

MAGNETIC EFFECTS OF CURRENT

MAGNET:

A magnet is a substance that attracts pieces of iron, cobalt, nickel, etc and aligns itself in the north-south direction when suspended freely. The Greeks knew the phenomenon of magnetism, as early as around 800 BC. They discovered that certain stones, now called magnetite (Fe_3O_4), attract pieces of iron. The Chinese called it the Lodestone *i. e.* the leading stone. In 1269 Pierre de Maricourt found that magnet has two poles, called north and south poles: a north seeking called North Pole and a south seeking called South Pole. Subsequent experiments showed that every magnet, regardless of its shape, has two poles, which exhibit forces on each other in a manner analogous to electrical charges. That is, like poles repel each other and unlike poles attract each other.

In 1600 William Gilbert extended these experiments to a variety of materials. Using the fact that a compass needle orients in preferred directions, he suggested that the earth itself is a large permanent magnet. It was Oersted who gave the first evidence of the connection between electricity and magnetism. The cause of magnetism is the motion of charges.

All magnets can be classified into two types (i) Natural and (ii) Artificial or man made

The natural magnets are the one, which occur naturally in nature *e.g.* Magnetite ore (Fe_3O_4) is a natural magnet. It is also called lodestone. A lodestone occurs in all types of shapes and has a weak magnetic field strength.

An artificial magnet is one, which is made by man by magnetising small pieces of iron or nickel. The artificial magnets are usually made of an alloy called Alnico (aluminium, nickel, cobalt and iron) and Nipermag (iron, nickel, aluminium and titanium).

A Magnetic Needle: It is a small piece of magnet in the form of a needle. The arrow head of the needle is the north pole of the compass and the tail acts as the South Pole. The North Pole is usually coloured red. This needle is pivoted at the centre and enclosed by plastic or glass pieces on both sides. This needle is used to find the direction of earth's magnetic field and to test the polarity of another magnetic pole.

MAGNETIC FIELD:

The magnetic force is action at a distance force, which can be best understood by the lines of forces. According to Faraday a magnet modifies the space around itself in such a manner that if any other magnetic substance moves into this space it experiences a force. This is termed as the magnetic force. The region itself is termed as the magnetic field of the magnet. **The region around a magnet in which its magnetic force can be experienced by another magnetic substance is called magnetic field of the magnet.** A magnetic field around a magnet can be visualised by drawing magnetic field lines around the magnet. The SI unit of magnetic field is tesla (T).

1 tesla = 1 newton /ampere-metre

It has been found that tesla is a fairly large unit. The other smaller unit of magnetic field is gauss (G) which is related to tesla as 1 tesla = 10^4 gauss.

BAR MAGNET AND ITS PROPERTIES

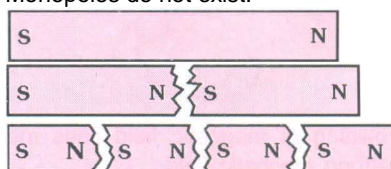
A magnet in the form of a rectangular bar or has a circular cross section. A bar magnet has two poles, North Pole and South Pole. These poles are situated a small distance inwards from the two faces. The distance between the two poles is called the magnetic length. The face-to-face distance is called geometric length. The magnetic length is $7/8$ of the geometric length. A bar magnet possesses the following properties.

1. **Directive property:** When a magnet is suspended freely, it always orients itself in the north-

south direction. If the bar magnet is free to rotate, one end points north. This end is called the North Pole or N-pole; the other end is the South Pole or S-pole. The north pole of a magnet is usually coloured red or a red dot is placed on its side. Actually the north and south poles of a magnet point towards the south and north magnetic poles of the earth and not towards the earth's geographic poles.

2. **Attractive property:** A magnet can attract small pieces of magnetic substances like iron, steel, cobalt, alnico etc. The attraction is a maximum at the two ends called the poles. It is minimum or zero at the centre of the magnet.
3. **Isolated poles do not exist:** If a magnet is cut into small pieces each piece by itself is a magnet. It follows that monopoles don't exist. If a magnet is cut parallel to its length then its pole strength becomes half. If the magnet is cut perpendicular to its length there is no change in its pole strength.
4. **Like poles repel each other and unlike poles attract each other:** When a south and a north pole are brought closer they attract each other, whereas when two north or two south poles are brought closer they repel each other.

Monopoles do not exist.



MAGNETIC FIELD LINES

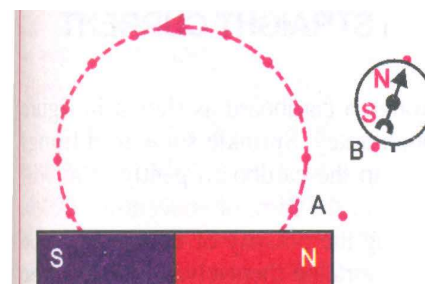
The concept of magnetic field lines was put forward by Michael Faraday in order to explain the interaction between the poles separated by some distance. A magnetic field line is a pictorial representation of the magnetic field around a magnet. It is a path which will be followed by a "hypothetical" north pole in the magnetic field of another magnet if it is allowed to move freely.

Magnetic field lines possess the following properties.

1. They travel from the north to the south pole of a magnet outside the magnet and from South to the North Pole inside the magnet.
2. They are continuous closed curves.
3. The tangent drawn at any point of the magnetic lines of force represents the direction of the magnetic field at that point.
4. Two magnetic field lines do not intersect each other. This is because if they do so then the magnetic field at that point will have two directions which is not possible.
5. They contract longitudinally and repel each other laterally.
6. The field lines of a uniform magnetic field are parallel to each other.
7. The relative closeness of the magnetic field lines represents the magnetic field strength. The more crowded the magnetic field lines the stronger is the field.

Plotting of a Magnetic Field of a Magnet

To trace the magnetic field lines, place the bar magnet NS on a sheet of paper and mark its boundary. Mark a point A near the North Pole of the given magnet. Place the compass needle so that one of its ends (south) lies exactly over point A as in Fig. Mark point B on the paper at the opposite (north) end of the compass needle. Move the compass needle so that the south end of the compass needle lies over B and mark point C at the north end of

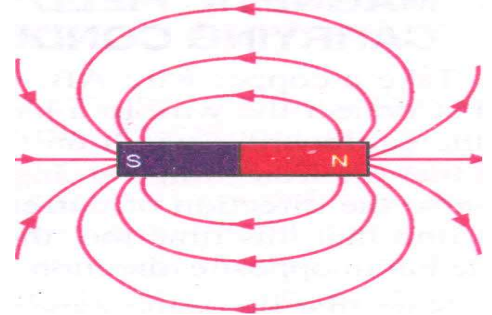


the needle and so on. Go on doing so till a point is reached near the south pole of the given magnet. Join all these points with a free hand curve so as to form a smooth dotted curve.

Mark an arrow head to show the direction of magnetic line of force; which will be North Pole to South Pole outside the magnet. This dotted curve marked with an arrow head represents a magnetic field line. Similarly starting from other points near the North Pole of the magnet, draw other magnetic lines of force.

Magnetic field lines plotted for a bar magnet are as shown in figure.

We can visualise the magnetic field lines around a bar magnet by sprinkling some iron filings near a bar magnet and tapping the sheet on which the magnet is placed. The iron filings will orient themselves as shown in figure. The magnetic field lines around a bar magnet are not uniform. The magnetic field within a bar magnet is uniform.



OERSTED'S DISCOVERY

In 1819, Oersted was able to show that an electric current flowing through a wire produces a magnetic field around it. Oersted's observation was the first that indicated a connection between electricity and magnetism.

Consider a wire connected to a battery in such a way that current flows as shown in figure. Place a compass directly over a horizontal wire. The needle points north when there is no current. When a current is passed towards the north, the needle deflects towards the east. When the current is passed towards the south, the needle deflections are reversed. Since a magnetic needle can be deflected only due to the presence of a magnetic field, therefore Oersted concluded that a magnetic field is produced around the current carrying wire.

Thus the phenomenon due to which a magnetic field is produced around a current carrying conductor is called electromagnetism or magnetic effect of current. The direction of the deflection of the needle can be determined by:

1. Ampere's swimming Rule: Imagine a man swimming along a wire in the direction of the current with his face towards the needle so that the current enters at his feet and leaves at his head. The north pole of the needle will be deflected towards his left.
2. SNOW Rule: *If the direction of the current flowing through the wire is from south (S) to north (N) and the wire is placed over the needle, the north pole of the needle is deflected towards the west.*

MAGNETIC FIELD DUE TO A STRAIGHT CURRENT CARRYING CONDUCTOR

Take a copper wire AB. Pass it through a cardboard as shown in figure. Connect the wire to a battery through a key. Sprinkle some iron filings on the cardboard. Switch on the key and tap the cardboard gently. You will find that the iron filings arrange themselves in the form of concentric circles. Reverse the direction of current by changing the polarity of the battery. You will find that this time too, the iron filings arrange themselves in concentric circles but in opposite direction. Note that the same experiment can be carried out by plotting magnetic field lines using a compass.

Hence, the magnetic field lines of force around a straight conductor carrying electric current are concentric circles with the conductor at the centre. The direction of magnetic field changes when the direction of current is reversed.

It is found that the magnitude of magnetic field around a straight wire carrying current is

- (i) directly proportional to the strength of current passed through the wire.

i.e., $B \propto I$

- (ii) Inversely proportional to the distance of the point of observation from the straight current carrying wire

i.e. $B \propto 1/d$

Thus, $B \propto I/d$

$$B = \mu_0 I/d$$

Where μ_0 is called magnetic permeability of free space and $\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$

It is worth noting that as we move away from the straight current carrying conductor the distance between the magnetic field lines increases continuously. This shows that as we move away the magnetic field decreases continuously.

Right Hand Thumb Rule or Palm Rule The right hand thumb rule or palm rule gives the direction of magnetic field due to a straight current carrying conductor. According to the rule, "Grasp the conductor in the right hand with the thumb pointing in the direction of current, and then the direction in which the fingers curl gives the direction of the magnetic field."

Maxwell's Cork Screw Rule or Right Hand Screw Rule :

Imagine a right handed screw to be rotated in the direction of current, and then the direction of rotation gives the direction of magnetic field lines.

MAGNETIC FIELD DUE TO A CURRENT CARRYING CIRCULAR COIL

Let us bend the wire into a circular shape. Pass the coil through a cardboard as shown in figure. Connect the free ends of the coil to a battery and a key. Sprinkle some iron filings on the cardboard. Put on the key you will find that the iron filings arrange themselves in the form of concentric circles as shown in the figure. The magnetic lines of forces near each segment of wire are circular and form concentric circles, whereas the lines of force near the centre of the coil are almost straight lines.

Note that at the centre of the coil, the magnetic field is uniform and perpendicular to the plane of the coil. The same experiment can be performed by using a magnetic compass and plotting the lines of forces.

On a careful study of figure, we find that at every point near the wire the magnetic field lines are concentric circles with ever increasing radii as we move away from the wire. When we reach the centre of the circular loop, the arcs of these big circles start appearing as straight lines. It is to be noted that every point on the circular current carrying wire gives rise to the magnetic field appearing as straight lines at the centre. By applying the right hand thumb rule, we find that every section of the wire contributes to the magnetic field lines in the same direction within the loop. Thus, if there is a circular coil having n turns, the magnetic field produced by this current-carrying circular coil will be n times as large as that produced by a circular loop of a single turn of wire. This is because the current in each circular turn of coil flows in the same direction and magnetic field produced by each turn of circular coil then just adds up.

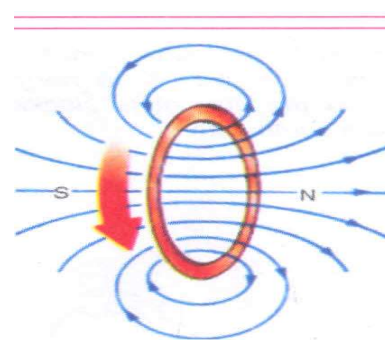
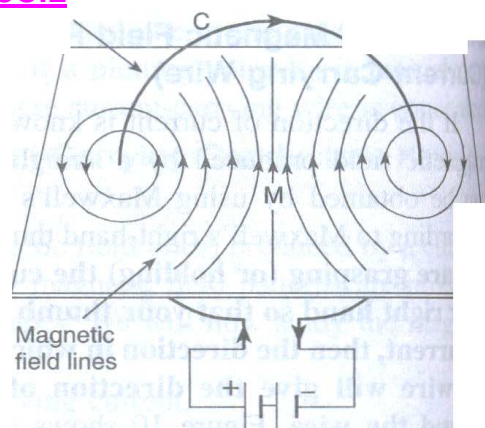
The magnitude of magnetic field at the centre of a circular current carrying wire is

- (i) directly proportional to the strength of current passed through the wire.

i.e., $B \propto I$

- (ii) Inversely proportional to the radius of they coil

i.e., $B \propto 1/r$



- (iii) directly proportional to the number of turns of the wire
i.e., $B \propto n$.

Thus, $B \propto nl / r$

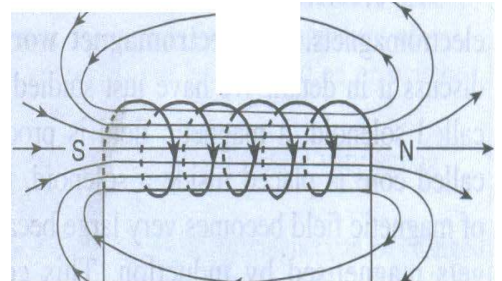
The polarity of the current carrying coil is found by:

- i. **Right Hand Palm Rule:** Curl the palm of your right hand around a circular wire with the fingers pointing in the direction of current, then the right hand thumb gives the direction of the magnetic field.
- ii. **Clock Rule.** The face or end of the coil behaves as a north pole when current in a coil is anticlockwise and when the current is clockwise the end behaves as a south pole.

MAGNETIC FIELD DUE TO A CURRENT CARRYING SOLENOID

A solenoid is a cylindrical coil of many tightly wound turns of insulated wires with generally diameter of the coil smaller than its length. When a current is passed through a solenoid, a magnetic field is developed in it. As the electric current in each circular coil flows in the same direction, the magnetic field of the loop makes one end of a solenoid act as a North Pole and the other end as the South Pole.

The magnetic field around a current carrying solenoid is similar to the magnetic field produced by a bar magnet as shown in figure. The magnetic field lines inside the solenoid are in the form of *parallel straight lines*. This indicates that the strength of magnetic field is the *same* at all the points inside the solenoid. Thus, the magnetic field is *uniform* inside a current-carrying solenoid.



The end of the solenoid at which the current flows in anticlockwise direction acts as a North Pole, whereas the ends in which current flows in clockwise direction acts as a South pole as shown in figure. Inside the solenoid, the magnetic field is constant in magnitude and direction and acts along the axis of the solenoid.

Experiments show that the magnitude of the magnetic field inside a solenoid is:

- (i) directly proportional to the number of turns in the coil i.e., $B \propto n$
- (ii) directly proportional to the strength of the current. i.e., $B \propto I$
- (iii) depends upon the nature of the core material.

When a soft iron core is used as a core material, a very strong magnetic field is produced. Commonly an insulated wire is coiled over a non conducting hollow cylindrical tube. An iron rod is usually placed inside the hollow tube. This iron rod is called the core.

We can also determine the north and south poles of a current-carrying solenoid by using a bar magnet. Bring the north pole of a bar magnet near both the ends of a current-carrying solenoid. The end of solenoid which will be repelled by the north pole of bar magnet will be its north pole, and the end of solenoid which will be attracted by the north pole of bar magnet will be its south pole.

The current in each turn of a current-carrying solenoid flows in the same direction due to which the magnetic field produced by each turn of the solenoid adds up, giving a strong magnetic field inside the solenoid. The strong magnetic field produced inside a current-carrying solenoid can be used to magnetise a piece of magnetic material like soft iron, when placed inside the solenoid. The magnet thus formed is called an electromagnet. So, a solenoid is used for making electromagnets.

ELECTROMAGNET

An electromagnet is a coil of wire wound around a soft iron core. It behaves as a permanent magnet except that it can be turned off. It is a temporary magnet. It begins to behave as a magnet when an electric current is passed through it. It usually contains a soft iron core. The purpose of the core is to increase the intensity of the magnetic field. In fact an electromagnet is a solenoid with an iron core at its centre. The strength of the magnetic field of an electromagnet depends upon the same factors as that of a solenoid. An electromagnet works on the magnetic effect of current.

Factors Affecting the Strength of an Electromagnet. The strength of an electromagnet depends

on:

- (i) **The number of turns in the coil:** If we increase the number of turns in the coil, the strength of electromagnet increases.
- (ii) **The current flowing in the coil:** If the current in the coil is increased, the strength of electromagnet increases.
- (iii) **The length of air gap between its poles:** If we reduce the length of air gap between the poles of an electromagnet, then its strength increases. For example, the air gap between the poles of a straight, bar type electromagnet is quite large, so a bar type electromagnet is not very strong. On the other hand, the air gap between the poles of a U-shaped electromagnet is small, so it is a very strong electromagnet.

The core of an electromagnet must be of soft iron because soft iron loses all of its magnetism when current in the coil is switched off. On the other hand, if steel is used for making the core of an electromagnet, the steel does not lose all its magnetism when the current is stopped and it becomes a permanent magnet. This is why steel is not used for making electromagnets. Electromagnets can be made in different shapes and sizes depending on the purpose for which they are to be used.

It should be noted that in many respects an electromagnet is better than a permanent magnet because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil or by changing the current flowing through the coil.

DIFFERENCES BETWEEN A BAR MAGNET AND AN ELECTROMAGNET

<u>Bar Magnet</u>	<u>Electromagnet</u>
1. The bar magnet is a permanent magnet.	1. An electromagnet is a temporary magnet. Its magnetism is only for the duration of current passing through it.
2. A permanent magnet produces a comparatively weak force of attraction.	2. An electromagnet can produce very strong magnetic force.
3. The strength of a permanent magnet cannot be changed.	3. The strength of an electromagnet can be changed by changing the number of turns in its coil or current passing through it.
4. The (north-south) polarity of a permanent magnet is fixed	4. Its polarity can be changed by changing the direction of current

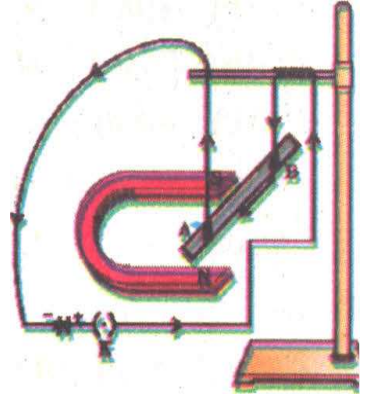
FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD:

Oersted found that an electric current flowing through a conductor produces a magnetic field around itself. The field so produced exerts a force on a magnet placed in the vicinity of the conductor. French scientist Andre Marie Ampere (1715-1836) suggested that the magnet must also exert an equal and opposite force on the current-carrying conductor in accordance with third law of motion. The force due to magnetic field acting on a current carrying conductor can be demonstrated through the following activity.

- i. Take a small aluminium rod AB (of about 5 cm). Using two connecting wires suspend it horizontally from a stand, as shown in Fig.
- ii. Place a strong horse-shoe magnet in such a way that the rod lies between the two poles with the magnetic field directed upwards. For this put the North Pole of the magnet vertically below and South Pole vertically above the aluminium rod.
- iii. Connect the aluminium rod in series with a battery, a key and a rheostat.
- iv. Now pass a current through the aluminium rod from end B to end A.

- v. It is observed that the rod is displaced towards the left.
- vi. Reverse the direction of current flowing through the rod and observe the direction of its displacement. It is now towards the right.

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. 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. Experiments have shown that the displacement of the rod is largest (or 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.



In Activity, 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. The three directions can be illustrated through a simple rule, called Fleming's left-hand rule. Experimentally it has been found that the force experienced by the current carrying conductor, in a magnetic field is directly proportional to:

- (i) the magnitude of current flowing through the conductor *i.e.*, $F \propto I$
- (ii) the magnitude of the magnetic field of the magnet *i.e.*, $F \propto B$
- (iii) the length of the conductor inside the magnetic field *i.e.*, $F \propto L$
- (iv) the sine of the angle between the conductor and the magnetic field *i.e.*, $F \propto \sin\theta$

Combining the above we get

$$F = BLI \sin \theta$$

This force is maximum if $\theta = 90^\circ$ *i.e.*, the rod is perpendicular to the direction of the magnetic field. Then $F = B I L$

FLEMING'S LEFT HAND RULE: According to this rule, "Stretch the thumb, forefinger and middle finger: of your left hand mutually perpendicular to each other such that 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 motion or the force acting on the conductor". (Remember this rule by FBI). The direction of force experienced by a current carrying conductor placed in a magnetic field can be found by Fleming's left hand rule

THE ELECTRIC MOTOR

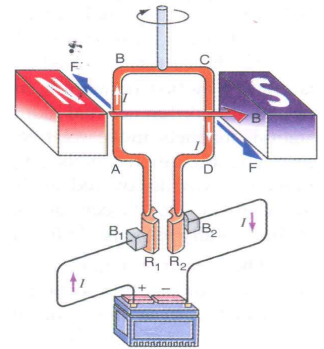
An electric motor is a device that converts electrical energy into mechanical energy (kinetic energy). Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, MP3 players etc. There are two kinds of motors that we use in our day to day life.

(i) ac motor that uses ac. supply e.g. Motor of a fan.

(ii) dc motor that uses dc supply e.g. motors of battery operated toys.

An electric motor, as shown in Fig. 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 R_1 and R_2 of a split ring. The inner sides of these halves are insulated and attached to an axle. The external conducting edges of R_1 and R_2 touch two conducting stationary brushes B_1 and B_2 , respectively, as shown in the figure.

Current in the coil ABCD enters from the source battery through conducting brush B_1 and flows back to the battery through brush B_2 . Notice that in the current in arm AB of the coil flows from A to B. In arm CD it flows from C to D that is, opposite to the direction of current through arm AB. On applying Fleming's left hand rule for the direction of force on a current-carrying conductor in a magnetic field (see Fig.). We find that 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, mounted free to turn about an axis, rotate anti-clockwise. At half rotation, R_1 makes contact with the brush B_2 and R_2 with brush B_1 . Therefore the current in the coil gets reversed and flows along the path DCBA. 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. The reversal of current 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.



The commercial motors use (i) an electromagnet in place of permanent magnet; (ii) large number of turns of the conducting wire in the current-carrying coil; and (iii) 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.

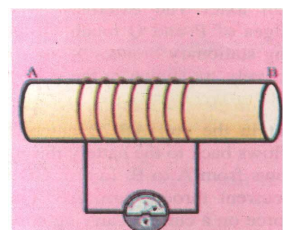
The speed of the motor depends on the strength of the magnetic field, the current and on the number of turns in the armature coil.

The speed of the motor depends on the strength of the magnetic field, the current and on the number of turns in the armature coil.

Galvanometer: A galvanometer is an instrument that can detect the presence of a current in a circuit. The pointer remains at zero (the centre of the scale) for zero current flowing through it. It can deflect either to the left or to the right of the zero mark depending on the direction of current.

ELECTROMAGNETIC INDUCTION

We have studied that when a current-carrying conductor is placed, in a magnetic field such that the direction of current is perpendicular to the magnetic field, it experiences a force. This force causes the conductor to move. Now let us imagine a situation in which a conductor is moving inside a magnetic field or a magnetic field is changing around a fixed conductor. What will happen? This was first studied by English physicist Michael Faraday. In 1831, Faraday made an important breakthrough by discovering how a moving Magnet can be used to generate electric currents. To observe this effect, let us perform the following activity:



Activity:

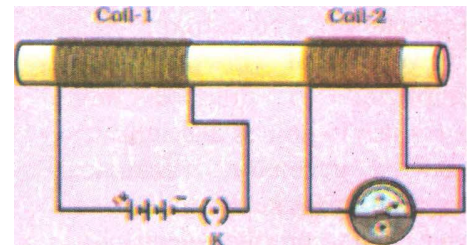
- i. Take a coil of wire AB having a large number of turns.
- ii. Connect the ends of the coil to a galvanometer as shown in Fig.
- iii. Take a bar magnet and move its north pole towards the end B of the coil.
- iv. There is a momentary deflection in the needle of the galvanometer say to the right. This indicates the presence of a current in coil AB. The deflection becomes zero the moment the motion of the magnet stops.
- v. 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.
- vi. Place the magnet stationary at a point near to the coil, keeping its north pole towards the end B of the coil. We see that the galvanometer needle deflects toward the right when the coil is moved towards the north pole of the magnet. Similarly the needle moves toward left when the coil is moved away.
- vii. When the coil and the magnet are both stationary, there is no deflection in the galvanometer.

It is, thus, clear from this activity that motion of a magnet with respect to the coil produces an induced potential difference, which sets up an induced electric current in the circuit.

Activity:

Let, us now perform a variation of above Activity in which the moving magnet is replaced by a current-carrying coil and the current in the coil can be varied.

- i. Take two different coils of copper wire having large number of turns (say 50 and 100 turns respectively).
- ii. Insert them over a non-conducting cylindrical roll, as shown in Fig. (You may use a thick paper roll for this purpose.)
- iii. Connect the coil-I, having larger number of turns, in series with a battery and a plug key.
- iv. Also connect the other coil-2 with a galvanometer as shown.
- v. Plug in the key. Observe the galvanometer.
- vi. You will observe that the needle of the galvanometer instantly jumps to one side and just as quickly returns to zero, indicating a momentary current in coil-2.
- vii. Disconnect coil-I from the battery. You will observe that the needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in coil-2.



In this activity we observe that as soon as the current in coil-1 reaches either a steady value or zero, the galvanometer in coil-2 shows no deflection.

From these observations, we conclude that 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.

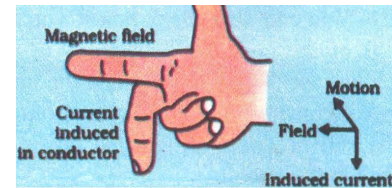
As the current in the first coil changes, the magnetic field associated with it also changes. Thus the magnetic field lines around the secondary coil also change. Hence the change in magnetic field lines associated with the secondary coil is the cause of induced electric current in it.

Thus, if magnetic field (more appropriately magnetic flux) through a circuit changes, an emf (voltage) and hence a current are induced in a circuit. The emf is called induced emf and the current is called induced current. This process, by which a changing magnetic field in a conductor induces a current in another conductor, is called electromagnetic induction. In practice we can induce current in a coil either by moving it in a magnetic field or by changing the magnetic field around it. It is convenient in most situations to move the coil in a magnetic field.

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. In this situation, we can use a simple rule to know the direction of the induced current called Fleming's right hand rule. .

FLEMING'S RIGHT HAND RULE :

Stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other, as shown in Fig. 4.18. 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. This simple rule is called Fleming's right-hand rule.



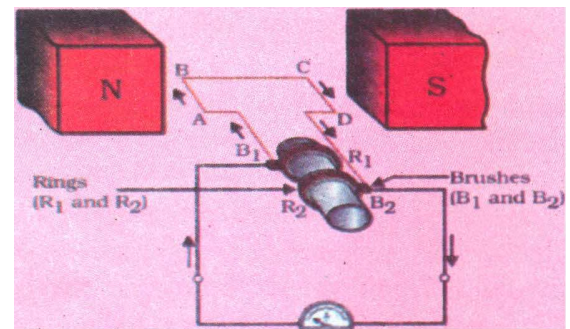
ELECTRIC GENERATOR

Electric generator is a device in which mechanical energy is used to rotate a conductor in a magnetic field to produce electricity. It is of two types namely AC Generator and DC Generator (Dynamo)

An electric generator, as shown in Figure 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 R₁ and R₂. The inner side of these rings are made insulated. The two conducting stationary brushes B₁ and B₂ are kept pressed separately on the rings R₁ and R₂, respectively. The two rings R₁ and

R₂ are internally attached to an axle. The axle may be mechanically rotated from Brushes outside to rotate the coil inside the magnetic field. (B₁ and 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. Let us say the coil ABCD is rotated clockwise in the arrangement shown in Fig. 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. If there are larger numbers of turns in the coil, the current generated in each turn adds up to give a large current through the coil. This means that the current in the external circuit flows from B₂ to B₁. 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 B₁ to B₂. Thus 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 (abbreviated as 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. 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. We have seen the working of a split ring commutator in the case of an electric motor (see Fig.). Thus a unidirectional current is produced. The generator is thus called a DC generator.

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. Most power stations constructed these days produce AC. In India, the AC changes direction after every 1 / 100 second, that is, the frequency of AC is 50 Hz. An Important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.

DOMESTIC ELECTRIC CIRCUITS

In our homes, we receive supply of electric power through a main supply (also called mains), either supported through overhead electric poles or by underground cables. One of the wires in this supply, usually with red insulation cover, is called live wire (or positive). Another wire, with black insulation, is called neutral wire (or negative). In our country, the potential difference between the two is 220 V.

At the meter-board in the house, these wires pass into an electricity meter through a main fuse. Through the main switch they are connected to the line wires in the house. These wires supply electricity to separate circuits within the house. Often, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air coolers, etc. The other circuit is of 5 A current rating for bulbs, fans, etc. The earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc. The metallic body is connected to the earth wire, which provides a low resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

In each separate circuit, different appliances can be connected across the live and neutral wires. Each appliance has a separate switch to 'ON'/'OFF' the flow of current through it. In order that each appliance has equal potential difference, they are connected parallel to each other.

SHORT CIRCUITING AND OVERLOADING

Short circuit means the coming together of the live and the neutral wire. This can happen due to the (i) damage to the appliance or (ii) wearing out of the wires carrying current. When a circuit is short circuited the resistance of the circuit becomes very small as the current follows the shortest circuit. This results in a large current flowing in the circuit. This large current, at times, may heat up the wires to such an extent that a fire may break out due to the intense heat.

Every electrical circuit in the house is designed to carry a certain maximum value of current. If the current in the circuit exceeds the predetermined value, then the circuit is said to be overloaded. This may be due to the connection of a large number of appliances to the same circuit. Overloading also makes a large current flow through the wires and may also be a cause of electrical fire.

ELECTRIC FUSE

Electric fuse is an important safety device of all domestic circuits. An electric fuse is a short length of easily fusible wire put into an electrical circuit for protection purposes. A fuse in a circuit prevents damage to the appliances and the circuit due to overloading. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of unduly high electric current. The Joule heating that takes place in the fuse melts it to break the electric circuit.

It is usually made of an alloy of lead and tin (63 % tin + 37 % lead). It has a high resistivity and low melting point. As soon as the safe limit of current exceeds the fuse "blows" and the electric circuit is cut off. A fuse is always connected to the live wire in the beginning of a circuit in series before an appliance is connected. A copper wire cannot be used as a fuse wire because it has low resistance.

A fuse is inserted with each gadget which needs protection, it is inserted in modern power plugs and it is of course there in each branch circuit and at the main supply input point to provide safety everywhere. These are essential for the safety of the person and building as well as for the protection of the electrical gadgets in use. Whenever there is high current (in excess of some predetermined value) the fuse "blows" (melts) and that part of the circuit is turned off. This prevents damage to the gadget and any fire that could have resulted from over heating due to excess current.

The 'fuse rating' is the maximum safe current permitted to flow in a fuse before it breaks. For lighting purpose, the current required in a lamp is 0.5 A only. So, with a few lamps in a circuit the maximum

current may be about 3 or 4 A. The protective fuse wire in a lighting circuit is usually rated at 5 A. For heating purposes large currents are needed. So, fuse wire of 10 to 15 A rating may be used.

There are different types of fuses. The old type of fuse is made of two metal clamps fixed on a porcelain base with a groove in between (Fig) The fuse wire is connected in between the metal clamps which are inserted in the appropriate section of the circuit.

These days' costly appliances are fitted with a cartridge type fuse (Fig). It consists of a length of fuse wire connected to metal caps at the end of a short glass tube.

Nowadays miniature circuit breaker (MCB's) are being utilised for lighting circuits.

Fuses blow off due to the following reasons.

1. Short circuit due to worn out insulation on connecting wires.
2. Overloading of an electrical circuit.

EARTHING: (GROUNDING)

By earthing we mean the connecting of a device (or a system) to the earth. To ensure good contact with the earth, a large metal plate is buried under the earth at a depth where the soil is moist. The plate is surrounded by a mixture of charcoal and common salt to ensure good contact with the wet soil and hence the ground. The earthing wire is usually bare and thick. It provides a safe and easy path for the electric charge to flow down to the earth which acts as a very large sink.

Earthing the circuit or appliance is a very important safety precaution. If the metal casing of the appliance is connected to the earth with the help of a conductor, the metal casing will be then at the same potential as the earth i.e. zero volt. The metal cases of all electrical appliances used in the home, such as room heater, electric stove, electric iron, are connected by the earth cable E to the earth. In case, the insulation inside the appliance breaks down, or the live wire becomes loose and touches the case (body of the appliance), the case becomes 'live' and the user gets a severe shock, if the case is not earthed.

The power line used for operating high power gadgets such as oven, heater etc. has in addition to the two line wires - live (L) and neutral (N) - a third wire E which is the earthing wire. It is connected to the third terminal post.