# JSR IAS ACADEMY

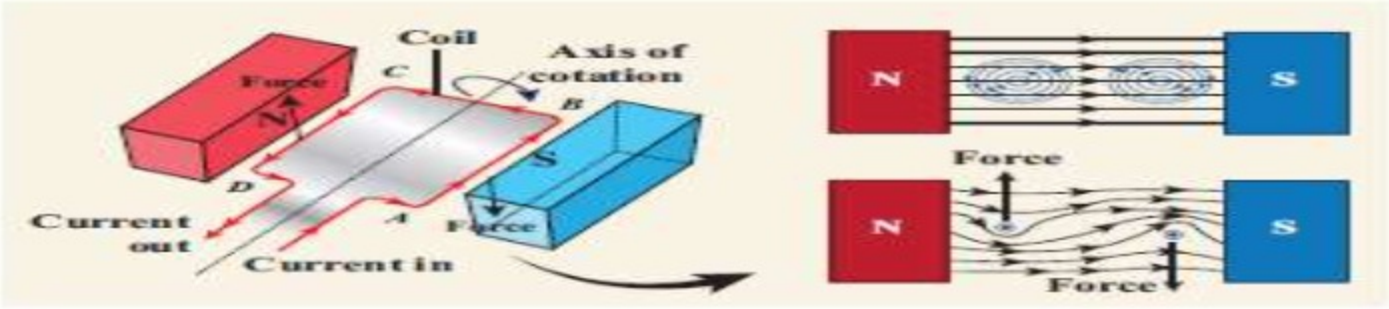
## GENERAL SCIENCE

## PHYSICS

# Magnetism - 2

**Electric motor**

- An electric motor is a device which converts electrical energy into mechanical energy.
- when electric current is passed through a conductor placed normally in a magnetic field, a force is acting on the conductor and this force makes the conductor to move.
- This is harnessed to construct an electric motor.



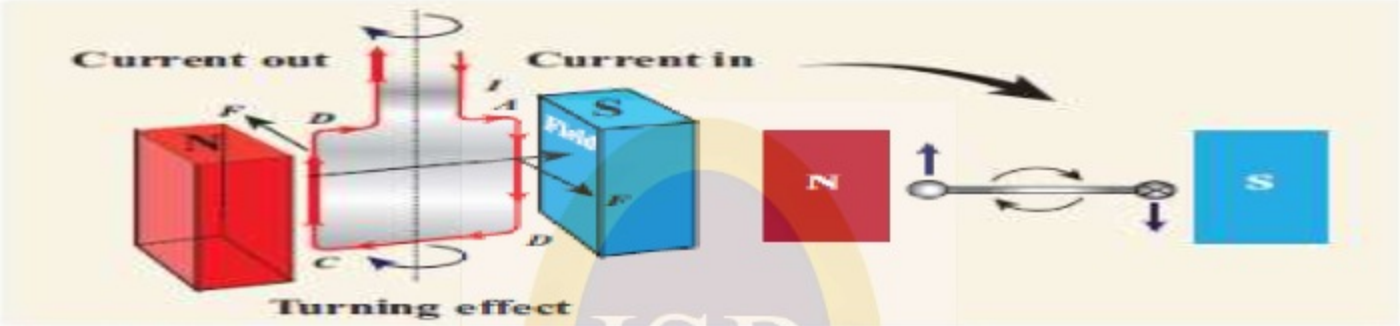




Figure 5.12 Turning effect in a coil

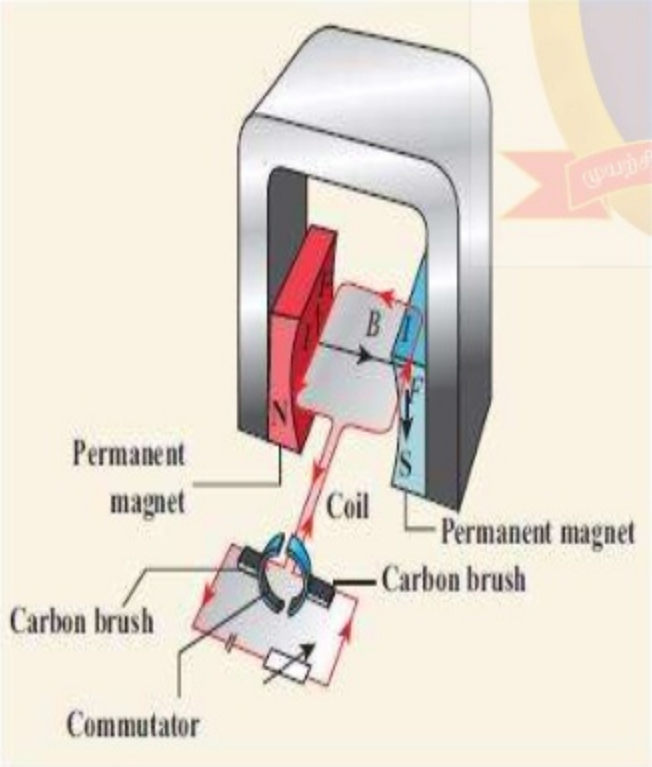



Figure 5.13 Principle of electric motor

- a simple coil is placed inside two poles of a magnet.
- Now look at the current carrying conductor segment AB.
- The direction of the current is towards B, whereas in the conductor segment CD the direction is opposite.
- As the current is flowing in opposite directions in the segments AB and CD, the direction of the motion of the segments would be in opposite directions according to Fleming's left hand rule.
- When two ends of the coil experience force in opposite direction, they rotate.
- the current flow is along the line ABCD, then the coil will rotate in clockwise direction first and then in anticlockwise direction.
- If we want to make the coil rotate in any one direction, say clockwise, then the direction of the current should be along ABCD in the first half of the rotation and along DCBA in the second half of the rotation.
- To change the direction of the current, a small device called split ring commutator is used.

**The speed of rotation of coil can be increased by:**

i. increasing the strength of current in the coil.
ii. increasing the number of turns in the coil.
iii. increasing the area of the coil and
iv. increasing the strength of the magnetic field.

**Electromagnetic Induction**

When it was shown by Oersted that magnetic field is produced around a conductor carrying current, the reverse effect was also attempted.

In 1831, Michael Faraday explained the possibility of producing an e.m.f across the conductor when the magnetic flux linked with the conductor is changed. In order to demonstrate this, Faraday conducted few experiments.

- The direction of the induced current was given by Lenz's law, which states that the induced current in the coil flows in such a direction as to oppose the change that causes it.
- The direction of induced current can also be given by another rule called Fleming's Right Hand Rule.

**Fleming's Right Hand Rule**

- Stretch the thumb, fore finger and middle finger of your right hand mutually perpendicular to each other.
- If the fore finger indicates the direction of magnetic field and the thumb indicates the direction of motion of the conductor, then the middle finger will indicate the direction of induced current.
- Fleming's Right hand rule is also called 'generator rule'.

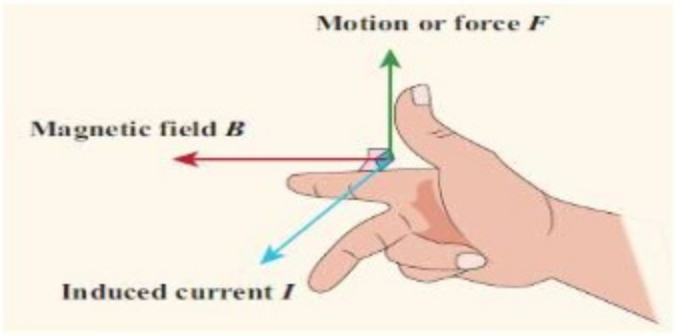



Figure 5.17 Fleming's right hand rule

**Electric generator**

- An alternating current (AC) generator, consists of a rotating rectangular coil ABCD called armature placed between the two poles of a permanent magnet.
- The two ends of this coil are connected to two slip rings S1 and S2.
- The inner sides of these rings are insulated.
- Two conducting stationary brushes B1 and B2 are kept separately on the rings S1 and S2 respectively.
- The two rings S1 and S2 are internally attached to an axle.
- The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field.
- Outer ends of the two brushes are connected to the external circuit.

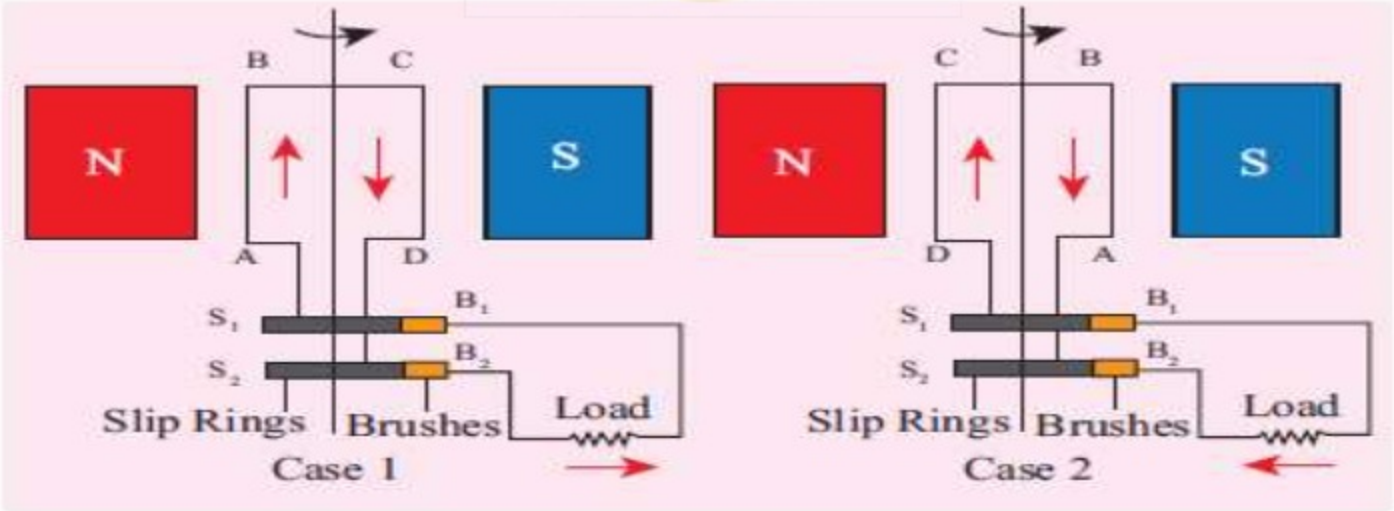



Figure 5.18 AC generator

- When the coil is rotated, the magnetic flux linked with the coil changes. This change in magnetic flux will lead to generation of induced current.
- The direction of the induced current, as given by Fleming's Right Hand Rule, is along ABCD in the coil and in the outer circuit it flows from B2 to B1.
- During the second half of rotation, the direction of current is along DCBA in the coil and in the outer circuit it flows from B1 to B2.
- As the rotation of the coil continues, the induced current in the external circuit is changing its direction for every half a rotation of the coil.
- To get a direct current (DC), a split ring type commutator must be used.
- With this arrangement,
- one brush is at all times in contact with the arm moving up in the field while the other is in contact with the arm moving down.
- Thus, a unidirectional current is produced. The generator is thus called a DC generator

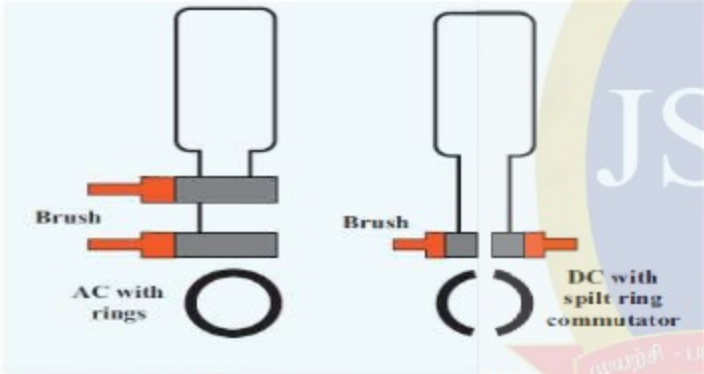
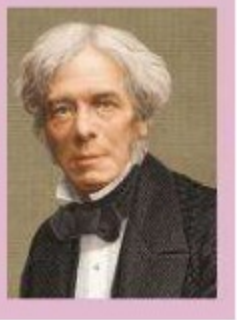



Figure 5.19 Comparison of AC and DC generators

## Know Your Scientist

Michael Faraday (22nd Sep,1791–25th Aug, 1867) was a British Scientist who contributed to the study of electromagnetism and electrochemistry. His main discoveries include the principles underlying electromagnetic induction, diamagnetism and electrolysis.



## Transformer

- Transformer is a device used for converting low voltage into high voltage and high voltage into low voltage.
- It works on the principle of electromagnetic induction.
- It consists of primary and secondary coil insulated from each other.
- The alternating current flowing through the primary coil induces magnetic field in the iron ring.
- The magnetic field of the iron ring induces a varying emf in the secondary coil.

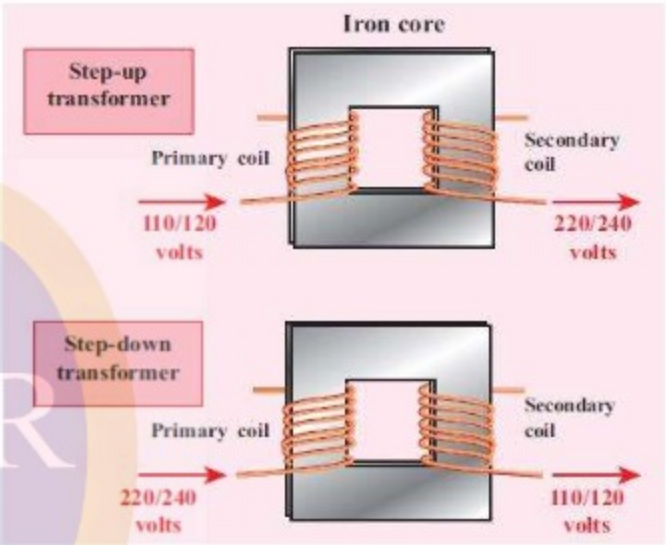



Figure 5.20 Step up and step down transformers

Depending upon the number of turns in the primary and secondary coils, we can step-up or step-down the voltage in the secondary coil

**Step up transformer:**

- The transformer used to change a low alternativing voltage to a high alternating voltage is called a step up transformer. ie Vs > Vp.
- In a step up transformer, the number of turns in the secondary coil is more than the number of turns in the primary coil (Ns > Np).

**Step down transformer:**

- The transformer used to change a high alternating voltage to a low alternating voltage is called a step down transformer (Vs < Vp).
- In a step down transformer, the number of turns in the secondary coils are less than the number of turns in the primary coil (Ns < Np).


A step up transformer increases the voltage but it decreases the current and vice versa. Basically there will be loss of energy in a transformer in the form of heat, sound etc.

**The formulae pertaining to the transformers are given in the following equations.**

$$\frac{\text{Number of primary turns } N_p}{\text{Number of secondary turns } N_s} = \frac{\text{Number of secondary turns } N_s}{\text{Number of primary turns } N_p}$$

- A transformer cannot be used with the direct current (DC) source because, current in the primary coil is constant (ie. DC).
- Then there will be no change in the number of magnetic field lines linked with the secondary coil and hence no emf will be induced in the secondary coil.

**Problem 3**

The primary coil of a transformer has 800 turns and the secondary coil has 8 turns. It is connected to a 220 V ac supply. What will be the output voltage?

Solution:

In a transformer, $E_s / E_p = N_s / N_p$

$E_s = N_s / N_p \times E_p$

$= 8/800 \times 220 = 220/100 = 2.2$ volt

**Applications of Electromagnets**

**Speaker**

- Inside the speaker, an electromagnet is placed in front of a permanent magnet.
- The permanent magnet is fixed firmly in position whereas the electromagnet is mobile.
- As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed.
- This means that it is in turn attracted to and repelled from the permanent magnet vibrating back and forth.
- The electromagnet is attached to a cone made of a flexible material such as paper or plastic which amplifies these vibrations, pumping sound waves into the surrounding air towards our ears.

**Magnetic Levitation Trains**

- Magnetic levitation (Maglev) is a method by which an object is suspended with no support other than magnetic fields.
- In maglev trains two sets of magnets are used, one set to repel and push the train up off the track, then another set to move the fl oating train ahead at great speed without friction.
- In this technology, there is no moving part.
- The train travels along a guideway of magnets which controls the train's stability and speed using the basic principles of magnets.

**Medical System**

- Nowadays electromagnetic fields play a key role in advanced medical equipments such as hyperthermia treatments for cancer, implants and magnetic resonance imaging (MRI).
- Sophisticated equipments working based on electromagnetism can scan even minute details of the human body.

Many of the medical equipments such as scanners, x-ray equipments and other equipments also use the principle of electromagnetism for their functioning.

**Magnetic Properties**

**Attractive Property**

A magnet always attracts materials like iron, cobalt and nickel.

the attractive property of a magnet is more at the poles.

Magnetic poles always exist in pairs.

**Repulsive Property**

- ❖ This activity explains another property of a magnet that like poles repel each other i.e., a north pole repels another north pole and a south pole repels another south pole.
- ❖ unlike poles of a magnet attract each other.

**Directive Property**

- ❖ The property of a magnet, by which it aligns itself along the geographic north-south direction, when it is freely suspended, is known as the directive property of a magnet.
- ❖ The north pole of the magnet points towards the geographic north direction and the south pole of the magnet points towards the geographic south direction.

**Magnetic Field**

- ❖ Th e space around the bar magnet where the arrangement of iron fi lings exists, represents the field of influence of the bar magnet. It is called the magnetic fi eld.
- ❖ It is measured by the unit *tesla* or *gauss* (1 tesla =10,000 gauss).

**Uses of Magnets**

In ancient times the magnet in the form of **'direction stone'** helped seamen to find the directions during a voyage.

Nowadays, magnets are used to generate electricity in **dynamos.**

They are used in **electric bells and electric motors.**

They are used in **loudspeakers and microphones.**

- ❖ In banks, the magnets enable the computers to read the MICR numbers printed on a cheque.
- ❖ The tip of the screw drivers are made slightly magnetic so that the screws remain attached to the tip.
- ❖ At hospitals, extremely strong electro magnets are used in the MRI (Magnetic Resonance Imaging) to scan the specified internal organ.


The strip on the back of a credit card/debit card is a magnetic strip, often called a magstripe. The magstripe is made up of tiny iron-based magnetic particles in a thin plastic film. Each particle is really a very tiny bar magnet about 20 millionth of an inch long.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| **Magnet** | A piece of iron or other material, which can attract things containing iron. |
| **Magnetic axis** | The line joining the magnetic poles. |
| **Magnetic field** | The space around the magnet, in which the magnetic force is experienced within a particular region. |
| **Magnetism** | The branch of physics which deals with the property of a magnet. |
| **Magnetisation** | A process in which a substance is made a permanent or temporary magnet by exposing it to an external magnetic field. |
| **Magnetite** | A rock which has magnetic properties. |