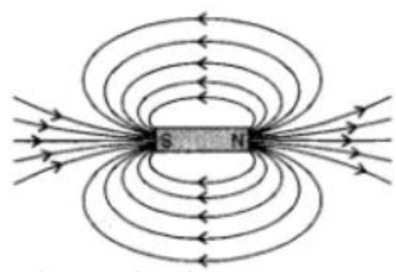
THE RADIANT EDUCATION POINT
(MRITUNJAY MISHRA)
H.N. 1256, 33-FEET ROAD, S.G.M. NAGAR
FARIDABAD
MOB: 9711725517. 9643125430

MAGNETIC EFFECT OF CURRENT

Magnet
A Magnet is an object which attracts pieces of iron, steel, nickel and cobalt i.e. it applies force on these objects. It has various types.

Properties
→The end of a freely suspended magnet always points towards north — south direction.
→The end which points towards north is the north pole of the magnet whereas the end which points towards south direction is the south pole of the magnet.
→If two magnets are placed together with similar poles towards each other, then they repel each other (tends to move away), whereas if two different poles are towards each other, then they attract (tends to move towards each other). In simple words, Like poles repels each other and unlike poles attract each other.
→If we cut a bar magnet then we get two magnets. Both having north and South Pole.

Magnetic field: The area around a magnet where a magnetic force is experienced is called a magnetic field. It is a quantity that has both direction & magnitude.



→ Field lines arise from North Pole and end into South pole of the magnet.
→ Field lines are closed curves.
→ Field lines are closer in stronger magnetic field.
→ Field lines never intersect each other as for two lines to intersect, there must be two north directions at a point, which is not possible.
→ Direction of field lines inside a magnet is from South to North.
→ The relative strength of magnetic field is shown by degree of closeness of field
lines.

***Direction of field line*:** Outside the magnet, the direction of magnetic field line is taken from North pole to South Pole. Inside the magnet, the direction of magnetic field line is taken from South pole to North pole.

Strength of magnetic field: The closeness of field lines shows the relative strength of magnetic field, i.e. closer lines show stronger magnetic field and vice – versa. Crowded field lines near the poles of magnet show more strength.

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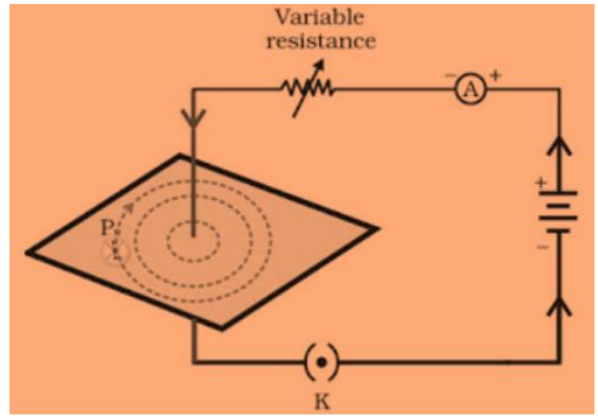
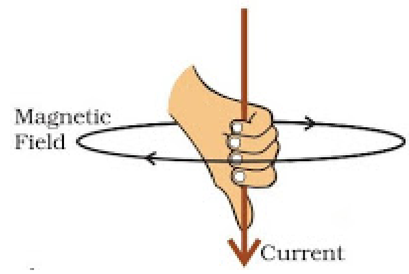
Magnetic field due to Current Carrying Wire



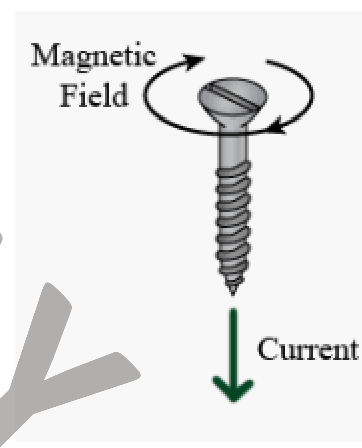
→ A physicist and chemist Hans Christian Oersted, once performing an experiment saw that a current flowing in a circuit caused deflection of compass needle which was kept near to it.
→ He then concluded that current carrying wire produces Magnetic field.
→ Magnetic field lines due to current carrying wire can also be plotted using iron fillings in the same manner as in case of Bar Magnet. **Magnitude of magnetic field is directly proportional to current and inversely proportional to the distance from the wire.**

Right Hand Thumb Rule



→ Imagine you are holding a current carrying straight conductor in your right hand such that the thumb is pointing towards the direction of current.
→ Then the fingers wrapped around the conductor give the direction of magnetic field.

Maxwell's Corkscrew rule: As per Maxwell's Corkscrew Rule, if the direction of forward movement of screw shows the direction of the current, then the direction of rotation of screw shows the direction of magnetic field.

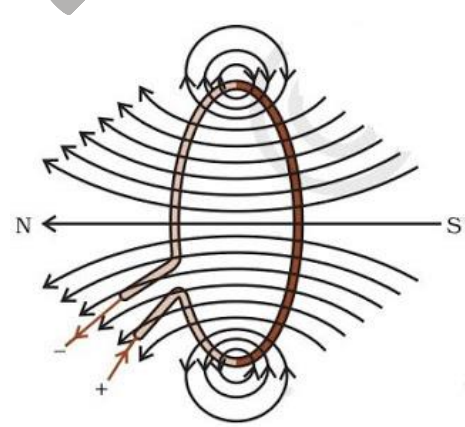


Magnetic Field due to Current through a Straight Conductor

→ It can be represented by concentric circles at every point on conductor.
→ Direction can be given by right hand thumb rule or compass.
→ Circles are closer near the conductor.
→ Magnetic field ∝ Strength of current.
→ Magnetic field ∝ 1/Distance from conductor

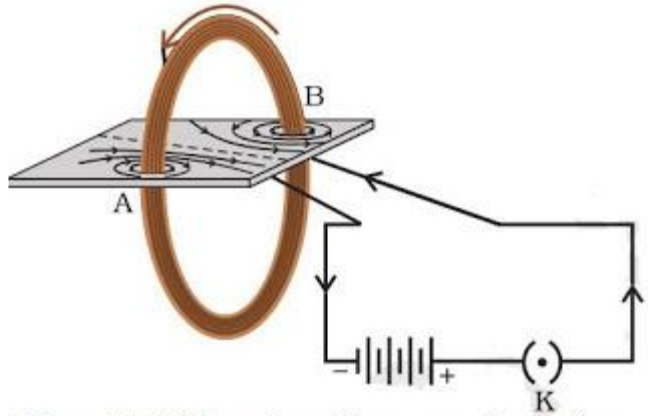
Magnetic Field due to Current through a Circular Loop

→ It can be represented by concentric circle at every point.
→ Circles become larger and larger as we move away.
→ Every point on wire carrying current would give rise to magnetic field appearing as straight line at center of the loop.
→ The direction of magnetic field inside the loop is same.



Factors affecting magnetic field of a circular current carrying conductor

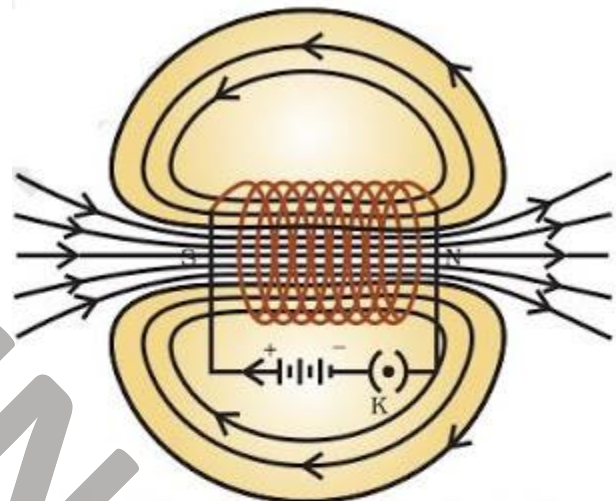
→ Magnetic field ∝ Current passing through the conductor
→ Magnetic ∝ 1/Distance from conductor
→ Magnetic field ∝ No. of turns in the coil
→ Magnetic field is additive in nature i.e., magnetic field of one loop adds up to magnetic field of another loop. This is because the current in each circular turn has same direction.



Magnetic field produced by a current carrying circular coil.

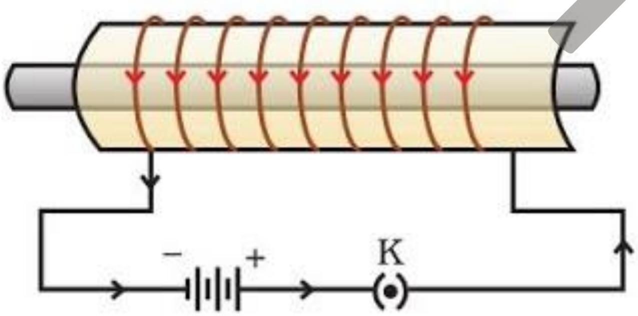
Solenoid

→ A coil of many circular turns of insulated copper wire wrapped closely in a cylindrical form.
→ Magnetic field of a solenoid is similar to that of a bar magnet.
→ Magnetic field is uniform inside the solenoid and represented by parallel field lines.



Field lines of the magnetic field through and around a current carrying solenoid.

Direction of magnetic field



A current-carrying solenoid coil is used to magnetise steel rod inside it – an electromagnet.

(i) Outside the solenoid: North to South
(ii) Inside the solenoid: South to North
→ Solenoid can be used to magnetise a magnetic material like soft iron.

Electromagnet

→ It is a temporary magnet, so, can be easily demagnetized.
→ Strength can be varied.
→ Polarity can be reversed.
→ Generally strong magnet.

Permanent Magnet

→ Cannot be easily demagnetized.
→ Strength is fixed.
→ Polarity cannot be reversed.
→ Generally weak magnet.

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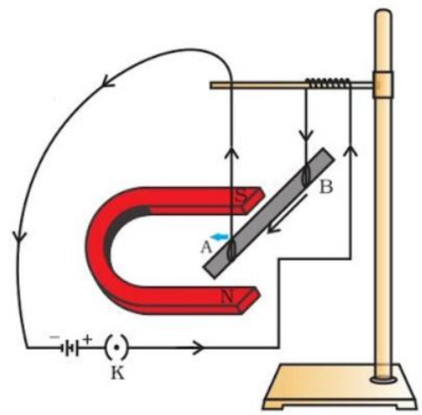
Magnetic force on a current carrying wire

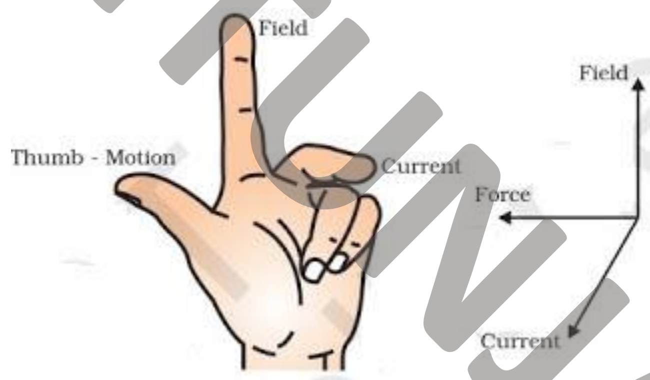
If a current carrying wire is placed between a magnetic field, then force acts **on that** wire. **This** phenomenon was discovered by Ampere. As the direction **of** current (i) is reversed, the magnetic force also acts in different direction.



- As current increases, force acting on wire also increases.
- As length of the wire increases, value of force increases.
- More magnetic field, more force acting on wire.
- Direction of force depends on direction of current and magnetic field.

Fleming's Left Hand Rule

→ Stretch the thumb, fore finger and middle finger of your left hand such that they are mutually perpendicular.



→ If fore finger points in the direction of magnetic field, middle finger in the direction of current then thumb will point in the direction of motion or force.

Galvanometer: Instrument that can detect the presence of current in a circuit. It also detects the direction of current.

Electric motor: A device that converts electrical energy to mechanical energy. Electrical energy is converted into mechanical energy by using and electric motor

PRINCIPLE OF ELECTRIC MOTOR:

When a rectangular coil is placed in a magnetic field and a current is passed through it, force acts on the coil, which rotates it continuously. With the rotation of the coil, the shaft attached to it also rotates.

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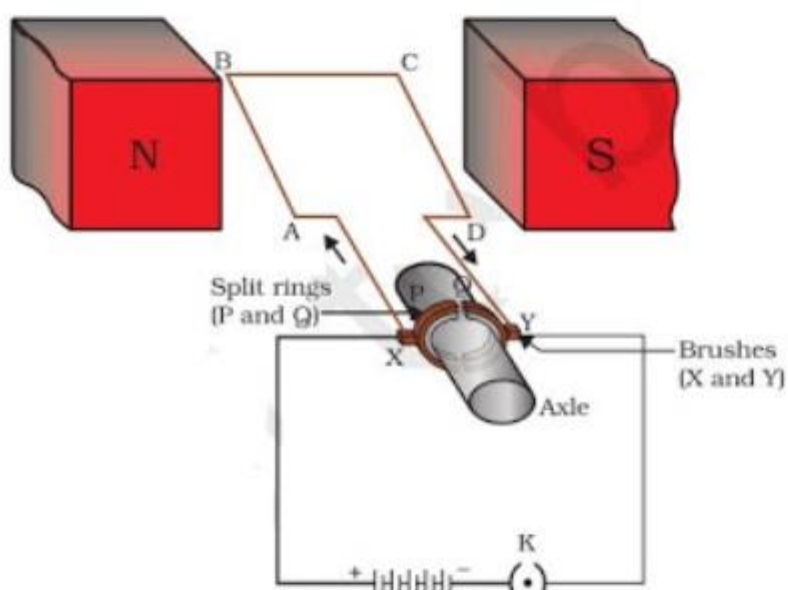

CONSTRUCTION:
It consists of the following parts :

- **Armature**: It is a rectangular coil (ABCD) which is suspended between the two poles of a magnetic field.
  The electric supply to the coil is connected with a commutator.
- **Commutator or Split ring**: Commutator is a device which reverses the direction of flow of electric current through a circuit. It is two halves of the same metallic ring.
- **Magnet:** Magnetic field is supplied bv a permanent magnet NS.
- **Sliding contacts or Brushes** Q which are fixed.
- **Battery**: These are consists of few cells.

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WORKING
→ An electric motor consists of a rectangular coil ABCD of insulated copper wire. The coil is placed between the two poles of a magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field.
→ The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides of these halves are insulated and attached to an axle.
→ The external conducting edges of P and Q touch two conducting stationary brushes X and Y, respectively.
→ Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y.
→ 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 split ring acts as a commutator which reverse the direction of current and 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.

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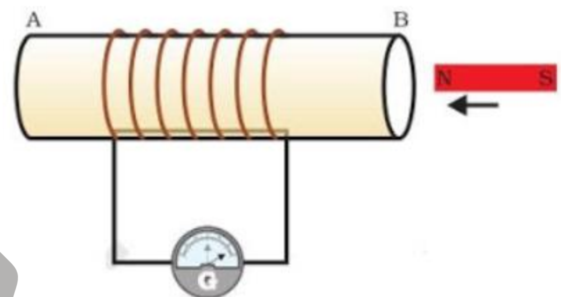
Commutator: A device that reverses the direction of flow of current through a circuit is called a commutator.

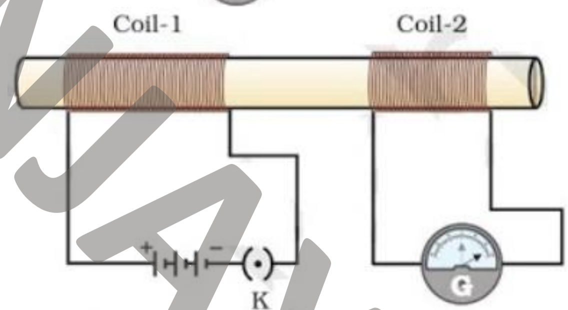
Armature: The soft iron core, on which the coil is wound including the coils is called armature. It enhances the power of the motor.

Commercial use of motors
(i) an electromagnet in place of permanent magnet
(ii) large number of turns of the conducting wire in the current-carrying coil
(iii) a soft iron core on which the coil is wound.

Electromagnetic Induction: Michael Faraday, an English Physicist is supposed to have studied the generation of electric current using a magnetic field and a conductor.
Electricity production as a result of magnetism (induced current) is called Electromagnetic Induction.
When a conductor is set to move inside a magnetic field or a magnetic field is set to be changing around a conductor, electric current is induced in the conductor.

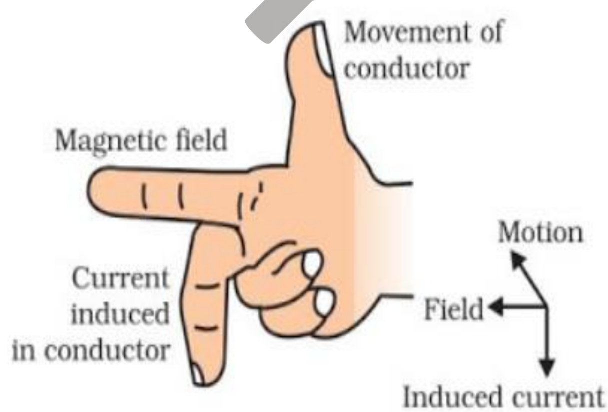


Activity No. 1
(i) Magnet moved into the coil: Momentary deflection in G indicating presence of current.
(ii) Magnet kept stationary inside the coil: No deflection.
(iii) Magnet is withdrawn: Momentary deflection in G but in opposite direction of first case.



Activity No. 2
(i) Switched on: Momentary deflection in G.
(ii) Steady current: No deflection.
(iii) Switched off: Momentary deflection in G but in opposite direction of the first case.

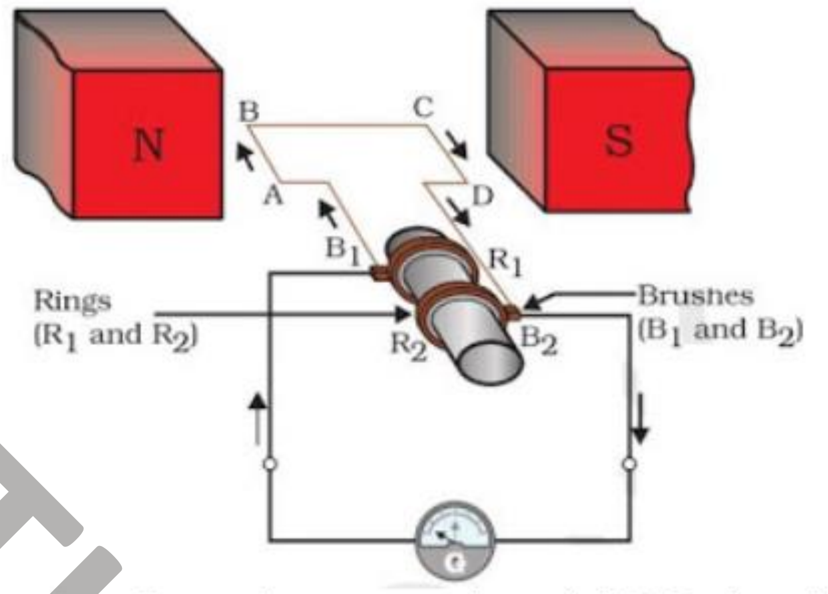
Fleming's Right Hand Rule
→ Hold the thumb, the fore finger and the middle finger of right hand at right angles to each other.
→ If the fore finger is in the direction of magnetic field and the thumb points in the direction of motion of conductor, then the direction of induced current is indicated by middle finger.
• Used to find direction of induced current.



Electric Generator

→ An electric generator, mechanical energy is used to rotate a conductor in a magnetic field to produce electricity.

→ An electric generator consists of a rotating rectangular coil ABCD placed between the two poles of a permanent magnet.



→ The two ends of this coil are connected to the two rings R_1 and R_2. The inner side of these rings are made insulated.

→ The inner side of these rings are made insulated. The two conducting stationary brushes B_1 and B_2 are kept pressed separately on the rings R_1 and R_2, respectively.

→ The two rings R_1 and R_2 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 galvanometer to show the flow of current in the given external circuit.

→ 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.

→ 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.

• 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.

• The direct current always flows in one direction, whereas the alternating current reverses its direction periodically.

Alternate Current (A. C.)

→ The current which reverses its direction periodically.

→ In India, A. C. reverses its direction in every 1/100 second.

Time period = 1/100 + 1/100 = 1/50 s

Frequency = 1/time period = 1/50 = 50 Hz

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A.C and D.C Current

A.C – Alternate Current: Current in which direction is changed periodically is called Alternate Current. In India, most of the power stations generate alternate current. The direction of current changes after every 1/100 second in India, i.e. the frequency of A.C in India is 50 Hz. A.C is transmitted up to a long distance without much loss of energy.

D.C – Direct Current: Current that flows in one direction only is called Direct current. Electrochemical cells produce direct current.

Advantages of A.C over D.C

- Cost of generator of A.C is much less than that of D.C.
- A.C can be easily converted to D.C.
- A.C can be controlled by the use of choke which involves less loss of power whereas, D.C can be controlled using resistances which involves high energy loss.
- AC can be transmitted over long distances without much loss of energy.
- AC machines are durable and do not need much maintenance.

Disadvantages of AC

- AC cannot be used for the electrolysis process or showing electromagnetism as it reverses its polarity.
- AC is more dangerous than DC.

Direct Current (D. C.)

→ The current which does not reverse its direction.
→ D. C. can be stored.
→ Loss of energy during transmission over long distance is high.
→ Sources of D. C.: Cell, Battery, Storage cells.

Domestic Electric Circuits: We receive electric supply through mains supported through the poles or cables. In our houses, we receive AC electric power of 220 V with a frequency of 50 Hz.
The 3 wires are as follows

- Live wire – (Red insulated, Positive)
- Neutral wire – (Black insulated, Negative)
- Earth wire – (Green insulated) for safety measure to ensure that any leakage of current to a metallic body does not give any serious shock to a user.

Short Circuit: Short-circuiting is caused by the touching of live wires and neutral wire and sudden a large current flows.
It happens due to

- damage of insulation in power lines.
- a fault in an electrical appliance.

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Overloading of an Electric Circuit: The overheating of electrical wire in any circuit due to the flow of a large current through it is called overloading of the electrical circuit.
A sudden large amount of current flows through the wire, which causes overheating of wire and may cause fire also.

Electric Fuse: It is a protective device used for protecting the circuit from short-circuiting and overloading. It is a piece of thin wire of material having a low melting point and high resistance.

- Fuse is always connected to live wire.
- Fuse is always connected in series to the electric circuit.
- Fuse is always connected to the beginning of an electric circuit.
- Fuse works on the heating effect.

Insulation of wire can be damaged due to:

a. Breaking of insulation over time

If an insulation breaks of the live wire and it comes in contact with metallic body of an appliance, it can be very dangerous.

b. Heating

Due to overheating of wires, the insulating cover of the wire may get damaged.

Importance of earthing:

Earth wire is connected to metallic appliances and other end is connected to large metallic plate which is dug deep in earth.
If live wire comes in contact with metallic body of an appliance, it can be very dangerous. On touching the body, we can get electric shock. But if earth wire touches the metallic body of appliance, any current through live wire flows through ground wire. It does not flow through our body.
Note: Ground wire goes to all appliances having metallic body.

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