CHAPTER 13

Magnetic Effect of Electric current

Acknowledgment

- Images & video clips have been taken from various sources on the internet.
- Some images and video clips have been modified according to the syllabus.

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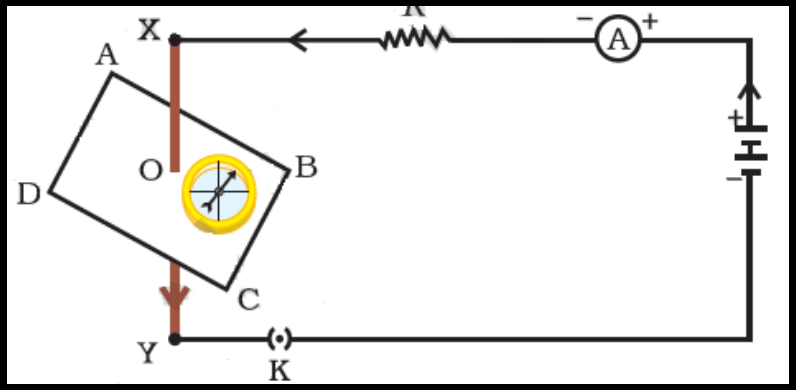
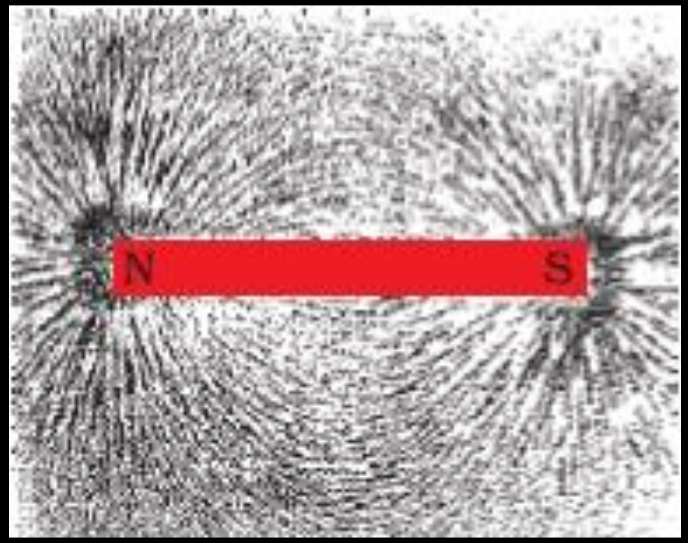
Contents

(Activity 13.1) Take a straight thick copper wire and place it between the points X and Y in an electric circuit, as shown in the figure. The wire XY is kept perpendicular to the plane of paper. Horizontally place a small compass near to this copper wire. See the position of its needle. Pass the current through the circuit by inserting the key into the plug. Observe the change in the position of the compass needle.



It is observed that when current passes in the wire, needle deflects. So we conclude that a current carrying wire produces magnetic field which deflects the magnetic compass needle.

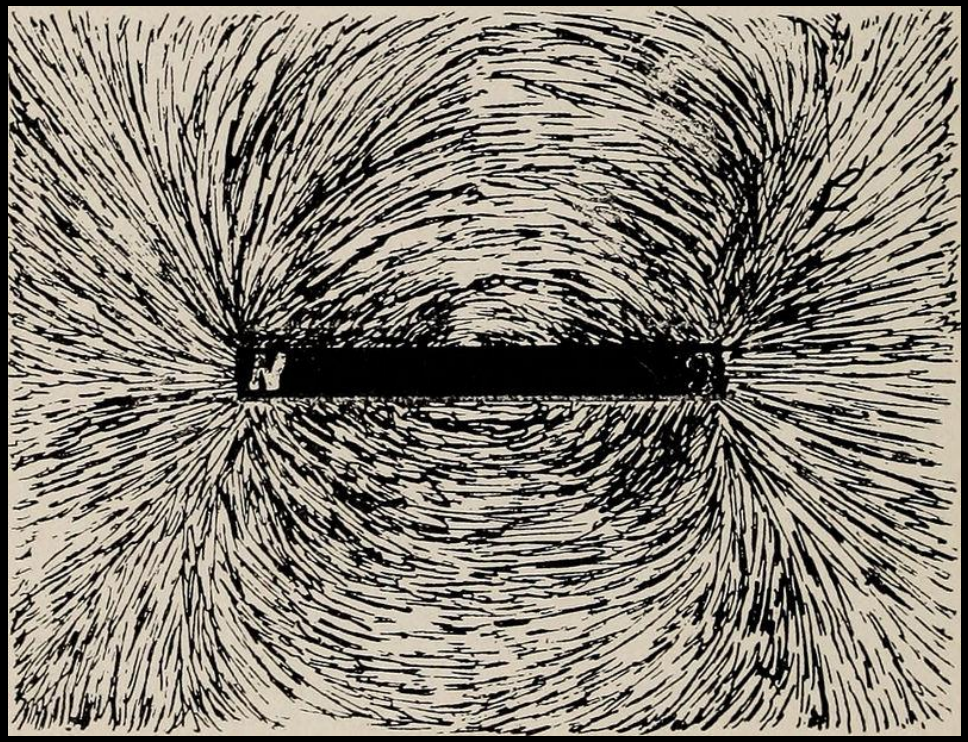
(Activity 13.2) Fix a sheet of white paper on a drawing board using some adhesive material. Place a bar magnet in the centre of it. Sprinkle some iron filings uniformly around the bar magnet. A salt-sprinkler may be used for this purpose. Now tap the board gently. What do you observe?



It is observed that when the board is gently tapped, the iron filings near the bar magnet align themselves along the field lines.

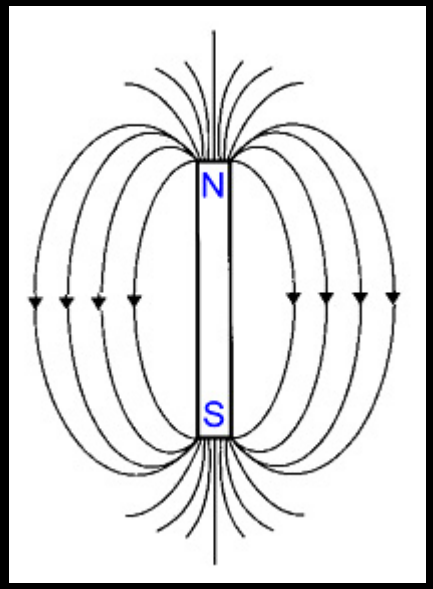
Magnetic field

The region surrounding a magnet, in which the force of the magnet can be experienced is called magnetic field.



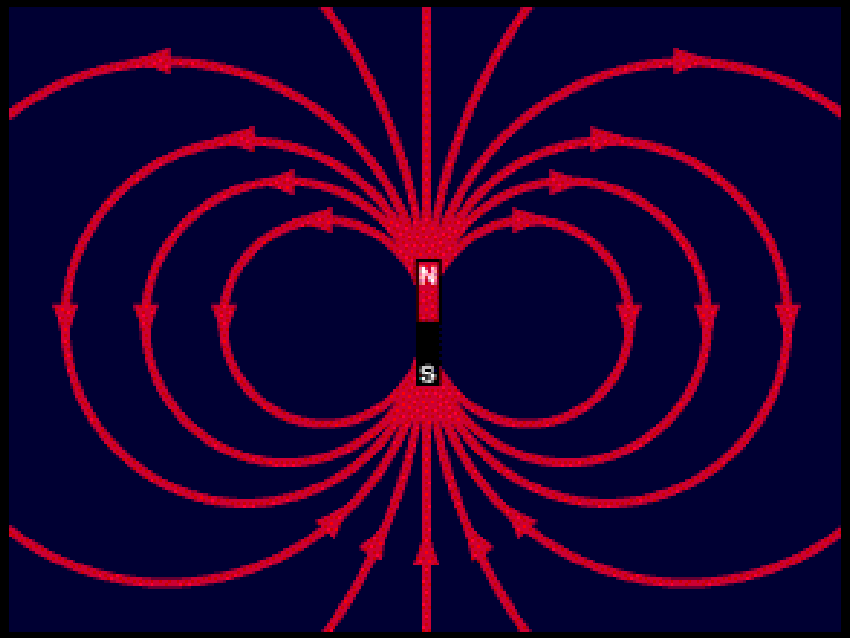
Magnetic field lines

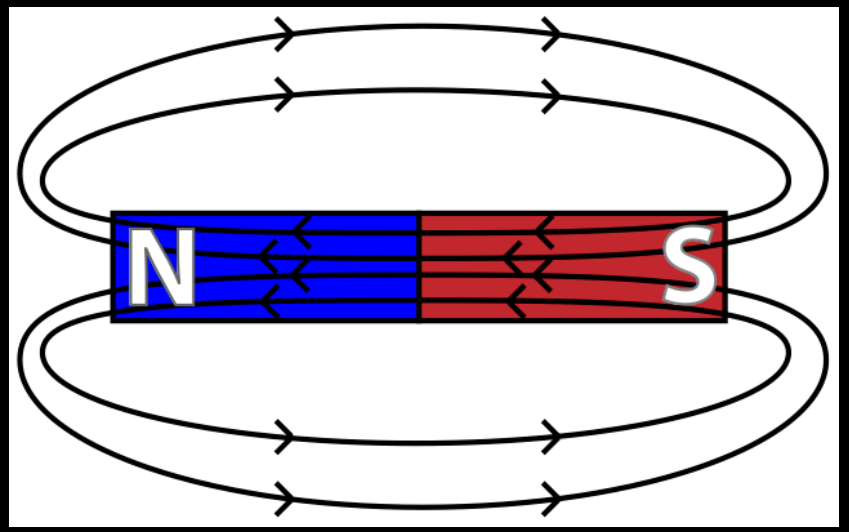
The lines along which the iron filings align themselves are called magnetic field lines.



Properties of Magnetic lines of force

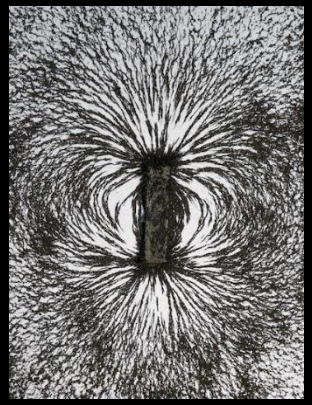
1. A magnetic field lines originate from North Pole and end at its south pole.
2. A magnetic field line is a closed and continuous curve.

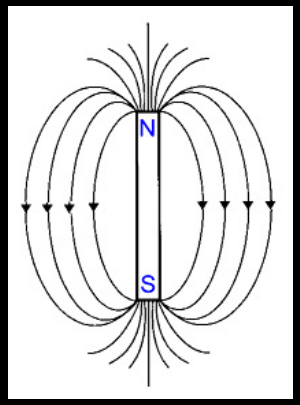


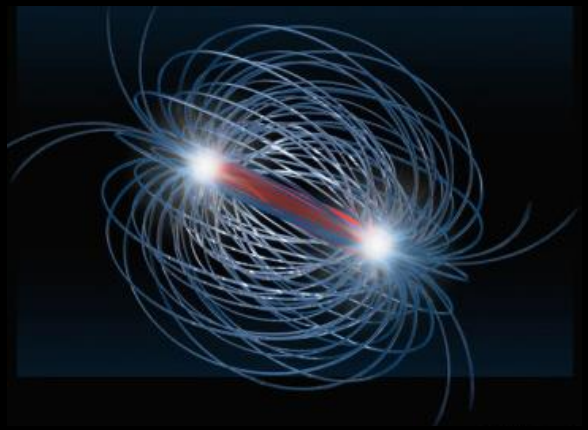


Properties of Magnetic lines of force

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.

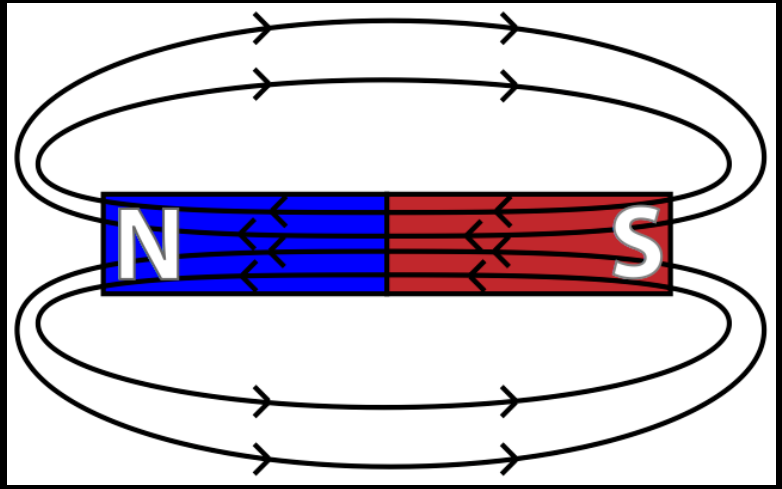






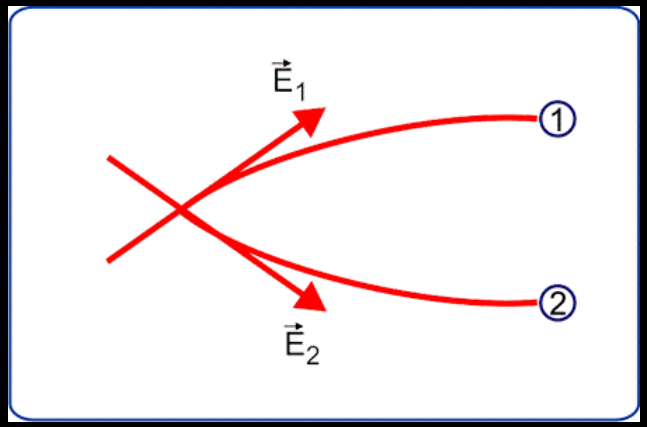
Why are the magnetic field lines closed curves?

The direction of field lines is from its south pole to its north pole. So the magnetic field lines closed curves.



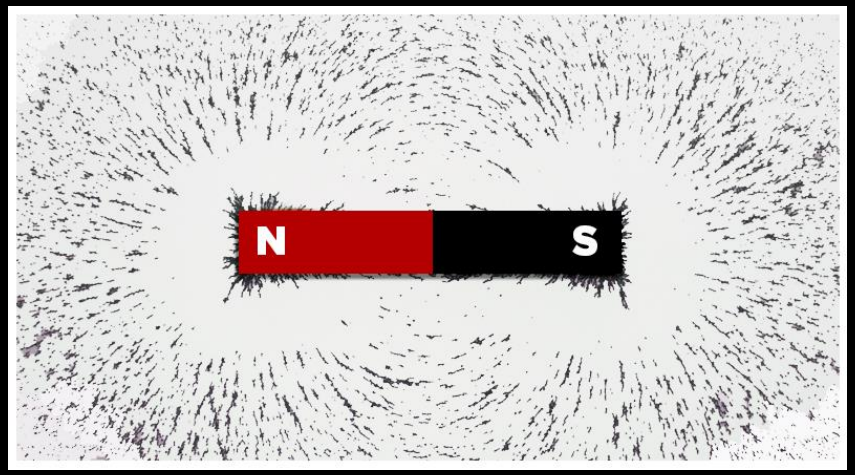
Why don't two magnetic lines of force intersect each other?

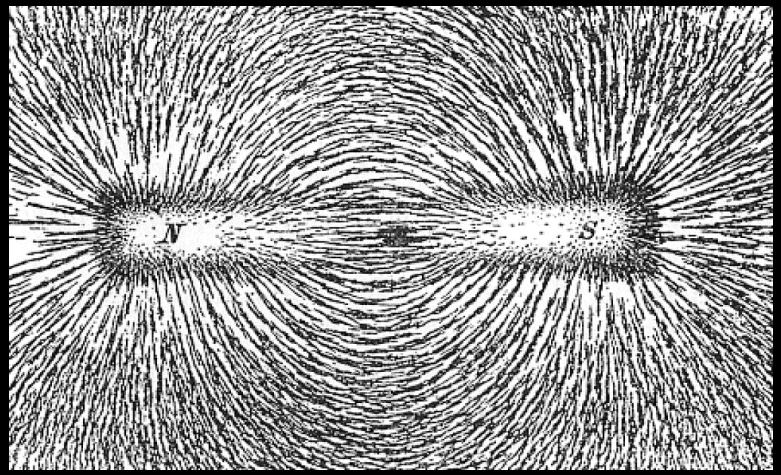
If two magnetic lines of force intersect, then there will be two tangents and hence two directions of the magnetic field at the point of intersection. This is not possible.



How does the degree of closeness of the field lines represent?

The degree of closeness of the field lines gives a measure of the strength of the magnetic field.

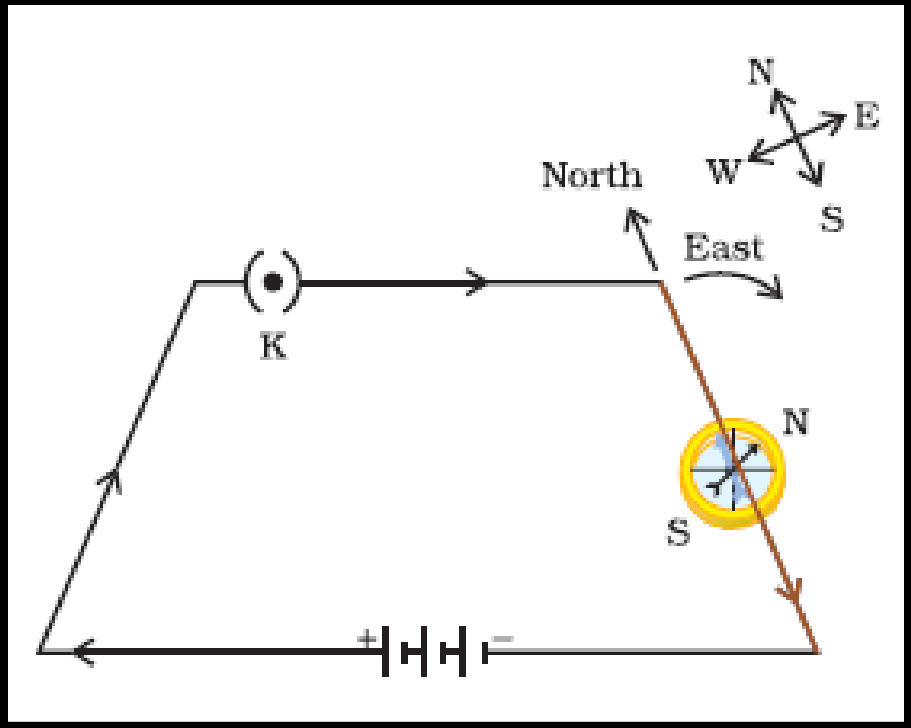




(Activity 13.4) Take a long straight copper wire, two or three cells of 1.5 V each, and a plug key. Connect all of them in series as shown in figure. Place the straight wire parallel to and over a compass needle. Plug the key in the circuit.

a) Observe the direction of deflection of the north pole of the needle.

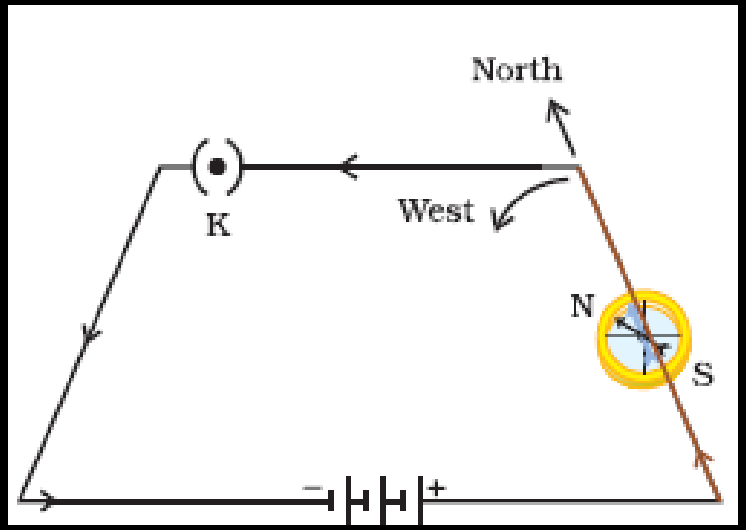
If the current flows from north to south, the north pole of the compass needle would move towards the east.



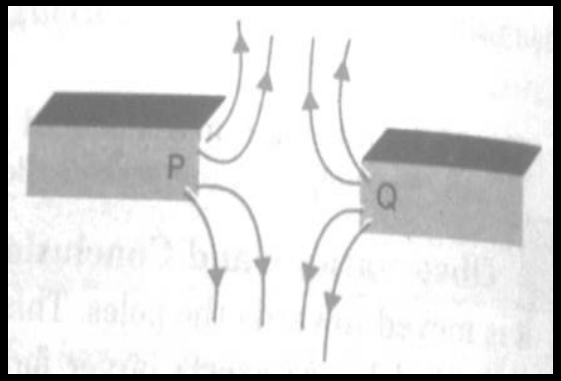
Take a long straight copper wire, two or three cells of 1.5 V each, and a plug key. Connect all of them in series as shown in figure. Place the straight wire parallel to and over a compass needle. Plug the key in the circuit.

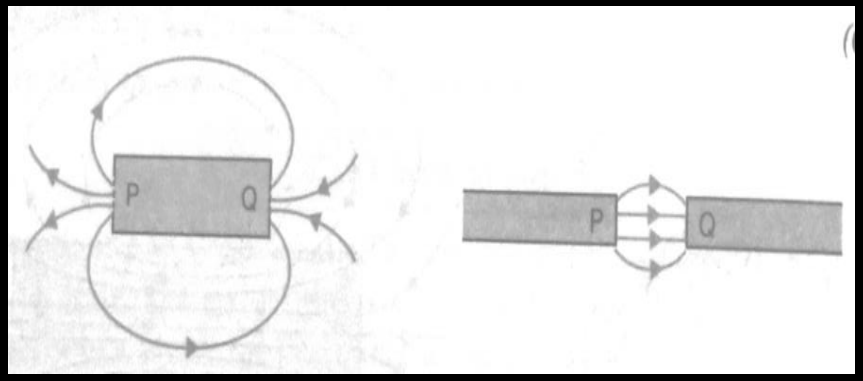
b) Reverse the cell connections in the circuit. This would result in the change of the direction of current through the copper wire, that is, from south to north. Observe the change in the direction of deflection of the needle.

You will see that now the needle moves in opposite direction, that is, towards the west. It means that the direction of magnetic field produced by the electric current is also reversed.



Identify the poles of the magnet in the given figures.





In fig 1, both P and Q are North poles as filed lines are coming out from the two poles.
In fig 2, P is North Pole and Q is South Pole.
In fig 3, P is North Pole and Q is South Pole.

Sources of magnetic field

1) Magnetic field due to a bar magnet.
2) Magnetic field due to a current-carrying conductor.
3) Magnetic field due to current carrying circular loop.

How does the magnitude of the magnetic field produced by straight current carrying conductor vary?

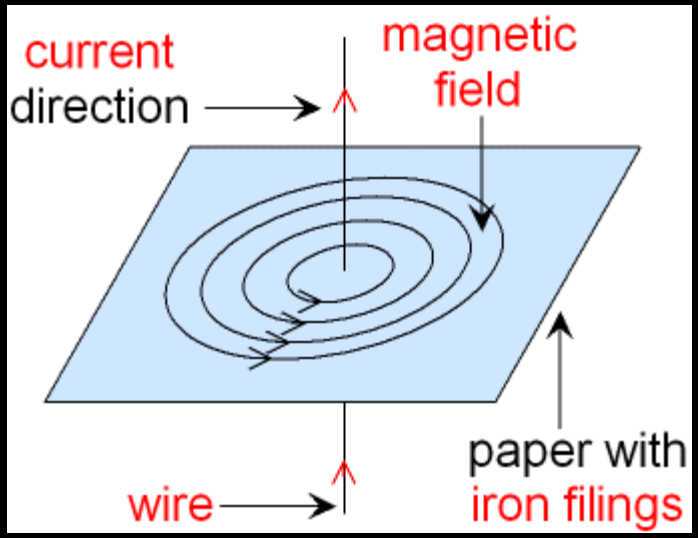
The magnitude of the magnetic field produced at a given point is:

1) Directly proportional to the current passing through the wire.
2) Inversely proportional to the distance of that point from the wire.

What changes in the deflection of the compass needle placed at a point near current carrying straight conductor is observed if

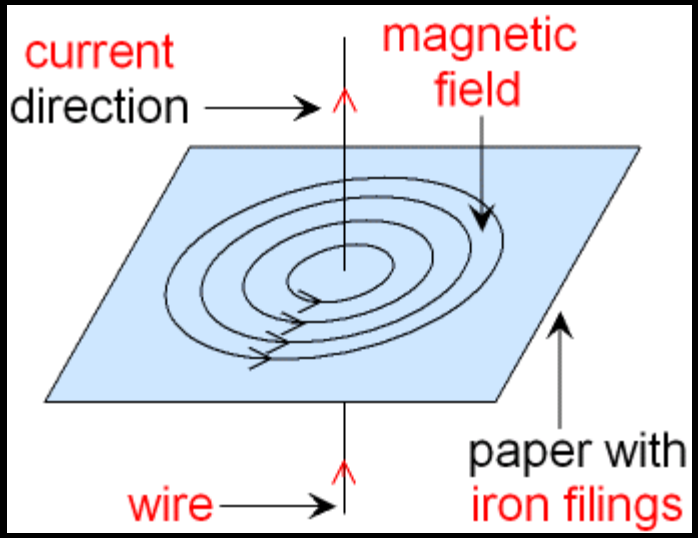
a) Current through the conductor is increased

The deflection of the compass needle increases because of the increase in the strength of the magnetic field.



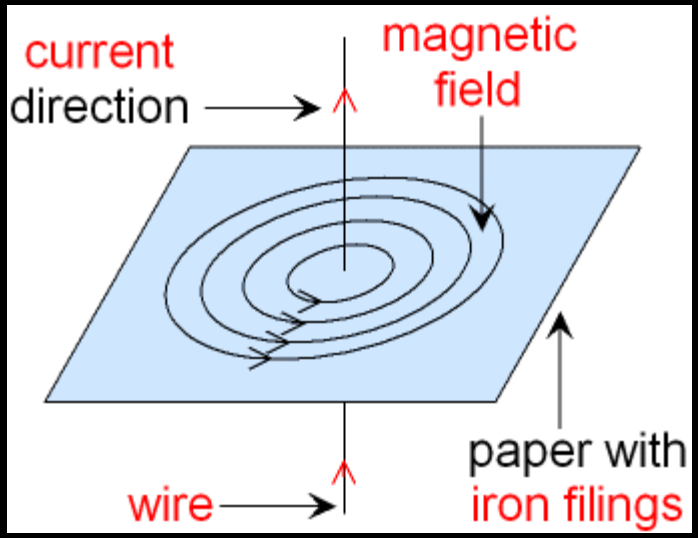
What changes in the deflection of the compass needle placed at a point near current carrying straight conductor is observed if
b) Direction of current in the conductor is reversed.

The direction of deflection of the compass needle is reversed because the direction of magnetic field is reversed.



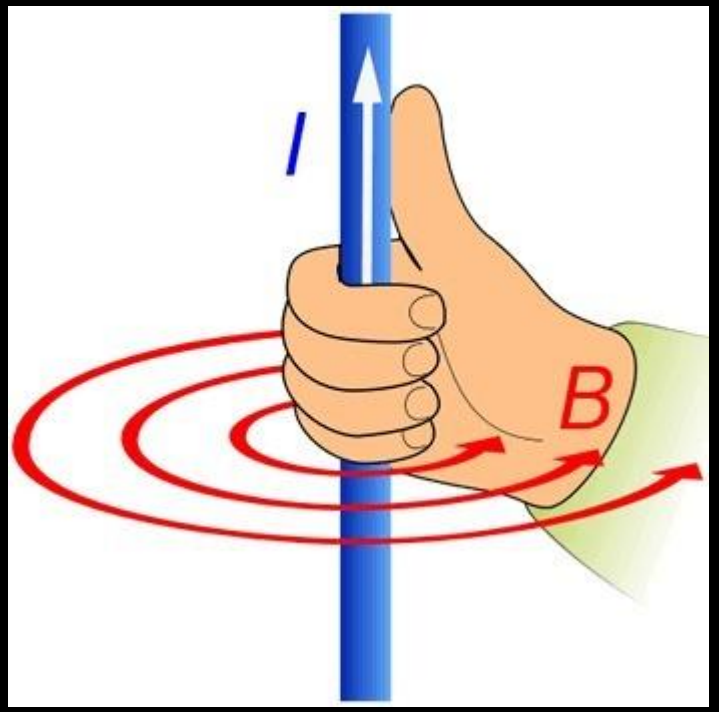
What changes in the deflection of the compass needle placed at a point near current carrying straight conductor is observed if
c) Compass is moved away from the conductor?

The deflection of the compass needle decreases because of the decrease in the strength of the magnetic field.



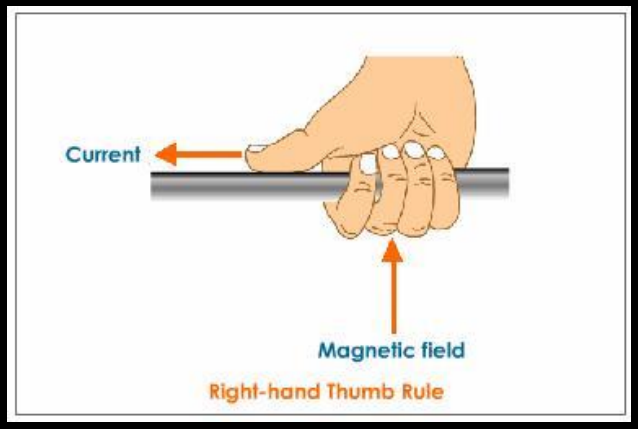
Right hand thumb rule

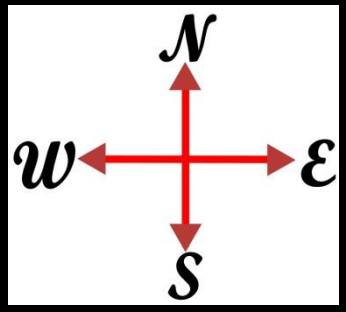
Imagine that you are holding a current-carrying straight conductor in your right hand such that the thumb points towards the direction of current, then the fingers that wrap around the conductor in the direction of the field lines of the magnetic field.



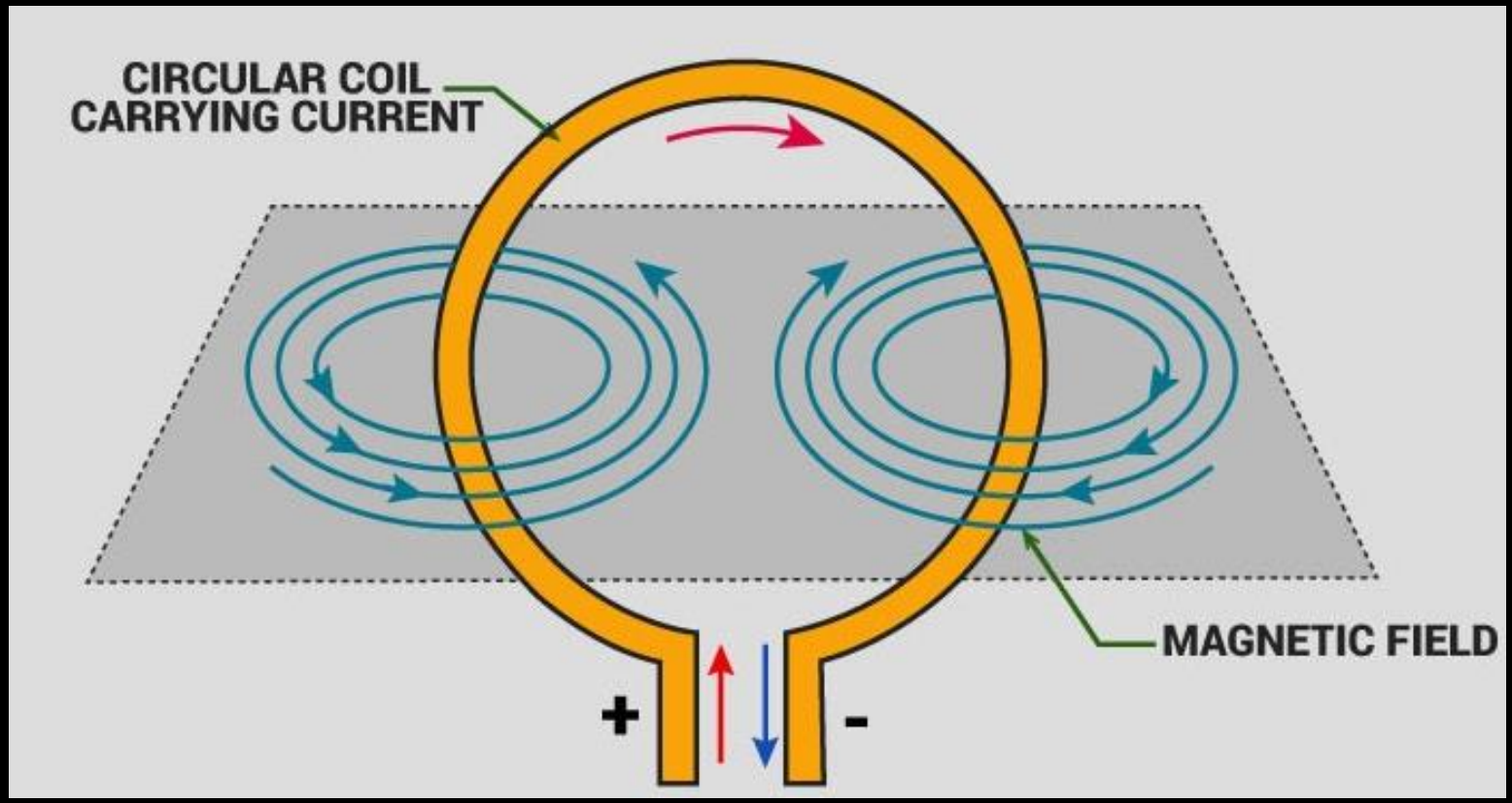
A current through a horizontal power line flows in east to west direction. What is the direction of magnetic field at a point directly below it and at a point directly above it?

The current is in the east-west direction. Applying the right-hand thumb rule, we get that the magnetic field (at any point below or above the wire) turns clockwise in a plane perpendicular to the wire, when viewed from the east end, and anti-clockwise, when viewed from the west end.





Magnetic field line due to a circular loop



Factors on which magnetic field produced by current carrying circular coil vary

The magnetic field produced at the centre of circular coil carrying current depends on:

a) It is inversely proportional to the radius of the coil.

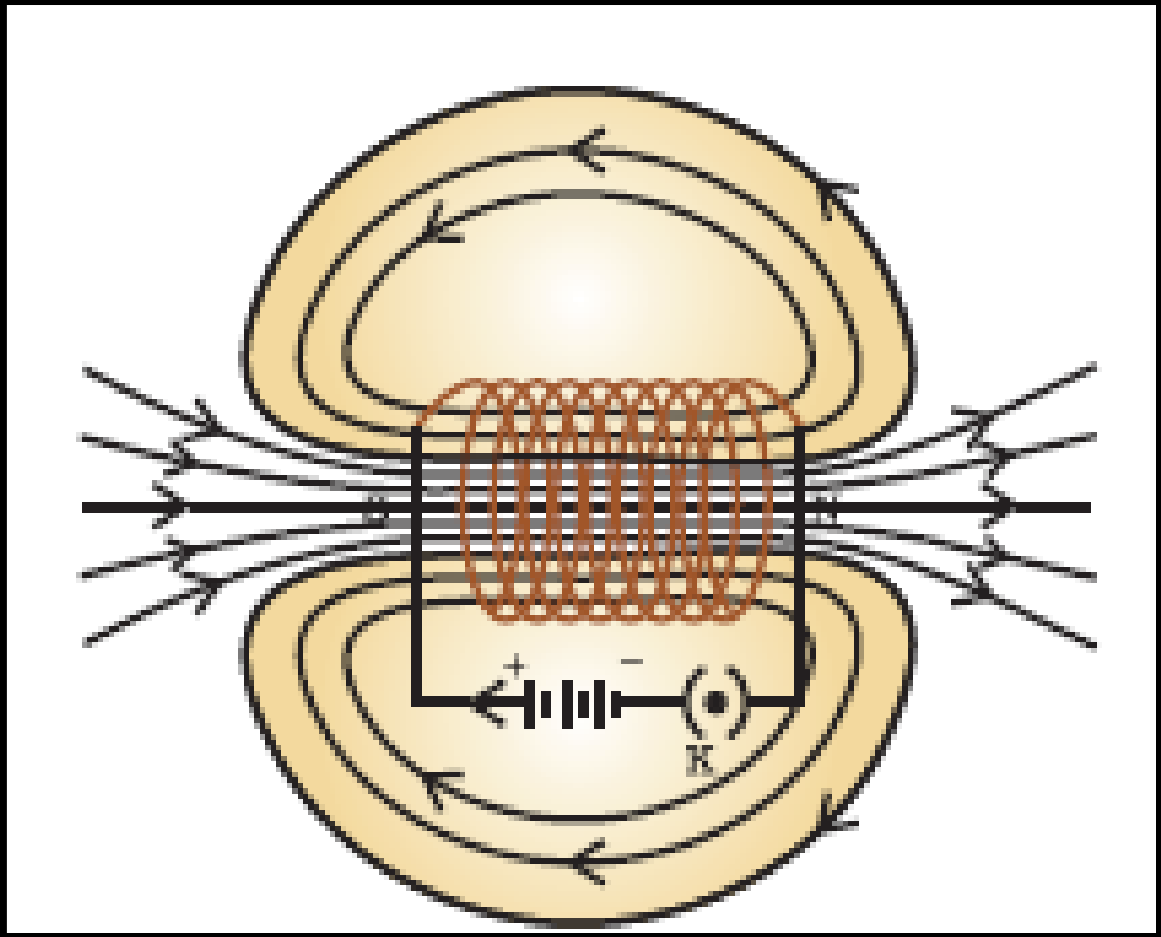
b) It is directly proportional to the number of turns of the coil.

c) It is directly proportional to the strength of current passing through the coil.

Solenoid

A coil of many circular turns of insulated copper wire wrapped closely in the shape of a cylinder is called solenoid.

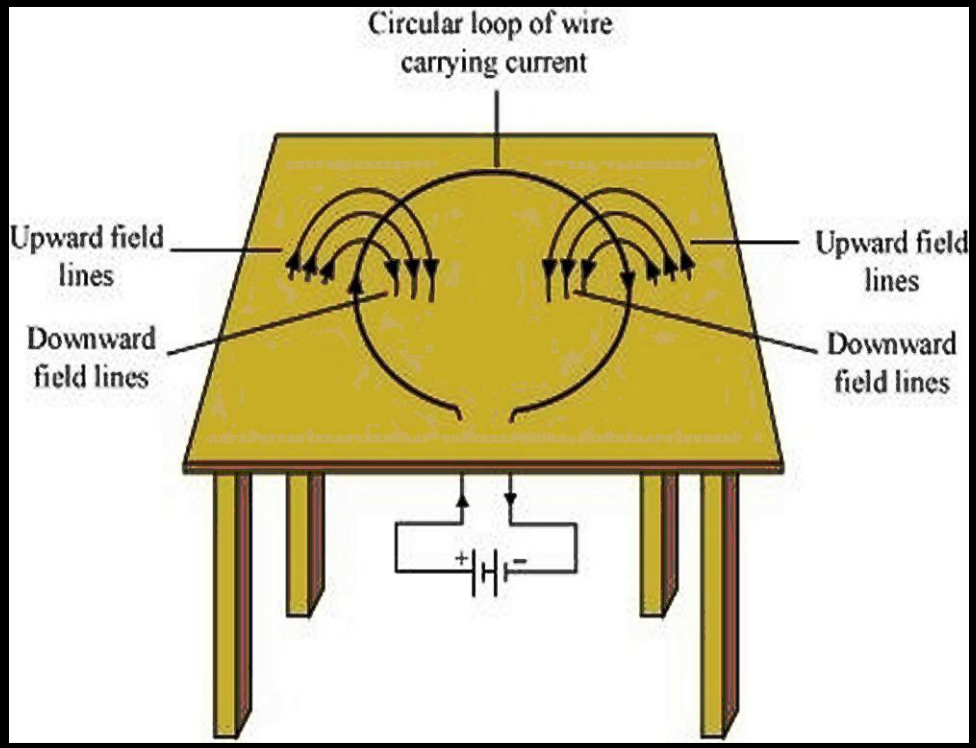
Magnetic field lines through a current carrying solenoid



Factors on which magnetic field produced by current carrying solenoid depend

1) Number of turns of the solenoid (n): The larger the number of turns in the solenoid, stronger is the magnetic field produced.
2) Strength of the current (I): Larger the current passed through the solenoid, stronger is the magnetic field produced.
3) Nature of the core material: By winding the coil over a soft iron cylinder, the magnetic field can be increased several times.

Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.

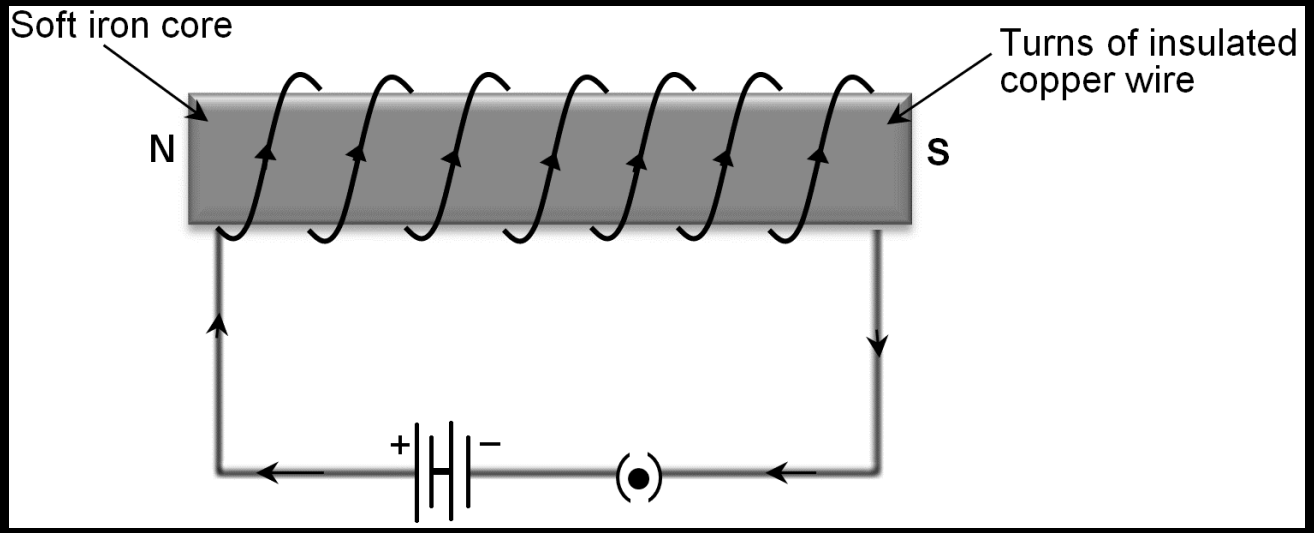


Use of solenoid

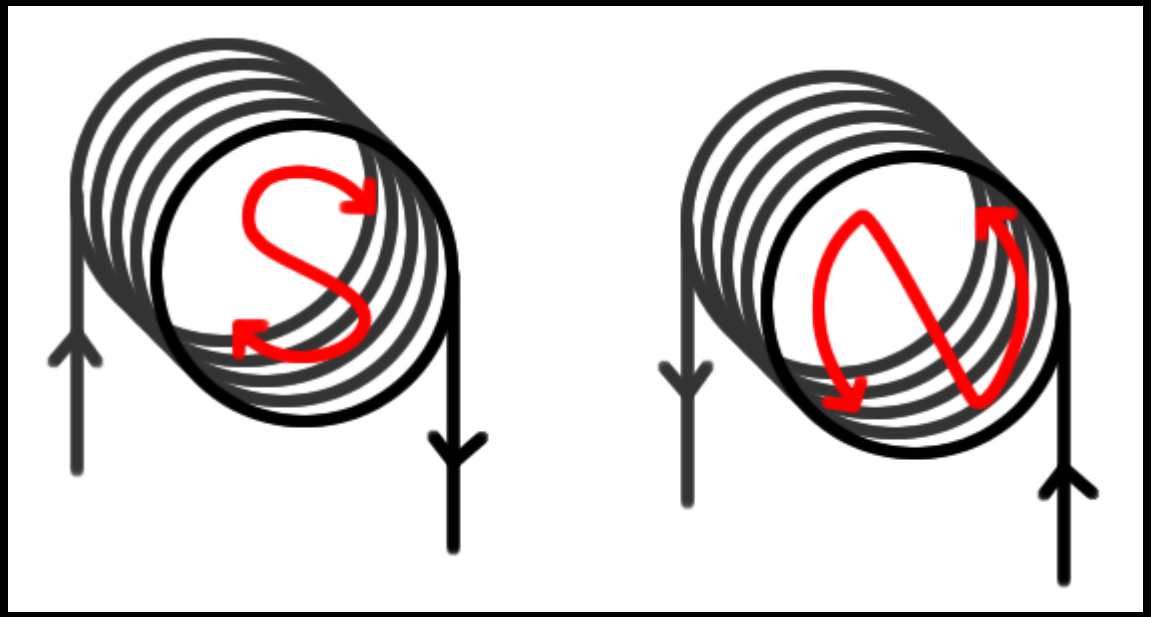
A solenoid can be used to produce uniform magnetic field in a given region.

Electromagnet

An electromagnet is a device in which soft iron core placed inside a solenoid behaves as a powerful magnet when a current is passed through the solenoid.

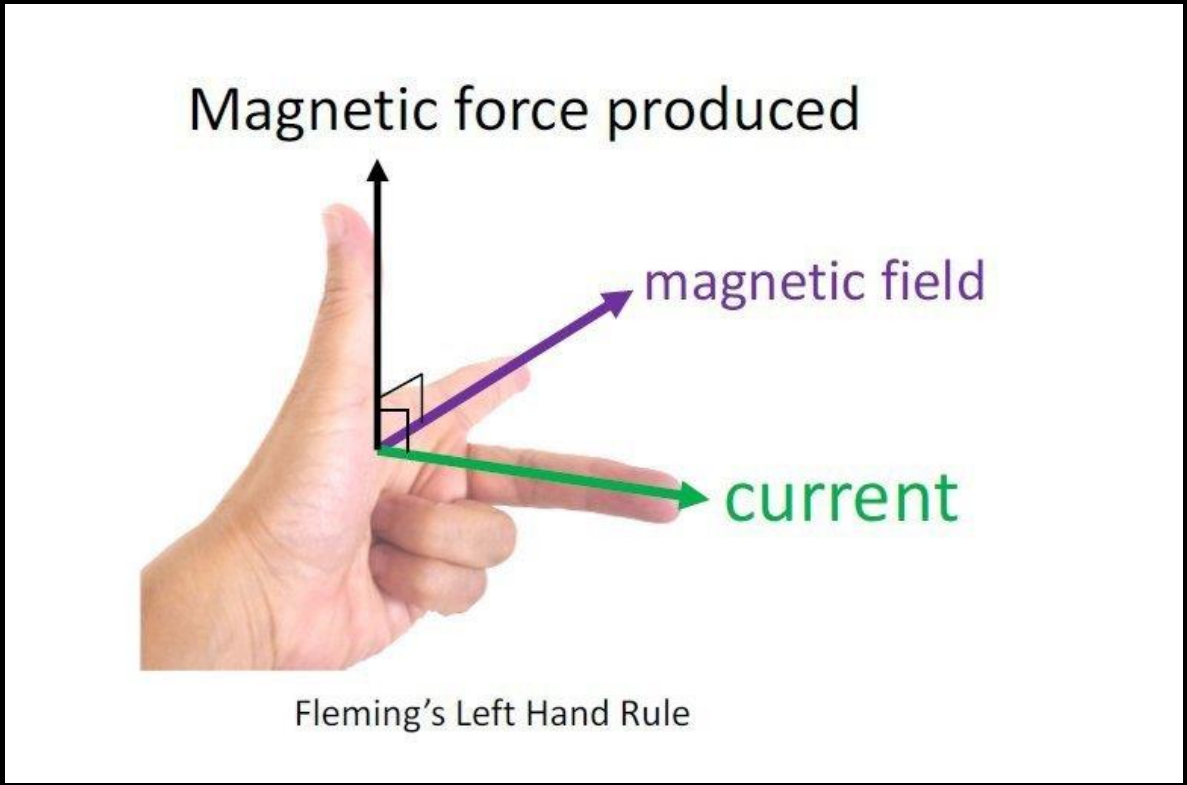


North & South pole of an Electromagnet



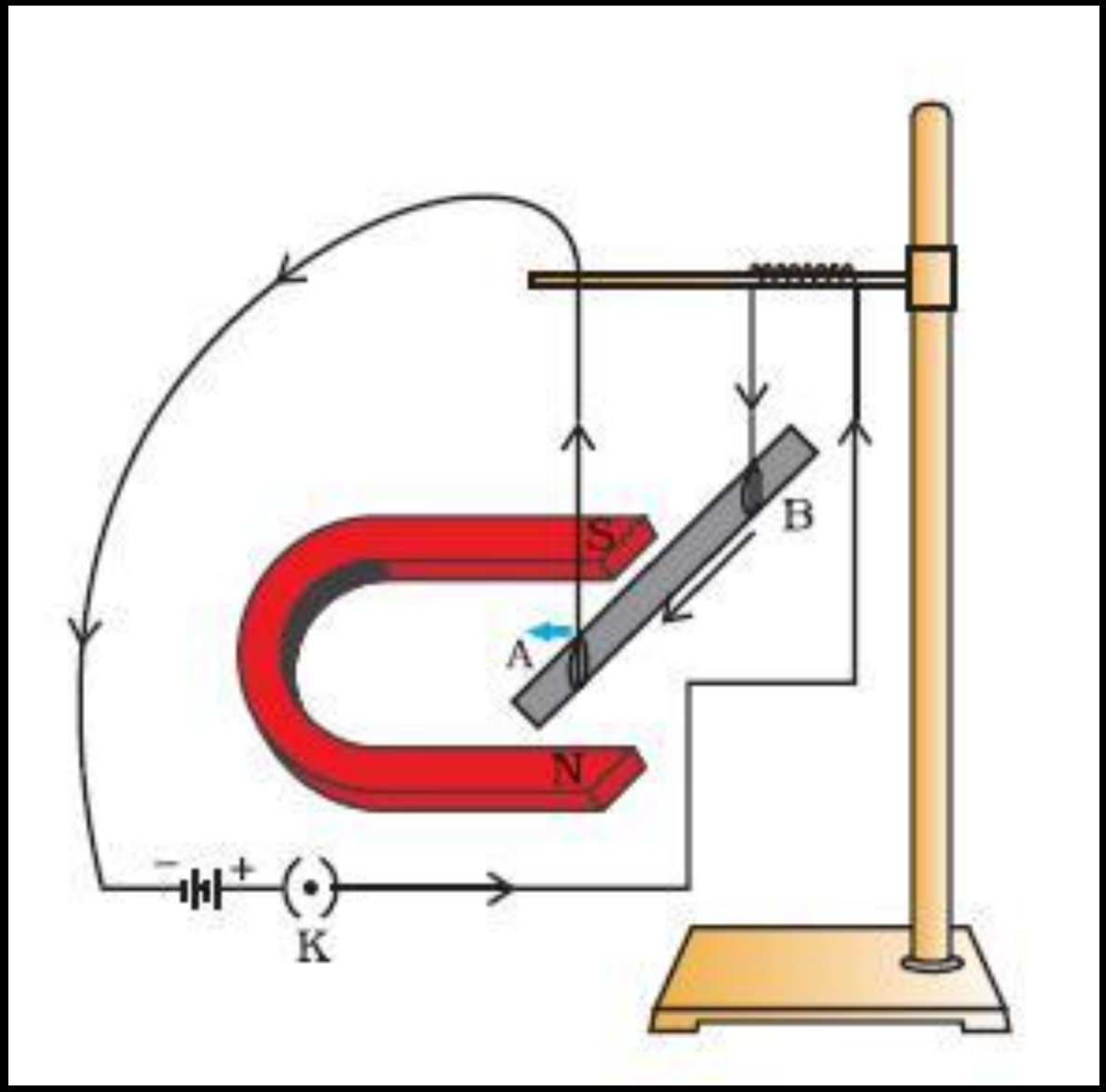
Fleming's left hand rule

Stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular. If the first finger points in the direction of magnetic field and the second finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor.



Fleming's Left Hand Rule

(Activity 13.7) A current-carrying rod experiences a force perpendicular to its length and the magnetic field.



Electric motor

An electric motor is a rotating device which converts electric energy into mechanical energy.

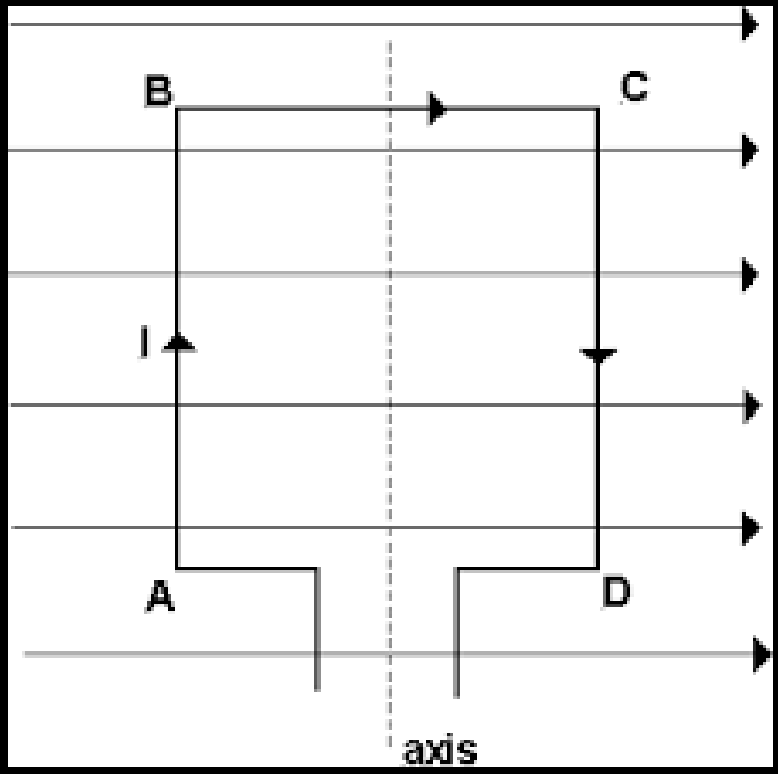
Principle of Electric motor

An electric motor works on the principle that a current carrying conductor placed in a magnetic field experiences a force.

Construction of DC Motor

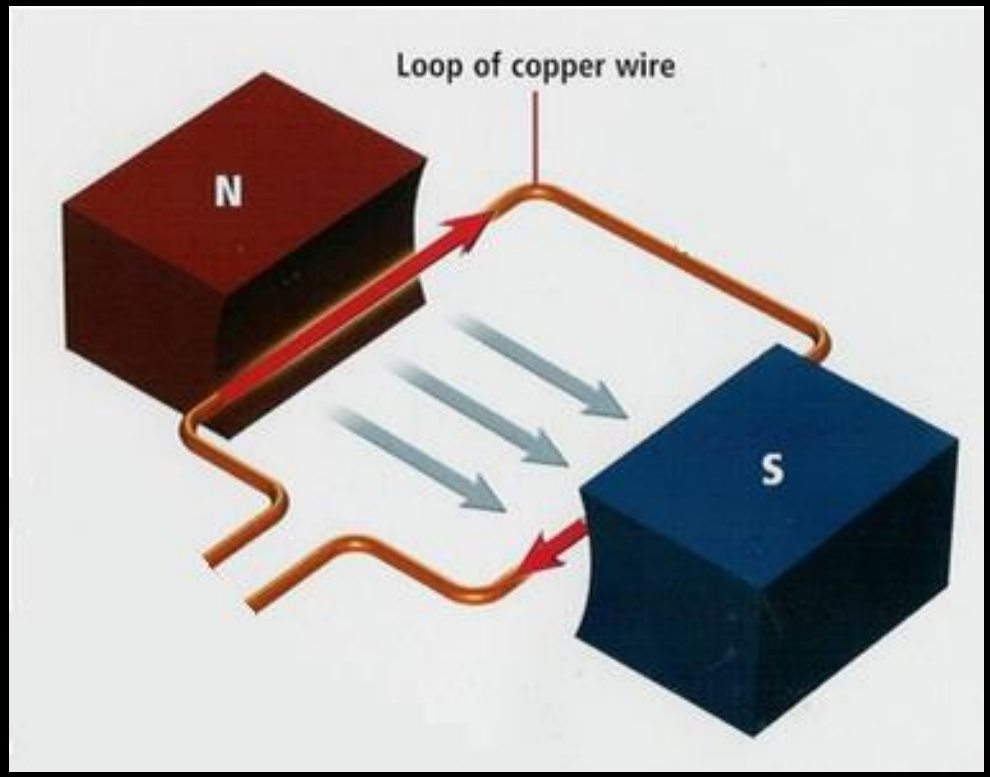
An DC motor consists of an insulated copper coil of many turns wound over a soft iron core.

In the figure ABCD represents the insulated coil.



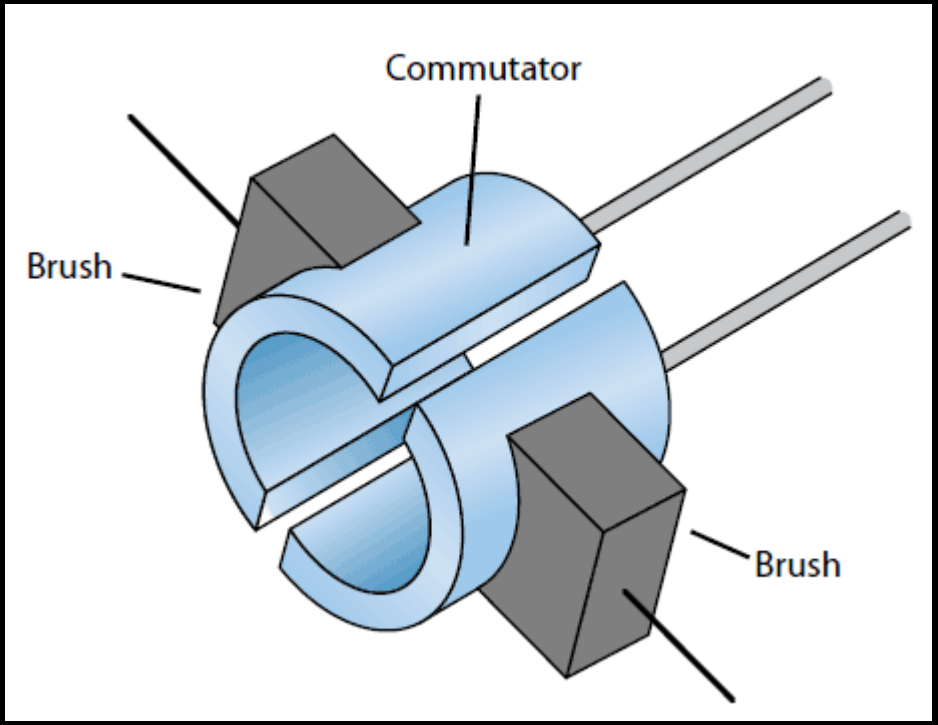
Construction of DC Motor

The coil is placed between the pole pieces of a concave cylindrical magnet.



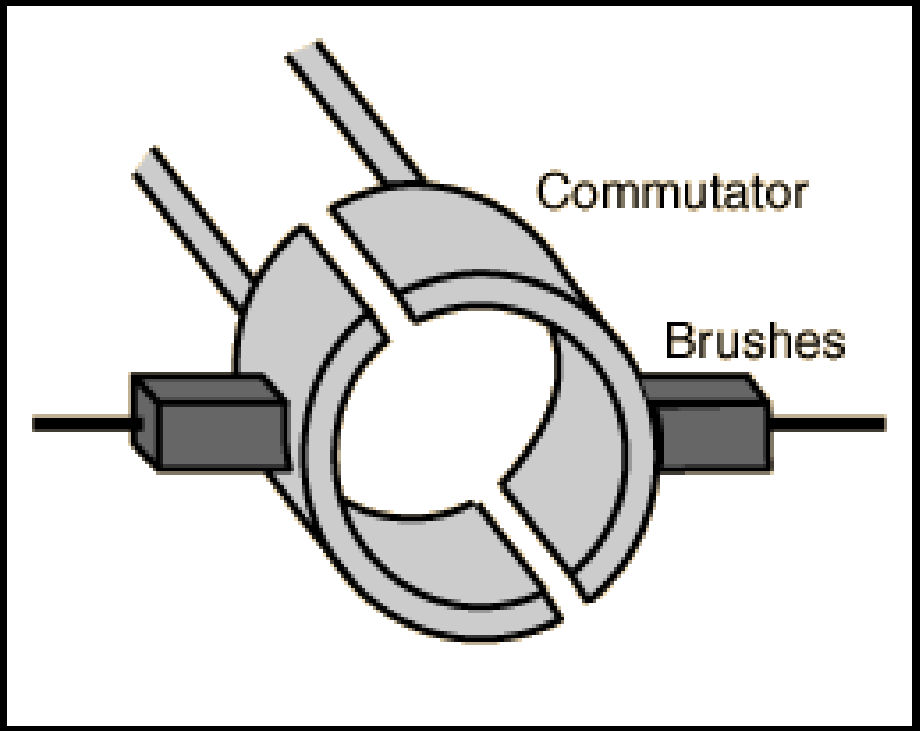
Construction of DC Motor

The free ends of the copper wire are connected to two half rings of copper.



Construction of DC Motor

Two carbon brushes touch the rings. The brushes are connected to the battery



Some devices in which electric motors are used.

(a) Water pumps

(b) Electric fans

(c) Electric mixers

(d) Washing machines

Parts of electric motor & function

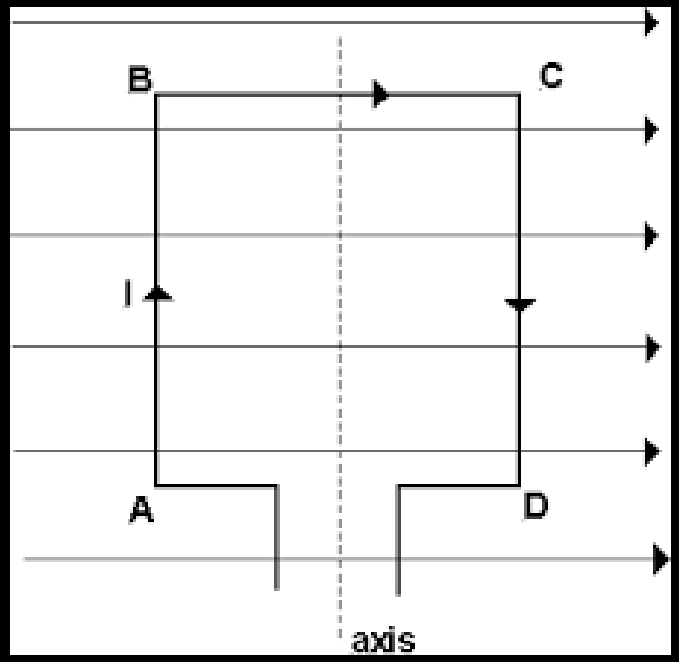
a) Field magnet

Field magnet: It is a strong horse shoe type magnet with concave poles.

Parts of electric motor & function

b) Armature

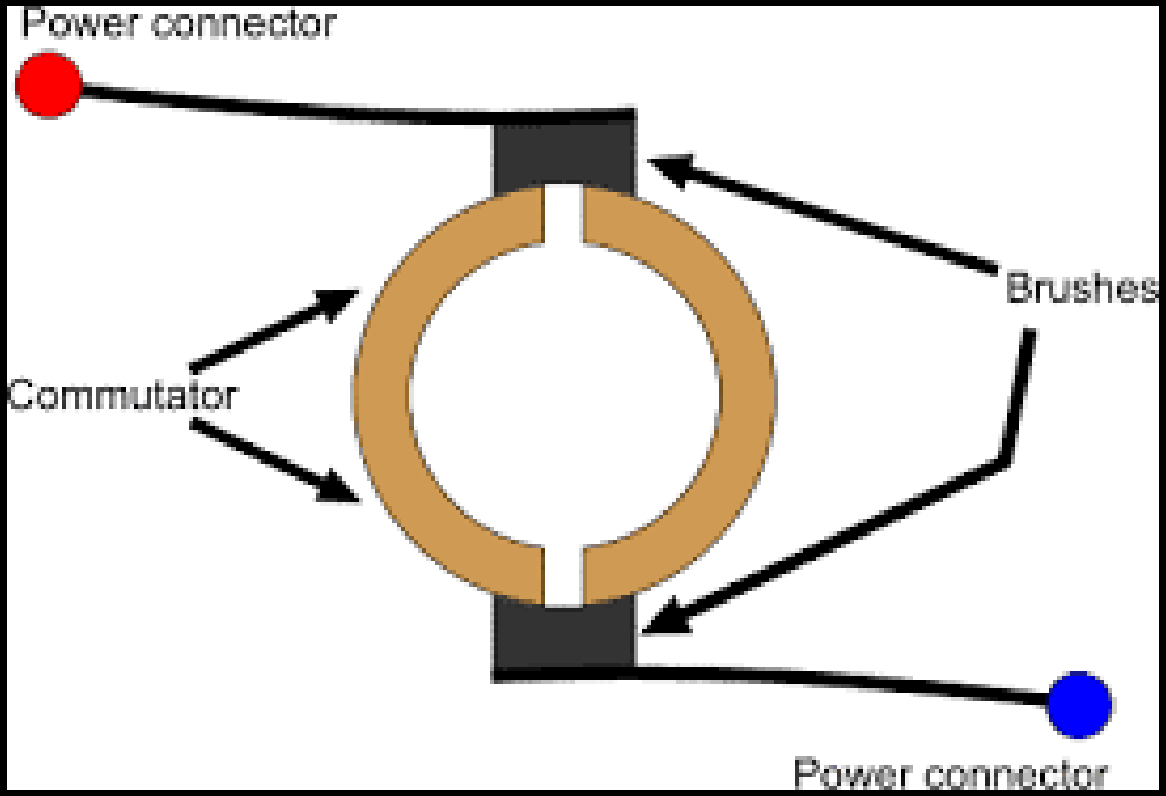
It is a rectangular coil having a large number of turns of thin insulated copper wire wound over a soft iron core.



Parts of electric motor & function

c) Split ring commutator

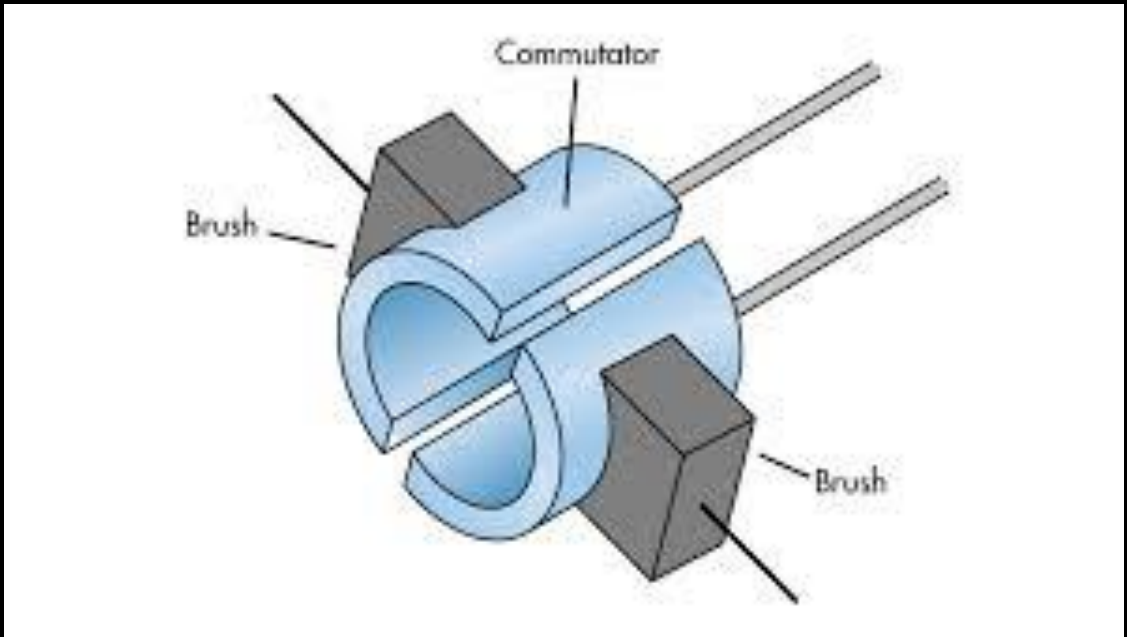
It is a cylindrical metal ring split into two halves.



Parts of electric motor & function

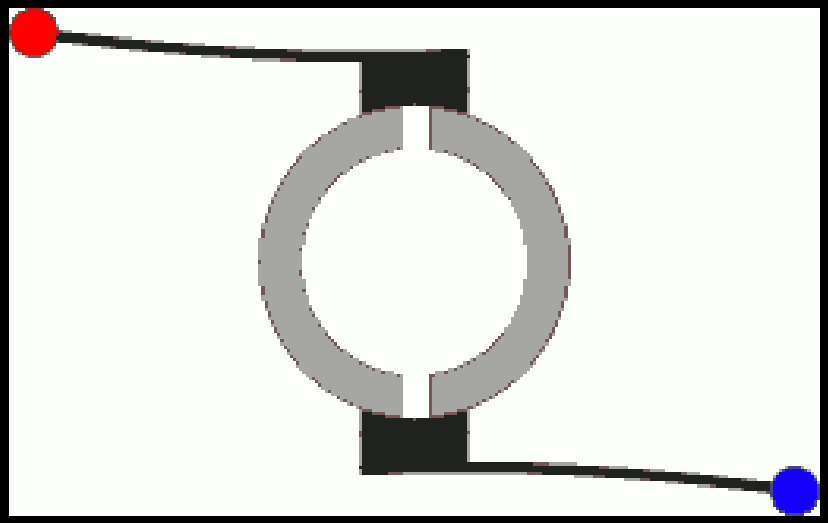
d) brushes

It is made of graphite. It maintains a sliding contact with split rings.



Role of split ring in an electric motor

The function of split ring commutator is to reverse the direction of current in the coil after every half rotation.



Factors which increase the speed of rotation of coil in a motor

The speed of rotation of the armature coil can be increased by increasing:

a) The strength of the magnetic field.

b) The number of turns in the coil.

c) The current in the coil.

When is the force experienced by a current carrying conductor placed in a magnetic field largest/maximum?

When direction of current is at right angles to the direction of magnetic field then the force experienced by the conductor is maximum.

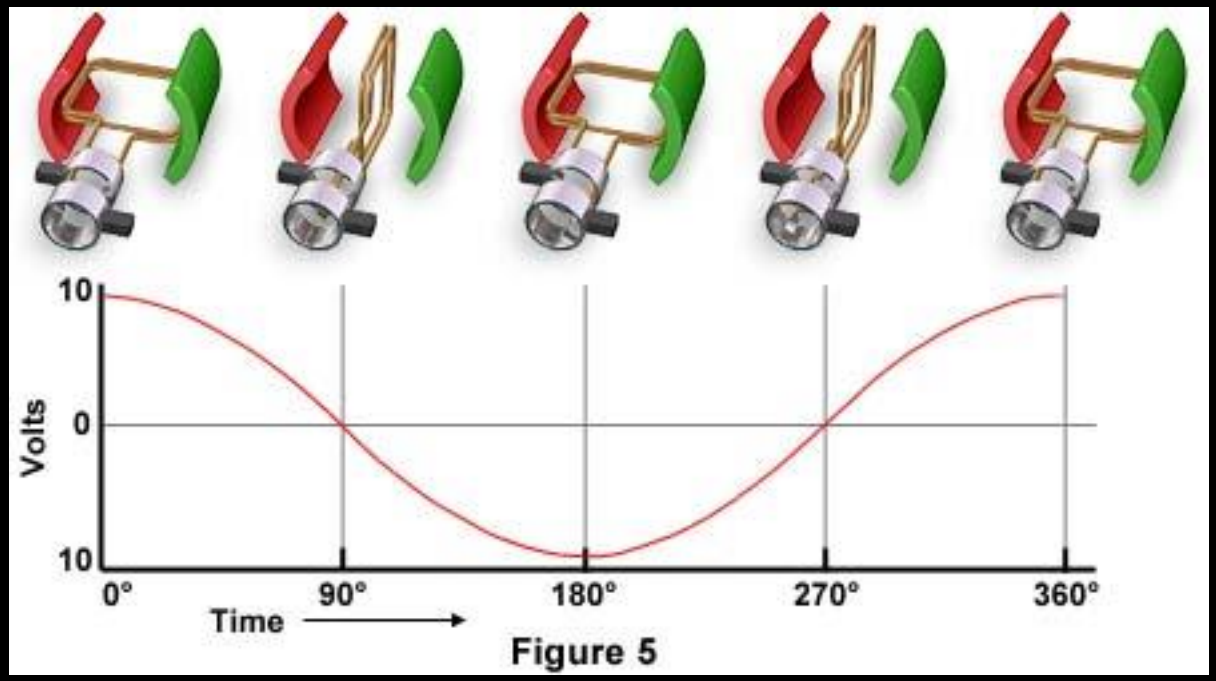


Figure 5

When is the force experienced by a current carrying conductor placed in a magnetic field minimum?

When the current carrying conductor is held parallel to the direction of the magnetic field, the force exerted on it is minimum or zero.

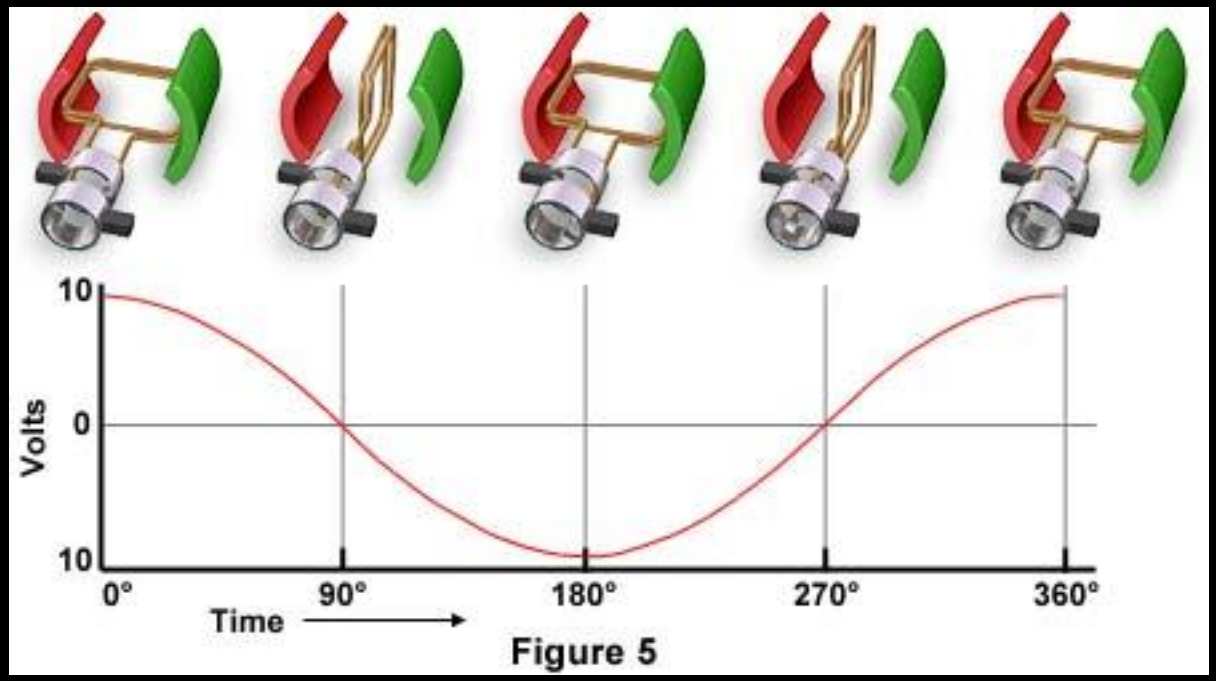


Figure 5

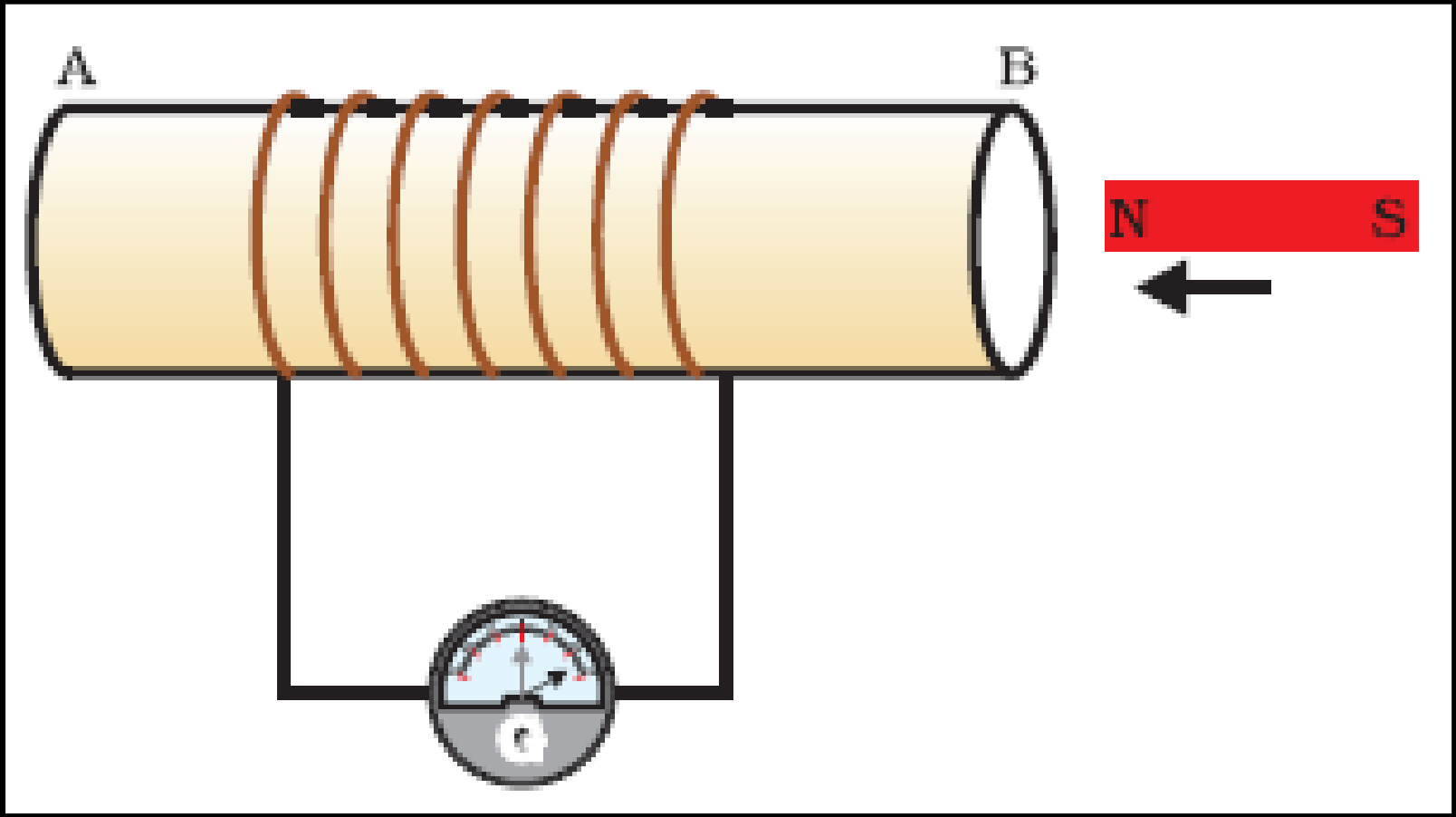
Electromagnetic induction

The phenomenon by which the electric current is generated by changing the magnetic field lines is called electromagnetic induction.

Cause of Electromagnetic induction

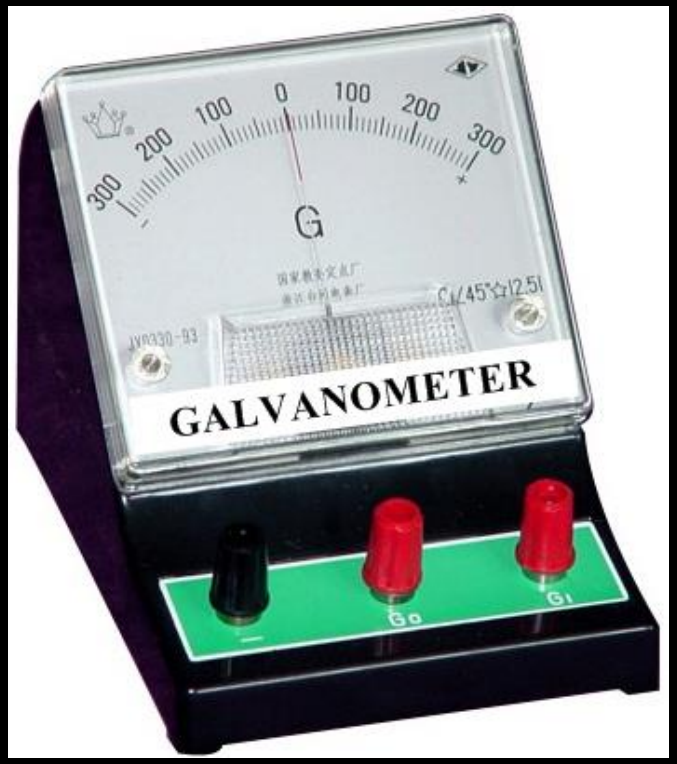
Relative motion between the magnet and the coil is responsible for the generation of electric current in the coil.

(Activity 13.8) Faraday's Experiment

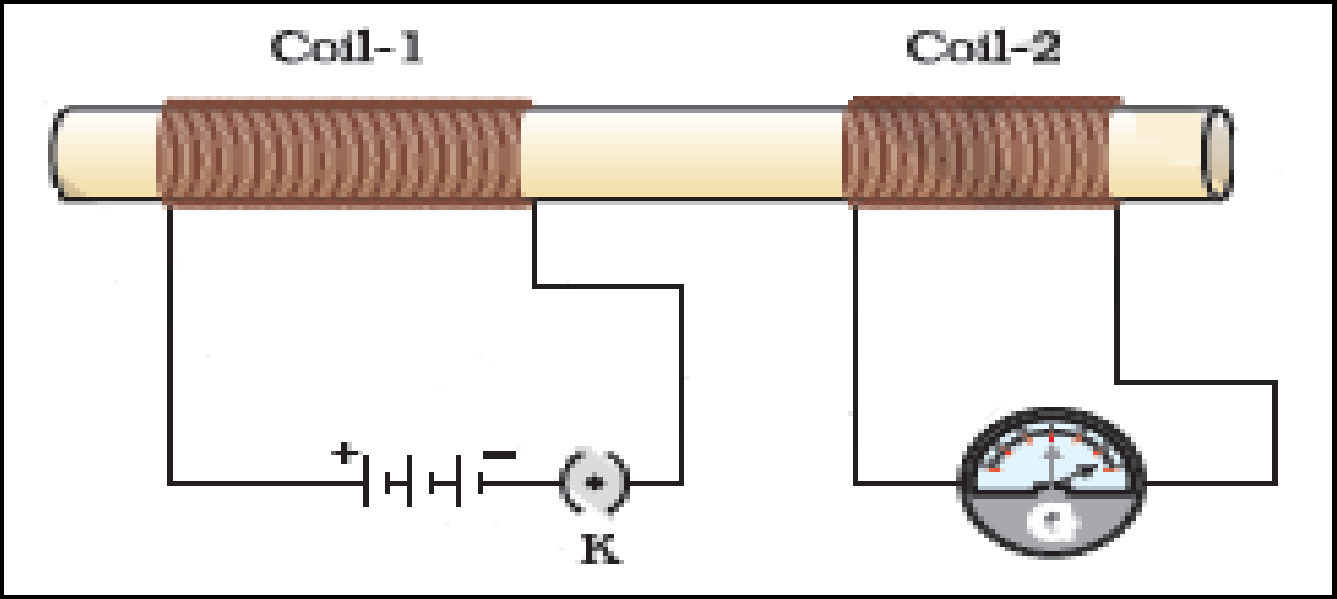


Galvanometer & its use

Galvanometer is a device used to measure the electric current flowing through a conductor.



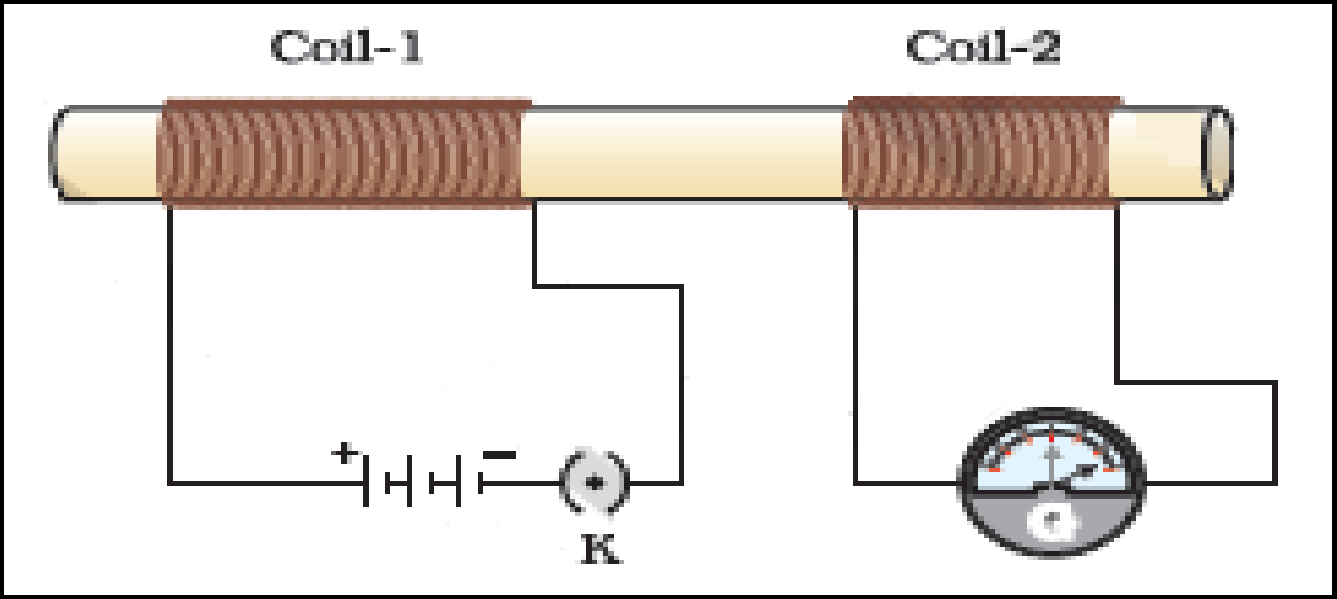
Activity 13.9



Observe the galvanometer. Is there a deflection in its needle?

The needle of the galvanometer instantly jumps to one side and just as quickly returns to zero, indicating a momentary current in coil-2.

Activity 13.9

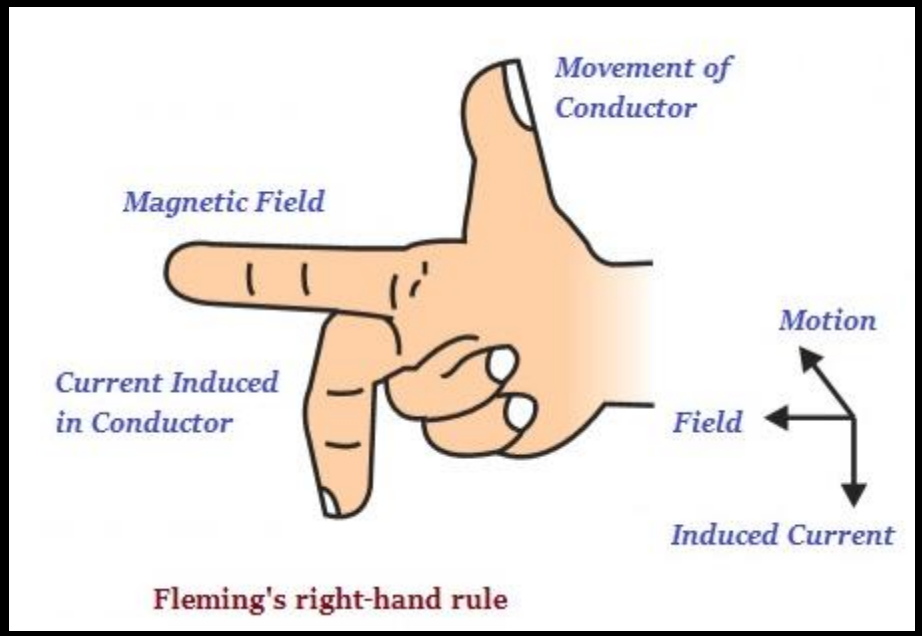


Observe the galvanometer when you disconnect coil-1 from the battery.

The needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in coil-2.

Fleming's Right hand rule

Stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other. If the forefinger indicates the direction of the magnetic field and the thumb shows the direction of motion of conductor, then the middle finger will show the direction of induced current.



Electric generator or dynamo

A generator is a device used to convert mechanical energy into electrical energy.

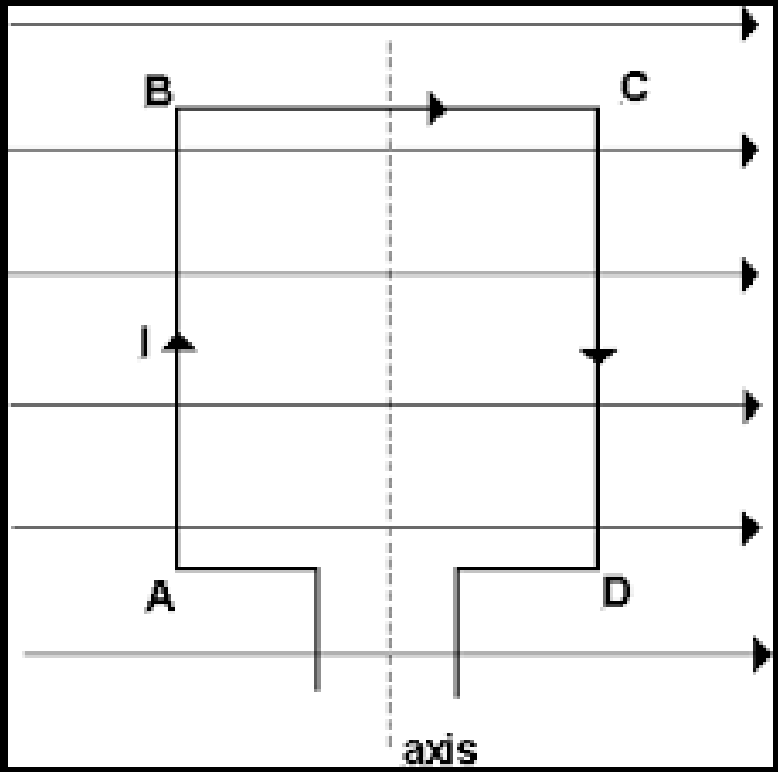
Principle of Electric generator

Electric generator works on the principle of electromagnetic induction.

Construction of AC Generator

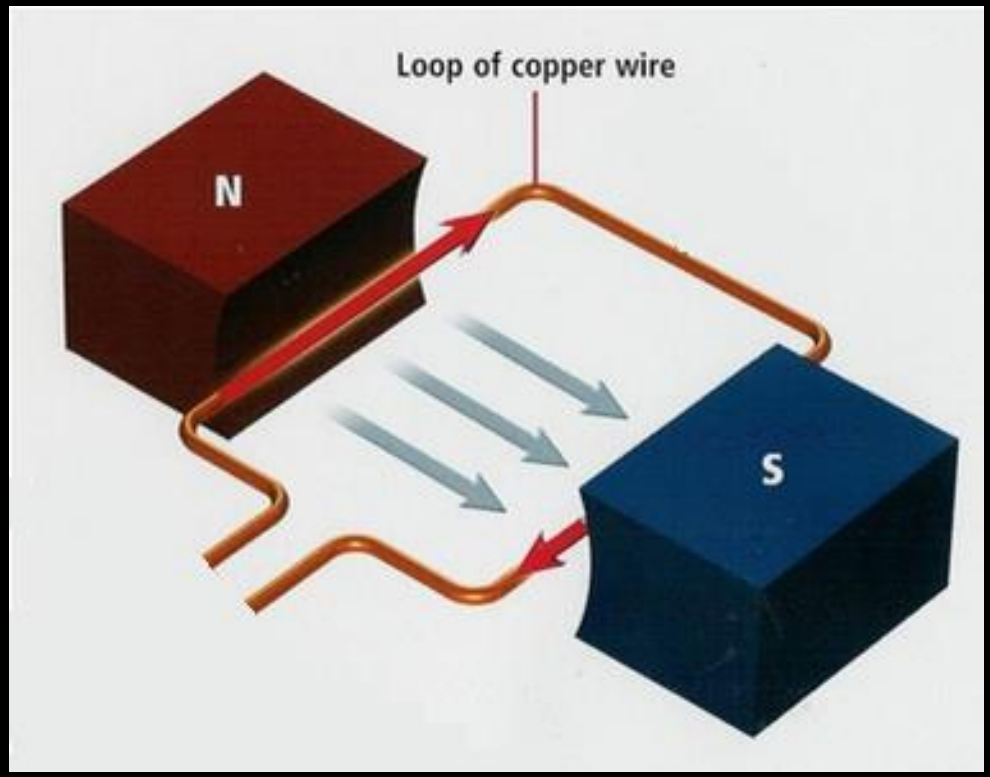
An AC generator consists of an insulated copper coil of many turns wound over a soft iron core.

In the figure ABCD represents the insulated coil.



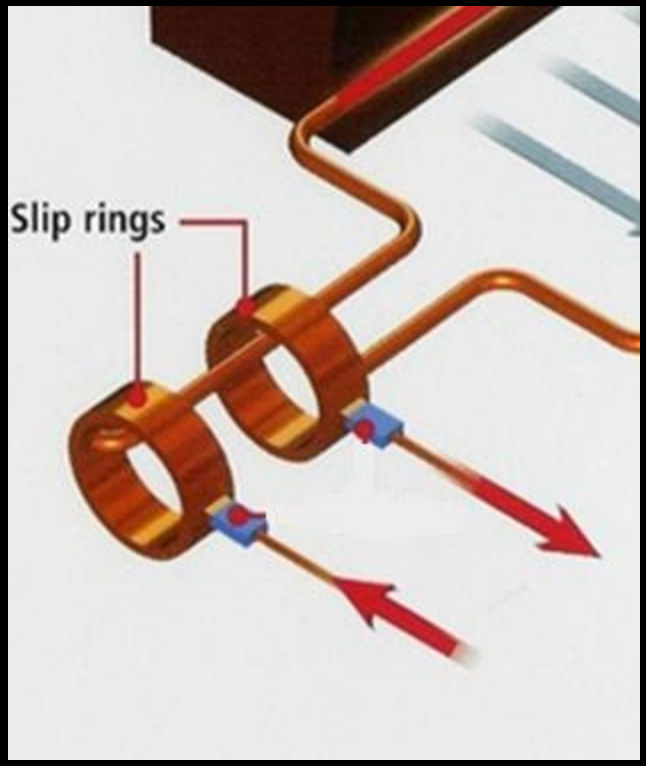
Construction of AC Generator

The coil is placed between the pole pieces of a concave cylindrical magnet.



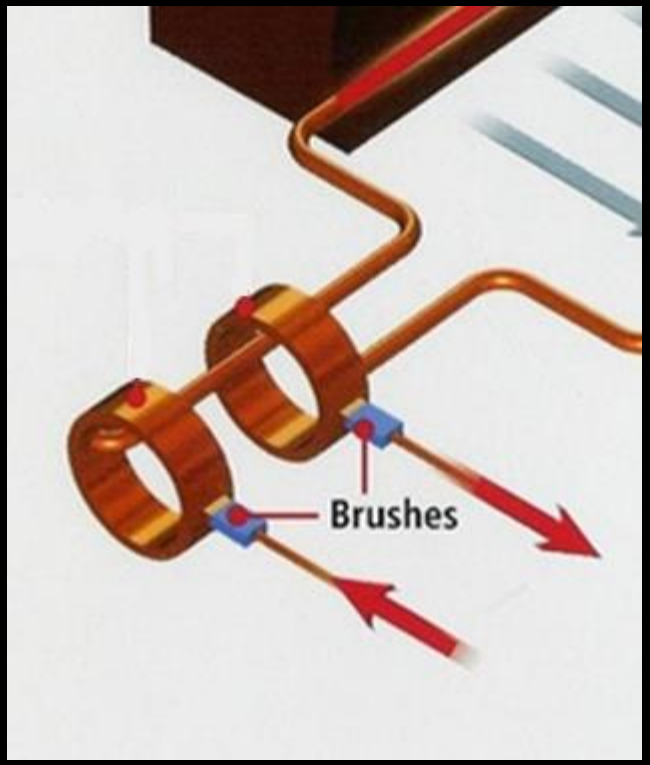
Construction of AC Generator

The free ends of the copper wire are connected to two rings R1 and R2 of copper.



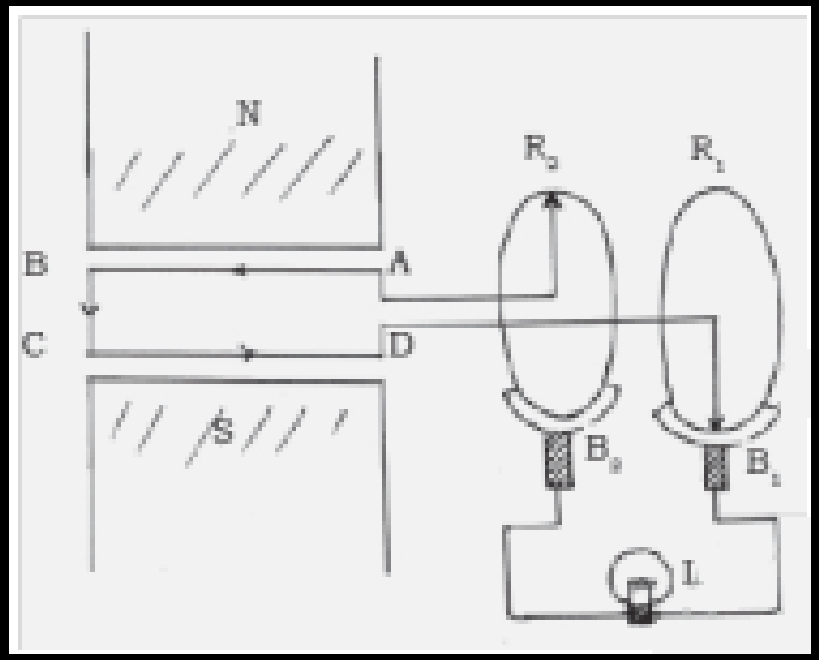
Construction of AC Generator

Two carbon brushes touch the rings. The brushes are connected to the battery



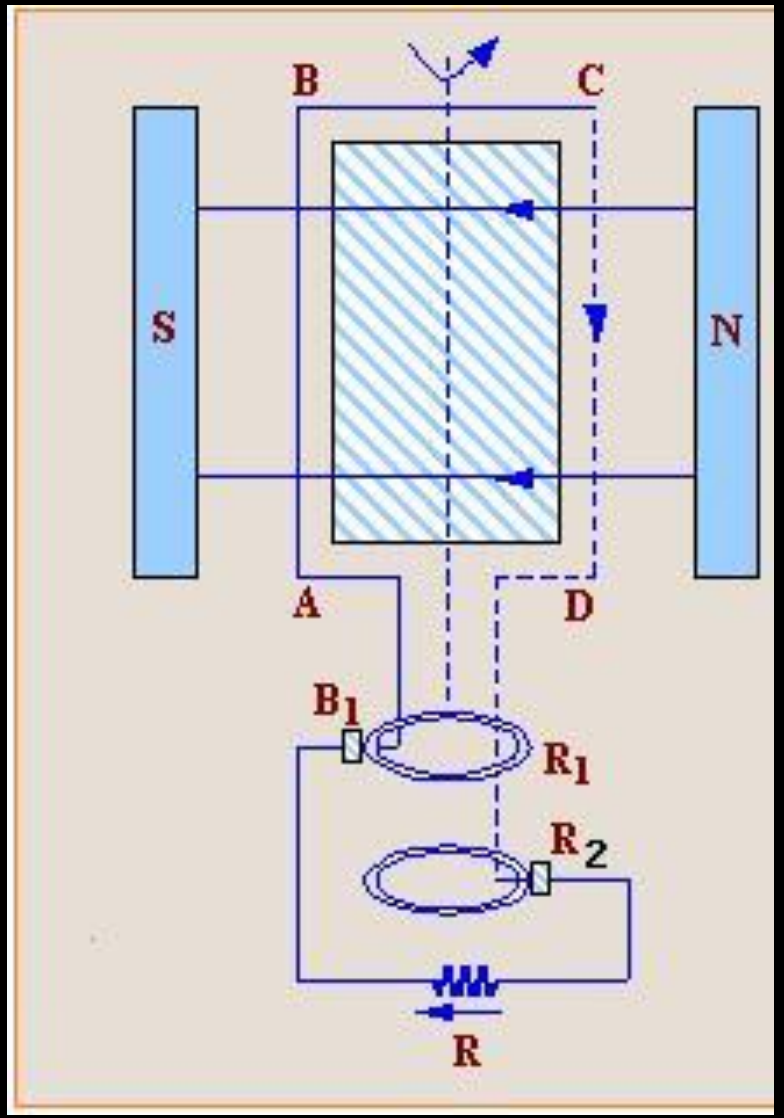
Working of AC Generator

When the coil is made to rotate in clockwise direction, the magnetic field linked with the coil changes. This induces an electric current in the coil ABCD.



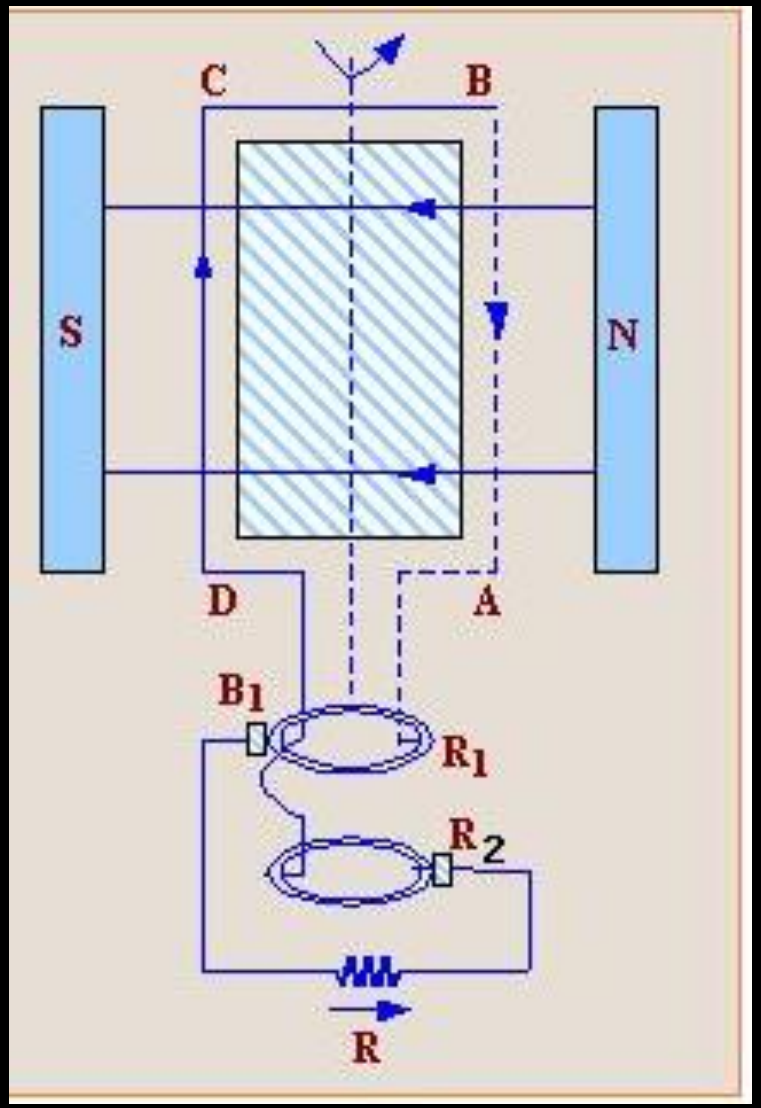
Working of AC Generator

During the first half of the rotation, the current flows along ABCD R_1 B_1B_2.



Working of AC Generator

During the second half of the rotation current is induced in the coil along DCBA $R_2B_2B_1$.



Alternating current

If the current changes its direction after equal interval of time is called alternating current.

Frequency of Alternating current

The frequency of an alternating current is the number of times the direction of electric current changes in one second. In India, the frequency of A.C. is 50Hz.

Direct current

A current in which the magnitude and the direction do not change with time is called direct current.

Sources of Direct current

Some sources of direct current are cell, DC generator, etc.

DC Generator

A Generator which produces unidirectional current is called DC Generator.

AC vs DC

AC Generator	DC Generator
1) The two ends of the coil are connected to two full rings of copper.	1) The two ends of the coil are connected to a commutator consisting of two half rings of copper.

AC vs DC

AC Generator	DC Generator
2) The direction of current produced changes every half revolution.	2) The direction of current produced is same in both revolutions

Generator Vs Motor

Generator	Motor
1) It converts mechanical energy into electric current.	1) It converts electrical energy into mechanical energy.

Generator Vs Motor

Generator	Motor
2) The coil is rotated in an electric field by an external force. It induces an electric current of the coil of the motor.	2) Current is supplied to the coil resulting in the rotation of the coil of the motor.

Why is an alternating current considered to be advantageous over direct current for long range transmission of electrical energy?

Only alternating voltage can be stepped up or stepped down by using transformer. This makes AC more suitable than DC for transmission of electric power over long distances without much loss of energy.

Why is alternating current preferred over direct current?

1. The generation of A.C is more economical than D.C
2. Alternating voltage can be easily stepped up or stepped down by using a transformer.
3. The alternating currents can be transmitted to distance places without any significant line loss.

Domestic Electric Circuits

What type of electricity is supplied to our homes?

OR

For the electricity supplied to our homes, write

a) the type of current

b) the voltage supplied

c) frequency of current supplied.

a) Alternating current (A.C.)

b) 220V

c) 50Hz

Live wire

The wire which is at 220V potential is called live wire.

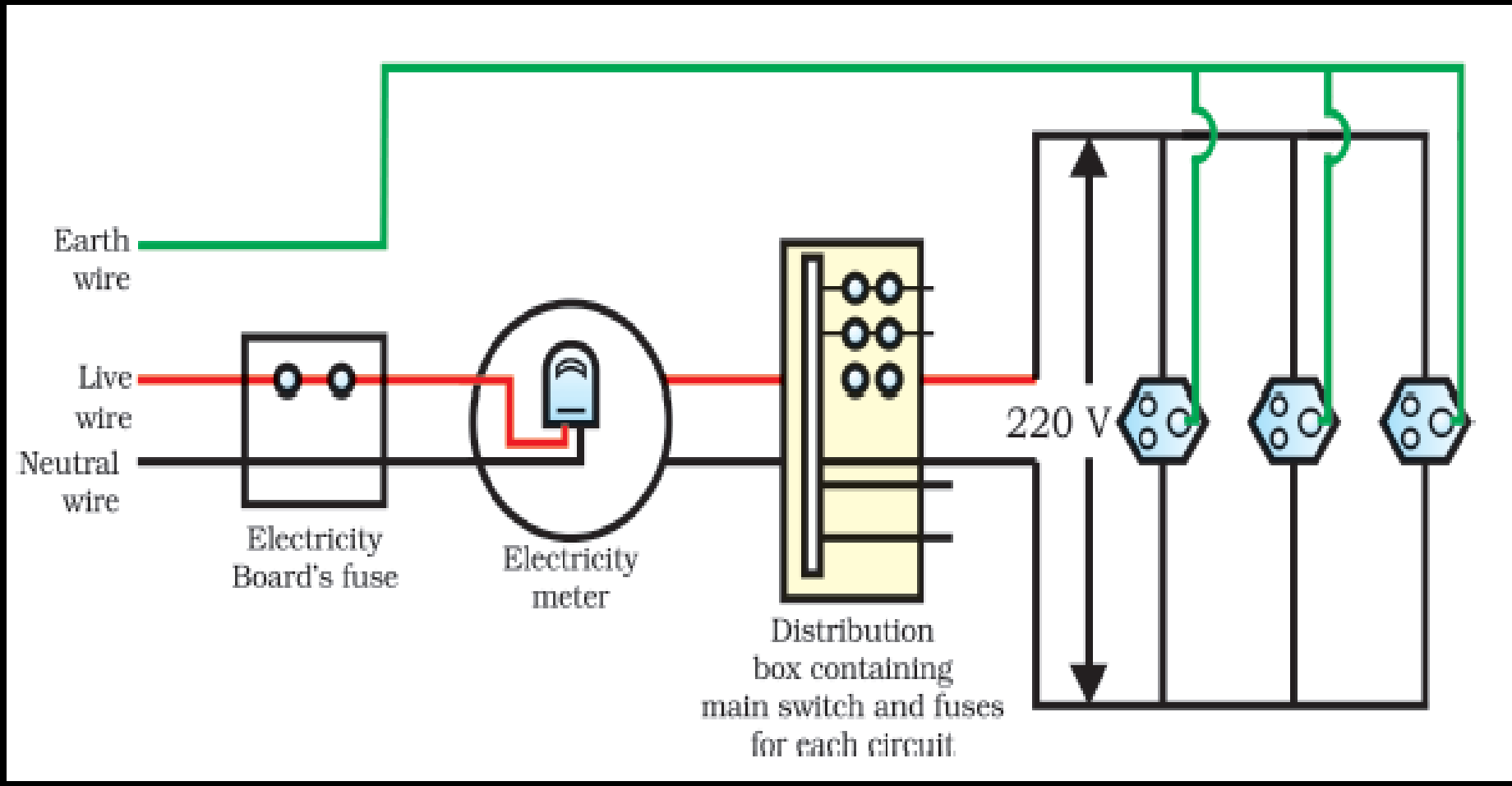
Neutral wire

The wire which is at 0V potential is called Neutral wire.

Earth wire

The wire which is connected to a plate deep in the earth near the house is called Earth wire.

Domestic circuit

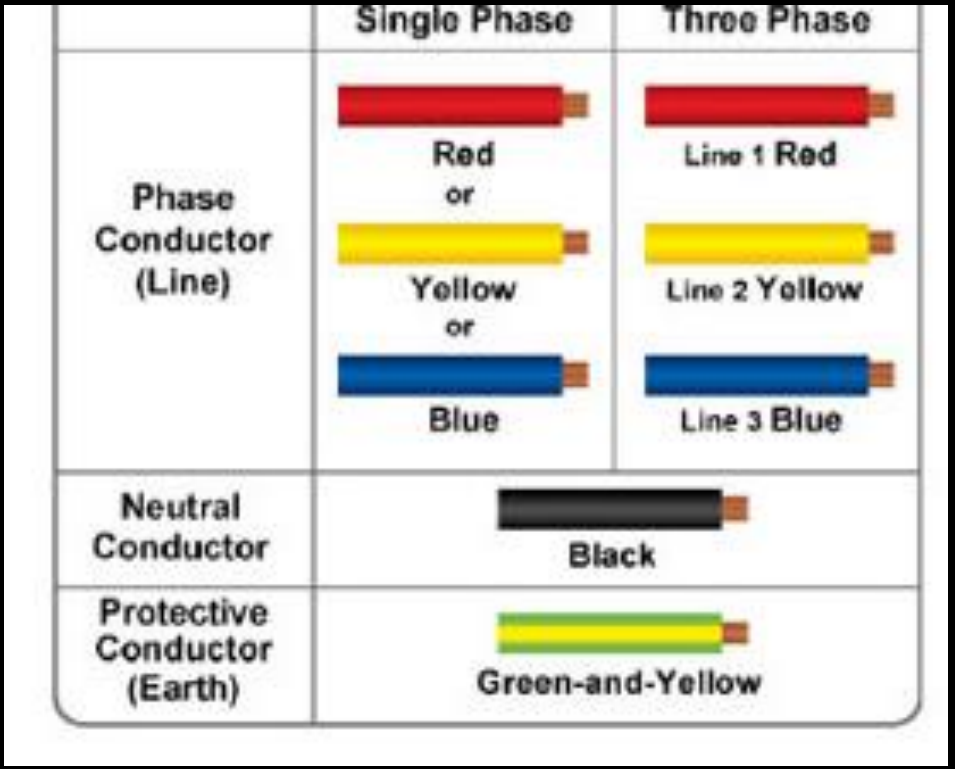


Colour coding for electric wires used in domestic circuits

Live wire (positive) : Red

Neutral wire (negative) : Black

Earth Wire : Green



Why do we use power supply of two different current ratings at our homes?

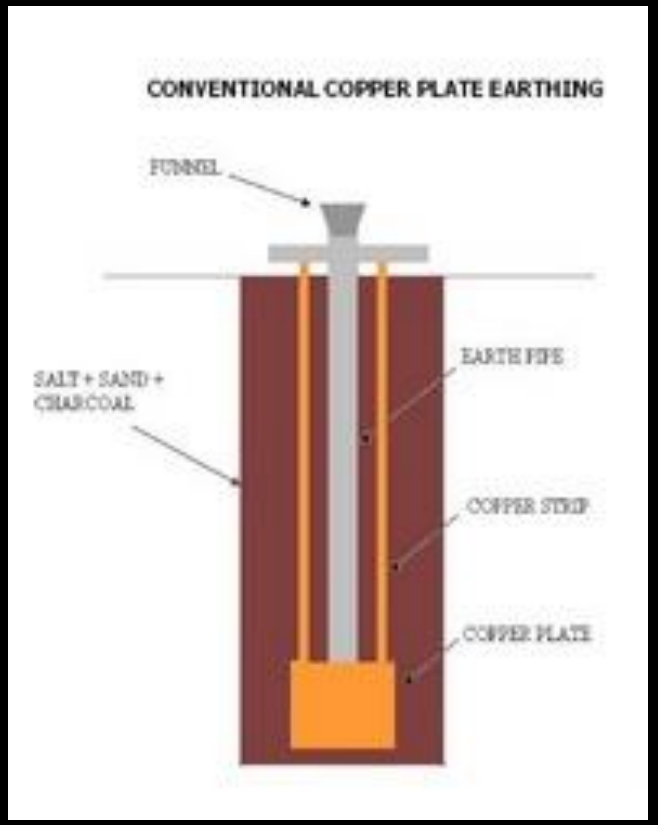
Different appliances have different power ratings.

The 5 Ampere current rating is used for electric bulbs, fans, etc.

The 15 Ampere current rating is used for heater, geysers, air conditioners, electric iron box etc.

Earthing

The earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house.

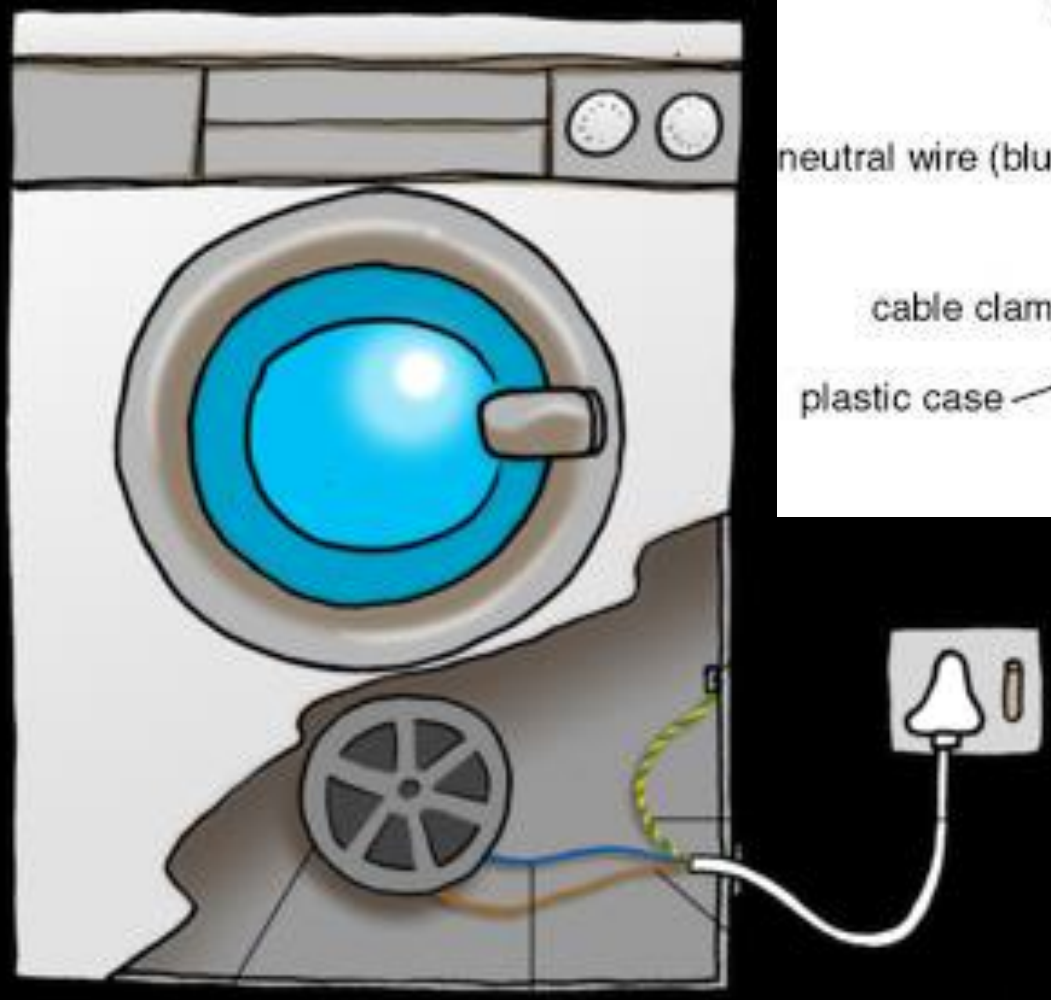


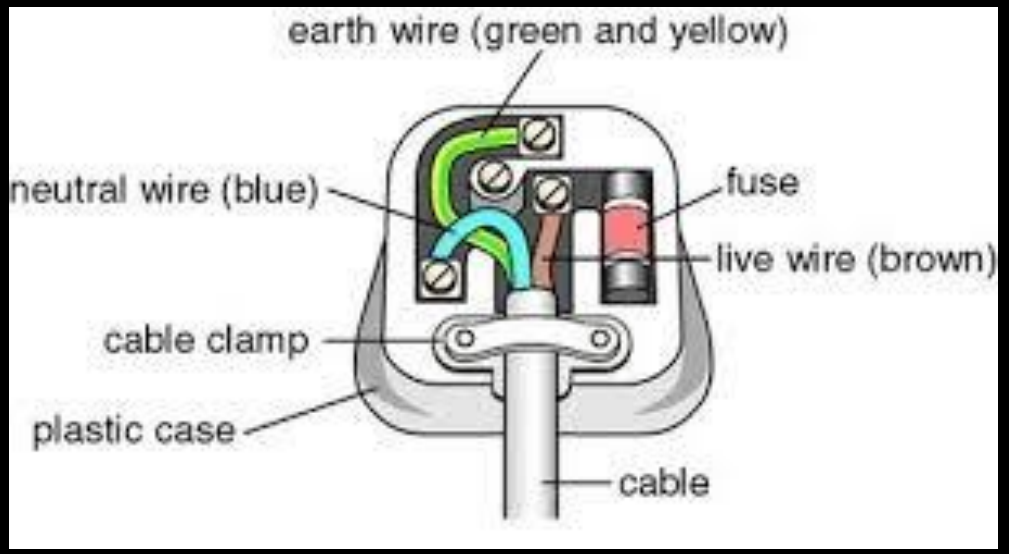
What is the function of an earth wire? Why is it necessary to earth the metallic appliances?

Earthing of an electrical appliance means connecting the metallic body of the high powered appliance (electric iron, toaster, refrigerator, oven etc.) to the earth through the earth wire of the domestic circuit.

This prevents any electric shock to the user. That is why earthing of the electrical appliances is necessary.

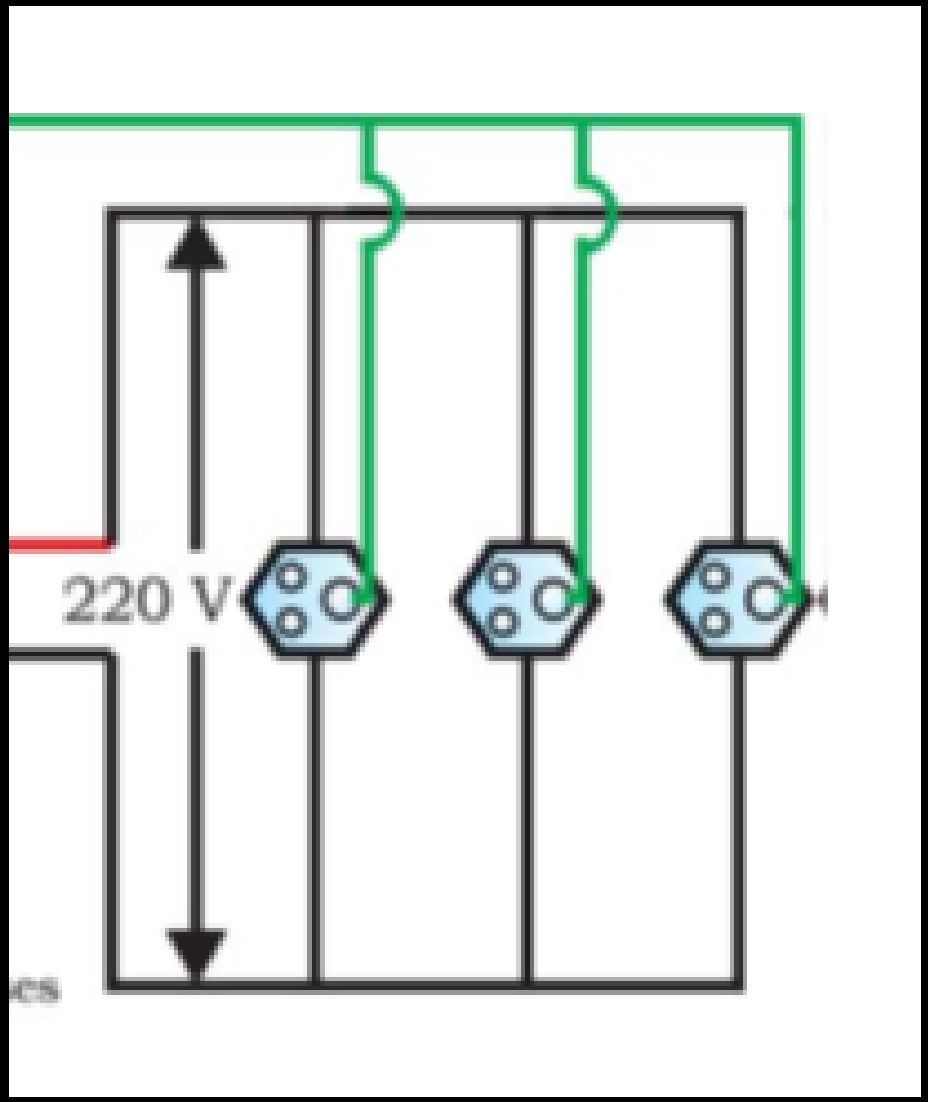
Earthing Appliances





Why are the appliances connected parallel to each other?

In order that each appliance has equal potential difference, they are connected parallel to each other.



Electric fuse

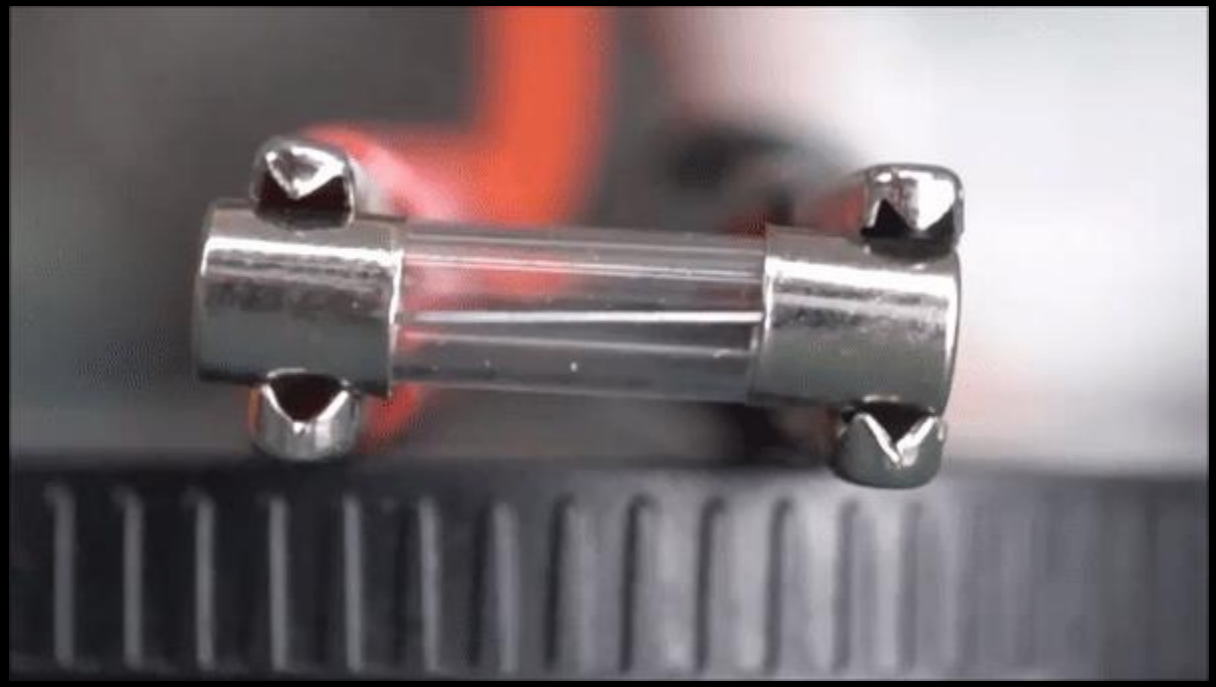
Electric Fuse consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc.

Principle of Electric fuse

Joule heating that takes place in the fuse melts it to break the electric circuit.

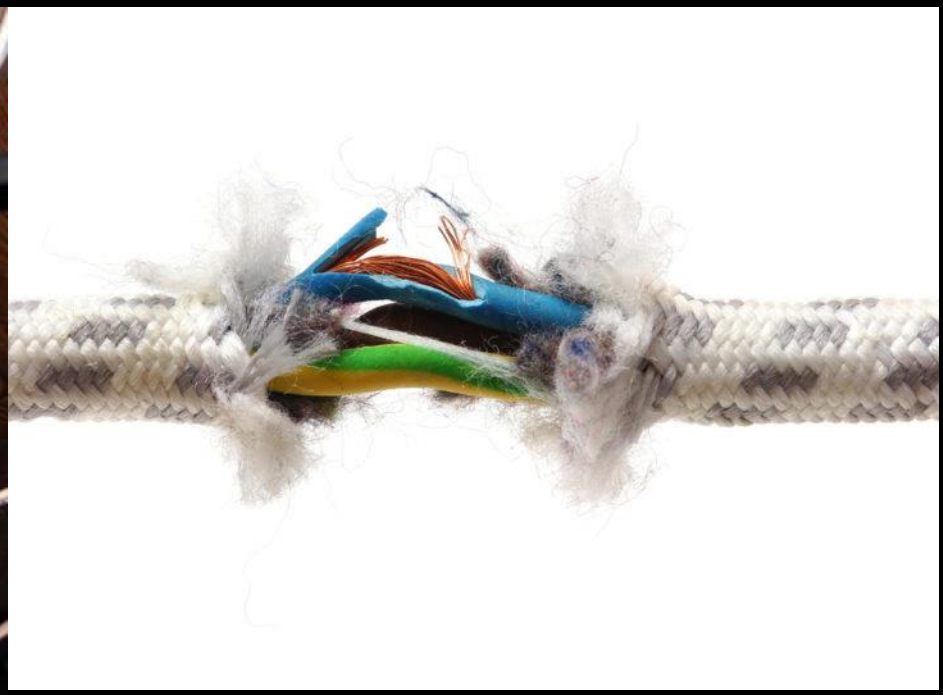
Electric fuse

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.



Overloading

It occurs when the insulation of wires is damaged or there is a fault in the appliance.



Overloading

Overloading can also occur due to an accidental hike in the supply voltage.

Short circuiting

Short circuiting occurs when the live wire and the neutral wire come in direct contact.

Precaution to be taken to avoid the overloading of domestic electric circuits

(a) Too many appliances should not be connected to a single socket.

(b) Too many appliances should not be used at the same time.

(c) Faulty appliances should not be connected in the circuit

(d) Fuse should be connected in the circuit.

Exercise (MCQ)

1) The magnetic field inside a long straight solenoid carrying current:

(a) is zero.

(b) decreases as we move towards its end.

(c) increases as we move towards its end.

(d) is the same at all points.

2. Which of the following property of a proton can change while it moves freely in a magnetic field? (There may be more than one correct answer.)

(a) mass
(b) speed
(c) velocity
(d) momentum

3. A positively-charged particle (alpha-particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is:

(a) towards south
(b) towards east
(c) downward
(d) upward

4. Choose the correct option: A rectangular coil of copper wires is rotated in a magnetic field. The direction of the induced current changes once in each:

(a) two revolutions
(b) one revolution
(c) half revolution
(d) one-fourth revolution

5. Which of the following correctly describes the magnetic field near a long straight wire?

(a) The field consists of straight lines perpendicular to the wire

(b) The field consists of straight lines parallel to the wire

(c) The field consists of radial lines originating from the wire

(d) The field consists of concentric circles centered on the wire

6. The phenomenon of electromagnetic induction is:

(a) the process of charging a body

(b) the process of generating magnetic field due to a current passing through a coil

(c) producing induced current in a coil due to relative motion between a magnet and the coil

(d) the process of rotating a coil of an electric motor

7. The device used for producing electric current is called a:

(a) generator.
(b) galvanometer.
(c) ammeter.
(d) motor.

8. The essential difference between an AC generator and a DC generator is that:

(a) AC generator has an electromagnet while a DC generator has permanent magnet.

(b) DC generator will generate a higher voltage.

(c) AC generator will generate a higher voltage.

(d) AC generator has slip rings while the DC generator has a commutator.

9. At the time of short circuit, the current in the circuit:

(a) reduces substantially.
(b) does not change.
(c) increases heavily.
(d) vary continuously.

State whether the following statements are true or false.

(a) An electric motor converts mechanical energy into electrical energy. False

(b) An electric generator works on the principle of electromagnetic induction. True

(c) The field at the centre of a long circular coil carrying current will be parallel straight lines. True

(d) A wire with a green insulation is usually the live wire of an electric supply. False

END

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