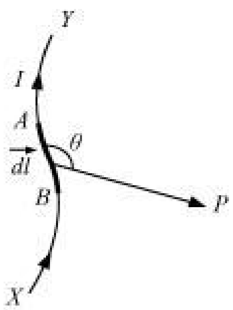
12. Magnetic Effect of an Electric Current

The magnetic effect of current was first discovered by H.C. Oersted. He observed that the flow of charges in a conductor produces magnetic effect around it.

Right-Hand Thumb Rule
According to this rule, if we grasp the current-carrying wire in our right hand such that our thumb points in the direction of current, then the direction in which our fingers encircle the wire will tell the direction of the magnetic field lines around the wire.

The Biot–Savart Law



According to this law, the magnetic field is proportional to the current and element length and inversely proportional to the square of the distance.

dB= Idlsinθr2

Magnetic field due to a current-carrying circular coil

At the centre, it is calculated to be equal to B.

B=μ0nIr

Here,
n = Number of turns in the coil
I = Current flowing through the circular coil
r = Radius of the coil

- The magnetic field at a point on the axis of a circular current-carrying coil is given by

B=μ0nIr22(r2+x2)32
Here,
n = Number of turns in the coil
I = Current flowing through the circular coil
r = Radius of the coil
x = Distance of the point from the centre of the coil

Moving Charges

- Moving charges produce magnetic field around them.
- SI unit of magnetic field is Tesla (T).

Lorentz Force

- It is the force experienced by a charged particle moving in a space where both electric and magnetic fields exist.
- $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$
- Where,
  - $q\vec{E}$ = Force due to electric field
  - $q(\vec{v} \times \vec{B})$ = Force due to magnetic field(magnetic force)

Magnetic force on a charged particle

- It is opposite on negative charge than that on positive charge.
- It vanishes, if v and B are parallel or anti-parallel
- Magnetic force is zero, if charge is at rest.

Magnetic force on a current carrying conductor

A straight conductor of length l and carrying a steady current I experiences a force F in a uniform external magnetic field B, $\vec{F} = I(\vec{l} \times \vec{B})$

- A current carrying the rod experiences a force when placed between two poles of strong magnets. The direction of force exerted on the rod is related with the direction of current.
- Magnitude of magnetic force depends upon three factors:

  (1) $F \propto I$ (current I flowing in the rod)(2) $F \propto B$ (Strength of magnetic field B)(3) $F \propto l$ (length of the rod l)

  where K is a constant and its value in SI unit is 1.
  So, $F = IBl$
  Fleming's left-hand rule
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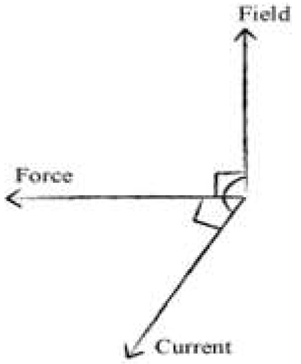
  - If the thumb, forefinger, and middle finger of the left hand are stretched in such a way that they are mutually perpendicular to each other and the forefinger points in the direction of the magnetic field and the middle finger in the direction of the current, then the thumb will point in the direction of the force acting on the conductor.

Fore finger = Magnetic field

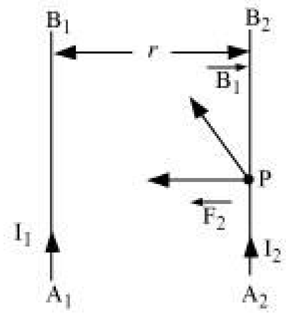
Middle finger = Current

Thumb = Force on conductor



- **Application** – Electric motor

Force between two parallel conductors carrying current



- Two linear parallel conductors carrying currents in the same direction attract each other.
- Two linear parallel conductors carrying currents in opposite directions repel each other.

Torque on a current carying loop

- A loop carrying current when placed in a uniform magnetic field experiences a torque that is given by
  - $\vec{\tau}=\vec{m}\times \vec{B}$
- Magnetic moment of a loop of area A carrying current I is given by m=IA.
- Direction of magnetic moment is determined by the right hand thumb rule . If we curl the fingers of the right hand inthedirectuion of the current the fdirection of the thumb gives the direction of the magnetic moment.
- DC motor works on this principle
  - It consists of a commutator that reverses the direction of the current after every half rotation
  - The direction of the force on the conductors of current carrying loop is determined by Fleming's left hand loop