PARMAR SSC

MAGNETIC EFFECT OF ELECTRIC CURRENT

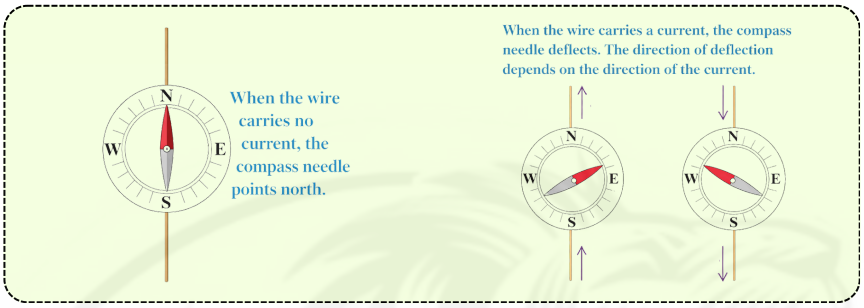
Lecture - 8

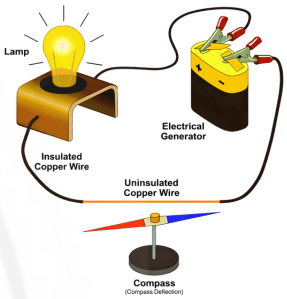


BY PARMAR SIR

MAGNETIC EFFECT OF ELECTRIC CURRENT

- The magnetic effect of electric current is the phenomenon where an electric current flowing through a conductor produces a magnetic field around it. This field can exert force on other magnets or moving charges.
- **E.g.** Deflection of a compass needle placed near a current-carrying wire.
- The strength of the magnetic field increases with the amount of current flowing through the wire.

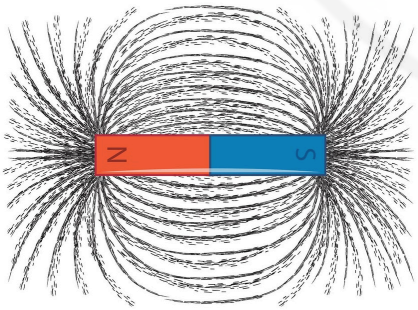


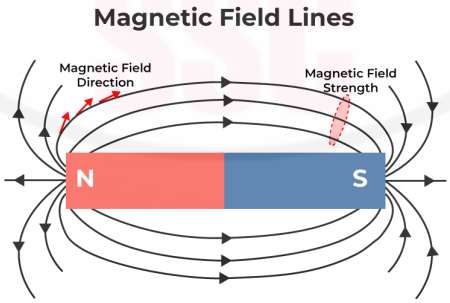


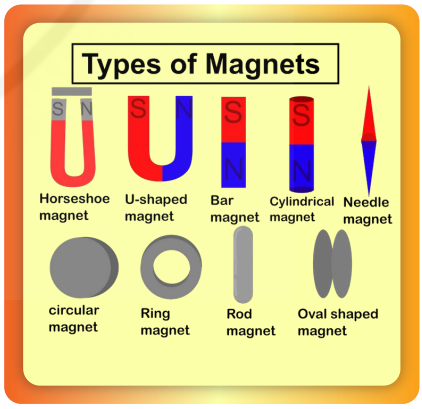
- The direction of magnetic field changes due to a change in direction of current in the wire.
- **Hans Christian Oersted** discovered the magnetic effect of electric current in 1820.

Magnetic Field Lines

- The magnetic field created by a current-carrying wire is a force field that influences other magnets and moving charges.
- When iron filings are scattered around a magnet, they become temporary magnets through magnetic induction and align end-to-end along the magnetic field lines.
- The filings clump more densely near the poles, showing that the magnetic field is the strongest near the poles. This pattern of filings gives a clear visual impression of the magnetic field around the magnet.
- Like poles repel each other and Unlike poles attract each other.





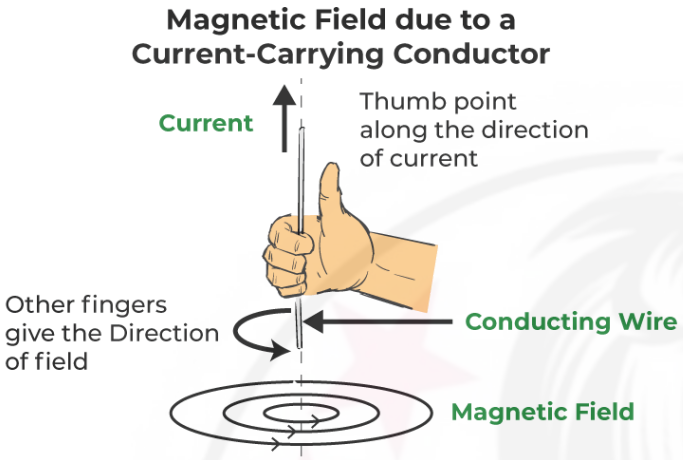


Properties of a Magnetic Field Lines

- They always go from the north pole to the south pole outside the magnet.
- Inside the magnet, they go from the south pole to the north pole, forming closed loops.
- The closer the lines are, the stronger the magnetic field.
- Magnetic field lines never cross each other. If they intersect, there will be two direction of magnetic field lines, which is not possible.
- They show the direction and strength of the magnetic field.

Magnetic Field Due to a Straight Current Carrying Conductor

- The magnetic field around a straight current-carrying conductor consists of concentric circles centered on the wire. These circular magnetic field lines form around the wire when electric current flows through it.
- The direction of the field can be found using the Right-Hand Thumb Rule:
  - If you point your right thumb in the direction of the current, your fingers will curl in the direction of the magnetic field lines.



Magnetic Field $\propto \frac{1}{\text{Distance}}$

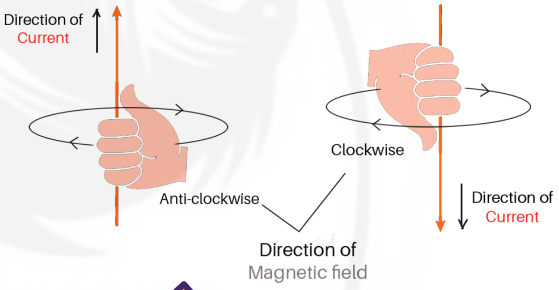
As you go farther from the wire, the magnetic field becomes weaker.

Magnetic Field $\propto$ **Current**

A stronger current produces a stronger magnetic field.



- Change in Current Direction → Change in Magnetic Field Direction
- If current flows downward, the magnetic field becomes clockwise.
- If the current flows upward, the magnetic field lines become anti-clockwise.

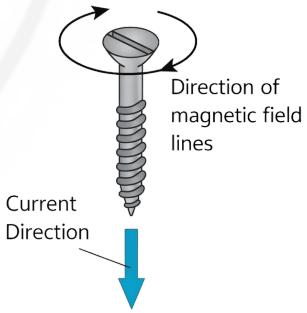


Maxwell's Screw Rule

- Maxwell's screw rule is a way to find the direction of the magnetic field around a current-carrying conductor.

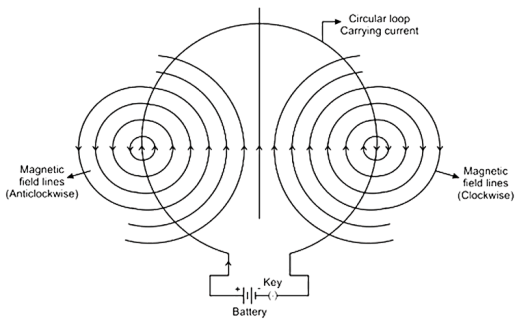
Rule

Imagine turning a right-handed screw (or corkscrew) in the direction of the current. Then, the direction in which the screw rotates gives the direction of the magnetic field lines.



Magnetic Field Lines Due to a Circular Current-Carrying Loop

- A circular loop is made of many small straight current-carrying segments.
- Each segment produces circular magnetic field lines (concentric circles).
- Direction of field is given by the Right-Hand Thumb Rule.



- Near the wire → field lines are circular; at centre → nearly straight & parallel.
- Anticlockwise current → field out of plane (North pole).
- Clockwise current → field into plane (South pole).
- Reversing current reverses magnetic field direction.

- **Increasing the number of loops/turns in a current-carrying wire coil strengthens the magnetic field.**

$$M_f \propto n$$

- **E.g. On doubling the number of turns the magnetic field also doubles.**

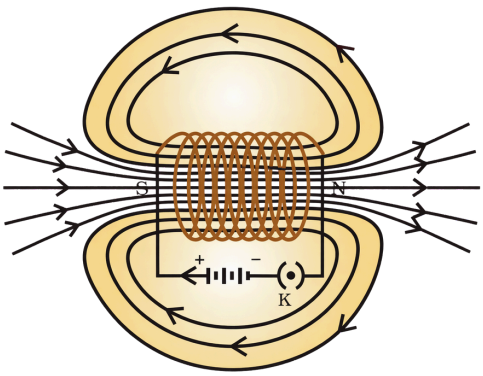
Ampere's Law

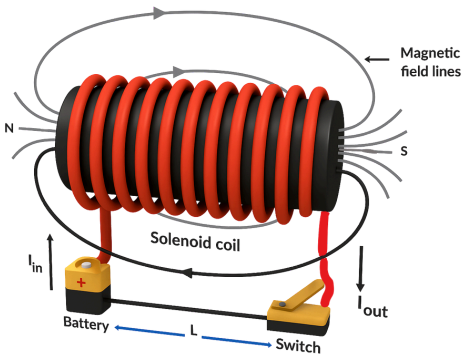
- Ampere's Law essentially states that "The line integral of the magnetic field around a closed loop is proportional to the total current passing through the loop". It is used to calculate the magnetic field in various configurations, such as around straight wires and solenoids.

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

Magnetic Field Current Due to a Current Carrying Solenoid

- The magnetic field inside a solenoid is uniform and strongest in the center.
- For a long, ideal solenoid (where the length is much greater than the radius), the magnetic field outside is considered to be zero.
- A solenoid behaves like a magnet when a current flows through it because it creates a magnetic field that resembles that of a bar magnet.
- When current flows through the coils of a solenoid, each turn of the coil generates its own magnetic field. These fields combine to create a strong, relatively uniform magnetic field inside the solenoid.
- If the direction of current is reversed, the direction of magnetic field is also reversed.

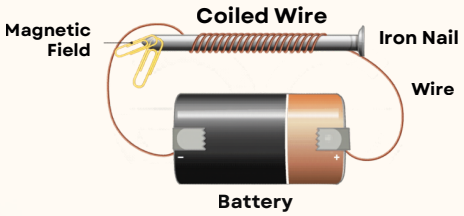




Electromagnet

- An electromagnet is a temporary magnet, meaning it only exhibits magnetic properties when an electric current is flowing through its coil, and loses its magnetism when the current is switched off.

If a soft iron core is placed inside this coil, the magnetic field from the coil will induce magnetism in the soft iron. The induced magnetism is temporary. As long as the current flows, the soft iron remains magnetized. Once the current stops, the soft iron loses its magnetism.

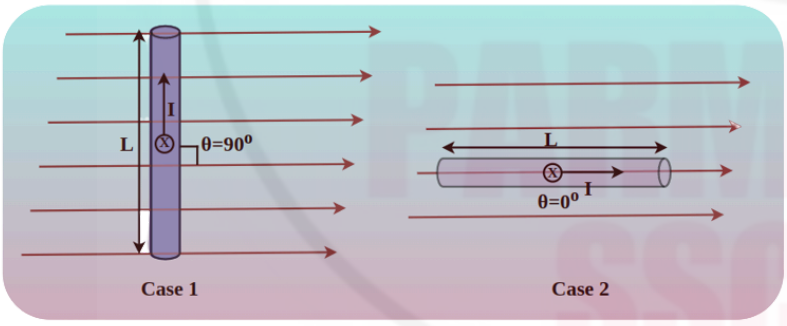


Force on a Current Carrying Conductor in a Magnetic Field

- A current-carrying conductor experiences a force when placed in a magnetic field. This force is caused by the interaction between the magnetic field generated by the current in the conductor and the external magnetic field.

$$\vec{F} = I(\vec{L} \times \vec{B})$$

F : Magnetic force on the conductor.
I : Current in the conductor.
L : Length of the conductor in the direction of current.
B : Magnetic field.



If the angle between L and B is θ, then:

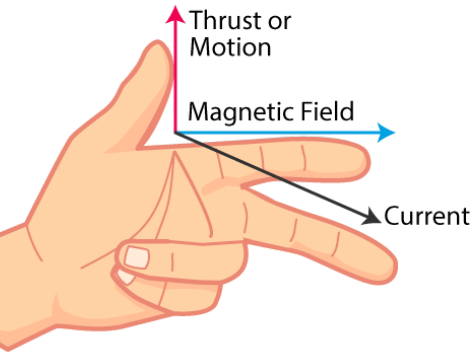
$$F = ILB \sin \theta$$

Conditions

- The maximum force is experienced when the angle is 90°, because the sinθ becomes 1, which is the maximum value.
- When the angle is 0°, the force experienced is zero because sinθ is zero.
- When the angle is 180°, the force experienced is also zero because sinθ is again zero.

Maximum value of sin(θ) = 1, when θ = 90°
Minimum value of sin(θ) = 0, when θ = 0° or 180°

Fleming's Left Hand Rule

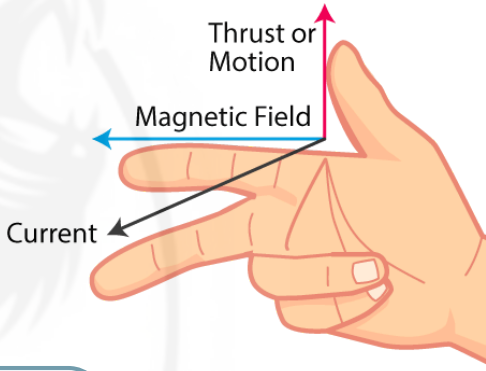


- Fleming's Left Hand Rule states that "**If you extend your left thumb, index finger, and middle finger at right angles to each other, the thumb points in the direction of the force, the index finger points in the direction of the magnetic field, and the middle finger points in the direction of the current.**"
- An electric motor converts electrical energy into mechanical energy.
- It is used to determine the direction of force (motion) on a current carrying conductor placed in a magnetic field.

- The direction of electric current is taken as the direction of motion of positive charges (p^+).
- This direction is exactly opposite to the direction of flow of electrons (e^-).

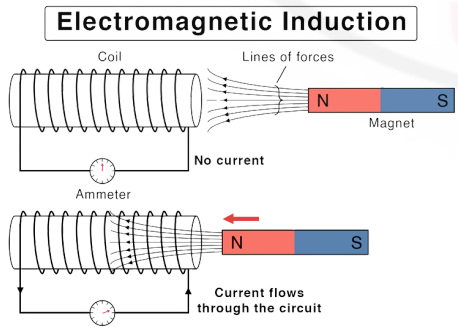
Fleming's Right Hand Rule

- Fleming's Right-Hand Rule helps determine the direction of induced current in a generator (mechanical energy is converted into electrical energy).
- It uses the right hand "**where the thumb indicates the direction of motion, the first finger (forefinger) indicates the magnetic field, and the second finger (middle finger) indicates the direction of induced current**" .



Electromagnetic Induction

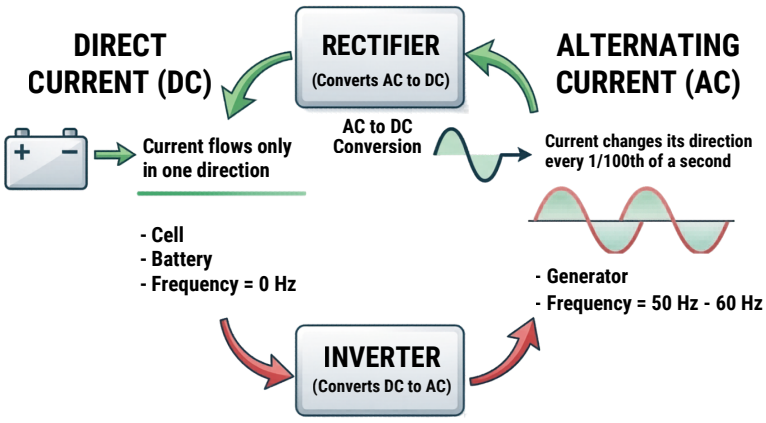
- Electromagnetic Induction is a phenomenon in which current is produced because of voltage production (electromotive force) due to a changing magnetic field.
- This either happens when a conductor is placed in a moving magnetic field (when using an AC power source) or when a conductor is constantly moving in a stationary magnetic field.
- Electromagnetic induction was discovered by Michael Faraday in 1831.



When the bar magnet is pushed towards the coil, the pointer in the galvanometer deflects.

Short Circuit

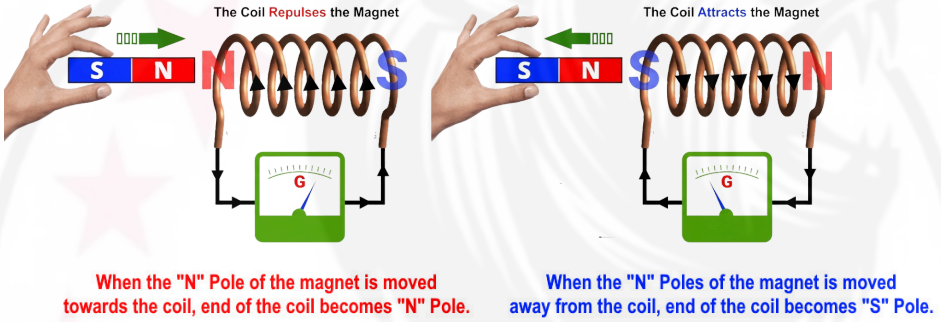
- Short Circuit is caused due to breaking of insulation of wires, forming the contact between live wire and neutral wire.
- During a short circuit, the current in a circuit increases abruptly and significantly. This is because a short circuit creates a very low resistance path, allowing a large amount of current to flow.



Live wire: red colour (220V)
Neutral wire: black colour (0V)

Lenz's Law

- **Basic Principle:** The direction of induced current always opposes the cause that produces it.



Current Controller (Rheostat)

- **Type of Device:** Variable resistor
- **Main Function:** To control electric current in a circuit by increasing or decreasing resistance without changing the voltage

Cyclotron

- **Type of Device:** Particle accelerator
- **Main Function:** To accelerate charged particles (such as protons or ions) to very high speeds and energy



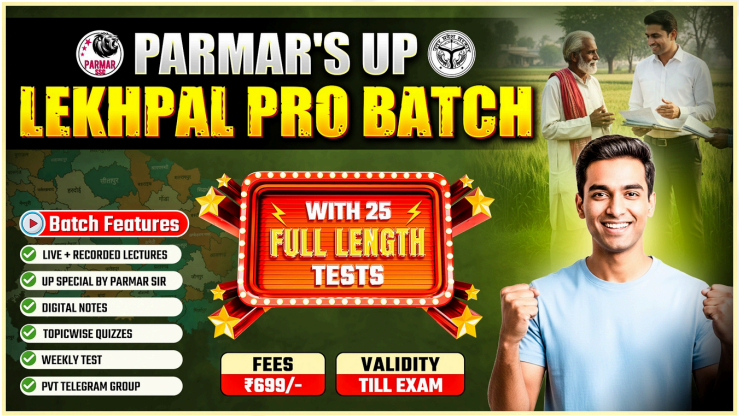
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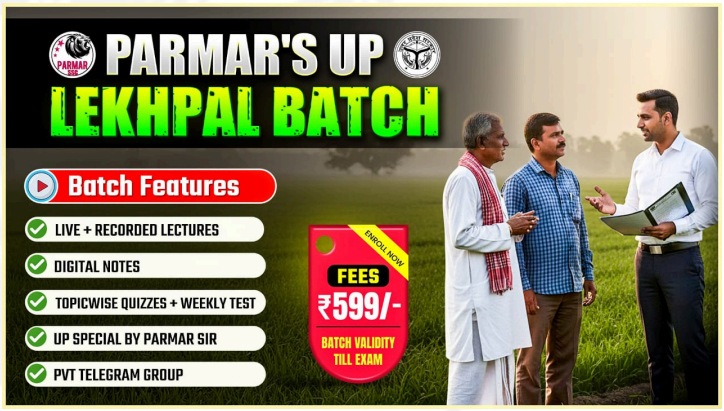
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