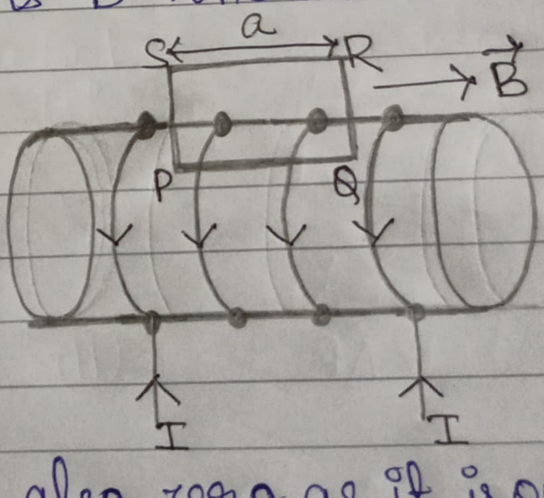
6/7/21

Home Assignment - 3

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 carring a current I.

ans Ampere's circuital law states that the line integral of 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
i.e., $\oint B \cdot dl = \mu_0 I$

Let the current flowing in the solenoid having no. of turns per unit length be I. Magnitude of magnetic field inside the solenoid is B wheras outside is zero.



Here the second and forth term i.e., QR and SP are zero because the angle bet? $d\vec{l}$ and $\vec{B}$ is 90°.

The third term i.e., SR is also zero as it is out of the solenoid.

$$\oint B \cdot d\vec{l} = \int_P^Q \vec{B} \cdot d\vec{l} + \int_Q^R \vec{B} \cdot d\vec{l} + \int_R^S \vec{B} \cdot d\vec{l} + \int_S^P \vec{B} \cdot d\vec{l}$$

$$= \int B\,dl\cos 0^\circ + \int B\,dl\cos 90^\circ + \int 0\,dl + \int B\,dl\cos 90^\circ$$

$$= \int B\,dl$$

$$= B\int dl = Ba$$

Total current = nlI

For length $a = (\mu_0 I_0) = (naI)\mu_0$

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

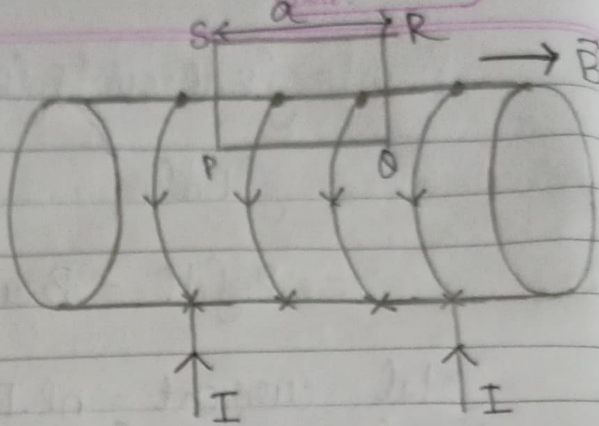
2. <u>Answer the following</u> :-

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

b) In what respect, is 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?

ans (a) Here, current flowing through each current = I
Magnetic field is zero outside the solenoid and is present only in the horizontal axis as, while taking ~~part~~ each term the vertical components cancels out each other.



Length of the solenoid = l
$PQ = RS = a$
Current through length a = I_0

According to Ampere's circuital law.,

$\oint B dl = \mu_0 I$

LHS:- $\oint \vec{B} d\vec{l} = \int_P^Q \vec{B}\cdot d\vec{l} + \int_Q^R \vec{B}\cdot d\vec{l} + \int_R^S \vec{B}\cdot d\vec{l} + \int_S^P \vec{B}\cdot d\vec{l}$

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

$= \oint B dl + B\oint dl$

$= Ba$ — (I)

Now, $\oint \vec{B}\cdot d\vec{l} = Ba$

No. of turns per unit length = $\frac{nl}{l}$

Total current = nlI
$= nlI$

For length $a = (naI)\mu_0$ — (II)
Equating (I) and (II) we get;
$Ba = (naI)\mu_0$

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

(b) In solenoid, the magnetic field is present inside it, where it is uniformly present at the axis but

decreases towards the end, and doesn't exist outside the solenoid.
whereas, in toroid, the magnetic field is present in the tubular area bounded by the coil and is not present inside and outside the toroid.

Diagram of solenoid

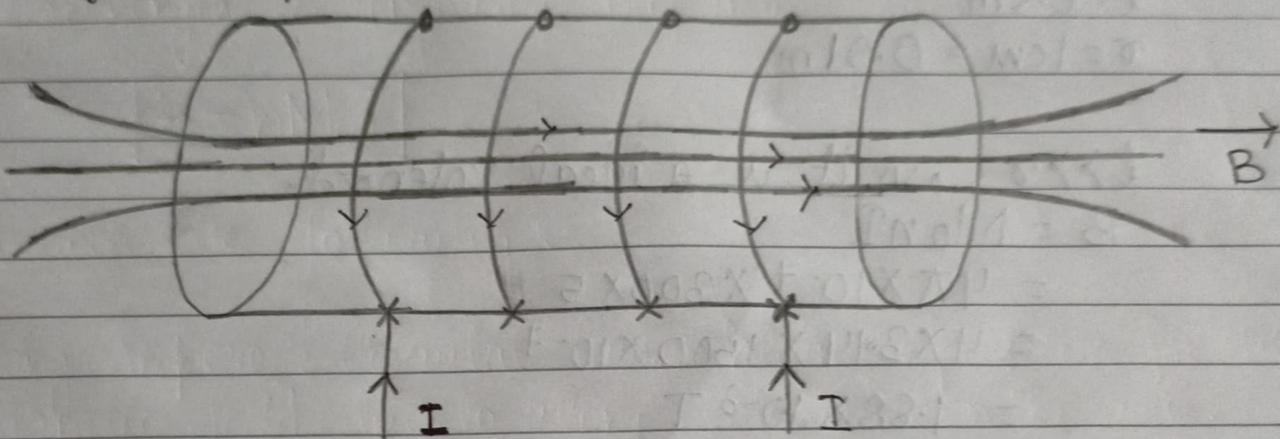
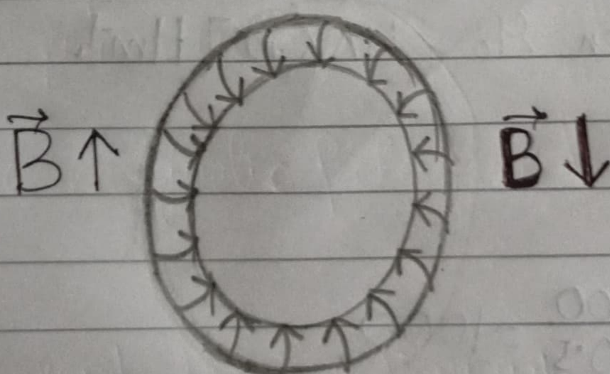


Diagram of toroid



(c) The magnetic field can be increased by:

→ Increasing the no. of turns per unit length.
→ Increasing the current through it.

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3. 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 1 cm. Find the magnitude field inside the solenoid.

ans:- $n = 300$
$I = 5A$
$l = 0.5m$
$r = 1cm = 0.01m$

$l >> r$, so it is a ideal solenoid.

$B = \mu_0 n I$
$= 4\pi \times 10^{-7} \times 300 \times 5$
$= 4 \times 3.14 \times 1500 \times 10^{-7}$
$= 1.88 \times 10^{-3}$ T

4. A 0.5m 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 $l = 0.5m$
$N = 500$
$n = \frac{N}{l} = \frac{500}{0.5} = 1000$

Flux density $(B) = 2.52 \times 10^{-3}$

As we know,
$B = \mu_0 n I$
$\Rightarrow 2.52 \times 10^{-3} = 4\pi \times 10^{-7} \times 1000 \times I$

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

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

$$= \underline{\underline{2A}}$$