = \mu_0 n I = 4\pi \times 10^{-7} \times 300 \times 5$
$= 20 \times 300 \times \pi \times 10^{-7}$
$= 6000 \times \pi \times 10^{-7}$
$= 6\pi \times 10^{-4}$
$= 1.88 \times 10^{-3}$ T

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

A- $B = 2.52 \times 10^{-3}$ T

$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}

$l = 0.5$ m

$N = 500$

$n = \frac{N}{l} = \frac{500}{0.5} = 1000$ m^{-1}

$B = \mu_0 n I$

$\Rightarrow$ ~~ans~~ $I = \frac{B}{\mu_0 n} = \frac{2.52 \times 10^{-3}}{4\pi \times 10^{-7} \times 1000}$

$= \frac{2.52 \times 10^{-3}}{4\pi \times 10^{-7} \times 10^{3}} = \frac{2.52 \times 10^{-3} \times 10^{4}}{4 \times 3.14}$

$= 2.0$ A