Electromagnetism

Magnetic Effect of a Current

Properties of the Magnetic Field of a Current-carrying Conductor

- A current-carrying conductor produces a **magnetic field** around it.

Methods to Determine the Magnetic Field Around The Wire

1. Grip the wire with your right hand such that your thumb points in the direction of current flow.
2. The direction in which your fingers curl indicates whether the magnetic field is clockwise or anticlockwise.

Symbols

- **Dot** at the middle shows wire carrying current **out** of the wire
- **Cross** at the middle shows wire carrying current **into** of the wire

Properties

- Magnetic fields of a long, straight current-carrying conductor are represented by **concentric circles** which are centered at the conductor itself.
- The **closer** the field lines, the **greater**, the magnetic field strength (or the **stronger the magnetic field**)

Factors affecting Magnetic Field Strength of a Solenoid

- A solenoid is a coil of insulated wire coiled into a cylinder shape.
- The magnetic field of a solenoid resembles that of a bar magnet.
- The **Right-hand Grip Rule** can be applied to the solenoid to determine the direction of the magnetic field inside the solenoid.
    - Curl your **fingers** around in the direction of the **current** flow.
    - Your **thumb** will point to the **North** pole.

Factors that affect the strength of an electromagnet.

The magnetic field strength of a solenoid can be increased by:

1. Increase the magnitude of the **current**
2. Increase the **number of turns on the solenoid**, or
3. Placing a soft iron core within the solenoid to concentrate the magnetic field lines.

Note: The magnetic field strength **inside** the solenoid is stronger than the magnetic field strength outside the solenoid.

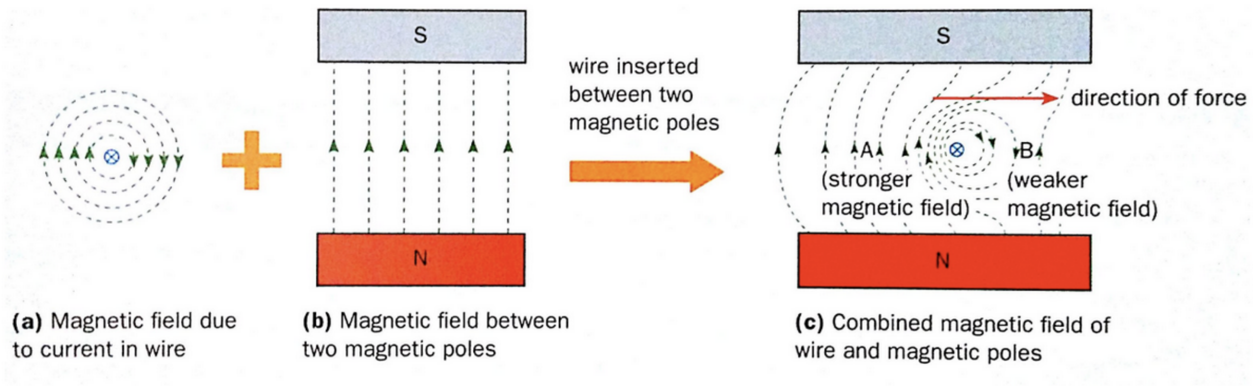
Force on a Current-carrying Conductor (Lorentz Force)

Cases	**Observations**
Spacing Between Magnets (Field Strength)	The wire gets a larger force when the spacing decreases (magnetic field gets stronger)
Reversing Current Flow Direction	The wire gets a force in the opposite direction when direction of the current is reversed.
Reversing Magnetic Field Direction	The wire gets a force in the opposite direction when direction of the magnetic field is reversed.

Conclusion

The **magnetic force** produced on the current-carrying wire:

1. **Increases** when the **magnetic field** gets **stronger**
2. **Reverses** in direction when the direction of the **electric current** is **reversed,** and
3. **Reverses** in direction when the direction of the **magnetic field** is **reversed**



- The diagram shows how the magnetic fields, produced by a current-carrying wire and a pair of magnets, interact with each other.
- There is a stronger magnetic field on the one side of the wire at A. All the magnetic field lines at A act in the same direction.
- There is a weaker magnetic field on one side of the wire at B. The magnetic field lines of the current carrying conductor act in the opposite direction of that of the magnet.
- The **interaction** between the **current flowing in the conductor** and the **external magnetic field** produced a **force acting on the conductor.**
- The direction of the force acting on the conductor can be determined by Fleming's left hand rule.

Fleming's Left Hand Rule

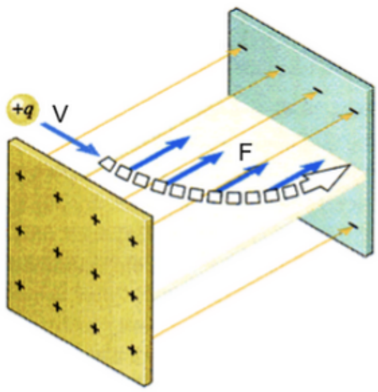
- Fleming's left-hand rule is used to find the direction of force when the direction of magnetic field and conventional current are known.
- The first three fingers are positioned at **right angles** to each other.

1. Thumb: **Force** on conductor
2. First finger: **Field** (magnetic field)
3. Second finger: Conventional **Current**

Force on a Moving Charge in a Magnetic Field

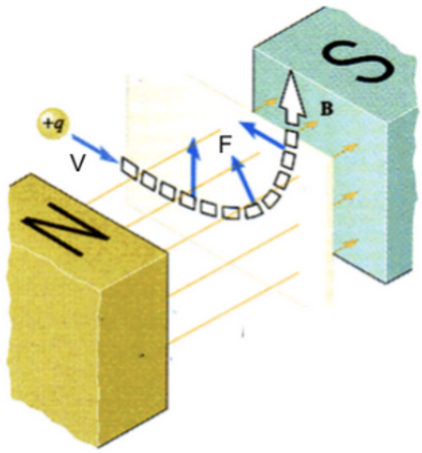
- Fleming's left-hand rule can be applied to all **moving charges.**
- **NOTE:** For a beam of **charged particles** (e.g electrons or protons), we need to follow the direction of the **conventional current**, which is **opposite in direction to the motion of negative charges.**

Electric Force on Positive Charge



Electric force is parallel to the plane of the electric field.

Magnetic Force on Positive Charge



Magnetic force is perpendicular to the plane of the electric field.

- While an electric force is always exerted on a charge within an electric field, a magnetic force is only exerted on a charge within a magnetic field if it is **moving.**
- For a **stationary** charge within a magnetic field experiences **zero magnetic force.**
- For a **moving charge**, the direction of the force acting on the charge is perpendicular to the direction of travel.
- The **moving particle** is deflected in a **circular path** towards the centre of the circle.

The DC Motor

- A DC motor converts **electrical energy** into **mechanical energy**.
- A DC motor consists of the following components.
    - **Rectangular coil** connected in series to a battery and rheostat.
    - **Permanent magnets**

    - **Split-ring commutator**
        - The ends of the coil are **fixed** to the split-ring commutator
    - **Two carbon brushes**
        - The carbon brushes rub against the commutator and keep the coil connected to the battery.

When the switch is closed, current will flow through the (rectangular) **conducting coil.**

The sides of the coil lie in between two **permanent magnets**.

Forces are produced on the current-carrying wires of the coil as the magnetic fields interact, which cause the coil to rotate about its axle

The ends of the rotating coil are connected to two halves of a copper ring known as the **split ring commutator** and they **rotate together with the coil.**

Electric current is passed from the circuit to the two halves of the copper ring via two separate **carbon brushes**.

The rheostat is used to control the **amount of current in the coil**, which affects the **strength of magnetic forces** produced on the sides of the coil, the amount of the moment of these forces about PQ and hence the **rotational speed** of the coil.

How it Functions

- When an electric current flows through the coil ABCD, a **backward force is produced on side AB and an upward force on side CD** (using Fleming's left-hand rule).
    - This causes the coil to **rotate anticlockwise** about axis PQ.
- But when the rotating coil reaches **vertical position**, the split ring commutator (X and Y) **loses contact with the carbon brushes**, causing the current to be **cut off** and the forces to **disappear.**
- However, the **inertia** of the rotating coil keeps it rotating and the commutator to make contact with the brushes again but in the reverse manner.
- This **reverses the current direction in the coil**, and consequently side **AB now gets an upward force** while **CD gets a downward force.**
- This allows the coil to continue rotating in the same anticlockwise direction.

Total Moment

- The **total moment of the magnetic forces** and the **rotational speed** can be **increased by**:
    - **Increasing** the magnitude of the **current** in the coil.
    - Increasing the __number of turns __on the coil.
    - Inserting a **soft iron core** into the coil.
    - Using a **stronger** magnet.