AMPERE’S CIRCUITAL LAW

Ampere's law states that the **line integral** of the magnetic field around any closed path is equal to **μ_0 times** the total **current enclosed by the path**

ie

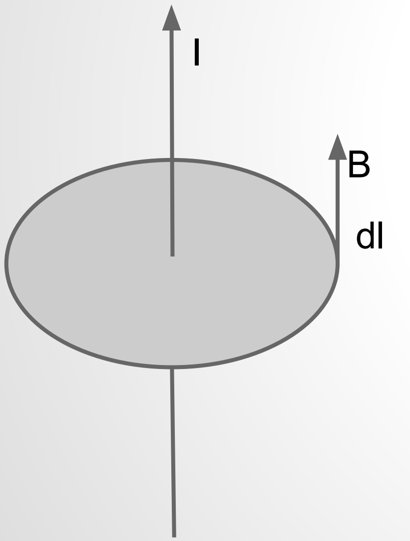
$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$$

choose the loop (called an amperian loop) such that at each point of the loop, either

(i) B is tangential to the loop and is a non-zero constant B, or

(ii) B is normal to the loop, or

(iii) B vanishes.



$$\int B \cdot dl = \mu_0 I$$

$$B \int dl = \mu_0 I$$

$$B\, 2\pi R = \mu_0 I$$

that is

$$B \times 2\pi r = \mu_0 I,$$

$$B = \mu_0 \; I / \; (2\pi r)$$

the magnetic field field at every point on a circle of radius r, is same in magnitude. In other words, the magnetic field possesses what is called a cylindrical symmetry

Magnetic field lines form closed loops. This is unlike the electrostatic field lines which originate from positive charges and end at negative charges.

The field is directly proportional to the current and inversely proportional to the distance from the (infinitely long) current source

right-hand rule

Grasp the wire in your right hand with your extended thumb pointing in the direction of the current. Your fingers will curl around in the direction of the magnetic field.

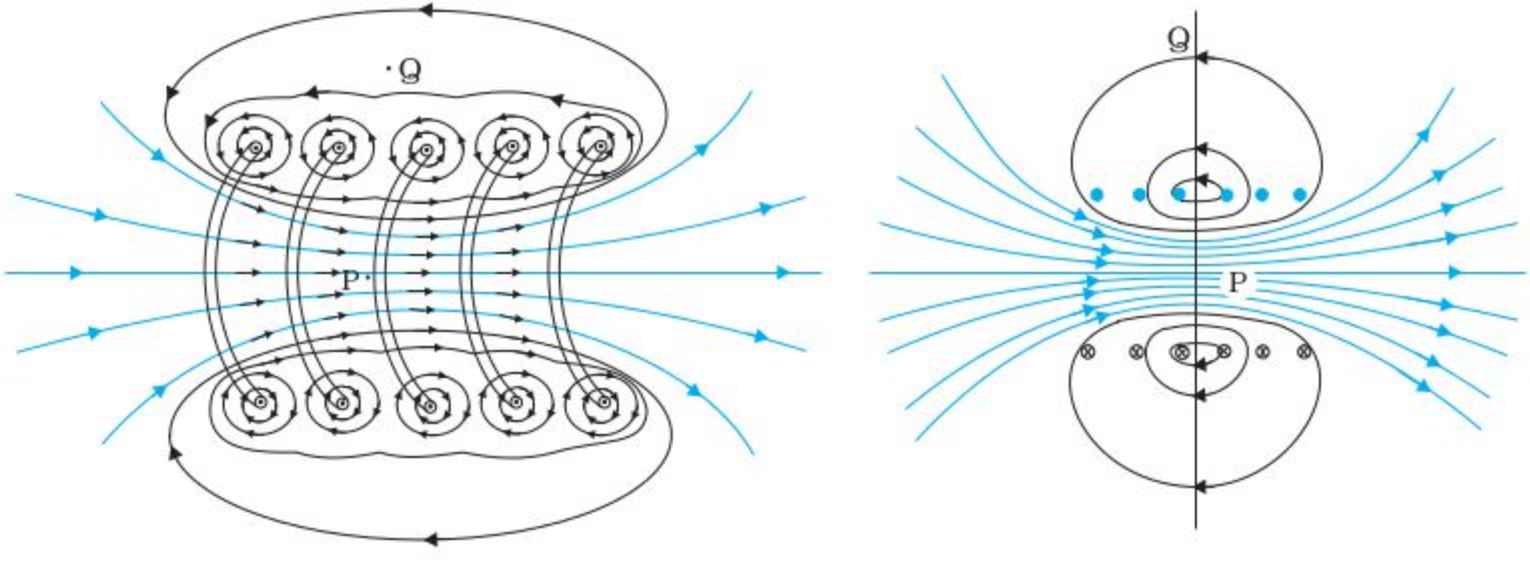
Ampere’s circuital law is not new in content from Biot-Savart law.

Both relate the magnetic field and the current, and both express the same physical consequences of a steady electrical current.

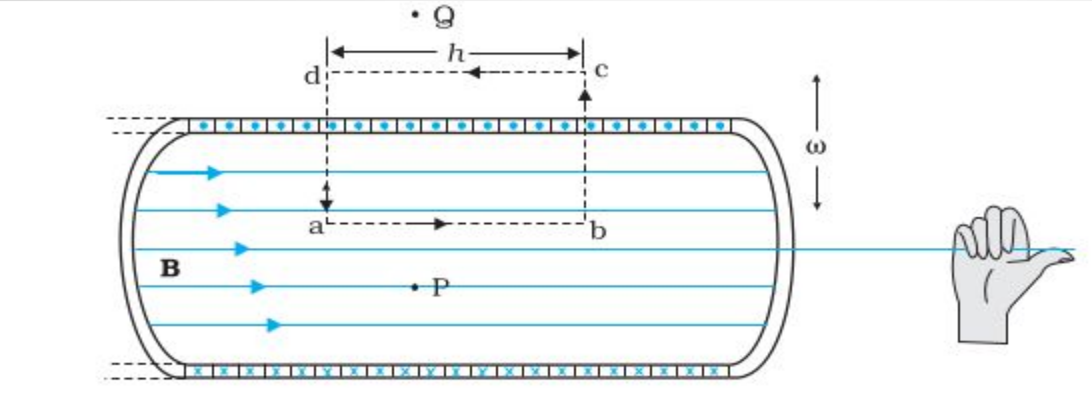
Ampere’s law is to Biot-Savart law, what Gauss’s law is to Coulomb’s law.

THE SOLENOID AND THE TOROID

It consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced. So each turn can be regarded as a circular loop. The net magnetic field is the vector sum of the fields due to all the turns. Enamelled wires are used for winding so that turns are insulated from each other.



(a) (b)



Consider a rectangular Amperian loop abcd. The field outside the solenoid approaches zero. We shall assume that the field outside is zero. The field inside becomes everywhere parallel to the axis.

Along transverse sections **bc** and **ad**, the field component is zero. Thus, these two sections make no contribution.

Let the field along **ab** be B. Thus, the relevant length of the Amperian loop is, L = h.

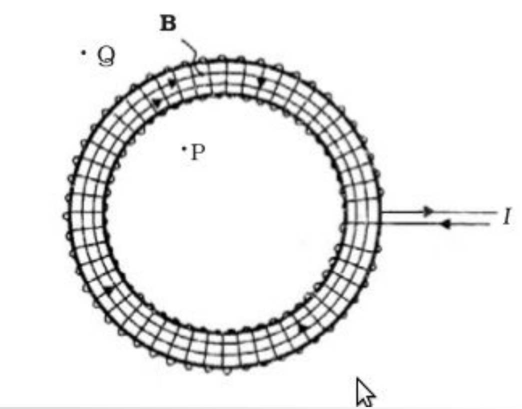
Let n be the number of turns per unit length, then the total number of turns is nh.

The enclosed current is, Ie = I (n h), where I is the current in the solenoid.

Using amperes Circutal theorem

$$\int_a^b B \cdot dl + \int_b^c B \cdot dl + \int_c^d B \cdot dl + \int_d^a B \cdot dl = \mu_0 n h I$$

The toroid



The toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. It can be viewed as a solenoid which has been bent into a circular shape to close on itself.

It is an endless solenoid

We shall see that the magnetic field in the open space inside (point P) and exterior to the toroid (point Q) is zero.

The field B inside the toroid is constant in magnitude for the ideal toroid of closely wound turns.

Consider an amperian loop along the axis of a toroid. Applying Ampere’s circuital theorem

$$\int B \cdot dl = \mu_0 N I$$

Where N is the total number of turns of the toroid

$$B\int dl = \mu_0 N I$$

$$B 2\pi r = \mu_0 N I$$

$$B = \frac{\mu_0 N I}{2\pi r}$$

Let r be the average radius of the toroid and n be the number of turns per unit length. Then

$N = 2\pi r\, n$ = (average) perimeter of the toroid × number of turns per unit length

$B = \mu_0\, n\, I$, i.e., the result for the solenoid!