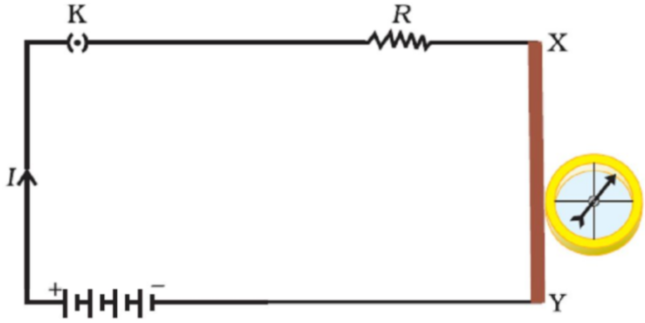
# CHAPTER – 13
## MAGNETIC EFFECT OF CURRENT

The term magnetic effect of electric current means that an electric current flowing in a wire produces a magnetic field around it.

Electromagnetism: In 1820, Oersted performed an experiment to show that a current flowing through a wire produces a magnetic field around it.

- In this experiment, he found that when a magnetic needle was placed under a wire having no current flowing through it, the needle remained parallel to the wire as shown in the figure.
- But when electric current was allowed to flow through it by connecting it with a battery, a deflection was observed in the magnetic needle showing that a current carrying wire produces a magnetic field around it, which lasts as long as the current is flowing through the wire.
- This phenomenon is referred to as electromagnetism.




**MAGNET**

A magnet is an object, which attracts pieces of iron, steel, nickel and cobalt. It has two poles at ends – South and North Pole.

- Like magnetic poles repel each other.
- Unlike magnetic poles attract each other.

**MAGNETIC FIELD**

The space surrounding a magnet in which the force of attraction and repulsion is exerted is called a magnetic field.

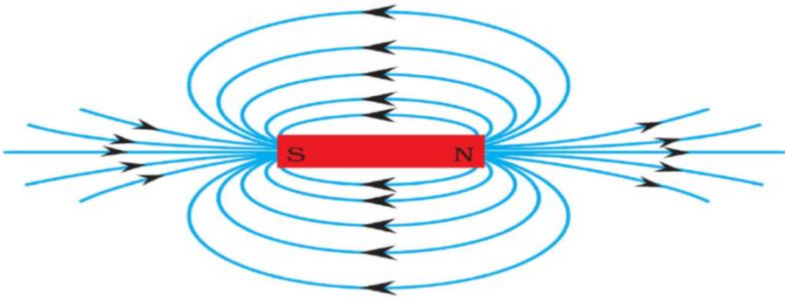
**MAGNETIC FIELD LINES**

A field line is the path along which a hypothetical free north pole would tend to move.

*The direction of the magnetic field at a point is given by the direction that a north pole placed at that point would take.*

**PROPERTIES OF MAGNETIC FIELD LINES**

1. A magnetic field lines originate from north pole and end at its south pole.
2. A magnetic field line is a closed and continuous curve.
3. The magnetic field lines are closer near the poles of a magnet where the magnetic field is strong and farther apart where the magnetic field is weak.
4. The magnetic field lines never intersect each other.
5. A uniform magnetic field is represented by parallel and equidistant field lines.
6. *Field lines are shown closer together where the magnetic field is greater.*
7. *Magnetic field is a vector quantity.*

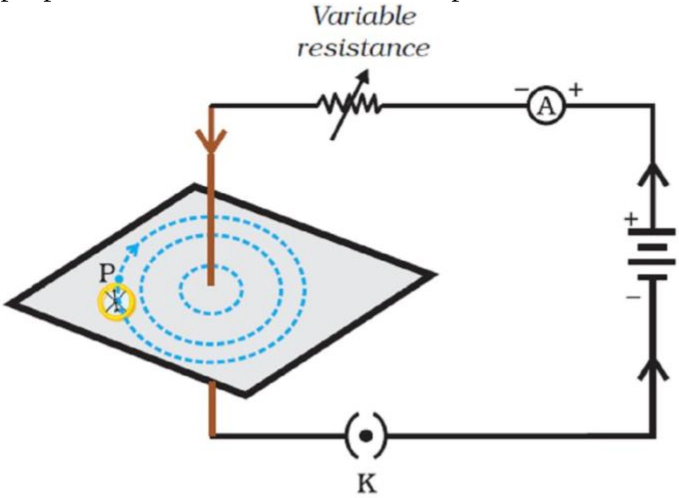



**MAGNETIC FIELD DUE TO A CURRENT THROUGH A STRAIGHT CONDUCTOR**

The magnetic field lines around a straight conductor carrying current are concentric circles whose centres lies on the wire.

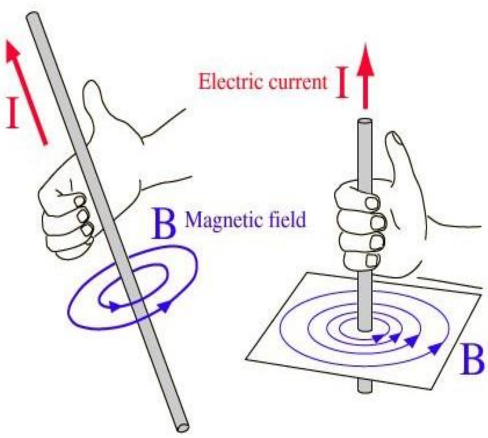
The magnitude of magnetic field produced by a straight current carrying wire at a point-

- directly proportional to current passing in the wire.
- inversely proportional to the distance of that point from the wire.




**RIGHT-HAND THUMB RULE**

When a current-carrying straight conductor is holding in right hand such that the thumb points towards the direction of current. Then fingers will wrap around the conductor in the direction of the field lines of the magnetic field, as shown in below figure. This is known as the right-hand thumb rule



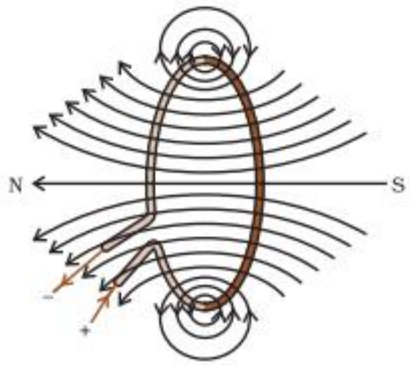
**MAGNETIC FIELD DUE TO A CURRENT THROUGH A CIRCULAR LOOP**

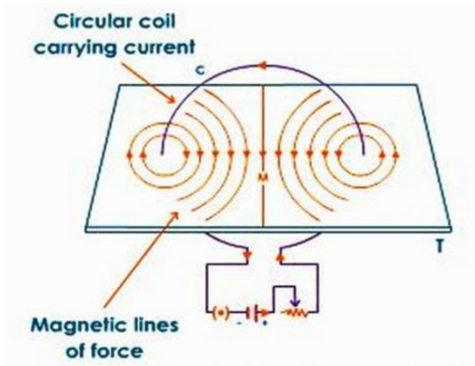
- The magnetic field lines are circular near the current carrying loop. As we move away, the concentric circles becomes bigger and bigger.

- At the centre, the lines are straight.
- At the centre, all the magnetic field lines are in the same direction due to which the strength of magnetic field increase.

The magnetic of magnetic field produced by a current carrying circular loop at its centre is

- directly proportional to the current passing
- inversely proportional to the radius of the circular loop




**<u>MAGNETIC FIELD DUE TO A CURRENT IN A SOLENOID</u>**

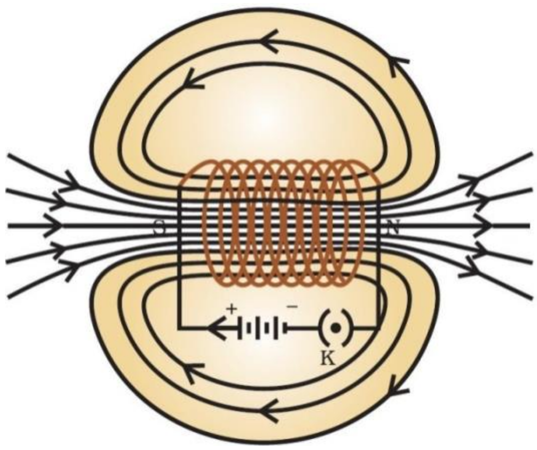
**<u>SOLENOID</u>** -A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called a solenoid.

The solenoid is from greek word for channel.

- The solenoid is a long coil containing a large number of close turns of insulated copper wire.
- The magnetic field produced by a current carrying solenoid is similar to the magnetic field produced by a bar magnet.
- The current in each turn of a current carrying solenoid flows in the same direction due to which the magnetic field produced by each turn of the solenoid ads up, giving a strong magnetic field inside the solenoid.

**APPLICATION OF SOLENOID**

The strong magnetic field produced inside a current-carrying solenoid can be used to magnetise a piece of magnetic material like soft iron, when placed inside the solenoid. The magnet thus formed is called an electromagnet



**<u>The strength of magnetic field produced by a carrying current solenoid depends on</u>**

- number of turns(n)
- strength of current(I)
- nature of core material used in solenoid – use of soft iron as core in a solenoid produces the strongest magnetism.

## ELECTROMAGNETS AND PERMANENT MAGNETS

An electromagnet is a temporary strong magnet and is just a solenoid with its winding on soft iron core.

A permanent magnet is made from steel. As steel has more retentivity than iron, it does not lose its magnetism easily.

**<u>Difference between Electromagnet and permanent magnet</u>**

| Electromagnet | Permanent magnet |
|---|---|
| 1. An electromagnet is a temporary magnet as it can readily demagnetized by stopping the current through the solenoid. | 1. A permanent magnet cannot be readily demagnetized. |
| 2. Strength can be changed. | 2. Strength cannot be changed. |
| 3. It produces very strong magnetic forces. | 3. It produces weal forces of attraction. |
| 4. Polarity can be changed by changing the direction of the current. | 4. Polarity is fixed and cannot be changed. |

*<u>Q. Why soft iron is used for making the core of an electromagnet?</u>*

*Soft iron is used for making the core of an electromagnet because soft iron loses all of its magnetism when current in the coil is switched off.*

*<u>Q. Why steel is not used for making the core of an electromagnet?</u>*

*Steel is not used for making the core of an electromagnet because steel does not loses all of its magnetism when current in the coil is switched off.*

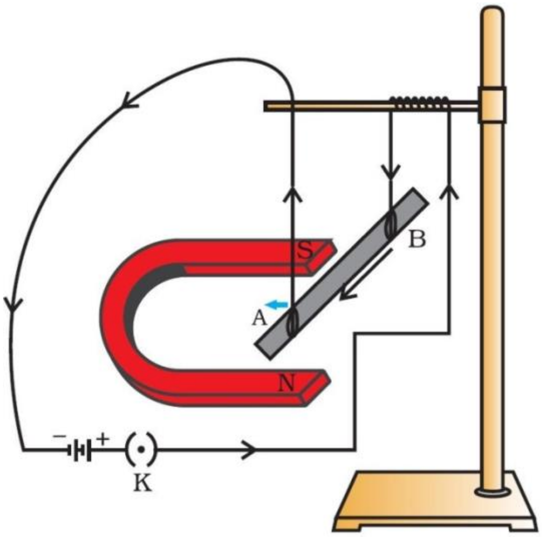
## FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

When a current carrying conductor is placed in a magnetic field it experiences a force, except when it is placed parallel to the magnetic field.

The force acting on a current carrying conductor in a magnetic field is due to interaction between:

1. Magnetic force due to current-carrying conductor and

2. External magnetic field in which the conductor is placed.




**FACTORS AFFECTING FORCE ACTING ON A TSRAIGHT CURRENT CARRING CONDUCTOR**

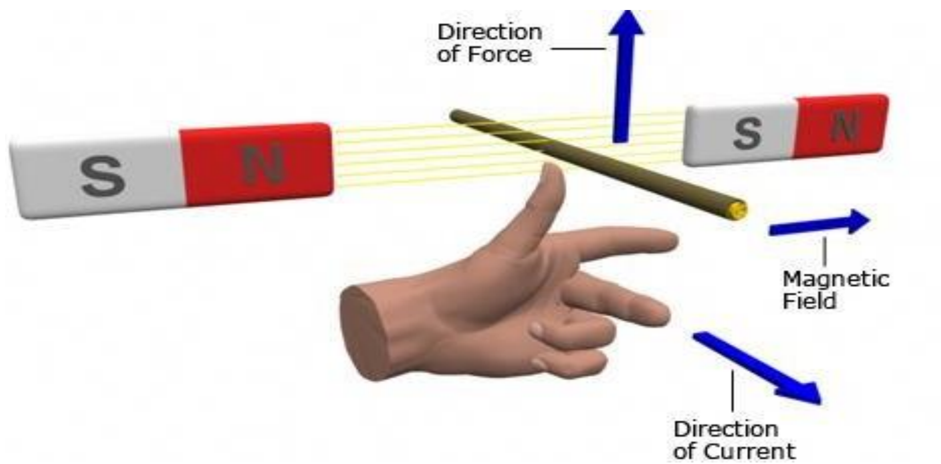
- Directly proportional to the current flowing through conductor.
- Directly proportional to the strength of magnetic field in which conductor is placed.
- Orientation of conductor in magnetic field.

**FLEMING'S LEFT HAND RULE**

Fleming's left hand rule (for electric motors) shows the direction of the force on a conductor carrying a current in a magnetic field.

The left hand is held with the thumb, index finger and middle finger mutually at right angles.

- The First finger (INDEX FINGER) represents the direction of the magnetic Field.
- The Second finger(MIDDLE FINGRE) represents the direction of the Current .
- The Thumb represents the direction of the force or resultant Motion.



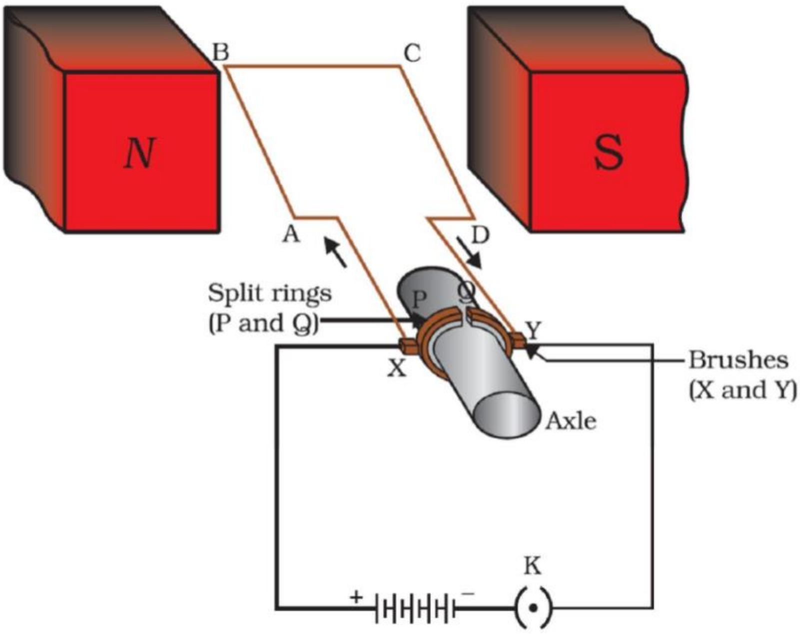
## ELECTRIC MOTOR

**INTRODUCTION**-An electric motor is a rotating device that converts electrical energy to mechanical energy.

**Principle:** When a coil carrying current is placed in a magnetic field, it experiences a torque. As a result of this torque, the coil begins to rotate.

**Construction:**

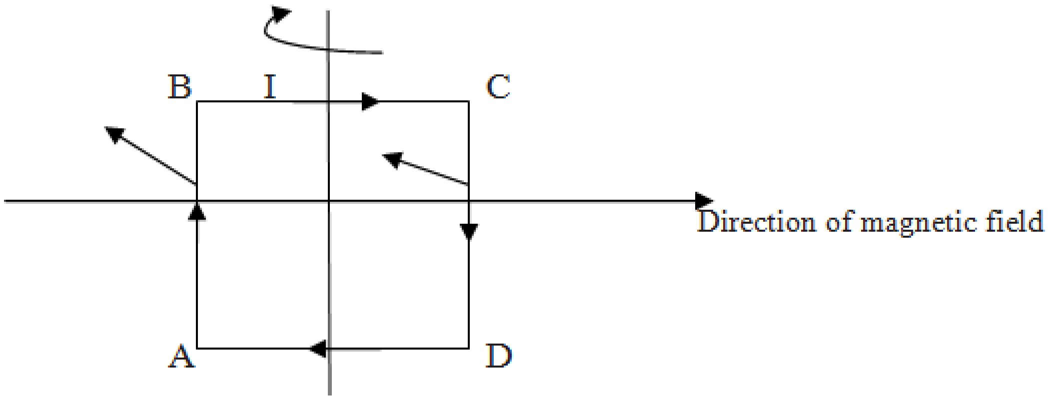
- Armature :- the armature ABCD consists of a large number of turns of insulated copper wire wound over a soft iron core.
- Field magnet :- the magnetic field (B) is supplied by a permanent magnet NS.
- Split-ring or commutator :- These are two halves of the same metallic ring(P and Q). The ends of the armature coil are connected to these halves which also rotate with the armature. The inner sides of these halves are insulated and attached to an axle.
- Brushes or sliding contacts :- these are two flexible metal plates or carbon rods X and Y which are so fixed that they constantly touch the revolving rings.




**Working:**

- Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y. The direction of current is from A-B-C-D.

- The split ring P is connected with X while Q is connected With Y.




- On applying Fleming's left hand rule for the direction of force on a current-carrying conductor in a magnetic field..
- We find that the force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards.
- Thus the coil and the axle O, mounted free to turn about an axis, rotate anti-clockwise.
- At half rotation, Q makes contact with the brush X and P with brush Y. Therefore the current in the coil gets reversed and flows along the path DCBA.
- The reversal of current also reverses the direction of force acting on the two arms AB and CD.
- Thus the arm AB of the coil that was earlier pushed down is now pushed up and the arm CD previously pushed up is now pushed down.
- Therefore the coil and the axle rotate half a turn more in the same direction.
- The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil and to the axle.

**The commercial motors use**

- an electromagnet in place of permanent magnet;
- large number of turns of the conducting wire in the current-carrying coil; and
- a soft iron core on which the coil is wound. The soft iron core, on which the coil is wound, plus the coils, is called an armature. This enhances the power of the motor.

## ELECTROMAGNETIC INDUCTION

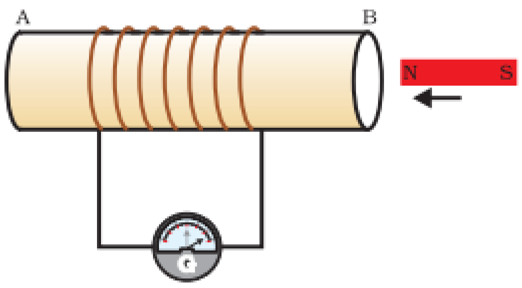
Electromagnetic Induction : The process of inducing emf and hence electric current as a result of change in magnetic field or magnetic flux linked with a conductor.

Michel Faraday and Joseph Henry demonstrated that a moving magnetic field (changing magnetic flus) can produce emf and hence electric current.

**Experiments:**

1) Coil-Magnet experiment –

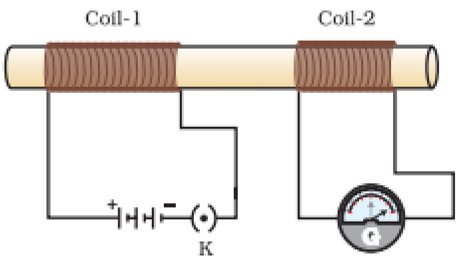
- Galvanometer show deflection when N-pole moving towards the coil.
- It shows deflection in the opposite direction if the pole is moving away from the coil.
- It shows Zero deflection when the magnet is kept stationery inside the coil.
- Thus an emf hence electric current is induced in the coil due to the relative motion of the magnet.(Source of Magnetic field)




Moving a magnet towards a coil sets up a current in the coil circuit, as indicated by deflection in the galvanometer needle.

**2) Coil - Coil experiment**

By making and breaking the current through the coil 1, an emf and hence electric current is induced in the coil 2.



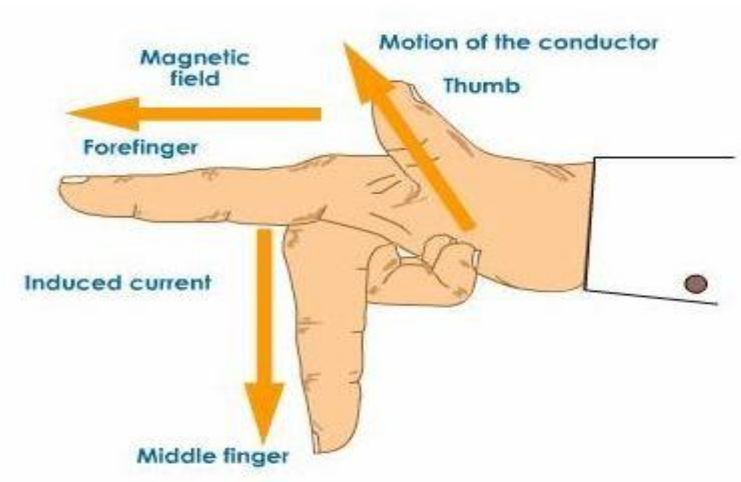

Current is induced in coil-2 when current in coil-1 is changed

**FLEMING'S RIGHT HAND RULE**

Fleming's right hand rule (for generators) shows the direction of induced current when a conductor moves in a magnetic field.

The right hand is held with the thumb, first finger and second finger mutually perpendicular to each other {at right angles}, as shown in the diagram .

- The Thumb represents the direction of Motion of the conductor.
- The First finger(INDEX FINGER) represents the direction of the Field.
- The Second finger(MIDDLE FINGER) represents the direction of the induced or generated Current .




**1.** Explain different ways to induce current in a coil.
The different ways to induce current in a coil are as follows:
(a) If a coil is moved rapidly between the two poles of a horse-shoe magnet, then an electric current is induced in the coil.
(b) If a magnet is moved relative to a coil, then an electric current is induced in the coil

A.C. Generator (or A.C. Dynamo) : "A.C. generator" means "Alternating Current generator". That is, an A.C. generator produces alternating current, which alternates (changes) in polarity continuously. Construction of an A.C. Generator :

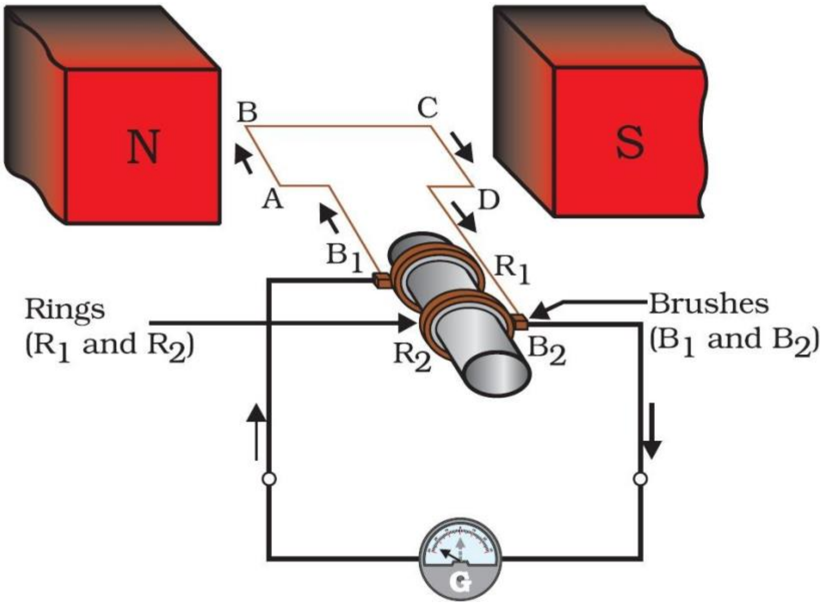
A simple A.C. generator of a consists of he following important parts :

- Armature. It consists of a coil ABCD having a large number of insulated copper wire wound over a soft iron core . The coil is called an armature. The armature is mounted on an axle which can be rotated by force exerted by falling water, wind or steam.

- Field Magnet. The coil is held between the pole-pieces of a strong magnet called the field magnet.

- Slip Rings. These consist of two hollow metallic rings $R_1$ and $R_2$ mounted on the axle of the coil. The ends of limbs AB and CD of the coil are connected to the rings $R_1$ and $R_2$ respectively. These rings rotate along with the rotation of the armature

- Brushes. This consists of metal or carbon plates $B_1$ and $B_2$ which lightly touch the rings during the rotation of the armature.Current from $B_1$, $B_2$ are taken out to load connected across two brushes.




**Working:**

- When the axle  attached to the two rings is rotated such that the arm AB moves up  (and the arm CD moves down) in the magnetic field produced by the permanent magnet.
- Let us say the coil ABCD is rotated clockwise in  the arrangement shown in the above figure.
- By applying Fleming's right-hand rule, the induced currents are set up in these arms along the directions AB and CD. Thus an induced current flows in the direction ABCD.
- The current in the external circuit  flows from $B_2$ to $B_1$.
- After half a rotation, arm CD starts moving up and AB moving down. As a result, the directions of the induced currents in both the arms change, giving rise to the net induced current in the direction DCBA.
- The current in the external circuit now flows from $B_1$ to $B_2$.
- Thus after every half rotation the polarity of the current in the respective arms changes.
- Such a current, which changes direction after equal intervals of time, is called an alternating current (abbreviated as AC). This device is called an  AC generator.

**<u>How to get a direct current generator</u>**

To get a direct current (DC, which does not change its direction with time), 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.

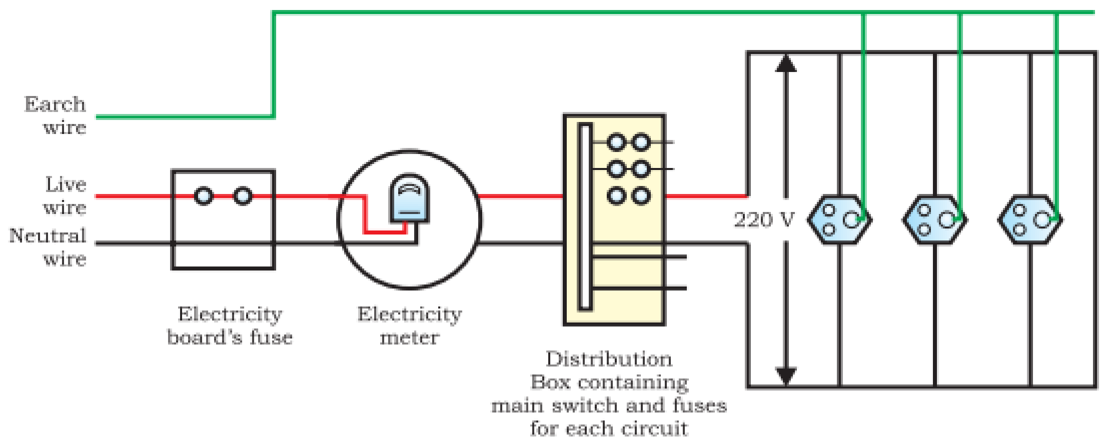
The difference between the direct and alternating currents is that the direct current always flows in one direction, whereas the alternating current reverses  its direction periodically.

**<u>Alternating current</u>**- The current which changes its direction periodically is called alternating current.

**<u>Direct Current -</u>** The current which does not changes its direction periodically is called alternating current.

| ===DC current | ===AC current |
| --- | --- |
| ≥ IN DC current, electric charge flow only in one direction. | ≥ IN ac current, electric charge changes its direction periodicly. |
| ≥ DC current can not transfer at long distance because of very large energy loss. | ≥ Ac current safe travel at long distance. |
| ≥ The frequencies of dc current is zero. | ≥ The generating frequencies is 50 hz to 60 hz in ac current. |
| ≥ The current of magnitude verying with time is constant. | ≥ The current of magnitude verying with time. |
| ≥ The source of availability is battery or cell. | ≥ The source of availability is generator or mains. |

## DOMESTIC ELECTRIC CIRCUITS



*When does an electric short circuit occur?*

If the resistance of an electric circuit becomes very low, then the current flowing through the circuit becomes very high. This is caused by connecting too many appliances to a single socket or connecting high power rating appliances to the light circuits. This results in a short circuit.

When the insulation of live and neutral wires undergoes wear and tear and then touches each other, the current flowing in the circuit increases abruptly. Hence, a short circuit occurs.

*What is the function of an earth wire? Why is it necessary to earth metallic appliances?*

The metallic body of electric appliances is connected to the earth by means of earth wire so that any leakage of electric current is transferred to the ground. This prevents any electric shock to the user. That is why earthing of the electrical appliances is necessary.

*What is Electric fuse? What is the important of electric fuse?*

Electric Fuse consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc. If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases. This melts the fuse wire and breaks the circuit. Fuse is the most important safety device, used for protecting the circuits due to short-circuiting or overloading of the circuits. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of unduly high electric current. The fuses used for domestic purposes are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc.

Q-Name two safety measures commonly used in electric circuits and appliances.

Two safety measures commonly used in electric circuits and appliances are as follows:

(i) Each circuit must be connected with an electric fuse. This prevents the flow of excessive current through the circuit. When the current passing through the wire exceeds the maximum limit of the fuse element, the fuse melts to stop the flow of current through that circuit, hence protecting the appliances connected to the circuit.

(ii)Earthing is a must to prevent electric shocks. Any leakage of current in an electric appliance is transferred to the ground and people using the appliance do not get the shock.