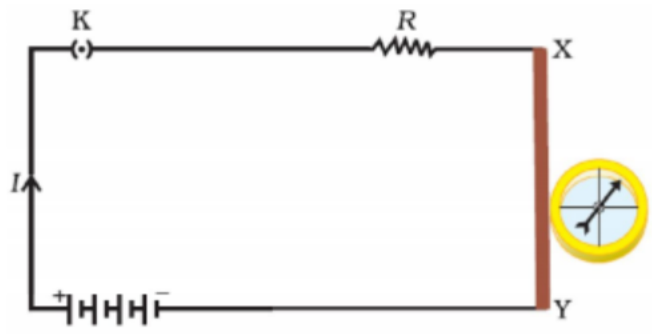
Class X
Magnetic effects of electric current

Magnetic effects of current – A current carrying conductor always creates a magnetic field around it. This is known as magnetic effects of current.
Magnetic effects of current was demonstrated by Hans Christian Oersted by his experiment.

Oersted Experiment



- In 1820, Hans Christian Oersted performed an important experiment which showed that there is a relation between electricity and magnetism.
- When the current is passed through the conductor, a magnetic needle placed close to the conductor deflects indicating the presence of magnetic field around it.
- When the current was switched off, magnetic needle of magnetic compass comes back to original N-S position
- When direction of current was reversed by reversing the terminals of the battery, it was observed that magnetic needle also showed deflection in opposite direction.
- The direction of deflection of the needle is given by **SNOW RULE**

SNOW RULE – According to this rule, if current flows from South to North, North of magnetic needle deflects towards the west.

What is magnetic field?

- It is the space around the magnet or current carrying conductor in which attraction or repulsion on another magnetic pole can be felt.
- Magnetic field is a vector quantity having magnitude as well as direction.
- The direction of the magnetic field is taken to be the direction in which a north pole of the compass needle moves inside it.

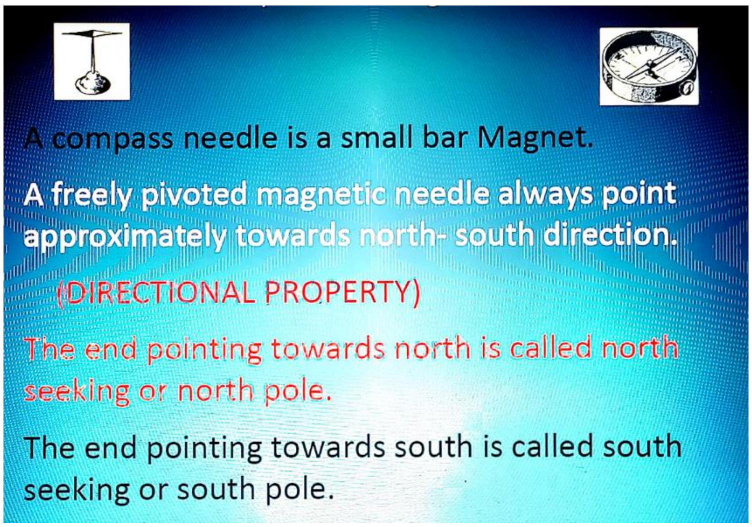
Magnetic field lines -

They are the path straight or curved in the magnetic field. Tangent drawn to any point on magnetic field lines gives the direction of magnetic field.
Magnetic field lines are the path along which north of magnetic compass will move.

Bar magnet

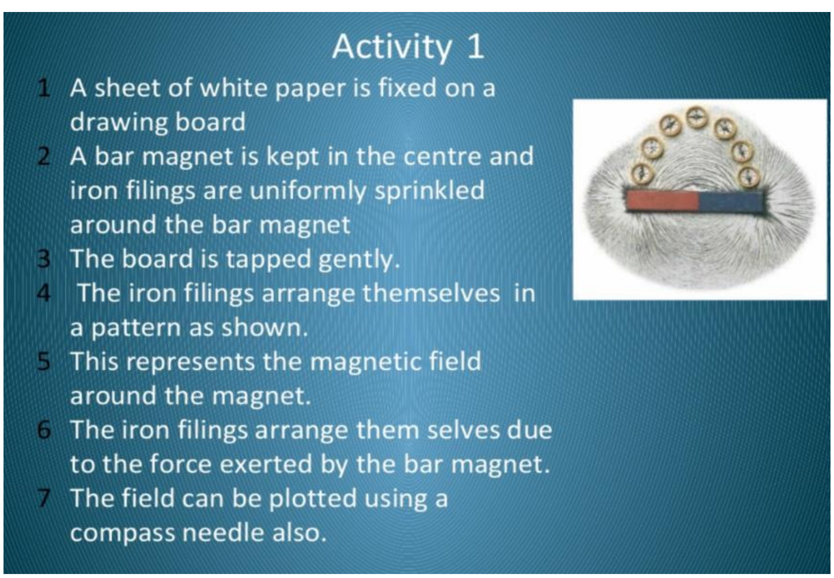
A bar magnet is a long rectangular bar of uniform cross section which attracts pieces of Iron, Nickel Cobalt towards it.

Magnetic compass

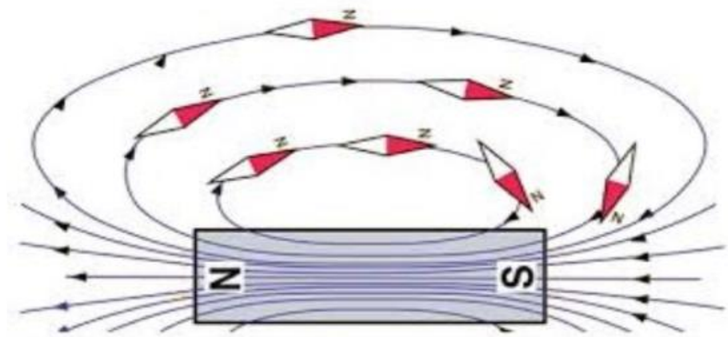


- A compass needle is a small bar magnet whose ends always point towards north south direction.
- The end pointing towards north is called North Pole and the end pointing towards south is called South Pole.

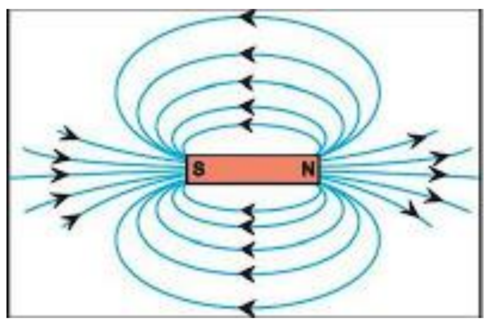
Magnetic field lines due to a Bar magnet

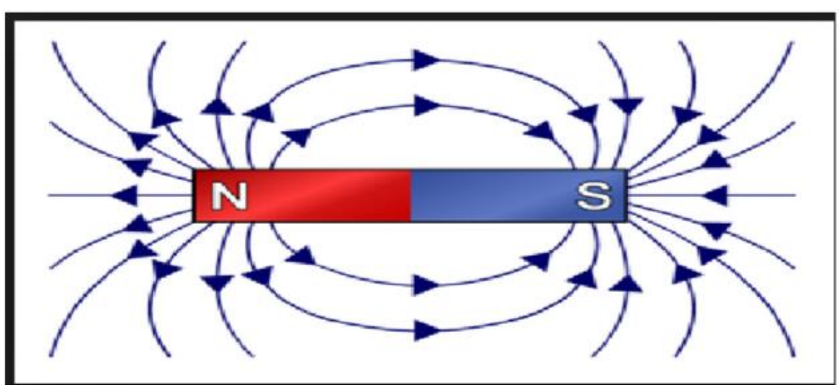


We can draw magnetic field lines by using a magnetic compass



<u>Magnetic field pattern due to a Bar magnet</u>

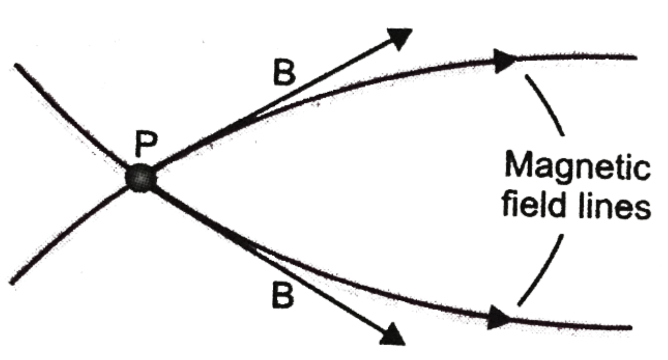




- The field lines emerge from the North pole and end at the south pole outside magnet.
- Inside the magnet, the direction of field lines is from its south pole to its north pole.
- Thus the magnetic field lines are closed curves.
- Magnetic field lines are closer to each other near the poles showing greater strength of magnetic field near poles.

Properties of magnetic field lines

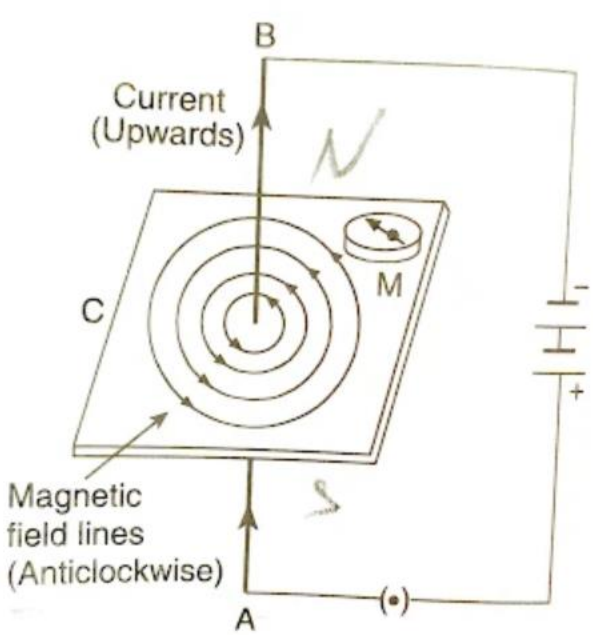
- Magnetic field lines are path straight or curved such that tangent drawn at any point on magnetic field lines gives the direction of magnetic field.
- Magnetic field lines forms closed curves outside the magnet.
- The direction of field lines is from North to South outside the magnet and from South to North inside the magnet.
- No two magnetic field lines can intersect each other. This is because if they intersect, there will two different directions of magnetic field given by two tangents at the point of intersection which is not possible.



- The degree closeness of magnetic field lines decides the relative strength of magnetic field. If field lines are closer to each other, it denotes that magnetic field will be stronger in that region.
- Parallel magnetic field lines denotes uniform magnetic field.

Why does a compass gets deflected when brought closer to a bar magnet?
Compass needle is a small magnet itself and it deflects due to interaction between the two magnets.

Magnetic field due to current carrying straight conductor



The shape of field lines is in form of concentric circles (around a common) center

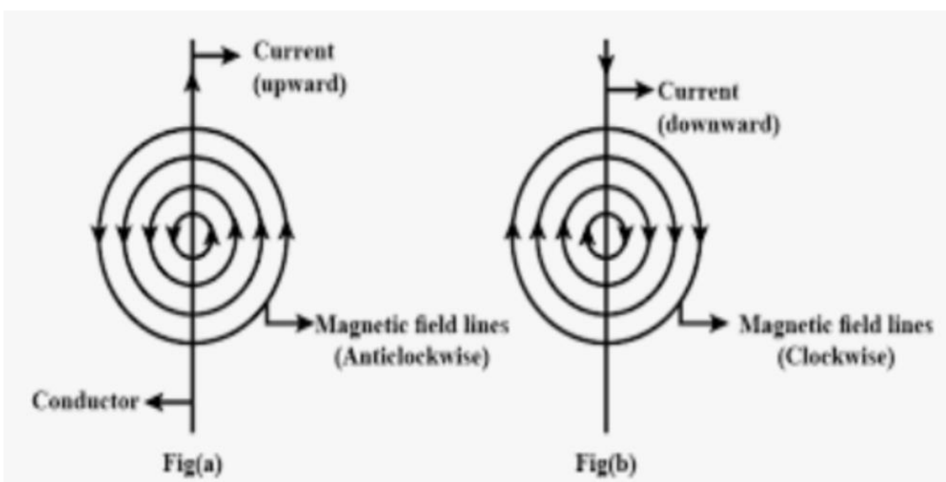
- The magnitude of the magnetic field produced at a given point increases as the current through the wire increases.
- The direction of magnetic field produced by the electric current depends upon the direction of flow of current.
- If we reverse the direction of current then the direction of magnetic field produced by the electric current gets changed.
- The concentric circles representing the magnetic field around a current-carrying straight wire become larger and larger as we move away from it.
- Strength of magnetic field produced – increases on increasing the current and decreases as we move away from the current carrying wire.
- The direction of magnetic field is given by **Right Hand Thumb Rule.**

Factors affecting strength of magnetic field around a current carrying straight conductor

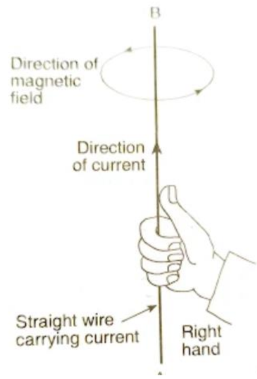
- Strength of magnetic field is directly proportional to the current passing through the conductor and inversely proportional to the distance from the conductor.

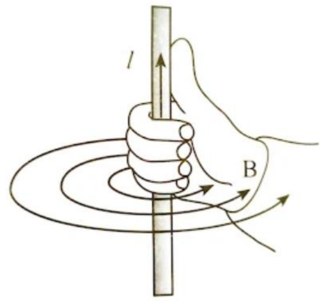
$$B = \frac{\mu_o I}{2\pi r}$$

Maxwell's Right Hand Thumb Rule



- If we hold a straight current conductor in our right hand such that the thumb represents the direction of current then the fingers encircling represent the direction of magnetic field lines.

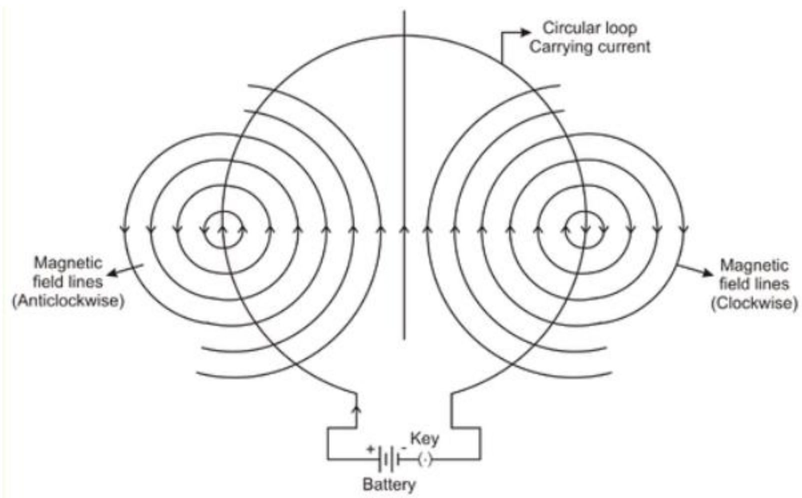




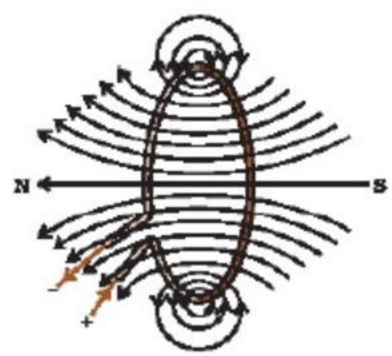
Current – upwards, Magnetic field lines – anticlockwise direction
Current – downwards, Magnetic field lines – clockwise direction

Magnetic field due to current carrying circular loop:

We consider a circular loop of radius R carrying current I in the direction shown below



Magnetic field lines due to circular loop carrying current



- Magnetic field produced at the center of the loop increases with increase in current
- Magnetic field at the center of the loop decreases if the radius of the circular loop is increased
- The direction of magnetic field lines is given by **Right Hand Thumb rule**
- This pattern is obtained when current is passed through the circular loop and iron fillings arrange themselves in the pattern of concentric circles.
- When the current is passed through circular loop or coil, the lines of force are circular near the wire but straight and parallel near the centre of loop or coil.

Factors affecting magnetic field due to current carrying circular loop or coil.

Magnetic field due to current carrying circular loop at its centre is–

- Directly proportional to the current passing through it.
- Inversely proportional to the radius of loop.

$$B = \frac{\mu_o I}{2\pi r}$$

Solenoid

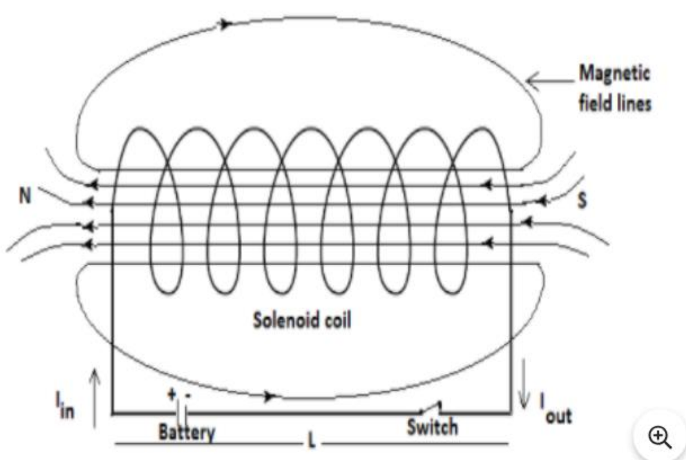
- A coil of many circular turns of insulated copper wire wrapped closely *in the shape of a cylinder* is called a **solenoid**.
- A solenoid produces a magnetic field when electric current is passed through it.
- The pattern of the magnetic field lines around a current-carrying solenoid is similar to that of a bar magnet.
- One end of the solenoid is like a magnetic north pole while the other is like the south pole

Magnetic field due to a current carrying solenoid

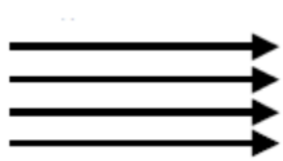
A solenoid is a circular coil of wire in the shape of a cylinder.

When current flows through a solenoid, it behaves like a bar magnet. The ends of the solenoid behaves like the North and South poles of a magnet. The magnetic field produced by a solenoid is similar to the magnetic field produced by a bar magnet.

The strength of the magnetic field depends upon the strength of the current and the number of turns of the coil.



The field lines inside the solenoid are in the form of straight parallel lines showing uniform magnetic field.



FACTORS AFFECTING MAGNETIC FIELD AROUND A SOLENOID :

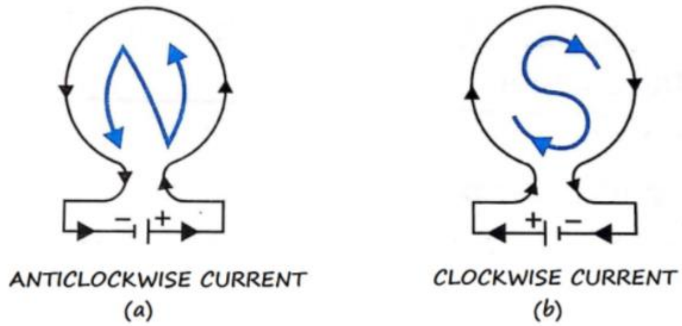
1. DIRECTLY PROPORTIONAL TO THE **STRENGTH OF CURRENT**
2. DIRECTLY PROPORTIONAL TO THE **NUMBER OF TURNS**
3. DIRECTLY PROPORTIONAL TO THE **MATERIAL USED AS A CORE**

CLOCK RULE:

- The clock face rule in a solenoid is used to determine the poles of the magnet that will be formed due to the current flow through the solenoid. The rule states that if you are look through a solenoid and form where you are viewing the current flows in a clockwise direction, that point will form the south pole. On the other hand, if viewing from the side where the current flows in an anticlockwise direction, the side will be the north pole.

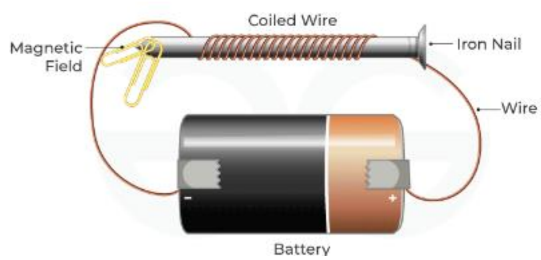
Clock rule :

Looking at the face of the loop, if the current around that face is in the anticlockwise direction, the face has the north polarity, while if the current at the face is in the clockwise direction, the face has the south polarity.



Electromagnet

- An electromagnet consists of a long coil of insulated copper wire wrapped around a soft iron core.
- Iron core inserted inside the current carrying solenoid becomes magnetized and is called electromagnet.
- Soft iron core is the best suited material to make electromagnet as it looses its magnetism immediately as the current is switched off.
- On the other hand if we use steel, it will not lose its magnetism immediately when current is switched off and turns into a permanent magnet.



Factors affecting the strength of magnetic field of an electromagnet
The strength of magnetic field of an electromagnet is –
1. Directly proportional to the number of turns.
2. Directly proportional to the current flowing through it.
3. Inversely proportional to the length of air gaps between the poles.

Difference between Electromagnet and permanent magnet

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.

Uses of electromagnet

- They are used in electrical devices such as electric bell, electric fan, motor, and generator.
- They are used for lifting and transporting large mass of iron.
- They are used in medical practices for removing pieces of iron from wound and used in MRI.

Q. Why soft iron is used for making the core of an electromagnet?

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.

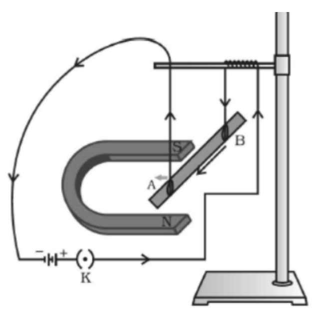
Q. Why steel is not used for making the core of an electromagnet?

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

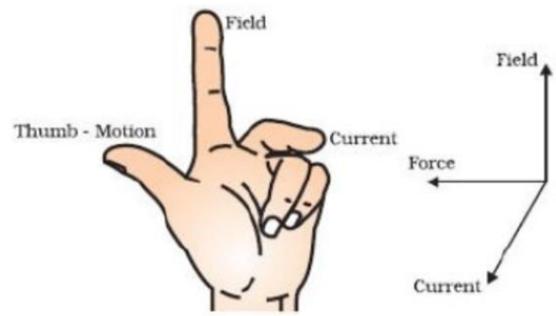
A current carrying conductor placed in a magnetic field experiences a force due to the interaction between ---

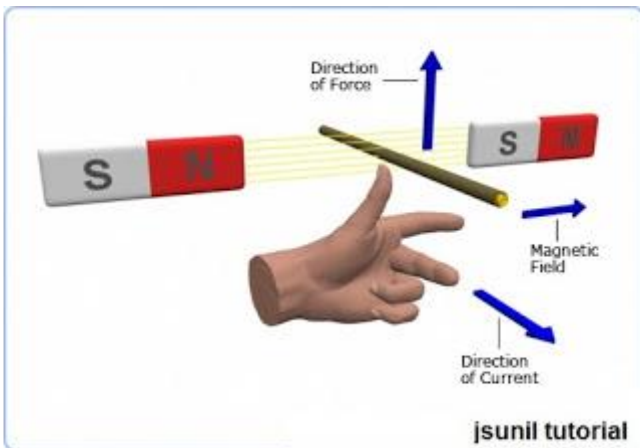
- Magnetic field due to current carrying conductor and
- External magnetic field in which conductor is placed.



In the above figure, a current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field.
The displacement of the rod in the above activity suggests that a force is exerted on the currentcarrying aluminium rod when it is placed in a magnetic field. It also suggests that the direction of force is also reversed when the direction of current through the conductor is reversed. Now change the direction of field to vertically downwards by interchanging the two poles of the magnet. It is once again observed that the direction of force acting on the current-carrying rod gets reversed. It shows that the direction of the force on the conductor depends upon the direction of current and the direction of the magnetic field. We considered the direction of the current and that of the magnetic field perpendicular to each other and found that the force is perpendicular to both of them.

Fleming's left hand rule





If we stretch our thumb, index finger and the central finger of our left hand such that they are mutually perpendicular to each other, if the index finger represents the direction of magnetic field and the central finger represents the direction of current then the thumb represents the direction of Force experienced by the conductor.

The difference between the direct and alternating currents

1. *The direct current always flows in one direction, whereas the alternating current reverses its direction periodically. In India, the AC changes direction after every 1/100 second, that is, the frequency of AC is 50 Hz.*

2. *An important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.*

DOMESTIC CIRCUITS

1) **Short Circuit:** Sometimes live & neutral wire comes in direct contact with each other. This may happens when the insulation of wires is damaged or there is a fault in the appliances due to which resistance of the circuit decreases to a very small value & consequently the current becomes very large. This is called Short Circuiting.

This may even cause firing in the building.

2) **Earth wire:** It is necessary to connect an earth wire to electrical appliances having metallic body to ensure that any leakage of current to metallic body does not give any severe shock to a user.

For this one end of the earth wire is connected to the metallic body & other end is usually connected to a metal plate, which is buried deep inside the earth near the house. If there is any leakage of current in the metallic body, earth wire provides a low resistance-conducting path for the current & keeps its potential to that of the earth & user may not get severe shock.

3) **Fuse wire:** The function of fuse wire is to protect the circuits due to short-circuiting or overloading of the circuits.

Fuse wire is always connected in series with the live wire

Fuse wire is made from an alloy of tin & copper. Fuse wire is having low melting point & high resistance.

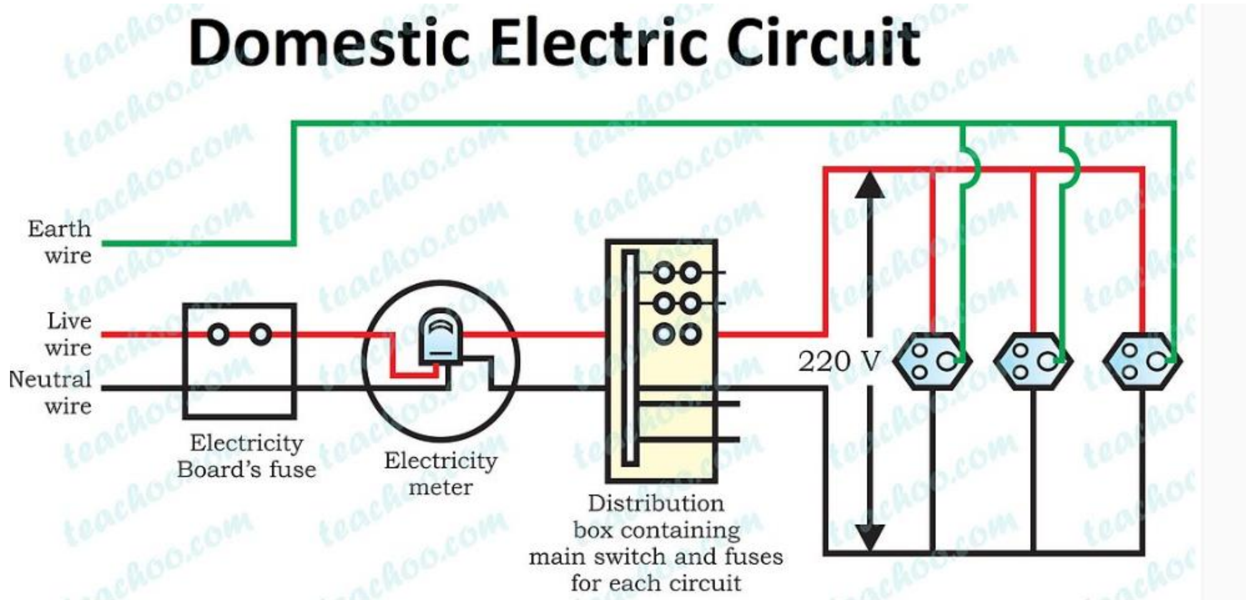
Rating of a fuse The maximum current which can flow through a fuse without melting it, is called its rating. For example, a fuse rated at 15A, can stand current upto 15A.

4) **Overloading of an electrical circuit:** The current flowing through an electric circuit depends upon the power rating of the electrical appliances connected to it. When the total power rating of the electrical appliances connected in the circuit exceeds certain limit, they draw large current. If this current exceeds the safety limit of the wiring, it may get overheated.

Overloading is also due to short circuiting & voltage fluctuation.

The overheating of electrical wiring in any circuit due to the flow of large current through it is called overloading of the electrical circuit.

Domestic circuits



Domestic Electric Circuit
Earth wire
Live wire
Neutral wire
Electricity Board's fuse
Electricity meter
Distribution box containing main switch and fuses for each circuit
220 V