# Magnetic Effects of Electric Current

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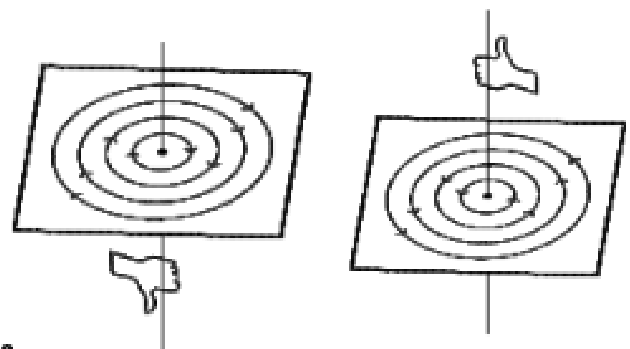
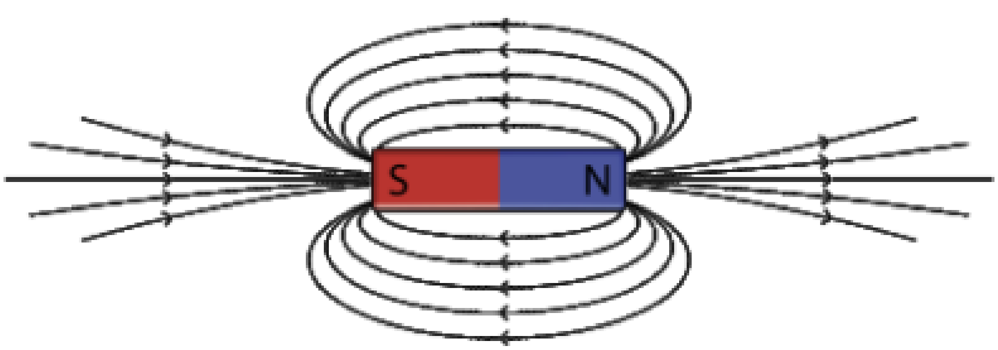




# Magnetic Effects of Electric Current

## Magnet

***"Is ab object which attracts pieces of iron towards it sell."***

## Properties of Magnet

(i) Attract Material like iron, nickel and cobalt.

(ii) Attraction is maximum at its poles.

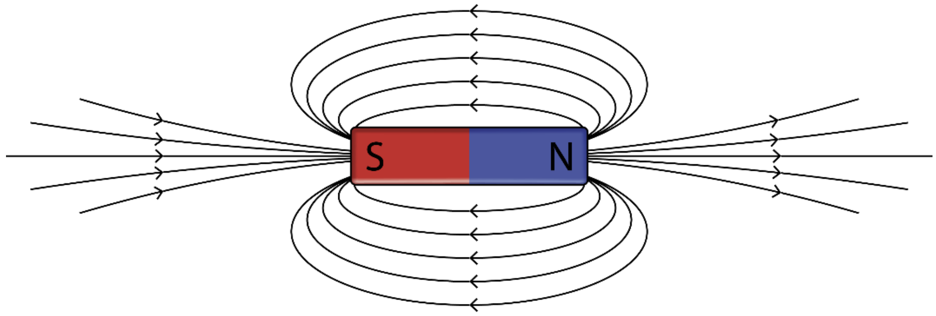
(iii) Magnet has two poles North and South, like poles repel each other unlike poles attract each other.


## Introduction

- In 1820, **Christian Oersted** discovered that a compass **needle get deflected when a current carrying metallic conductor** is placed nearby it.
- He concluded that the deflection of compass needle was due to the magnetic field produced by the electric current.
- Hence, it was deduced that electricity and magnetism are related to each other.
- The **SI unit** of magnetic field is **Tesla**.

## Magnetic lines

- They are the imaginary line representing magnetic field around a magnet. When iron fillings are kept near a magnet they get arranged in a pattern which represents the magnetic field lines.



## Properties of Magnetic filed lines

- They originate from North pole of a magnet and end at its South pole, by convention.
- These lines are closed and continuous curves.
- They are crowded near the poles, where the magnetic field is strong and separated far from the poles, where the magnetic field is weak.
- Field lines never intersect with each other. If they do, that would mean that there are two directions of the magnetic field at the point of intersection, which is impossible.

**Q.** List the properties of magnetic lines of force. **[NCERT Exercise]**

**Sol.** Properties of magnetic lines of force:

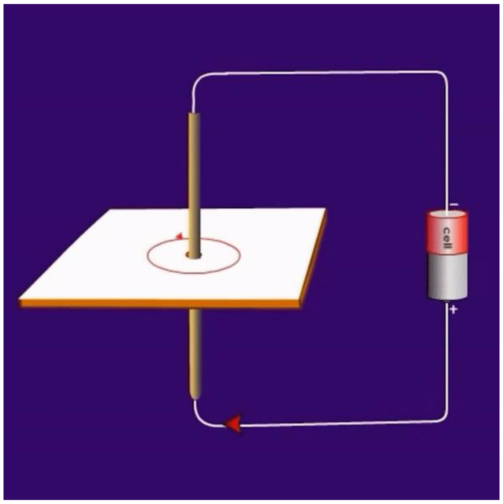
- The magnetic field lines originate from the north pole of a magnet and end at its south pole.
- The magnetic field lines become closer to each other near the poles of a magnet but they are widely separated at other places.
- Two magnetic field lines do not intersect one another.

**Q.** Why don't two magnetic lines of force intersect each other? **[NCERT Exercise]**

**Sol.** This is due to the fact that the resultant force on a north pole at any point can be only in one direction. But if the two magnetic field lines intersect one another, then the resultant force on north pole placed at the point of intersection will be along two directions, which is not possible.

## Magnetic Field due to a Current Carrying Conductor

- When electric current flows through a metallic conductor, a magnetic field is produced around it.
- The magnetic field lines around a current carrying straight conductor are concentric circles whose centres lie on the wire.

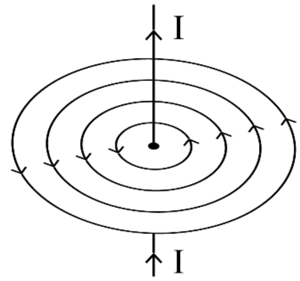



- The magnitude of magnetic field B produced by a straight current carrying wire at a given point is

**(i)** **Directly proportional** to the current I passing through the wire, i.e. $B \propto I$ …….. (i)

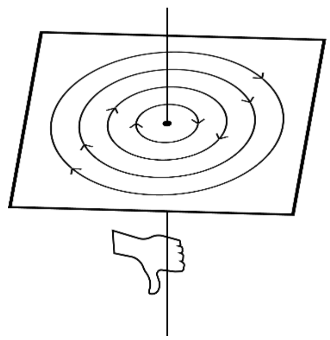
**(ii)** **Inversely proportional** to the distance r from the current carrying conductor,

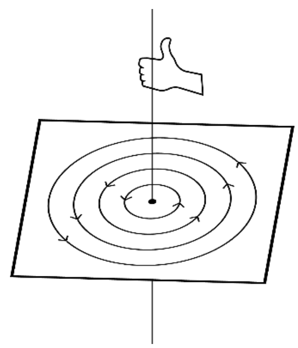
i.e. $B \propto \frac{1}{r}$ …….. (i)




## Right Hand Thumb Rule

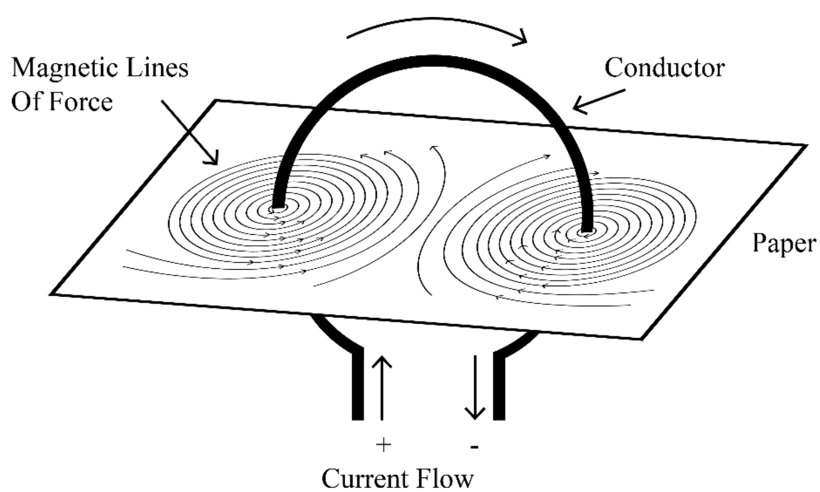
➢ It states that, if you hold the current carrying straight wire in the grip of your right hand in such a way that the stretched thumb points in the direction of current, then the direction of the **curl of the fingers will give the direction of the magnetic field**.





## Magnetic Field due to a Current through a Circular Loop

➢ The magnetic field produced by current carrying circular wire at a given point is




(i) Directly proportional to the amount of current (I) passing through it,

i.e. $B \propto I$ …….. (i)

(ii) Directly proportional to the number of turns (N) of the wire,

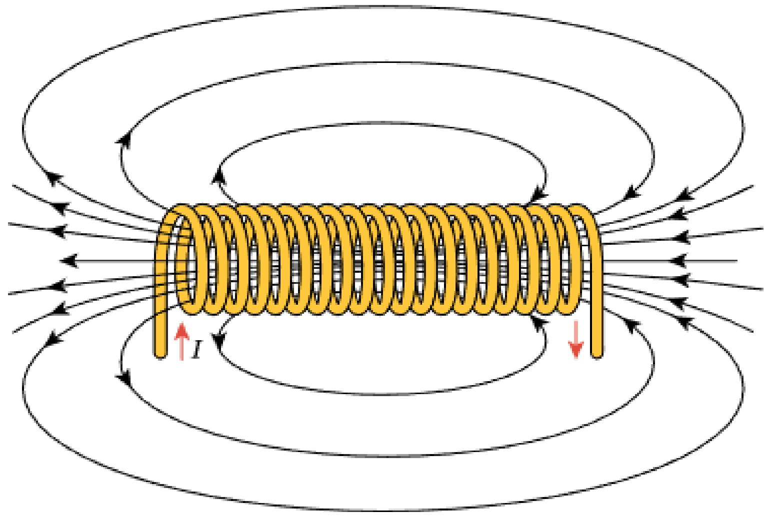
i.e. $B \propto N$ …….. (ii)

The strength of magnetic field produced by a current carrying circular coil can be increased by

- Increasing the number of turns of the coil.
- Increasing the current flowing through the coil.

## Magnetic Field due to a Current in a Solenoid

- A solenoid is defined as a coil consisting of large number of circular turns of insulated copper wire.
- These turns are wrapped closely to form a cylinder.




- The field lines around a current carrying solenoid are similar to that produced by a bar magnet.
- This means that a current carrying solenoid behaves as if it has North pole and South pole.
- The field lines inside the solenoid are parallel to each other.
- Thus, the strength of magnetic field is the same, i.e., uniform at all points inside a solenoid.

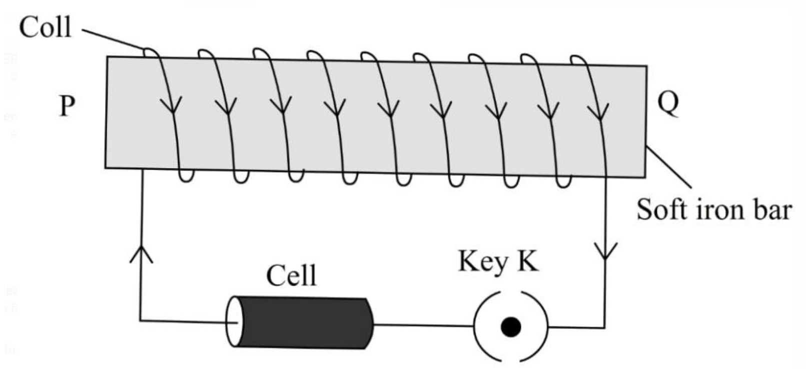
Strength of magnetic field can be increased by:

- Increasing the number of turns in the solenoid.
- Increasing the strength of current.
- Using soft iron rod as core.

## Electromagnet

- The strong magnetic field produced inside a solenoid can be used to magnetize a piece of magnetic material like soft iron when placed inside the coil. The magnet so formed is called electromagnet.
- The magnetic effect remains only till the current is flowing through the solenoid.

- An electromagnet is used in electric bells, electric motors, telephone diaphragms, loudspeakers and for sorting scrap metal.




## Force on a Current Carrying Conductor in a Magnetic Field

- When a current carrying conductor is placed in a magnetic field, it experiences a force.
- The force acting is due to interaction between magnetic field produced by the current carrying conductor and external magnetic field in which the conductor is placed.
- The direction of force on the conductor depends on the following factors.

### (i) Direction of current:

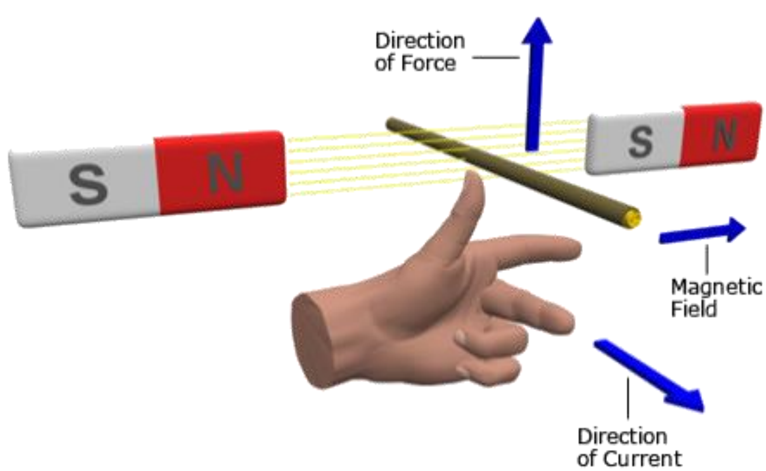
- The direction of force on the conductor can be reversed by reversing the direction of current.

### (ii) Direction of magnetic field:

- The direction of force on the conductor can be reversed by reversing the direction of magnetic field by interchanging the position of poles.

## Fleming's Left Hand Rule

- The direction of force which acts on a current carrying conductor placed in a magnetic field is given by Fleming's left hand rule.



- It states that, if the forefinger, thumb and middle finger of left hand are stretched mutually perpendicular to each other, such that the forefinger **points along the direction of external magnetic field, middle finger indicates the direction of current, then the thumb points towards the direction of force acting on the conductor.**

  Forefinger = Magnetic field (M)
  Middle finger = Direction of current (C)
  Thumb = Direction of force (F)

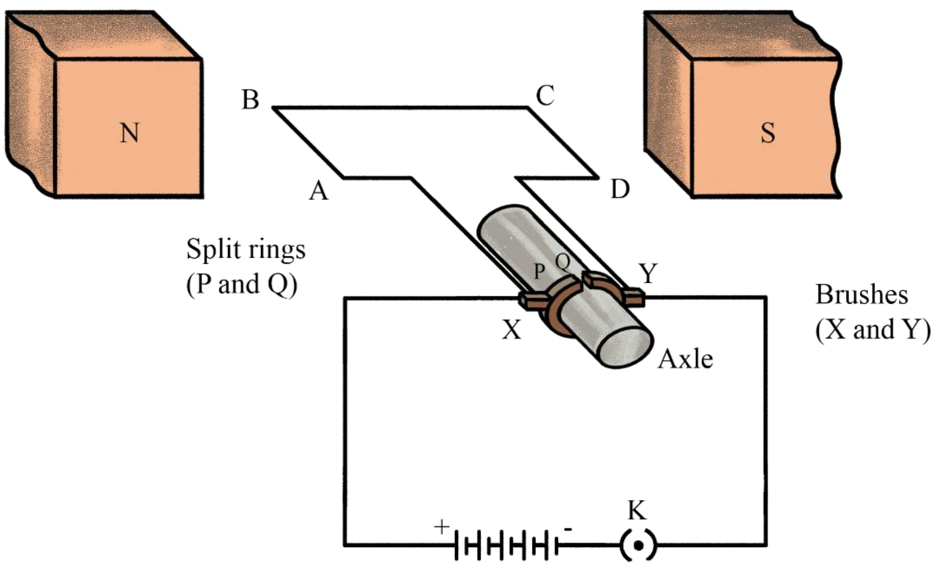
## Electric Motor

- It is a rotating device used for converting electric energy into mechanical energy.

## Principle

- It is based on the principle that when a rectangular coil is placed in a magnetic field and current is passed through it, two end equal and opposite forces act on the coil which rotate it continuously.

## Electric Motor



Electric Motor

## Construction

- **Magnet:** A motor has a strong permanent magnet such that a coil can rotate between its two poles i.e. north and south.
- **Armature:** An electric motor has a coil of insulated copper or aluminum wire wound on a soft iron core called armature.
- **Split rings:** Copper ring, split into two parts and insulated from each other are mounted on the axle of the motor and rotate with it.
- **Brushes:** Two carbon brushes press upon the two split rings. If the supply wires are directly connected to the rings, then on rotation, wires get twisted and broken.
- **Battery:** A strong battery is connected to the split rings through the carbon brushes.

## Working

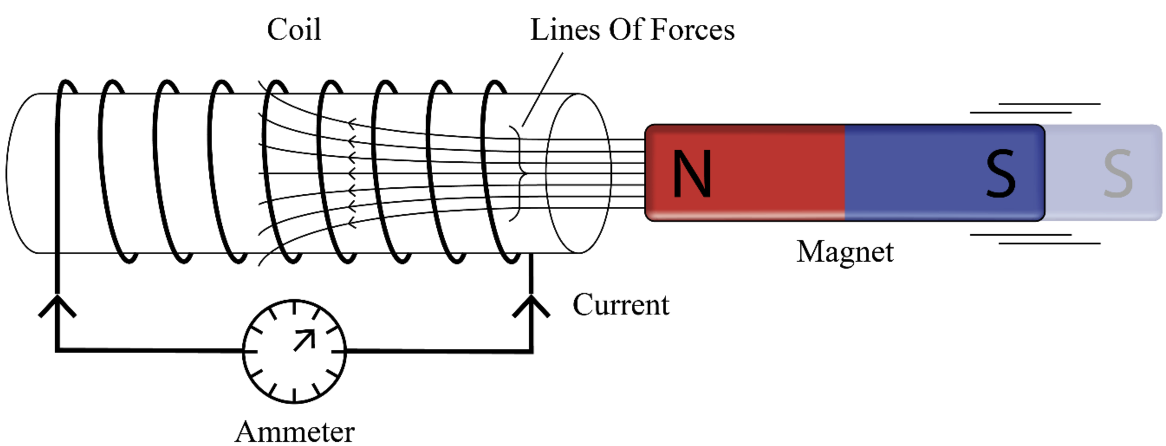
- The working of an electric motor is based on the fact that a current carrying conductor produces a magnetic field around it. To better understand, imagine the following situation.
- Take two bar magnets and keep the poles facing each other with a small space in between. Now, take a small length of a conducting wire and make a loop. Keep this loop in between the space between the magnets such that it is still within the sphere of influence of the magnets. Now for the last bit. Connect the ends of the loop to battery terminals.
- Once electricity flows through your simple circuit, you will notice that your loop "moves". So why does this happen? The magnetic field of the magnets interferes with that produced due to electric current flowing in the conductor. Since the loop has become a magnet, one side of it will be attracted to the north pole of the magnet and the other to the south pole. This causes the loop to rotate continuously. This is the principle of working of electric motor.

**The speed of rotation of the motor can be increased by**

- Increasing the strength of the current in the coil.
- Increasing the number of turns in the coil.
- Increasing the area of the coil.
- Increasing the strength of magnetic field.

## Electromagnetic Induction

- The phenomenon is which electric current is generated by varying magnetic fields is called electromagnetic induction.



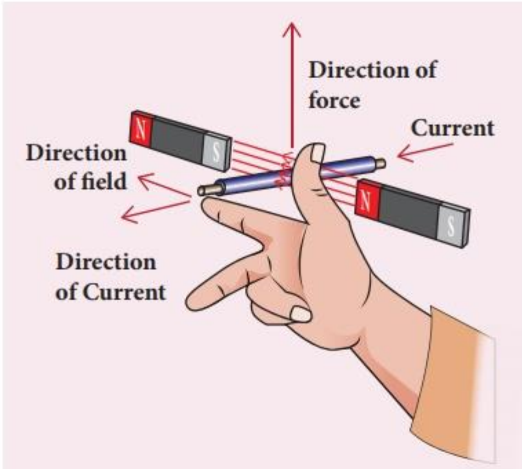
## Fleming's Right-Hand Rule

- The direction of induced current is given by Fleming's right-hand rule. It states, if the forefinger, middle finger and thumb of the right hand are stretched at right angles to each other, with the forefinger in the direction of the magnetic field and the thumb in the direction of the motion of the wire, then the induced current in the wire is in the direction of the middle finger.

  Forefinger = Direction of magnetic field

  Middle finger = Direction of induced current (C)

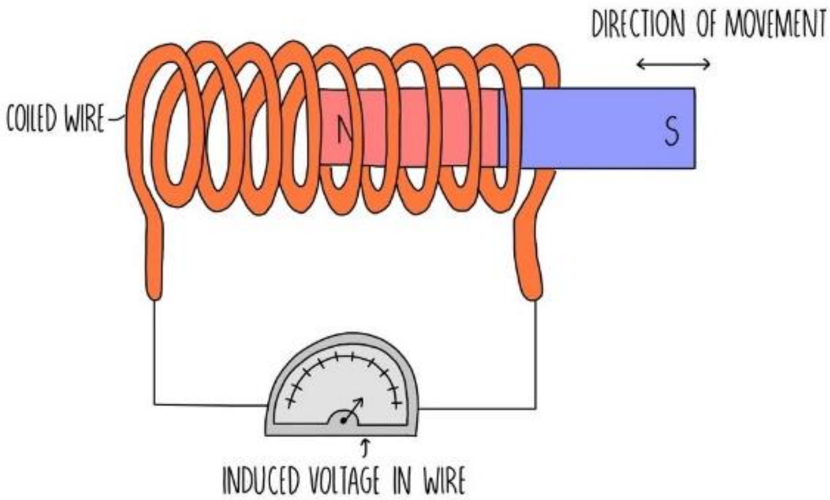
  Thumb = Direction of motion of wire




## Electromagnetic Induction

**We can induce Current in a Circuit By Moving magnet in the Coil**

- Current can be induced in coil either by moving it in a magnetic field or by changing the magnetic field around it as indicated by deflection in galvanometer needle.




## Electric Generator

- An electrical machine which converts mechanical energy into electrical energy is called generator.

## Principle

- An electric generator works on the principle of electromagnetic induction (EMI). When a coil is rotated in a uniform magnetic field, an e.m.f. is induced in it.

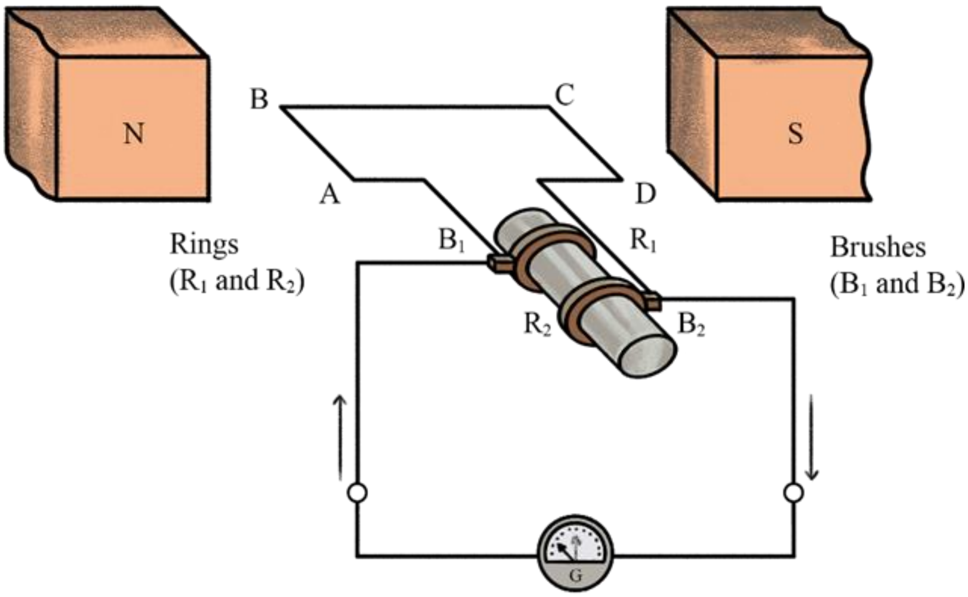
### Electric generators are of two types:

(i) Alternating current (AC) generator.

(ii) Direct current (DC) generator.

## AC Generator

### Construction:




Electric Generator

**The main parts of AC generator are given below:**

1. **Field magnet:** Strong permanent magnet is used as a field magnet. The armature is placed between the two poles of this magnet.
2. **Armature:** Armature consists of a coil of large number of turns of insulated copper wire wound over a soft iron core.
3. **Slip rings:** The two ends of the armature coil are connected to two slip rings R1 and R2. These rings rotate along with the armature coil.
4. **Brushes:** Two carbon brushes press lightly against the slip rings. The brushes remain fixed and do not rotate along with the armature coil.

### Working

When the armature rotates between the poles of the magnet upon an axis perpendicular to the magnetic field, the flux linkage of the armature changes continuously. As a result, an electric current flow through the galvanometer and the slip rings and brushes. The galvanometer swings between positive and negative values. This indicates that there is an alternating current flowing through the galvanometer. The direction of the induced current can be identified using Fleming's Right-Hand Rule.

## Frequency

Number of cycles of current or voltage per second is called frequency.

$$v = \frac{1}{T} \quad \text{where T is time period}$$

S.I. unit of frequency is hertz denoted by Hz.

## Difference between an electric generator and electric motor is given below.

| A.C. Generator | D.C. Generator |
|---|---|
| 1. A generator converts mechanical energy in to electrical energy. | 1. A motor converts electrical energy into mechanical energy. |
| 2. An a.c. generator uses a pair of slip rings. | 2. A d.c. motor running on battery uses a split ring. |
| 3. The direction of induced current is given by Flemming's right-hand rule. | 3. The direction of motion of the conductor is given by Flemming's left-hand rule. |
| 4. Generators require some prime mover (for example fuel engines) to rotate their armature. | 4. Motor act as prime mover i.e. they rotate other mechanical machines. |

## Types of Current

**There are mainly two types of electric currents:**

**(i) Direct current or D.C.**

➢ It is the electric current which flows in the same directions.

**(ii) Alternating current or A.C.**

➢ It is the electric current which reverses its direction after every fixed interval of time.

## Advantages of AC

(1) AC can be easily converted to D.C.

(2) A pure choke coil does not suffer from loss of energy when operated on A.C.

(3) Alternating current can be transmitted at very high voltage and lesser current over long distances with negligible loss of energy.

(4) A.C. machines like transformers are very efficient.

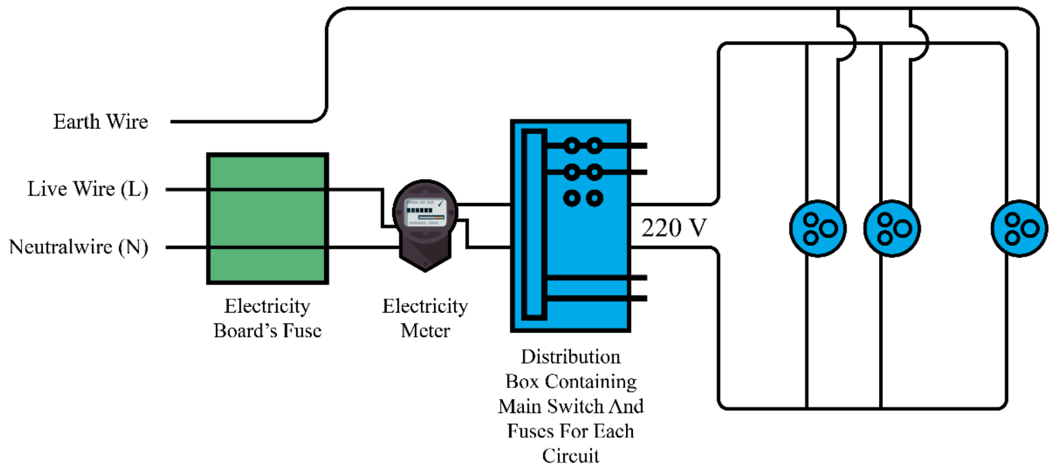
## Disadvantages of AC

(1) AC cannot be used for electric processes like electroplating, electrotyping, electrolysis etc.

(2) AC does not travel through the core of a conductor. It travels on the surface of a conductor so thicker conductors are required for transmission.

(3) It can be dangerous to work on AC system of same voltage as compared to DC because there are higher peak values in A.C. system for the same value of the voltage. For example, a 220 V a.c. has peak of 311 V.

## Domestic Electrical Circuits




**3 types of wires are involved in the domestic electric circuits, they are:**

- Earth wire
- Live wire
- Neutral wire

Earth wire is green in colour. Earth wire is connected to metal plates placed in the earth near the house for safety purposes. It provides safety for all the appliances and devices connected at home which have a metallic body. This is done to prevent shock when leakage of charges happens in the metallic body.

Live wire is red in colour. It is a positive conductor that helps to break the circuit when excess current flows through the circuit. Neutral wire is black in colour. It is a negative conductor.

**Notes End**

**Some Important Questions**

**Q1.** What is the principle of an electric motor ?

**Sol.** A motor works on the principle of magnetic effect of current. When a rectangular coil is placed in a magnetic field and current is passed through it, a force acts on the coil which rotates it continuously.

When the coil rotates, the shaft attached to it also rotates. In this way the electrical energy supplied to the motor is converted into the mechanical energy of rotation.

**Q2.** What is the role of the split ring in an electric motor ?

**Ans:** The split ring reverses the direction of current in the armature coil after every half rotation, i.e., it acts as a commutator. The reversed current reverses the direction of the forces acting on the two arms of the armature after every half rotation. This allows the armature coil to rotate continuously in the same direction.

**Q3.** State the principle of an electric generator.

**Ans:** The electric generator works on the principle that when a straight conductor is moved in a magnetic field, then current is induced in the conductor.

In an electric generator, a rectangular coil is made to rotate rapidly in the magnetic field between the poles of a horse-shoe type magnet. When the coil rotates, it cuts the magnetic field lines due to which a current is produced in the coil.

**Q4.** Name some sources of direct current.

**Ans:** Some of the sources of direct current are dry cells, button cells, lead accumulators.

**Q5.** Which sources produce alternating current ?

**Ans:** Alternating current is produced by AC generators of nuclear power plants, thermal power plants, hydroelectric power stations, etc.

**Q6.** An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain.

**Ans:** The electric oven draws a current given by

$$I = \frac{P}{V} = \frac{2\text{kW}}{220\,\text{V}} = \frac{2000\,\text{W}}{220\,\text{V}} = 9.09\,\text{A}$$

Thus the electric oven draws current much more than the current rating 5 A. That is the circuit is overloaded. Due to excessive current, the fuse wire will blow and the circuit will break.

What precautions should be taken to avoid the overloading of domestic electric circuits ?

To avoid the overloading of domestic electric circuits, the following precautions should be taken :

(i) The wires used in the circuit must be coated with good insulating materials like PVC, etc.

(ii) The circuit must be divided into different sections and a safety fuse must be used in each section.

(iii) High power appliances like air-conditioner, refrigerator, a water heater, etc. should not be used simultaneously.

**Q7.** How docs a solenoid behave like a magnet? Can you determine the north and south poles of a current-carrying solenoid with the help of a bar magnet? Explain.

**Ans:** A solenoid behaves like a magnet in the following ways.

- The magnetic field produced by a current carrying solenoid is very much similar to that of a bar magnet.
- Like a bar magnet, one end of the solenoid has N-polarity while the other end has S-polarity.

To determine the north and south poles, we bring N-pole of the bar magnet near one end of the solenoid. If there is an attraction, then that end of the solenoid has south polarity and the other has north polarity. If there is a repulsion, then that end of the solenoid has north polarity and the other end has south polarity because similar poles repel each other.

**Q8.** Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field ?

**Ans:** Here the electron beam is moving from our back wall to the front wall, so the direction of current will be in the opposite direction, from front wall towards back wall or towards us. The direction of deflection (or force) is towards our right side.

We now know two things :

- direction of current is from front towards us, and
- direction of force is towards our right side.

Let us now hold the forefinger, middle finger and thumb of our left hand at right angles to one another. We now adjust the hand in such a way that our centre finger points towards us (in the direction of current) and thumb points towards right side (in the direction of force). Now, if we look at our forefinger, it will be pointing vertically downwards. Since the direction of forefinger gives the direction of magnetic field, therefore, the magnetic field is in the vertically downward direction.