# MAGNETIC EFFECTS OF ELECTRIC CURRENT

**Introduction:** In early days, the Greeks observed that a naturally occurring substance called ‘Lodestone’ had the property of attracting iron pieces. So, lodestone is the naturally occurring magnet. Lodestone is a black coloured oxide are of iron called ‘magnetite’ ($Fe_3O_4$) which behaves like a magnet. It is called magnetite because it was found in Magnesia. Magnesia is the modern town of Manisa in Western Turkey.

**Magnet:** A magnet is an object which attract pieces of iron, nickel and cobalt, etc. and points at North South direction when suspended freely.

**Magnetism:** The property of an object of attracting pieces of iron, steel, cobalt and Nickle is called magnetism.

**Properties of Magnet:**

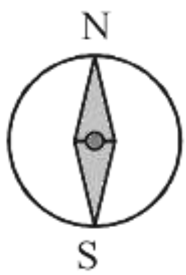
(1) Each Magnet has two poles – North pole and south pole.
(2) When magnet freely suspended, it always stay in North and South direction.
(3) Like magnetic poles repel each other whereas unlike magnetic poles attract each other.

**Artificial Magnets:** Those magnets which made from magnetic materials like iron, steel and nickel alloys by rubbing with natural magnet.

**Magnetic substances:** Those metallic substances from which magnet can be made are known as magnetic substances. Iron, nickel, cobalt, alnico (Al + Ni+ CO + Fe) etc are the examples of magnetic substances.

**Non - Magnetic substances:** Those substance from which magnet can’t be made are called non-magnetic substance. Aluminium, brass, copper wood, glass etc, are the examples of non-magnetic substances.

**Compass Needle:** <u>It is a tiny magnet which is free to move horizontally on a pivot.</u> The end of freely pivoted magnets which points towards the North direction is called North pole of magnet and the end of a freely pivoted magnets which point to south direction is called south pole of magnet. The North pole of the compass needle is painted with red colour and South pole painted with black colour.




Note: Magnetic poles exist in pairs. Single magnetic pole never exists.

**Knowledge Booster:**

- The Greek discovered the attractive property of the natural magnet, while the Chinese discovered the directive property of the natural magnet.
- In 1600, Dr. William Gilbert, the English physicist concluded that the earth behaves as a large permanent magnet.

**Uses of Magnet:**

(1) In children's toys, radio and stereo speakers.
(2) In hard disc and floppies for computers.
(3) In refrigerator and other doors, to snap them close.
(4) In audio and video cassette tapes.
(5) In medical therapy.
(6) In MRI (Magnetic Resonance Imaging).
(7) In production of electricity.

# Magnetic Field and magnetic lines of forces (or Magnetic field lines)

**Magnetic Field:** The space or region around a magnet within which it experiences a force of attraction or a force of repulsion due to presence of another magnet is called magnetic field.

Note: Thus, magnetic field is a vector quantity. Magnetic field is represented by $\vec{B}$.

**Magnetic Lines of Force:** The magnetic lines of force are the lines drawn in a magnetic field along which a north pole of compass needle would move.

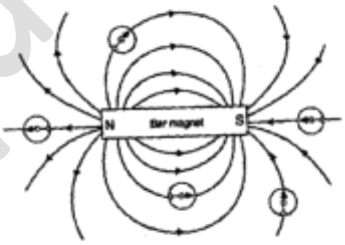
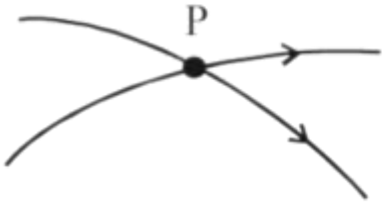



**Fig. The magnetic field pattern product by a bar magnet**

**Properties of Magnetic Lines of Force**

1. Magnetic lines of Force originate from the north pole of a magnet and close at a south pole of a magnet.
2. The magnetic lines of force close to each other near the poles of magnet but they are widely separated at other place.
3. Magnetic lines of Force do not intersect each other.

**Explanation:** Suppose two magnetic lines of force intersect each other at a point P. If We place a compass needle at point P then North pole of compass needle must show two directions at point P but this is not possible. This is because at a point at a time, the North pole of compass needle shows only one direction.




**Types of Magnetic Field:** There are two types of magnetic field:

(i) Uniform Magnetic field
(ii) Non-uniform Magnetic field

**Uniform magnetic field:** Magnetic field is said to be uniform if its magnitude is equal and direction is same at every point in the region. Uniform magnetic field is represented by equidistant parallel straight lines uniform magnetic field is shown in the below figure given below.

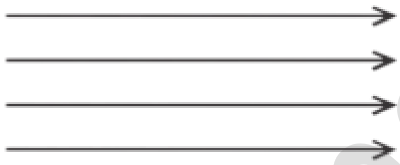


**Fig. Uniform magnetic field**

**Non-uniform magnetic field:** Magnetic field is said to be non-uniform if its magnitude is not equal and direction is not same at every point in the region. Non uniform magnetic field is shown in the below fig.

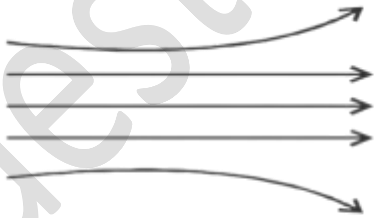


**Fig. Non-uniform magnetic field**

**Plotting of the magnetic lines of forces:** Magnetic lines of forces can be drawn by two methods:

(i) By using iron fillings
(ii) By using compass needle

## *Activity 1*

**Aim:** To study magnetic field by a bar magnet and iron fillings.

**Materials Required:** Iron fillings, bar magnet, white sheet, sprinkler and card-board.

**Procedure:**

**Step1:** Fix the white sheet on the cardboard.

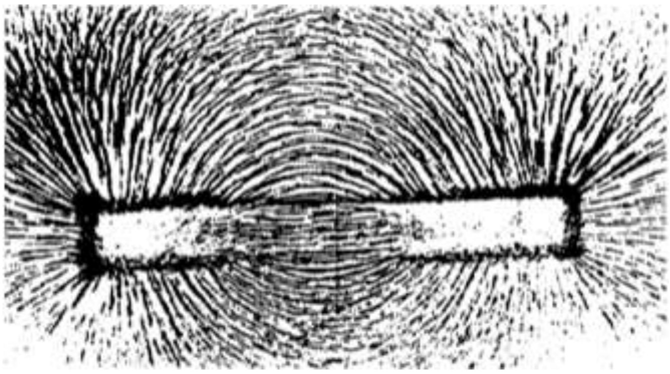
**Step2:** Place the bar magnet on the sheet and draw its boundary.

**Step3:** Sprinkle the iron fillings on the sheet.

**Step4:** Tape the cardboard gently.

**Observations:**

1. Most of the iron fillings get concentrated at the poles.
2. A definite pattern as drawn in the figure is observed formed by the iron fillings.



**Conclusion:**

1. The strength of magnetic field is maximum at the poles.
2. Iron fillings experience a definite force in a definite direction which makes them form the pattern.
3. The pattern can be taken as showing the pattern of magnetic field lines in the region.

## *Activity 2*

**Aim:** To draw magnetic field with the help of a bar magnet and compass needle.

**Material Required:** Bar magnet, magnetic compass needle, white sheet, card board and a pencil etc.

**Procedure:**

**Step1:** Fix the white sheet on the card board and keep it horizontal on the surface.

**Step2:** With the help of compass needle draw a line on white sheet in the North-South direction and make the North and South on the lines.

**Step3:** Place the bar magnet on the line according to poles mark on the line.

**Step4:** Place the compass needle on the north pole of the magnet and wait till it comes to rest.

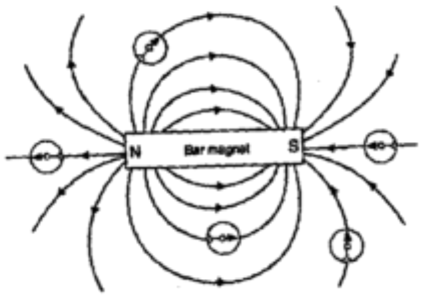
**Step5:** Mark the North and South of the compass needle as dots on the paper.

**Step6:** Place the compass needles South on the last marked N in step 5 and again led it rest and mark its N and S.

**Step7:** Repeat step 5 until you reach the South pole of the magnet.

**Step8:** Join the marked points by a smooth curve.

**Step9:** Repeat the step 4 to 6 on the other sides of the magnet and at little distance.



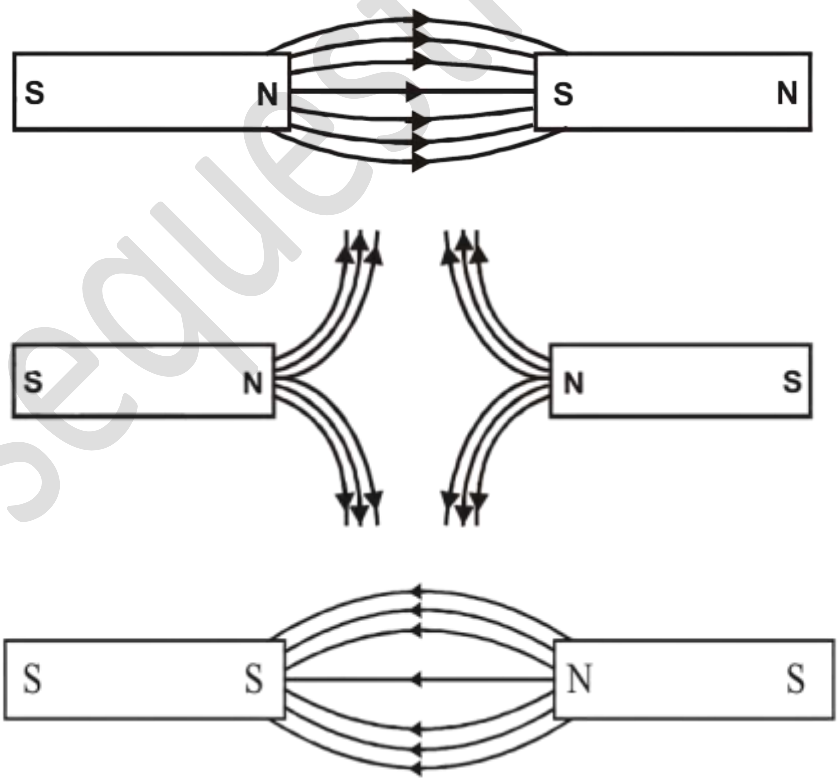

**Observation:**

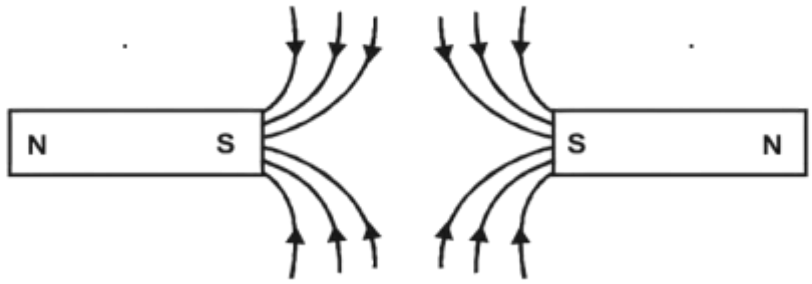
1. Lines drawn are similar to the pattern of iron fillings.
2. Pattern on either side of the magnet is symmetrical.
3. All lines appear to originate at the North pole and become rarer as we move away from the magnet. All lines sink in the South pole.

**Conclusion:**

1. Magnetic field lines exist surrounding a magnet.
2. Lines are diverging from poles or converging to poles.
3. Magnetic field lines form closed paths.

## Pattern of Magnetic lines of forces between two magnets:






**Sources of Magnetic Field:**

There are four types of sources of magnetic field these are:

(i) Natural Magnets
(ii) Current carrying conductor
(iii) A moving charge
(iv) By changing electric field

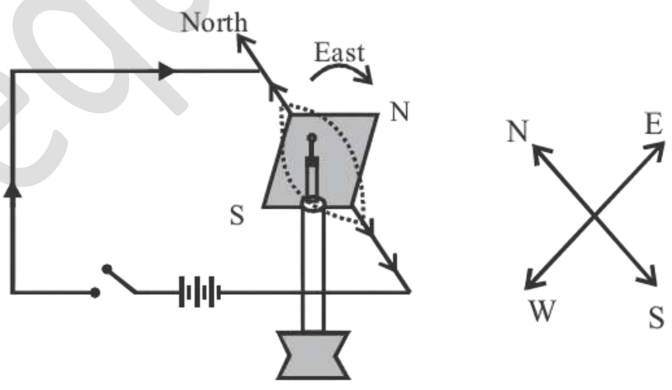
# Magnetic Effect of Current

In 1820, Oersted discovered that when an electric current is passed through a conductor then the conductor behaves like a magnet. This effect of electric current is called magnetic effect of electric current.

## *Activity 3*

**Aim:** To study the magnetic effect of electric current flowing through a straight conductor.

**Materials Required:** A long straight wire, four cells of 1.5V each (torch cells), compass needle and, key and a bulb.




**Procedure:**

**Step1:** Connect the circuit as shown in the figure with one cell only.

**Step2:** Keep the wire along the Direction as shown by the compass needle, and directly above it.

**Step3:** Complete the circuit by pressing the key and observe the compass needle.

**Step4:** Reserve the direction of current in wire and observe the direction of compass needle.

**Step5:** Replace the single cell by two, three and four cells and observe the compass needle each time.

**Step6:** Place the compass needle a little away from the wire and observe the compass needle.

**Observations:**

1. On pressing the key, the compass needle shows deflection.
2. If current flows from North to South in the wire, the compass needle deflects towards east.
3. On reversing the direction of current south to north compass needle deflects towards west.
4. On adding more number of cells (2, 3, 4), deflection in the needle increases.
5. On moving the compass needle away from the wire, the deflection in the needle decreases.

**Conclusions:**

1. Deflection of compass needle shows that the current carrying conductor behaves like a magnet.
2. Deflection in the magnetic needle depends on the direction of current in the wire.
3. Strength of magnetic field is directly proportional to the magnitude current in the wire i.e., ( $B \propto I$ )
4. Magnitude of magnetic field is inversely proportional to the distance from the current carrying wire i.e., ( $B \propto \frac{1}{r}$ ).

**Rules for the determinant of direction of motion of magnetic compass needle:** The direction of motion of the north pole of the magnetic needle can be determine by following methods:

(i) Snow Rule (ii) Ampere's Swimming Rule

**1. Snow Rule:** According snow rule if the current flows through a conductor from South to North over a magnetic compass needle, then North pole of compass needle deflect towards the west and if the current flows from North to South, then North pole of compass needle deflect towards the east.

**2. Ampere's Swimming Rule:** Imagine a person swimming along the direction of the current of a current carrying conductor. The current entering through the foot and leavings from the head then north pole of compass needle will be deflected towards his left hand.

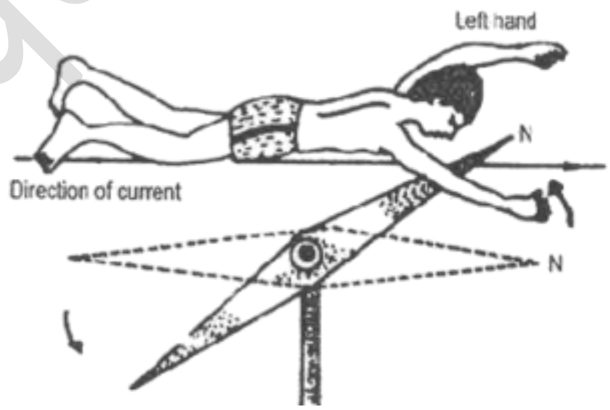



**Fig. Ampere's Swimming Rule**

# Magnetic Field Pattern due to a current carrying conductor

The magnetic field pattern produced by current carrying conductor depends on the shape of the conductor. There are three shapes of current carrying conductor. These are:

(1) Straight current carrying conductor.
(2) A circular loop current carrying conductor.
(3) A solenoid current carrying conductor.

## 1. Magnetic field pattern due to straight current carrying conductor

## *Activity 4*

**Aim:** To study the magnetic field pattern through a straight current carrying conductor.

**Materials Required:** A thick conducting wire, battery, rheostat, clamp stand, iron fillings, sprinkler magnetic compass needle, cardboard, key and ammeter.

**Procedure:**

**Step1:** Make a hole in the centre of the cardboard.

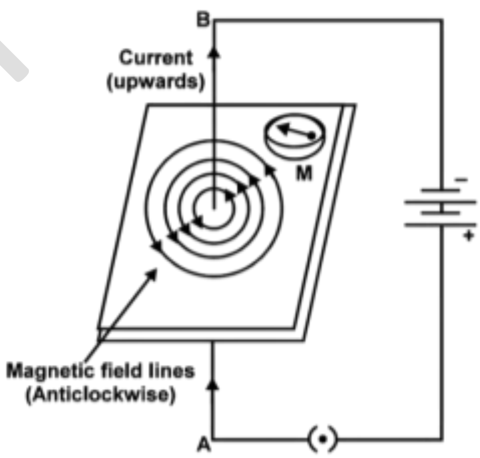
**Step2:** Attach the ends of the wire through a variable resistor, and an ammeter to the ends of a battery.

**Step3:** Spread the iron fillings uniformly on the cardboard and Press the key and observe the pattern formed by the iron fillings.

**Step4:** Keep the compass needle at various places (near or far) from the wire and observe the deflection.

**Step5:** Reverse the direction of current in the conductor and observe the iron fillings and the compass needle at various points.

**Step6:** Change the magnitude of current with the help of rheostat and observe the changes in the compass needle.




**Observations:**

1. The iron fillings form a definite circular pattern around the wire.
2. When the current is flowing downward direction the direction of circles are clockwise.
3. Needle shows more deflection near the wire than away from the wire.
4. When the current is flowing upward direction of the direction of circles are anti clockwise.

5. Increase in current shows closer patterns and more deflection in the needle.

**Conclusions:**

1. A current carrying conductor behaves as a magnet.
2. The pattern of magnetic field are concentric circles whose centre lies on the current carrying conductor.
3. The direction of magnetic field at a point depends on the direction of current flowing in the wire.
4. The strength of magnetic field is inversely proportional to the distance from the current 1 carrying conductor i.e., $B \propto \frac{1}{r}$
5. The strength of magnetic field around a current carrying conductor is directly proportional to current passing through the conductor i.e, $B \alpha I$.

**Direction of Magnetic field:** The direction of magnetic field at a point can be identity by Maxwell right hand thumb rule.

**Maxwell's Right Hand Thumb Rule:** According to Maxwell's right hand thumb rule imagine that you are holding the current - carrying wire in your right hand in such a way that your thumb in the direction of current, then the direction in which your fingers encircle i.e., the direction of magnetic field.

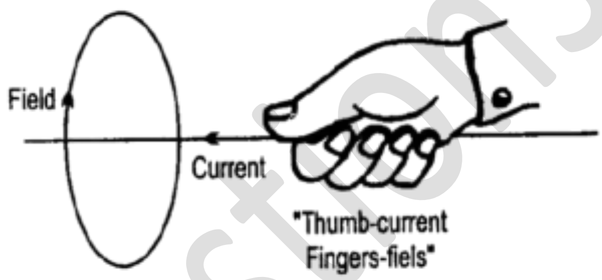



**Fig. Right hand rule to obtained the direction of the magnetic field around a wire carrying current.**

**Properties & strength of magnetic lines of forces around a straight conductor:**

1. The magnetic lines of forces are concentric circles around the current carrying conductor.
2. The plane of magnetic lines of force is a right angle to the plane of the current carrying conductor.
3. The direction of magnetic lines of force reverse with the reversal of the direction of current.
4. The strength of magnetic field is directly proportional to the current passing through the conductor. i.e., $B \alpha I$

5. The strength of magnetic field at a point around a current carrying conductor is inversely proportional to the distance of the point from the current carrying conductor i.e. $B \propto \frac{1}{r}$

**Knowledge Booster:**

- Magnitude of magnetic lines of forces (or magnetic field) at a point is given by

$$B = \frac{\mu_0 I}{2\pi r}$$

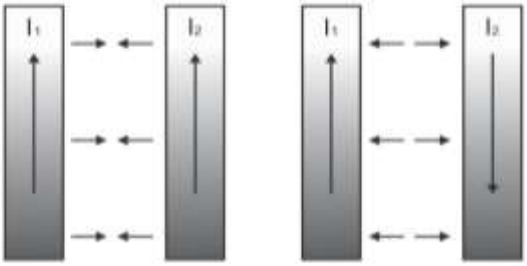
Where B = Magnitude of magnetic lines of forces, its unit is tesla (T)

$\mu_0$ = permeability of vaccum its value is $4\pi \times 10^{-7}$ Tm/A

I = Magnitude of current

r = Distance in metre where magnetic intensity is active.

- Two parallel conductor carrying current in the same direction attract each other.




- Two parallel conductors carrying current in the opposite directions repel each other.
- Moving beam of positively charged particles like protons and alpha (α) particles constitute electric current in the direction of their movement.
- Moving beam of neutrons does not constitute electric current. Hence, magnetic field is not set up around the beam of neutrons.
- Moving beam of negative changed particles constitute electric current in the opposite direction their movement.

## 2. Magnetic lines of forces through a circular coil

### *Activity 5*

**Aim:** To study the magnetic field pattern through a carrying current circular loop.

**Materials Required:** Circular coil of known thick cardboard, key, battery, rheostat, iron fillings, sprinkler.

**Procedure:**

**Step1:** Make a pair of holes in the cardboard and attach the wire as shown in the fig.

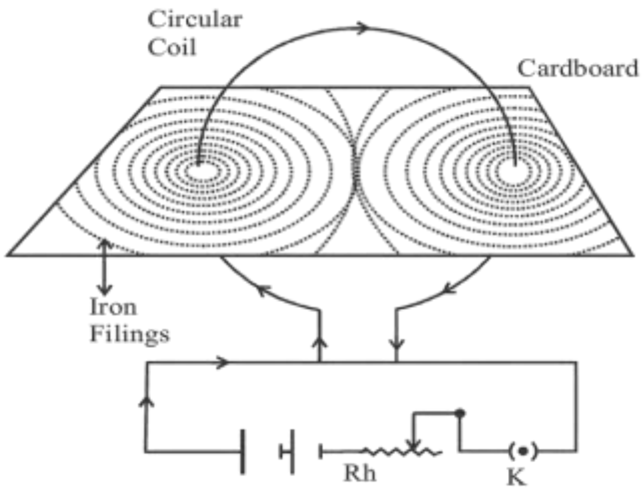
**Step2:** Connect the ends of the wire to a battery through a rheostat and a key.

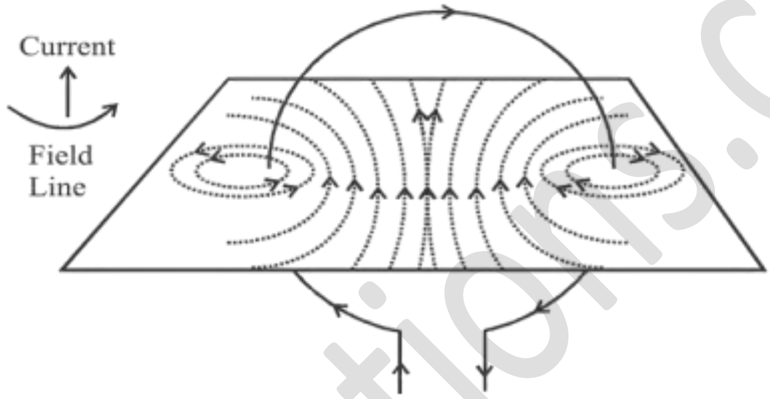
**Step3:** Spread the iron fillings uniformly on the cardboard.

**Step4:** Plug the key and observe pattern of the iron fillings.

**Step5:** Place the compass needle at various points and observe the direction of magnetic field at that point.

**Step6:** Reverse the direction of current and observe the direction of compass needle.




**Observations:**

1. The pattern formed by the iron filling is Circular near the wire.
2. Straight and parallel near the centre of the coil.
3. Pattern becomes denser as we move towards the centre of the coil.
4. Field lines are perpendicular to the plane of the coil.
5. Reversing the current shows opposite deflection of the magnetic needle.

**Conclusions:**

1. The pattern of magnetic field are concentric circles near of the arm of the coil.
2. The magnetic field increases as we move towards the centre of the coil.
3. The magnetic field at the centre of the coil become uniform parallel and perpendicular to the plane.

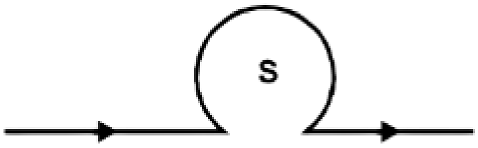
**Properties & strength of Magnetic lines of forces through a circular coil:**

(1) The magnetic field lines are concentric circles near the coil.
(2) Near the centre of the coil, the field lines are straight and parallel.
(3) The direction of the magnetic field is perpendicular to the plane of the coil.
(4) The strength of magnetic field is maximum at the centre of the coil.
(5) The strength of magnetic field at the centre of the coil is directly proportional to the current passing through a circular wire i.e. $B \propto I$
(6) The strength of magnetic field at the centre of the coil is inversely proportional to the radius of the circular loop i.e. $B \propto \frac{1}{r}$

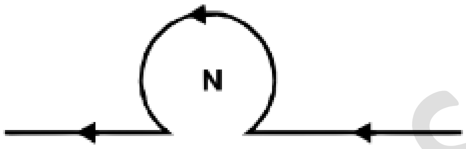
**Polarity of Circular Loop:** A current carrying circular loop behaves like a thin disc magnet whose one face is a north pole and other face is a south pole. The direction of north pole and south pole can be determined by clock face rule.

**Clock Face Rule:** According clock face rule, look at one face of a circular loop.

(i) If the current flows in the clock wise direction, then that face of loop will be a South Pole.



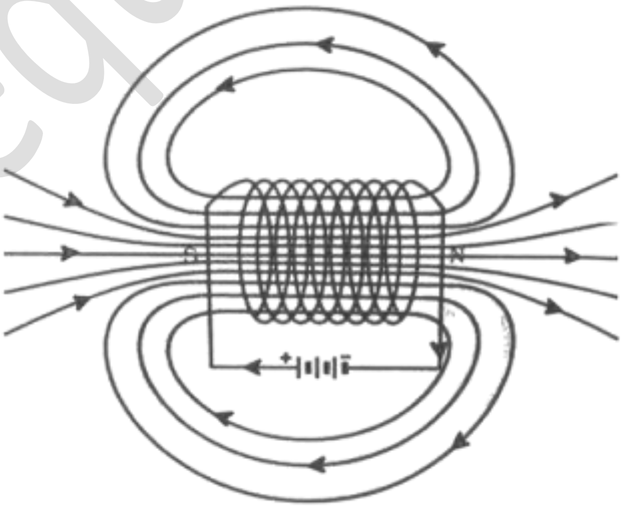

(ii) If the current flows in the anticlockwise direction, then that face of circular loop will be a North Pole.




**Units of Magnetic field:** The S.I. unit of magnetic field is Tesla (T) or weber/$m^2$ or $NsC^{-1}m^{-1}$

### 3. Magnetic Field pattern due to Solenoid

<u>The solenoid is a long coil consisting of large number of close turns of insulated copper wire.</u> When an electric current flows through a solenoid, a magnetic field is set up around the solenoid just like a bar magnet. The magnetic field due to a solenoid is shown in below fig.,




**Direction of Magnetic field:** Current carrying solenoid behaves like a bar magnet so, one end of the solenoid acts as South pole and the other end acts as North pole. The end of a solenoid through which electric current is flowing in clock wise direction, behaves as South Pole, if the current is flowing in anti-clockwise direction, it behaves as a North Pole.

**Properties of Magnetic field (or field lines) due to solenoid:**

(i) Magnetic field inside a solenoid is uniform and strong.
(ii) Magnetic field inside a solenoid decreases as we move towards the ends of the solenoid.
(iii) Magnetic field outside the solenoid is non uniform and weak.
(iv) Magnetic field inside the solenoid are from South to North pole and outside the solenoid, are from North to South pole.

**Strength of Magnetic field due to solenoid:** The strength of magnetic field produced by solenoid depends upon the following factors: -

1. The strength of magnetic field directly proportional to the number of turns of the solenoid i.e. $B \propto N$
2. The strength of magnetic field produce by solenoid is directly proportional to the current passing through the solenoid i.e. $B \propto I$
3. The strength of magnetic field produced by solenoids depends upon the nature of the 'core material' used in making solenoid.

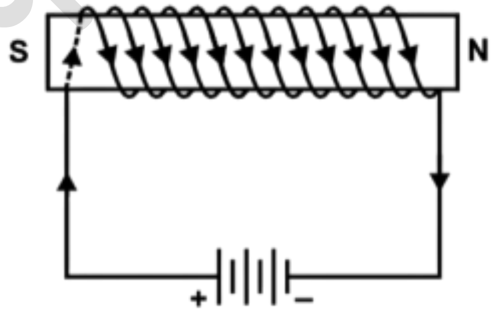
Note: Soft Iron core Produce strong magnetic field)

**Uses of Solenoid:** Solenoid is used for magnetising a piece of magnetic material by placing it within the solenoid.

Note: When the core of a solenoid is made of soft iron, it gets magnetised and behave as a strong magnet as long as current is flowing through the solenoid. When the core of hard steel, Alnico and nipermag placed inside the solenoid than it becomes permanent magnet.

# Electromagnets

An electro magnet consisting of long coil of Insulated copper wire wound on a soft iron core. An electromagnet works on the principle of magnetic effect of electric current. When electric current is passed through a solenoid, a magnetic field is setup around the solenoid. Due to presence of soft ion core placed inside solenoid, the strength of magnetic field becomes very large this is because, the iron core is also magnetised by induction.




Electromagnetic

Note: The core of electromagnet must be soft, iron. This is because soft iron loses all its magnetism when switched off.

**Strength of Electromagnet:** The strength electromagnet depends upon the following factors:

1. The strength of electromagnet is directly proportional to the current flowing through the solenoid i.e., $B \propto I$

2. The strength of electromagnet is directly proportional to the number of turns in the coil i.e., $B \propto N$
3. Strength of electro magnet is inversely proportional to air gap between poles. The strength of electromagnet depends upon the nature of core material.

Note: In horse shoe type magnet, the air gap is less as compared to Bar magnet. So the strength of horse shoe type magnet is higher than the bar magnet.

**Uses of Electromagnet**

1. In electrical appliances like electric bell, electric fan, relays, etc.
2. In electric motors and generators, a fairly strong electromagnet is used.
3. In separating iron from a mechanical mixture containing iron and other non-magnetic substances.
4. To break a large piece of rock into smaller pieces by lifting a large ball of iron to a height and then releasing it.

**Magnetism in Human beings and Animals:**

Extremely weak electric current is produced in the human body by the movement of charged particles called ions. These are called ionic currents. When the weak ionic currents flow along the nerve cells, they produce magnetic field in our body. The magnetism produced in the human body is very, very weak as compared to the earth's magnetism. The two main organs of the human body where the magnetic field is produced quite significantly are the heart and brain. The magnetism produced inside the human body forms the basis of a technique called Magnetic Resonance Imaging (MRI) which is used to obtain images of the internal parts of our body.

Note: The magnetism in animals like aquatic bacteria, shrimps, dolphins and whales, etc. is due to the presence of little crystals of magnetic (lodestone) in their bodies.

**Permanent Magnet:** The piece of a material which retains its magnetism even after removing the magnetic field is known as permanent magnet. Hard steel, Alnico and nipermag are the examples of permanent magnet, permanent magnet can be formed by placing magnetic material inside a strong solenoid.

**Formation of permanent magnet:** Hard steel is cobalt steel of tungsten steel or carbon steel. Alnico is an alloy of aluminium, Nickle, cobalt and iron (Al + Ni + CO + Fe) and Nipermag is an alloy of aluminium, Iron, Nickle and titatinum (Al + Fe + Ni + te).

**Characteristics of permanent magnet:**

(i) The polarity of permanent magnet cannot be changed.
(ii) The strength of magnetic field of a permanent magnet cannot be changed.
(iii) It cannot be demagnetise easily it can be demagnetise either by heating or throwing it again and again on the hard surface.

**Uses of Permanent Magnet:**

(i) It is used in ammeter voltmeter, galvanometer and speedometer etc
(ii) It is used in electrical devices such as loudspeakers, microphone and electric clock etc.

**Differences between a Bar magnet (permanent) & electromagnet**

| Bar magnet | Electromagnet |
|---|---|
| 1. The bar magnet is a permanent magnet. | 1. An electromagnet is a temporary magnet. |

| | |
|---|---|
| 2. A bar magnet produces a comparatively weak force of force of attraction or repulsion.<br>3. The strength of a bar magnet cannot be changed.<br>4. The polarity of a bar magnet is fixed and cannot be changed. | 2. An electromagnet can produce very strong force of attraction or attraction or repulsion.<br>3. The strength of an electromagnet can be changed by changing the number of turns and current.<br>4. The polarity of an electromagnet can be changed by changing the direction of current. |

# Force on current carrying conductor placed in Magnetic Field

When a current carrying conductor is placed in a magnetic field, a mechanical force is exerted on the conductor which makes it move. The direction of motion of the conductor or force applied on the conductor can be identify by using Fleming's left hand rule. **Fleming's Left Hand Rule:** According to Fleming's Left Hand Rule hold the fore finger, the central finger and thumb of your left hand at right angles to each other. The forefinger points in the direction of magnetic field, the central finger points in the direction of current then thumb points along the direction force acting on the conductor Fleming's left hand rule is also called motor rule.

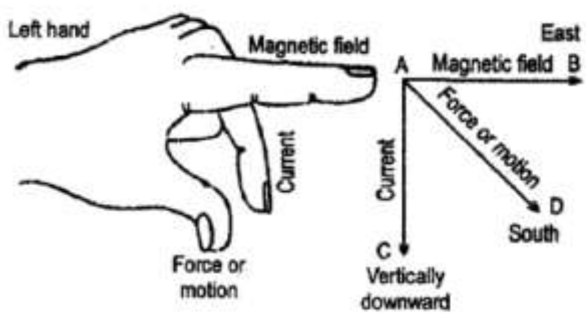



**Fig. Fleming's left hand rule**

## *Activity 6*

**Aim:** To study the relationship between direction of electric current, magnetic field and force acting on the conductor.

**Material Required:** A stand, horse shoe magnet, battery, key, connecting long wires, aluminium rod.

**Procedure:**

**Step1:** Suspend the aluminium rod between the two poles of the horse shoe magnet as shown in the fig.

**Step2:** Plug the key and observe the motion of the rod.

**Step3:** Reverse the direction of current and observe the motion of the rod.

**Step4:** Reverse the direction of magnetic field and observe the motion of the rod.

**Observations:**

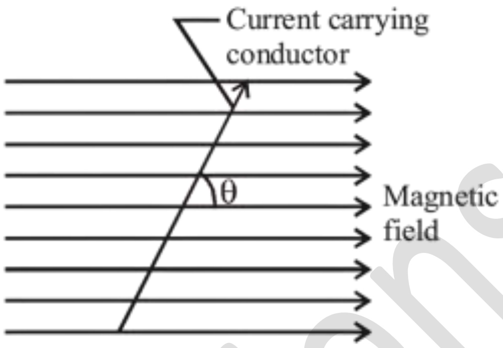
1. On plugging the key, the rod moves inside the magnet.

2. On reversing the direction of current, the rod moves outside the magnet.
3. On reversing the direction of magnetic field, the rod moves outside the magnet.

**Conclusions:**

1. A current carrying conductor experiences a force when placed in a magnetic field.
2. Direction of the force exerted on the conductor depends upon the direction of the current and the direction of magnetic field acting on it.

**Factors on which the force applied on the conductor depends:** The force experienced by a conductor in the magnetic field is depends upon the following factors:




Magnitude of force applied on conductor in the magnetic field is given by $F = BIL\sin\theta$. Where θ angle between magnetic field and current carrying conductor.

1. Force applied on the conductor is directly proportional to the strength of the magnetic field i.e., **F α B**
2. Force applied on the conductor is directly proportional to the current passing through the conductor i.e., **F α I**
3. Force applied on the conductor is directly proportional to length of the conductor which is in contact with the magnetic field i.e., **F α l**

Note: A conductor experiences maximum force when conductor is placed perpendicular to the magnetic field and a conductor experiences minimum force (zero) when conductor is placed parallel to the magnetic field.

**Knowledge Booster:**

- When a charged particle enters the magnetic field at right angle, then the charged particle starts moving in a circular path with a constant speed in the magnetic field.
- The velocity and momentum of the charged particle moving in a circular path change continuously.
- When the high energy charged particles coming out from the sun enter the earth's magnetic field they experience a force and get trapped near the earth's magnetic equator. These regions are called "**Van Allen Radiation Belts**". After the name of American physicist, James Van Allen who discovered them in 1958 with the help of early satellite.

# Electric Motor

Electric motor is a device which convert electrical energy into mechanical energy.

**Principal:** Electric motor works on the principal of magnetic effect of electric current. When a current carrying coil placed in a strong magnetic field, it experienced a force due to which rectangular coil starts rotating in the magnetic field. The direction of rotation of rectangular coil can be identified by Fleming's LHS.

**Construction:** An electric motor consists of a rectangular coil ABCD of insulated Copper wire, bound on a soft iron core called armature. The two ends of the coil are welded permanently to the two half rings of X and Y of the commutator. There are two Brushes P and Q press lightly against the two half rings of the commutator.

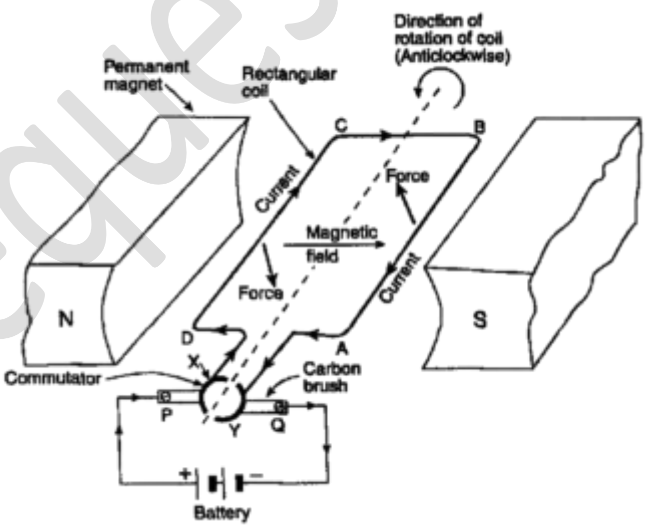



**Fig. Electric Motor**

**Working:** Suppose initially the coil ABCD is in the horizontal position, When current passes through the side AB of the coil from B to A then AB part of the coil experience a upward force. (According Fleming's Left Hand Rule) and when current passes through the side CD of the coil from D to C, then CD part of the coil experience a downward force (According Fleming's Left Hand Rule). These two equal, opposite and parallel forces acting on the two sides of the coil due to this coil starts rotating in the anticlockwise direction.

After half revolution the arms of the coil ABCD interchanged their position. Now current passes through the side AB of the coil from A to B due to which AB part experience a downward force (according Fleming's LHR) and current passes through the side CD of the coil from C to D due to which CD parts of the coil experience a upward force (according Fleming's LHR). This process is repeated again and again so coil continuous to rotate as long as current is passing.

**Function of Commutator:** Commutator is a device which reverse the direction of current flowing through the coil.

**Function of Brushes:** The function of Carbon Brushes is to make contact with the rotating rings of the commutator.

# Electromagnetic Induction

We know that electric current can be produce magnetism. The reverse of this is also true. That is magnetism can be produce an electric current. The production of electric current with the help of magnet is called electromagnetic induction. The phenomenon of electromagnetic induction was discovered by a British scientist Michale Faraday and an American Scientist Joseph Henry independently in 1831.

**Definition:** The phenomena due to which an electric current is produced in a coil or a conductor by relative motion between Magnetic Field and coil or conductor is called Electro Magnetic Induction. The direction of Induced current is determined by fleming's right hand rule. The electric current can be produced in a coil or conductor by following methods:

(i) By using a magnet
(ii) Without using a magnet

## *Activity 7*

**Aim:** To study the electromagnetic induction by using a magnet.

**Materials Required:** A coil of few turns, a sensitive galvanometer, and a magnet.

**Procedure:**

**Step1:** Observe the galvanometer when North Pole of the magnet is moved towards the coil.

**Step2:** Observe the galvanometer when North Pole of the magnet is moved away from the coil.

**Step3:** Observe the galvanometer when South Pole of the magnet is moved towards of the coil.

**Step4:** Keep the South pole stationary near the coil and observe the galvanometer.

**Step5:** Bring the North pole faster 1 towards the coil.

**Step6:** Move the North pole faster away from the coil.

**Step7:** Keep the magnet stationary and move the coil towards it.

**Observations:**

1. Galvanometer shows deflection towards right.
2. Galvanometer shows deflection towards left.

3. Galvanometer shows deflection towards left.
4. Galvanometer shows no deflection.
5. Galvanometer shows more deflection to right than in observation 1.
6. Galvanometer shows more deflection to left than in observation 2.
7. Galvanometer shows deflection towards right.

**Conclusions:**

1. Current is induced in the coil only when there is a relative motion between the coil and the magnet.
2. Direction of deflection is reversed if the direction of relative motion between the coil and the magnet is reversed.
3. More current is induced if the relative motion is faster.
4. Induced Current does not depend on whether the magnet is moved or the coil is moved.

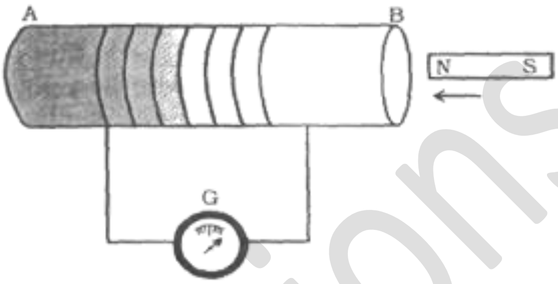


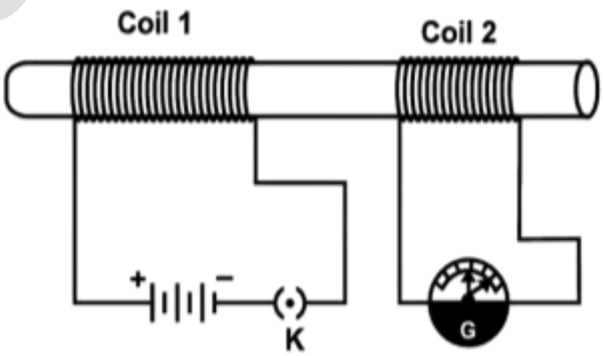

**Fig. Moving a magnet towards a coil sets up a current in the coil circuit, as indicated by deflection in the galvanometer.**

Note: A galvanometer is an instrument which can detect the presence of electric current in a circuit.

## *Activity 8*

**Aim:** To study the electromagnetic induction without using magnets.

**Materials Required:** Two copper wire coils of 50 and 100 turns, a non-conducting cylindrical roll, a sensitive galvanometer, a key, a battery, a rheostat.




**Procedure:**

**Step1:** Wound the two copper coils over the non-conducting cylindrical roll as shown in the figure.

**Step2:** Connect the coil-1, having larger number of turns, in series with a battery, a plug key and a rheostat.

**Step3:** Connect the second coil to the sensitive galvanometer.

**Step4:** Switch on the key and observe the galvanometer.

**Step5:** Switch off the key and observe the galvanometer.

**Step6:** Increase or decrease the current with the help of rheostat and observe the galvanometer.

**Step7:** Reverse the current and switch on the key and observe the galvanometer.

**Observations:**

1. Switching ON results in a momentary deflection in the galvanometer and then, galvanometer gets stationary at zero.
2. Switching OFF from ON results in a momentary deflection in the galvanometer and then gets stationary at zero.
3. Galvanometer shows a deflection as long as current is varied.
4. Reversing the current and then switching ON results in a momentary deflection in a direction opposite to that in step 1.

**Conclusions:**

1. The first coil produces a magnetic field which passes through the second coil.
2. Switching ON and OFF results in change in magnetic field from zero to zero respectively, hence it shows momentary deflection.
3. When the current is constant i.e., magnetic field is constant, there is no deflection in the galvanometer.
4. If the magnetic field changed through a coil or conductor then current is induced in the coil and conductor.

**Factors on which the induced current depends:**

From the above activities it is clear the value of induced current depends upon the following factors:

(1) The strength of induced current directly proportional to the no. of terms in the coil $I \propto n$.
(2) The strength of induced current directly proportional to strength of magnetic field $I \propto \vec{B}$.
(3) The strength induced current is directly proportional to the speed of relative motion between coil and magnet or magnetic field.
(4) The strength of induced current is directly proportional to changing the magnitude of the current.

**Cause of Induced current:** When conductor is moved in a magnetic field, the magnetic lines of force cut and induced current is produced in a conductor or in a coil.

**Fleming's Right Hand Rule:** According to Fleming's Right Hand Rule; hold the thumb, the forefinger and the central finger of your right hand at right angles. The forefinger points in the direction of magnetic field, thumb points in the direction of motion of conductor then central finger points in the direction of induce current in the conductor. Fleming's RHS also known as dynamo rule.

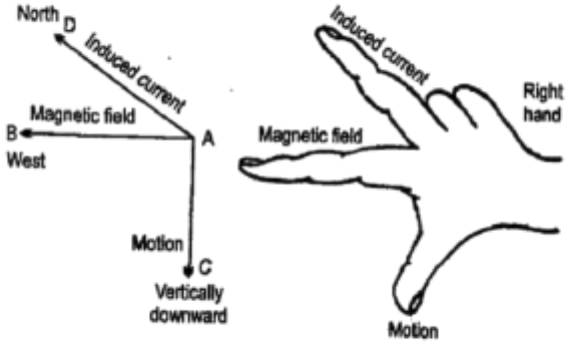



**Fig. Fleming's right hand rule.**

## Electric Generator

Electric Generator is a device which converts mechanical energy into electrical energy.

**Principle:** Electric Generator works on the principal of electromagnetic Induction. When a coil is moved in a magnetic field an induced current is produced in the coil. The direction of induced current can be identified by Fleming's Right Hand Rule.

### D.C. Generator

**Construction:** A DC generator consists of a rectangular coil ABCD of insulated copper wire. The two ends of the coil are connected to the two half rings. $R_1$ and $R_2$ of a commutator. There are two carbon brushes $B_1$ and $B_2$ press lightly against the two half rings. $R_1$ and $R_2$ when the coil is rotates the two half rings $R_1$ and $R_2$.

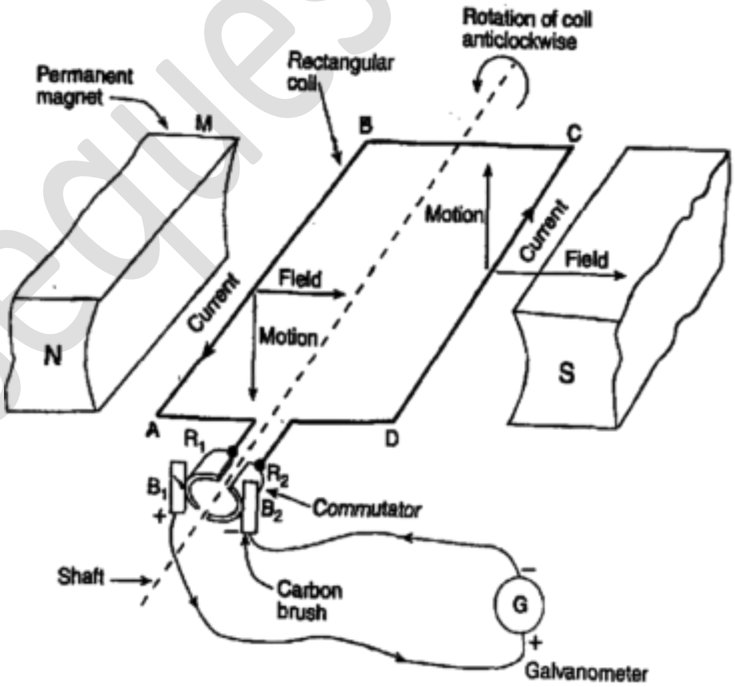



**Fig. D.C. Generator**

**Working:** Suppose initially the rectangular coil ABCD in the Horizontal position let it starts to rotates in anti-clockwise direction then side AB of the coil moves downward direction and side CD of the coil moves in upward direction. According Fleming's RHS induced current produced in the side AB of the coil from B to A and in the side CD of the coil from D to C finally induced current in the two sides of coil moved from Brash $B_1$ to $B_2$.

After half revolution the sides AB and DC of rectangular coil ABCD interchanged their positions along with half rings $R_1$ and $R_2$. Now side DC of the coil moves downward direction and side AB of the coil moves in upward direction. According Fleming's RHS induced current produced in the side CD of the coil from C to D and in the side AB from A to B. Finally induced current in the two sides of the coil moves from Brush $B_1$ to $B_2$ (or anticlockwise direction).

## A.C. Generator

**Construction:** A.C generator consists of a rectangular coil ABCD of insulated copper wire. The ends of coil are connected to two circular slip rings $R_1$ and $R_2$. There are two carbon brushes $B_1$ and $B_2$ press lightly against sliprings $R_1$ and $R_2$.

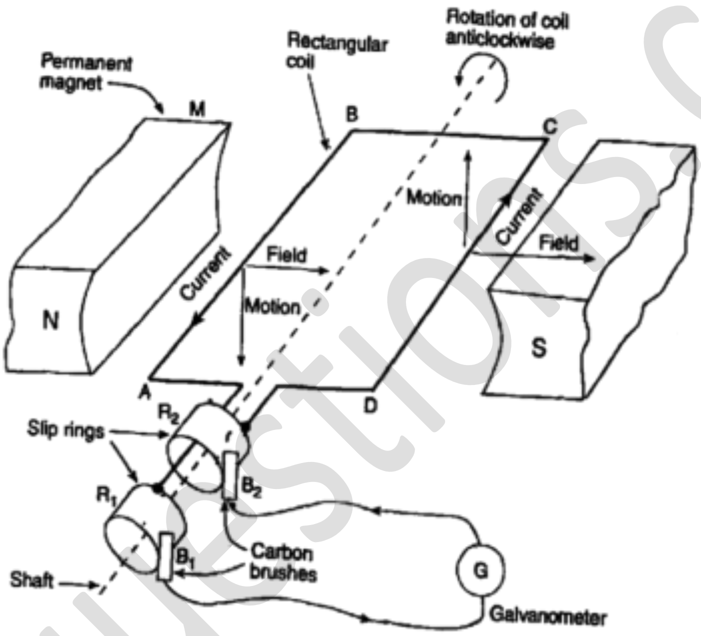



**Fig. A.C. Generator**

**Working:** Suppose initially the rectangular coil ABCD in the Horizontal position. Let it starts to rotate in anticlockwise direction, then side AB of the coil ABCD moves in downward direction and side CD of the coil moves in upward direction. According Fleming's RHS induced current in the side AB of the coil from B to A and in the side of the coil from D to C. Finally, the induced current in the coil moves from Brush $B_1$ to $B_2$.

After half reduction the side of rectangular coil ABCD interchanged their positions along with sliprings $R_1$ and $R_2$. Now side CD of the coil moves in the downward direction and the side AB of the coil moves in the upward direction. According Fleming's RHS induced current in the side CD from C to D and in the side AB from A to B. Finally induced current in the two sides of the coil moves from Brush $B_2$ to $B_1$.

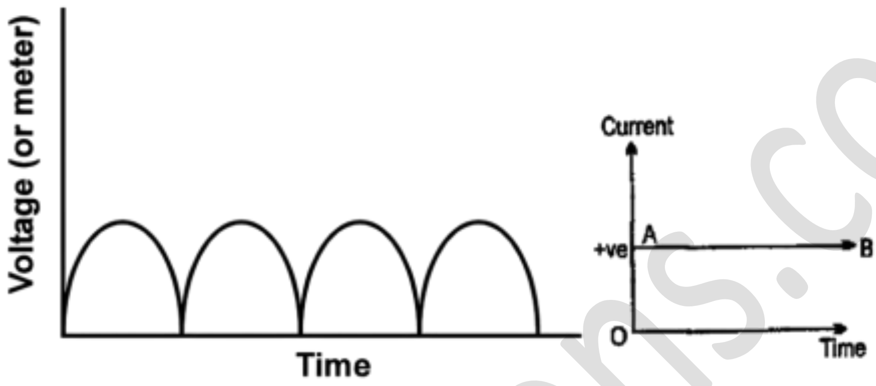
## Difference Between Motor and Generator

| Motor | Generator |
|---|---|
| 1. Electric motor converts electrical Energy into mechanical energy | 1. Generator converts mechanical energy to electrical energy. |

| | |
|---|---|
| 2. Electric motor works on principal of Magnetic effect of electric current. | 2. Generator works on principal of electromagnetic induction. |

# Direct Current and Alternating Current

**Direct Current:** If the current flows always in the same direction, it is called a direct current. The current-time graph or voltage-time for direct current is shown in below fig.,




**Sources of Direct Current:** The sources of direct current all given below:

(i) Batteries (ii) Dry cell (iii) Solar cells

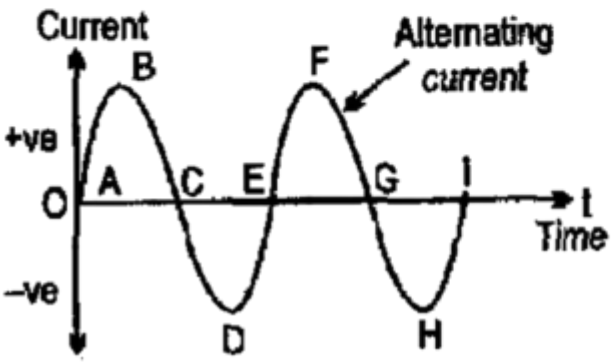
**Uses of Direct Current:**

(i) It is use to Charging the batteries.
(ii) It is used to production of metals like aluminium, sodium by electrolysis reduction.
(iii) It is used in electro chemical process.
(iv) It is used as the source of power supply in all electronic devices.
(v) It is used in electroplating.

**Disadvantages of Direct Current**

(i) When DC is transmitted over a long distance, a large amount of power is lost.
(ii) Direct current must be generated at the voltage required at the consumer label.

**Alternating Current:** If the direction of current changes after equal intervals of time, it is called alternating current. The current – time or voltage time graph for alternating current is shown in below fig.,




Note: Electricity supplied to our homes and industry is alternating current with frequency 50 Hz, i.e., it changes its polarity 100 times in one second.

**Sources of Alternating Current (A.C.)**

(i) Hydro power station.
(ii) Thermal power station.
(iii) Nuclear power station.
(iv) Wind power station.
(v) Geothermal power station

**Uses of Alternating Current (A.C.)**

(i) All electric motor uses in home and industries.
(ii) For lighting in homes and industries.
(iii) For operation of industrial devices.
(iv) To operate electric trains.

**Advantages of A.C. over D.C.**

(i) Generation cost of AC is much less than that of DC.
(ii) AC can be easily converted into DC by using rectifier.
(iii) AC can be transmitted over long distances without much loss of energy.
(iv) AC devices are highly efficient, more durable, less expensive and are simple in their functions.
(v) With the help of temperature AC at any desired voltage can be obtained.

**Disadvantages of A.C. over D.C.**

(i) AC cannot be used for electrolysis process.
(ii) AC is more dangerous than DC.
(iii) AC gives a serious shock to a person as compared to the DC.
(iv) D.C. electrical appliances cannot run on AC.
(v) At higher voltage of AC, more safety devices are required.

# Domestic Electric Circuit

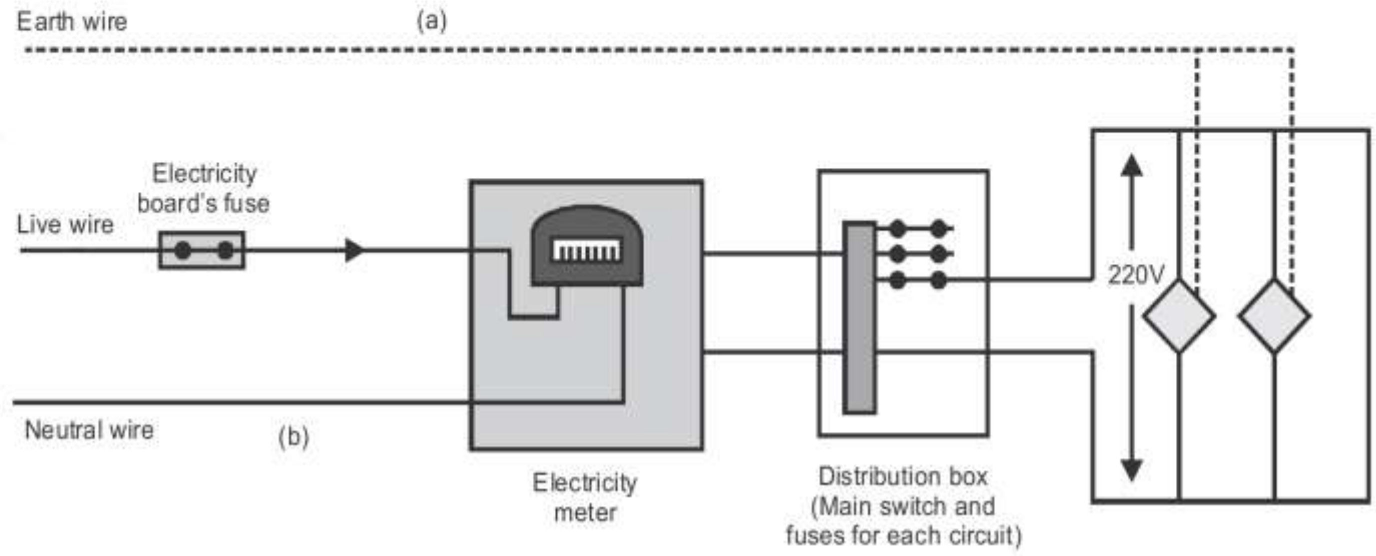



**Fig. A schematic diagram of one of the common domestic circuits.**

**Important points about domestic current**

1. There are two separate circuit in a house, Lightening circuit with 5 A fuse and power circuit with 15 A fuse.
2. Each distribution is provided with separate fuse (If fault occurs in one circuit, other circuit remain unaffected).
3. All the electrical appliances are connected in parallel across the live wire and neutral wire.
4. All the electrical appliances are provided with separate switches. All the switches are put in the live wire.
5. To avoid the risk of electric shock, the metal body of electric appliances is connected with the earth wire.
6. The connecting cables of an electric appliance containing three copper wire of three different colours.
    a. For live wire - Red or Brown
    b. For neutral wire - Black or Blue
    c. For Earth wire - Green or Yellow
7. In India live wire is maintained at 220 V, while the neutral wire is at zero volt.

**Earthing:** The connecting of the metallic body of an electrical device to a copper plate buried deep in the earth is called earthing.

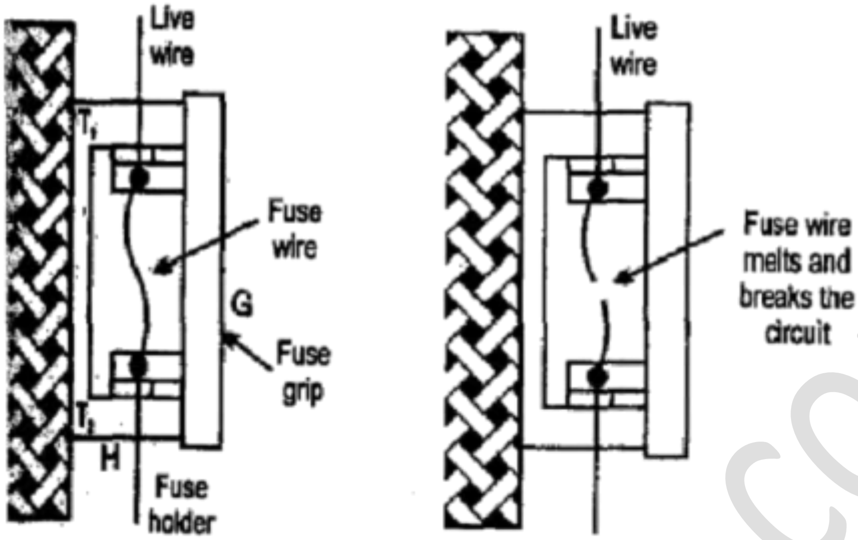
**Function of Earth wire:** There are two functions of Earth wire. These are

(i) Earth wire Provide low resistance path to the leakage of current.
(ii) Earth wire keeps the zero potential of metallic body of an electric appliance.

**Necessity of Earthing:** Any leakage of current in an electrical appliances to their metallic body is immediately transferred to the earth through the earth wire and user get protected from dangerous electric shock.

**Electric Fuse:** Electric Fuse is a safety device having a short length of thin wire made up of a tin lead alloy having low melting point, which melts and breaks the circuit if the current exceeds a safe value.

Note: A fuse wire connected in series in the electric circuit. An electric Fuse works on the principle of heating effect of electric current.




**Short Circuiting:** A sudden flow of very large amount of current due to direct contact of live wire and neutral wire is called short circuiting. When live wire and neutral wire touch each other due to some reason, the resistance of the circuit becomes very small due to this large amount of current starts flows through the wires and heat the wires, to a very high temperature, and fire may occur.

**Over Loading:** When an electric appliance draws more current than its rated value is called over loading. This happens if too many electrical appliances of high power rating are switched on at the same time or too many electrical appliances and connected to a multiple plug, they draw an extremely large amount current from the circuit. Due to this, the copper wire gets heated to a very high temperature and a fire may occur.

**Dangers of Electricity:**

1. If a person touches a live wire, he gets a severe electric shock. In some cases, electric shock can even kill a person.
2. Short-circuiting or overloading can cause electric fire in a building.
3. The defects in the house hold wiring can cause sparking and lead to fire.

**Precautions:**

1. If a person touches the live wire, the main switch should be turned off immediately.
2. The person who touches the live wire should be provided an Insulated Support.
3. All the power electrical appliances should be earthed.

**Knowledge Booster:**

A Freely Suspended magnet always points in the north-south direction even in the absence. of any other magnet. This suggests that the earth itself behaves as a magnet. The shape of the earth's magnetic field resembles that of a bar magnet of length about $\frac{1}{5}$ of its diameter. The axis of earth's s magnet is inclined at an angle of about 15° with the geographical axis.