O P JINDAL SCHOOL, SAVITRINAGAR

CLASS NOTES

CLASS XII PHYSICS

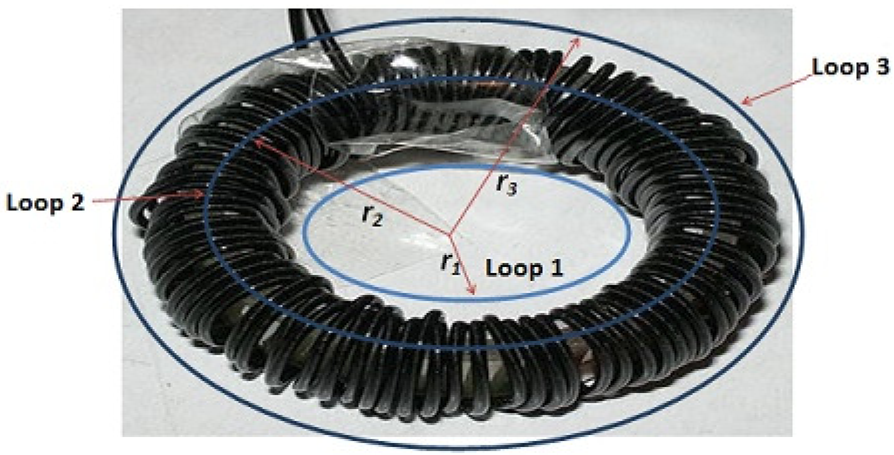
Date : 20/06/20

TOPIC : MOVING CHARGES AND MAGNETISM

SUB TOPIC: APPLICATION OF AMPERE'S CIRCUITAL LAW

THE TOROID:

- A toroid is simply a solenoid bent into a closed circular loop
- As toroid has no end points, magnetic flux leakage (loss) is minimized, and hence flux linkage is maximized as compared to a solenoid.



Toroid

- Case-1:Magnetic field at a point in the empty space inside the toroid. We will take an Amperian loop (loop 1). By the Ampere's circuital law:

$$\oint \vec{B_1}.\vec{dl} = \mu_o i$$

We can see in the diagram above that current passing through the inside of the loop 1 is **0**

$\int B_1.dl = \mu_o \times 0 = 0$

$\therefore B_1 = 0$

- Case-2:Magnetic field at a point inside the toroid (between the turns). We will take another Amperian loop (loop2) of radius r_2. By the Ampere's circuital law:

$$\oint \vec{B_2}.\vec{dl} = \mu_o i$$

We can see in the diagram above that net current passing through the inside of the loop 2 is **Ni**, where N is the total number of turns in the toroid

$B_2\int dl = \mu_o \times Ni$

$B_2 2\pi r_2 = \mu_o Ni$

$\therefore B_2 = \mu_o Ni/(2\pi r_2) = \mu_o ni$

Here n = number of turns per unit length of toroid = $N/(2\pi r_2)$

Note: The equation of magnetic field due to toroid is same as that of magnetic field due to solenoid.

- Case-3:Magnetic field at a point outside the toroid. We will take another Amperian loop (loop3) of radius r_3. By the Ampere's circuital law:

$$\oint \vec{B_3}.\vec{dl} = \mu_o i$$

We can see in the diagram above that net current passing through the inside of the loop 2 is **0** (**Ni** current going out of the loop, and **Ni** current entering the loop, so net current is **o**)

$$\int B_3.dl = \mu_o \times 0 = 0$$

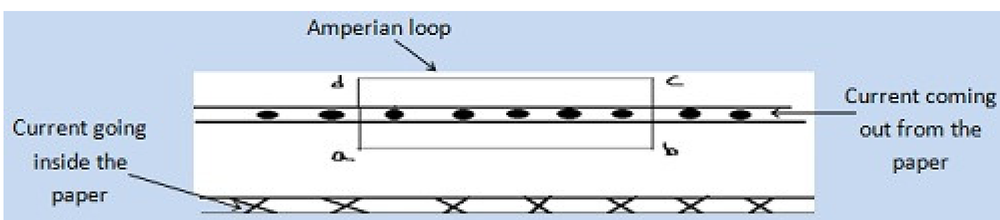
$$\therefore B_3 = 0$$

- Toroid are used in toroidal transformers, toroidal inductors etc.

Numerical Problem:

1)Using Ampere's circuital law, derive the magnetic field inside the solenoid of length L, carrying current i and having N number of turns.

Solution:



Using Ampere's circuital law:

i_L = iNl/LConsidering the Amperian loop abcd of sides l each, current passing through the loop will be:

$\int_a^b B.dl + \int_b^c B.dl + \int_c^d B.dl + \int_d^a B.dl = \mu_o Nil/L$

$Blcos0 + Blcos90 + 0lcos180 + Blcos270 = \mu_o Nil/L$

$Bl = \mu_o Nil/L$

$\therefore B = \mu_o Ni/L = \mu_o ni$

2)A closely wound solenoid has length of 80cm, and radius of 0.9cm with 5 layers of windings of 400 turns each. The current flowing through the solenoid is 8A. Find the magnitude of magnetic field inside the solenoid: i) at the center, and ii) at an end of solenoid.

Solution: Given, L = 0.8m, r = 0.009, N = 5×400 = 2000, i = 8A

Number of turns per unit length (n) = 2000/0.8 = 2500/m

1. i) Magnetic field at the center of solenoid is given by:

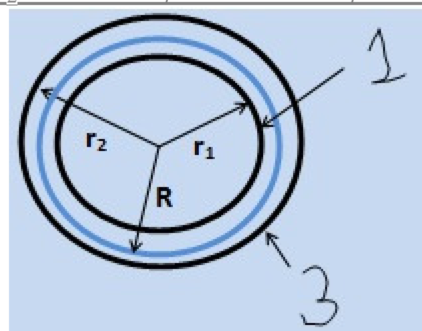
   $B = \mu_o ni = 4\pi\times10^{-7}\times2500\times8 = \mathbf{0.0251T = 251G}$ **(ans)**

1. ii) Magnetic field at one end of the solenoid is given by:

   $B = \mu_o ni/2 = 0.0251/2 = \mathbf{0.01255T = 125.5G}$ **(ans)**

   3) A toroid has inner radius 25cm and outer radius 26cm, with 3500 turns and 11A current flowing through it. Find the magnetic field:i) inside the core of the toroid,ii) outside the toroid and iii) in the empty space surrounded by the toroid.

   Solution: Given, r_1= 25cm, r_2 = 26cm, N = 3500, i = 11A



$R = r_1 + (r_2 – r_1)/2 = 25 + (26-25)/2 = 25.5cm$

Number of turns per unit length (n) = $N /(2\pi R)$

$\therefore n = 3500/(2\pi\times0.255) = 2184.5/m$

1. i) Magnetic field inside the core of toroid is given by:

   $B = \mu_o ni = 4\pi\times10^{-7}\times2184.5\times11 = \mathbf{0.0302T = 302G}$ **(ans)**

1. ii) Magnetic field outside the toroid is zero because net current through the Amperian loop(1) is zero, hence, by ampere circuital law:

   B = **0 (ans)**

   iii) Magnetic field inside the empty space surrounded by toroid is zero because net current through the Amperian loop(3) is zero, hence, by ampere circuital law:

   B = **0 (ans)**