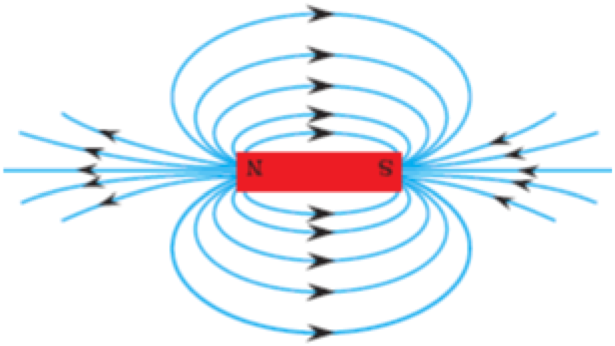
## MAGNETIC EFFECTS OF ELECTRIC CURRENT

**Magnetic effects of electric current deals with the magnetic effects produced by a current carrying wire.**

**Magnetic field:**
**The space around a magnet where its influence (attraction or repulsion) can be experienced is called the magnetic field of the magnet.**

**Magnetic field lines:**
**Magnetic field lines are imaginary lines around the magnet used to indicate the magnetic field in a given region.**

**Properties of magnetic field lines of a bar magnet**



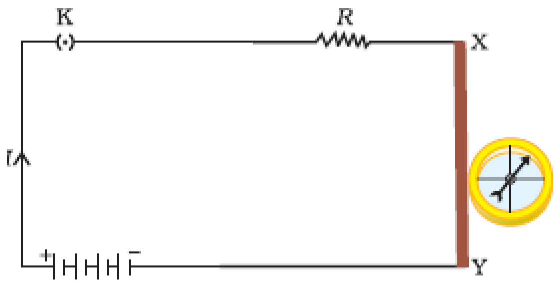

**1. Magnetic field lines are continuous closed curves directed from the north pole to the south pole of the magnet.**

**2. The tangent at any point on the magnetic field line gives the direction of the magnetic field at that point.**

**3. Magnetic field lines are closer together in the region where the magnetic field is strong.**

**4. Magnetic field lines do not intersect each other. It is because at the point of intersection, the compass needle will point towards two directions which is not possible.**

**Oersted's experiment**

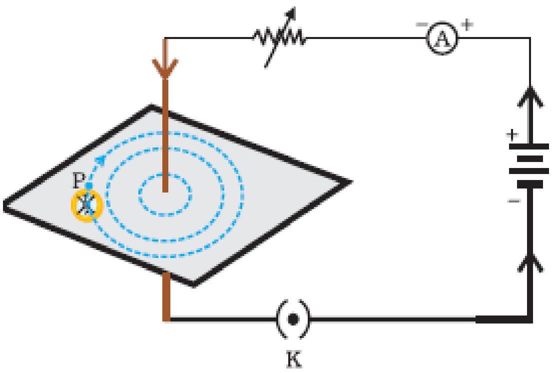



**1. Take a long straight copper wire XY, two or three cells and a plug key. Connect all of them in series as shown in the diagram.**
**2. Place the straight wire parallel to a compass needle.**
**3. Plug the key in the circuit.**
**4. Observe the direction of deflection of the north pole of the needle.**

5. If the current flows from north to south, the north pole of the compass needle would move towards the east.
6. Reverse the polarity of the cell connections in the circuit and this would result in the deflection in the opposite direction

<u>Conclusion</u>:
Oersted's experiment demonstrated that an electric current carrying wire produces a magnetic field.

**Magnetic Field due to current flowing through a Straight Conductor**




1. Take a battery , a rheostat, an ammeter , a plug key, and a long straight thick copper wire.
2. Insert the thick wire through the centre, normal to the plane of a rectangular cardboard.
3. Connect the copper wire vertically between the points X and Y.
4. Sprinkle some iron filings uniformly on the cardboard.
5. Close the key so that a current flows through the wire.
6. Gently tap the cardboard a few times. Observe the pattern of the iron filings.
7. The iron filings align themselves showing a pattern of concentric circles around the copper wire.

<u>Conclusion</u>:

1. The concentric circles represent the magnetic field lines.

2. The direction of magnetic field lines get reversed if the direction of current through the straight copper wire is reversed.

3. The magnitude of the magnetic field produced at a given point increases as the current through the wire increases.

<u>Factors affecting the magnetic field strength:</u>

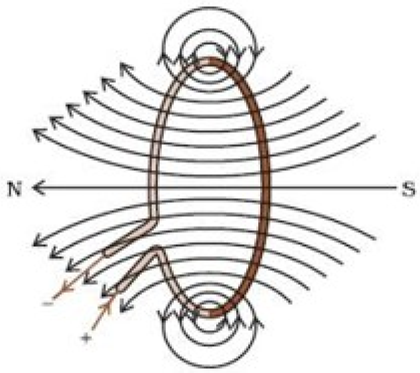
The magnetic field produced by a given conductor current in the decreases as the distance from it increases (the concentric circles representing the magnetic field around a current-carrying straight wire become larger and larger as we move away from it)

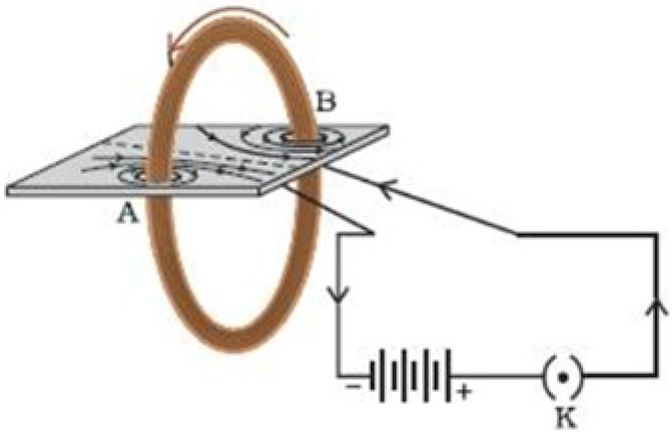
**Right-Hand Thumb Rule**

The direction of magnetic field associated with a current-carrying conductor is given by the right hand 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 your fingers will wrap around the conductor in the direction of the field lines of the magnetic field. This is known as the right-hand thumb rule.

## Magnetic Field due to a current through a Circular Loop (Activity)



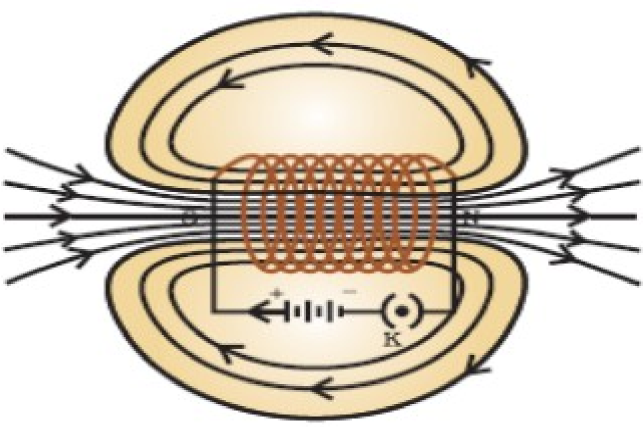

1. Take a rectangular cardboard having two holes.
2. Insert a circular coil having large number of turns through them, normal to the plane of the cardboard.
3. Connect the ends of the coil in series with a battery, a key and a rheostat.
4. Sprinkle iron filings uniformly on the cardboard.
5. Plug the key and tap the cardboard gently a few times.
6. Note the pattern of the iron filings that emerges on the cardboard.
7. By applying the right hand rule, every section of the wire contributes to the magnetic field lines in the same direction in the form of concentric circles.

8. Every point on the circular wire carrying current would give rise to the magnetic field appearing as straight lines at the centre of the loop.

Manetic field produced by a current carrying circular loop is

- Directly proportional to the strength of current flowing through it
- Directly proportional to the number of turns of the coil
- inversely proportional to the radius of the coil

## Magnetic field lines due to Current in a Solenoid



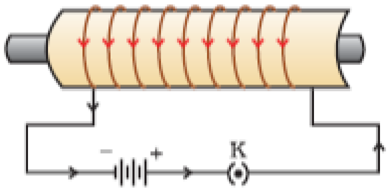
1. A coil of many circular turns of insulated copper wire wrapped closely in the shape of a helix is called a solenoid.

2. The pattern of the magnetic field lines around a current-carrying solenoid is similar to the pattern of the field lines around a bar magnet .

3.One end of the solenoid behaves as a magnetic north pole, while the other behaves as the south pole.

4.The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field is the same at all points inside the solenoid. That is, the field is uniform inside the solenoid.

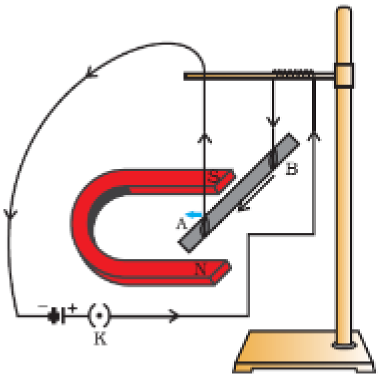
**How will you convert a solenoid into an electromagnet?**




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

**FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD (activity)**

The force acting on a current-carrying conductor due to a magnetic field can be demonstrated through the following activity




1. Take a small aluminium rod AB. Using two connecting wires suspend it horizontally from a stand.
2. Place a strong horse-shoe magnet in such a way that the rod lies between the two poles.
3. Connect the aluminium rod in series with a battery, a key and a rheostat.
4. Now pass a current through the aluminium rod from end B to end A. It is observed that the rod is displaced towards the left.
5. Reverse the direction of current flowing through the rod and observe the direction of its displacement. It is now displaced towards the right.

**Conclusion:**
**The displacement of the rod in the above activity suggests that a force is exerted on the current-carrying 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.**
**Experiments have shown that the magnitude of the force is the highest when the direction of current is at right angles to the direction of the magnetic field.**

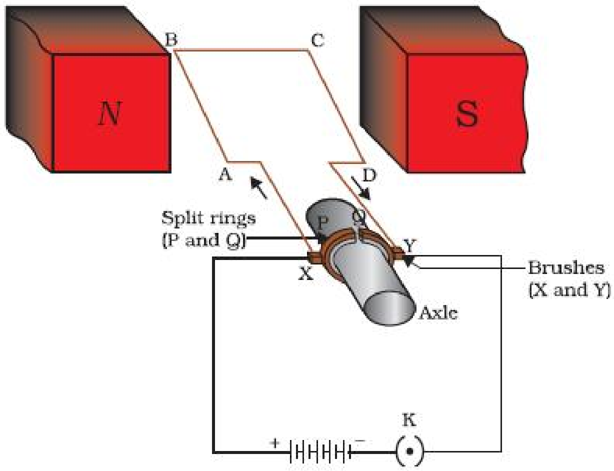
In such a condition we can use a simple rule to find the direction of the force on the conductor known as the Fleming's left-hand rule.

**Fleming's left-hand rule**

According to this rule, stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular to each other.
If the fore finger points in the direction of magnetic field and the middle finger in the direction of current, then the thumb will point in the direction of the force acting on the conductor.

## ELECTRIC MOTOR

**Principle:**
A current carrying conductor when placed in a magnetic field experiences a force
If the direction of the field and that of current are mutually perpendicular to each other , then the force acting on the conductor will be perpendicular to both and will be given by Fleming's left-hand rule. This is the basic principle of electric motor
An electric motor is a device that converts electrical energy to mechanical energy.




**Construction:**
**Armature:**
It consists of a rectangular coil ABCD of several turns of insulated copper wire wound on a soft iron core.
**Field magnets** The coil is placed between the two poles of a strong magnetic field .
**Split rings**:
The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides are insulated and attached to an axle.
**Brushes:**
The split rings P and Q touch two conducting stationary brushes X and Y.
**Working:**
1. During the first half rotation the current flows along the path ABCD and on applying Fleming's left hand rule for the direction of force on a current-carrying conductor in a magnetic field , 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, rotate in the anti-clockwise direction.
2. During the next half rotation the current in the coil gets reversed and flows along the path DCBA. Thus the arm AB of the coil is pushed up and the arm CD 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.

**Note:**

(a) The commercial motors use

- an electromagnet in place of permanent magnet
- large number of turns of the conducting wire in the current carrying coil and
- a soft iron core on which the coil is wound.

The soft iron core on which the coil is wound plus the coils is called an armature. This enhances the power of the motor.

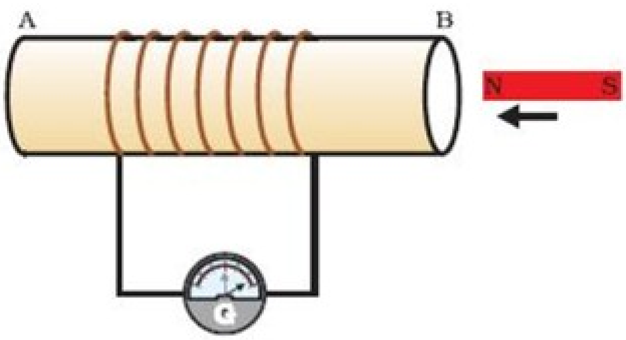
(b) A device that reverses the direction of flow of current through a circuit is called a commutator. In electric motors, the split ring acts as a commutator.

Applications:
Electric motor is used as an important component in electric fans, refrigerators,
mixers, washing machines, computers, MP3 players etc.

## ELECTRO MAGNETIC INDUCTION

The phenomenon of electromagnetic induction is the production of induced current in a coil placed in a region where the magnetic field changes with time.

### ACTIVITY 1:




1. Take a coil of wire AB having a large number of turns.
2. Connect the ends of the coil to a galvanometer.
3. Take a strong bar magnet and move its north pole towards the end B of the coil.
4. There is a momentary deflection in the needle of the galvanometer, say to the right.
5. This indicates the presence of a current in the coil AB. The deflection becomes zero the moment the motion of the magnet stops.
6. Now withdraw the north pole of the magnet away from the coil. Now the galvanometer is deflected toward the left, showing that the current is now set up in the direction opposite to the first.
7. When the south pole of the magnet moves towards the end B of the coil, the deflections in the galvanometer would just be opposite to the previous case.
8. Place the magnet stationary at a point near to the coil, keeping its north pole towards the end B of the coil. The galvanometer needle deflects toward the right when the coil is moved towards the north pole of the magnet.
9. Similarly the needle moves toward left when the coil is moved away from the magnet.
10. When the coil and the magnet are both stationary, there is no deflection in the galvanometer.

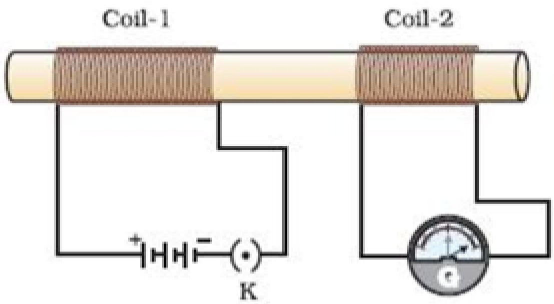
**CONCLUSION:** The motion of a magnet with respect to the coil produces an induced potential difference, which sets up an induced electric current in the circuit.
**Note:**
A galvanometer is an instrument that can detect the presence of current in a circuit. The pointer can deflect either to the left or to the right of the zero mark depending on the direction of current.

## Fleming's right hand rule

**The direction of the induced current is given by the 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.**

**Note**: The induced current is found to be the highest when the direction of motion of the coil is at right angles to the magnetic field.

## ACTIVITY :

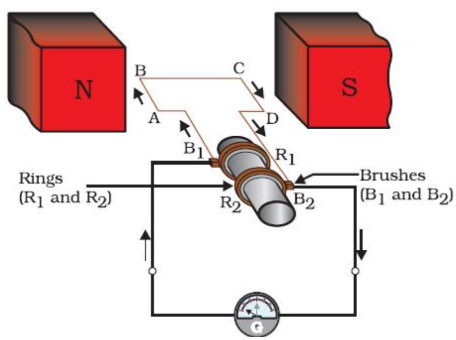



1. Take two different coils of copper wire having a large number of turns.
2. Connect the coil-1, having larger number of turns, in series with a battery and a plug key.
3. Also connect the other coil-2 with a galvanometer.
4. Plug in the key.
5. The needle of the galvanometer instantly deflects to one side and quickly returns to zero, indicating a momentary current in coil-2.
6. 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.
7. A potential difference is induced in the coil-2 whenever the electric current through the coil–1 is changing (starting or stopping).
(Coil-1 is called the primary coil and coil-2 is called the secondary coil)

**CONCLUSION**: As the current in the first coil changes, the magnetic field associated with it changes. Thus the magnetic field lines around the secondary coil also change.
Hence the change in magnetic field lines associated with the secondary coil is the cause of induced electric current in it

## ELECTRIC GENERATOR

**Principle:**
It is based on the phenomenon of electromagnetic induction.
**Construction:**



**Armature:**
**It consists of a rectangular coil ABCD consisting of several turns of insulated copper wire.**
**Field magnets:**
**The coil is placed between the two poles of a permanent magnet.**
**Rings:**
**The two ends of this coil are connected to the two rings R1 and R2.**
**Brushes:**
**The two conducting stationary brushes B1 and B2 are kept pressed separately on the rings R1 and R2.**
**The two rings R1 and R2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field.**

**Working:**
**1. The coil is rotated such that the arm AB moves up and the arm CD moves down in the magnetic field produced by the permanent magnet.**
**By applying Fleming's right-hand rule, the induced currents are set up in these arms along the directions AB and CD. Thus an induced current flows in the direction ABCD. This means that the current in the external circuit flows from B2 to B1.**
**2. After half a rotation, arm CD starts moving up and AB moves 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 B1 to B2.**
**Note:**

**1. After every half rotation the polarity of the current in the respective arms changes. Such a current, which changes direction after equal intervals of time, is called an alternating current (AC). This device is called an AC generator. To get a direct current DC, which does not change its direction with time, a split-ring type commutator must be used.**
**2.The difference between the direct and alternating currents is that the direct current always flows in one direction, whereas the alternating current reverses its direction periodically.**
**3. In India, the AC changes direction after every 1/100 second, that is, the frequency of AC is 50 Hz.**
**4. An important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.**