CHAPTER

2

# Magnetic Effect of Electric Current

In the previous Chapter we have studied that an electric current can produce *heating effect*. We will now study that an electric current can also produce a *magnetic effect*. **The term 'magnetic effect of electric current' means that 'an electric current flowing in a wire produces a magnetic field around it'.** In other words, **electric current can produce magnetism.** This will become more clear from the following activity. Take about one metre long insulated copper wire and wind it round and round closely on a large iron nail (see Figure 1). Then connect the ends of the wire to a battery. We will find that the large iron nail can now attract tiny iron nails towards it (as shown in Figure 1). This has happened because an electric current flowing in the wire has produced a magnetic field which has turned the large iron nail into a magnet. Please note that the current-carrying straight electric wires (like an electric iron connecting cable) do not attract the nearby iron objects towards them because the strength of magnetic field produced by them is quite *weak*. We will now describe a magnet, poles of a magnet, magnetic field and magnetic field lines briefly. This is necessary to understand the magnetic effect of current.

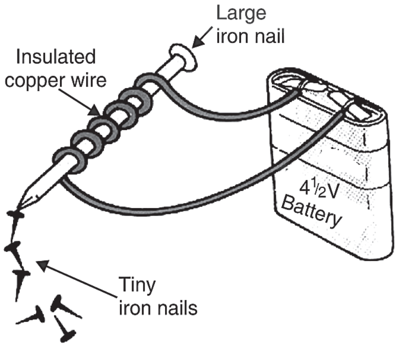



**Figure 1.** An electric current flowing in the coiled copper wire has turned the large iron nail into a magnet. This is an example of magnetic effect of current.

**A magnet is an object which attracts pieces of iron, steel, nickel and cobalt.** Magnets come in various shapes and sizes depending on their intended use. One of the most common magnets is the *bar* magnet. **A bar magnet is a long, rectangular bar of uniform cross-section which attracts pieces of iron, steel, nickel and cobalt.** We usually use bar magnets for

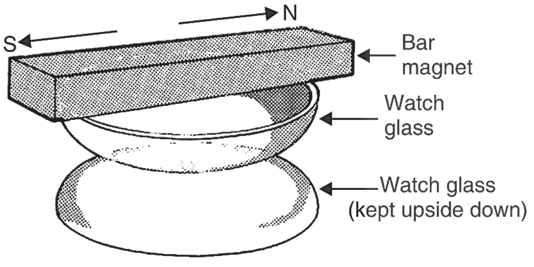



**Figure 2.** This diagram shows how to support a bar magnet on two watch glasses so that it can rotate freely.

performing practicals in a science laboratory. A magnet has two poles near its ends : north pole and south pole. The end of a freely suspended magnet (or a freely pivoted magnet) which points towards the north direction is called the **north pole of the magnet** (see Figure 2). And the end of a freely suspended magnet (or freely pivoted magnet) which points towards the south direction is called the **south pole of the magnet.** It has been found by experiments that **like magnetic poles repel each other** whereas **unlike magnetic poles attract each other.** This means that the north pole of a magnet repels the north pole of another magnet and the south pole of a magnet repels the south pole of another magnet; but the north pole of a magnet attracts the south pole of another magnet. These days magnets are used for a variety of purposes. Magnets are used in radio, television, and stereo speakers, in refrigerator doors, on audio and video cassette tapes, on hard discs and floppies for computers, and in children's toys. Magnets are also used in making electric generators and electric motors. The Magnetic Resonance Imaging (MRI) technique which is used to scan inner human body parts in hospitals also uses magnets for its working.

**Figure 3.** A magnetic strip in the refrigerator door is used to keep it closed properly.

## Magnetic Field

Just as an electric charge creates an electric field, in the same way, a magnet creates a magnetic field around it. **The space surrounding a magnet in which magnetic force is exerted, is called a magnetic field.** A compass needle placed near a magnet gets deflected due to the magnetic force exerted by the magnet, and the iron filings also cling to the magnet due to magnetic force. The magnetic field pattern due to a bar magnet is shown in Figure 8. The magnetic field has both, *magnitude* as well as *direction.* **The direction of magnetic field at a point is the direction of the resultant force acting on a hypothetical north pole placed at that point.** The north end of the needle of a compass indicates the direction of magnetic field at a point where it is placed.

## Magnetic Field Lines

A magnetic field is described by drawing the magnetic field lines. When a small north magnetic pole is placed in the magnetic field created by a magnet, it will experience a force. And if the north pole is free, it will move under the influence of magnetic field. The path traced by a north magnetic pole free to move under the influence of a magnetic field is called a magnetic field line. In other words, **the magnetic field lines are the lines drawn in a magnetic field along which a north magnetic pole would move.** The *magnetic field lines* are also known as *magnetic lines of force.* The direction of a magnetic field line at any point gives the direction of the magnetic force on a north pole placed at that point. Since the direction of magnetic field line is the direction of force on a north pole, so **the magnetic field lines always begin from the N-pole of a magnet and end on the S-pole of the magnet** (see Figure 8). Inside the magnet, however, the direction of magnetic field lines is from the S-pole of the magnet to the N-pole of the magnet. Thus, the magnetic field lines are closed curves. The magnetic field lines due to a bar magnet are shown in Figure 8. When a small compass is moved along a magnetic field line, the compass needle always sets itself along the line tangential to it. So, a line drawn from the south pole of the compass needle to its north pole indicates the direction of the magnetic field at that point. We will now describe how the magnetic field lines (or magnetic field) produced by a bar magnet can be plotted on paper.

### 1. To Plot the Magnetic Field Pattern Due to a Bar Magnet by Using Iron Filings

Place a card (thick, stiff paper) over a strong bar magnet (as shown in Figure 4). Sprinkle a thin layer of iron filings over the card with the help of a sprinkler, and then tap the card gently. The iron filings arrange themselves in a regular pattern as shown in Figure 5. This arrangement of iron filings gives us a rough picture of the pattern of magnetic field produced by a bar magnet. This happens as follows : The bar magnet exerts a magnetic field all around it. The iron filings experience the force of magnetic field of the

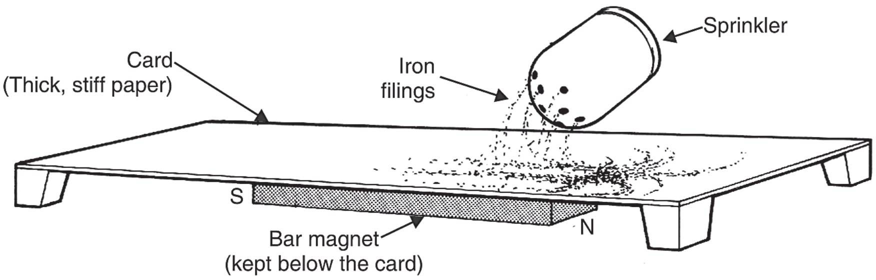



**Figure 4.** Experiment to trace the magnetic field pattern of a bar magnet by using iron filings.

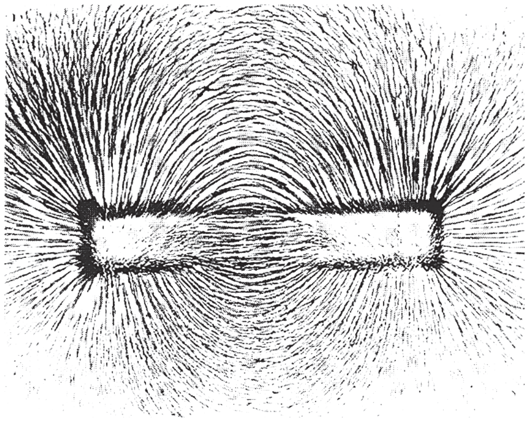


**Figure 5.** This picture shows the magnetic field pattern of a bar magnet as traced by iron filings. The black lines in the above picture consist of iron filings lying along the magnetic field lines of the bar magnet.

bar magnet. The force of magnetic field of the bar magnet makes the iron filings to arrange themselves in a particular pattern. Actually, under the influence of the magnetic field of the bar magnet, the iron filings behave like tiny magnets and align themselves along the directions of magnetic field lines. Thus, **iron filings show the shape of magnetic field produced by a bar magnet by aligning themselves with the magnetic field lines.**

There is also another method of obtaining the magnetic field pattern around a bar magnet. This is done by using a compass. A compass is a device used to show magnetic field direction at a point. A compass is also known as a plotting compass. **A compass (or plotting compass) consists of a tiny pivoted magnet usually in the form of a pointer which can turn freely in the horizontal plane.** It is enclosed in a *non-magnetic* metal case having a glass top (see Figure 6). The tiny magnet of the compass is also called 'magnetic needle' (or just 'needle'). The ends of the compass needle point approximately towards the *north* and *south* directions. Actually, the tip of compass needle points towards the north direction whereas its tail points in the south direction. When the compass is placed in a magnetic field (say, in the magnetic field due to a bar magnet), then a force acts on it and it is deflected from its usual north-south position (the axis of needle lines up in the direction of magnetic field). Thus, a compass needle gets deflected when brought near a bar magnet because the bar magnet exerts a magnetic force on the compass needle, which is itself a tiny pivoted magnet (free to move in the horizontal plane). We can trace the magnetic field lines around a bar magnet by using a plotting compass as decribed below.

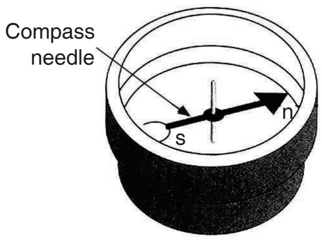



**Figure 6.** A compass (or plotting compass). Its north pole has been marked n and south pole s.

## 2. To Plot the Magnetic Field Pattern Due to a Bar Magnet by Using a Compass

The bar magnet *M* whose magnetic field pattern is to be traced is placed on a sheet of paper and its boundary is marked with a pencil (see Figure 7). A plotting compass is now brought near the N-pole of the bar magnet (see position *X* in Figure 7). In this position, the N-pole of magnet repels the n-pole of compass needle due to which the tip of the compass needle moves away from the N-pole of the magnet. On the other hand, the N-pole of magnet attracts the s-pole of compass needle due to which the tail of compass needle comes near the N-pole of the magnet (see position *X* in Figure 7). We mark the positions of the tip and the tail of compass needle by pencil dots *B* and *A*. That is, we mark the positions of the two poles of the compass needle by pencil dots *B* and *A* (tip representing north pole and tail representing south pole).

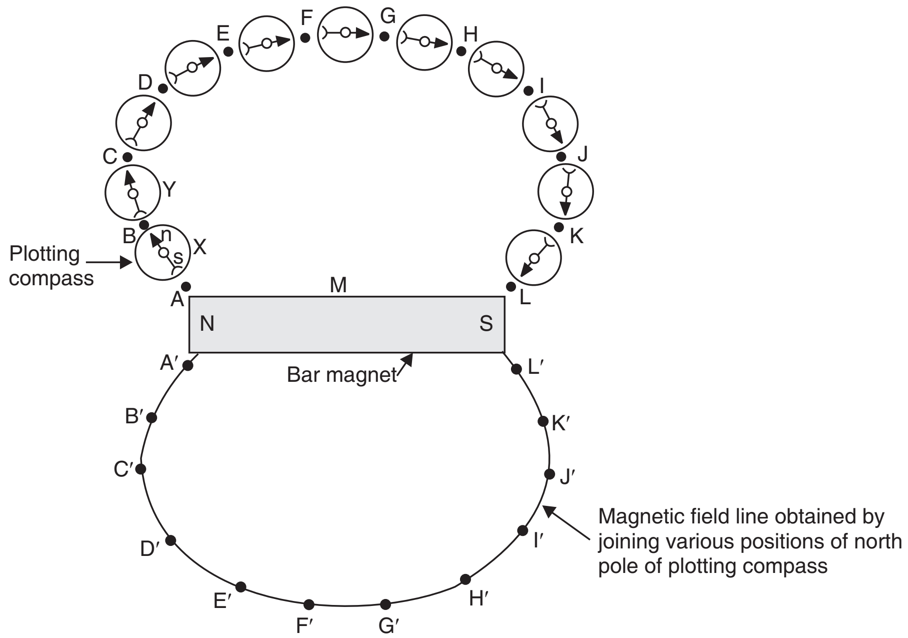



**Figure 7.** To draw the magnetic field pattern (or magnetic field lines) due to a bar magnet by using a plotting compass.

We now move the compass to position *Y* so that the tail of compass needle (or south pole) points at dot *B* (previously occupied by n-pole of compass needle). We mark a dot *C* at the tip of the compass needle to show the position of its north pole. In this manner we go on step by step till we reach the south pole of the magnet. By doing this we get the various dots *A, B, C, D, E, F, G, H, I, J, K* and *L*, all denoting the path in which the north pole of the compass needle moves. By joining the various dots, we get a smooth curve representing a magnetic field line, which begins on the north pole of the bar magnet and ends on its south pole (see Figure 7). We can draw a large number of lines of force in the same way by starting from different points near the magnet. Every line is labelled with an arrow to indicate its direction. In this way we will get the complete pattern of the magnetic field around a bar magnet.

The magnetic field pattern around a bar magnet is shown in Figure 8. This has been traced by using a plotting compass. **The magnetic field lines leave the north pole of a magnet and enter its south pole** (as shown in Figure 8). In other words, each magnetic field line is directed from the north pole of a magnet to its south pole. Each field line indicates, at every point on it, the direction of magnetic force that would act on a north pole if it were placed at that point. **The strength of magnetic field is indicated by the degree of closeness of the field lines. Where the field lines are closest together, the magnetic field is the strongest.** For example, the field lines are closest together at the two poles of the bar magnet, so the magnetic field is the strongest at the poles. Please note that no two magnetic field lines are found to cross each other. If two field lines crossed each other, it would mean that at the point of intersection, the compass needle would point in two directions at the same time, which is not possible. It should be noted that we have drawn the magnetic lines

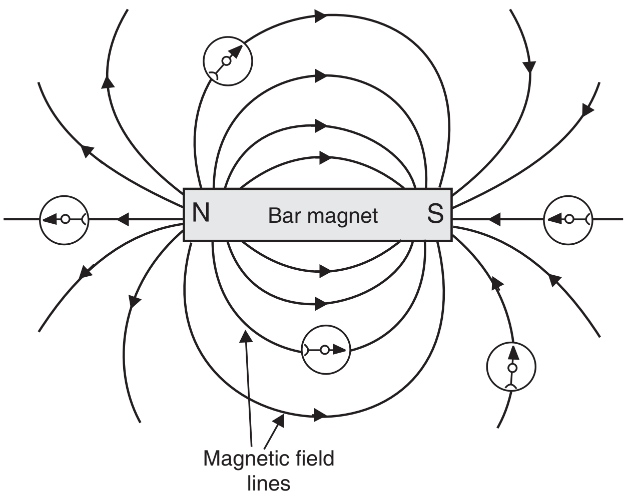



**Figure 8.** The magnetic field pattern (or magnetic field lines) produced by a bar magnet (These have been traced by using a plotting compass).

of force only in one plane around the magnet. Actually, **the magnetic field and hence the magnetic lines of force exist in all the planes all round the magnet.**

## Properties (or Characteristics) of the Magnetic Field Lines

1. **The magnetic field lines originate from the north pole of a magnet and end at its south pole.**

2. **The magnetic field lines come closer to one another near the poles of a magnet but they are widely separated at other places.** A north magnetic pole experiences a stronger force when it approaches one of the poles of the magnet. This means that the magnetic field is stronger near the poles. From this we conclude that where magnetic field lines are closer together, it indicates a stronger magnetic field. On the other hand, when magnetic field lines are widely separated, then it indicates a weak magnetic field.

3. **The magnetic field lines do not intersect (or cross) one another.** This is due to the fact that the resultant force on a north pole at any point can be only in one direction. But if the two magnetic field lines intersect one another, then the resultant force on a north pole placed at the point of intersection will be along two directions, which is not possible.

## Magnetic Field of Earth

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** which causes a freely suspended magnet (or magnetic needle) to point always in a particular direction : north and south. **The shape of the earth's magnetic field resembles that of an imaginary bar magnet** of length one-fifth of earth's diameter buried at its centre (see Figure 9).

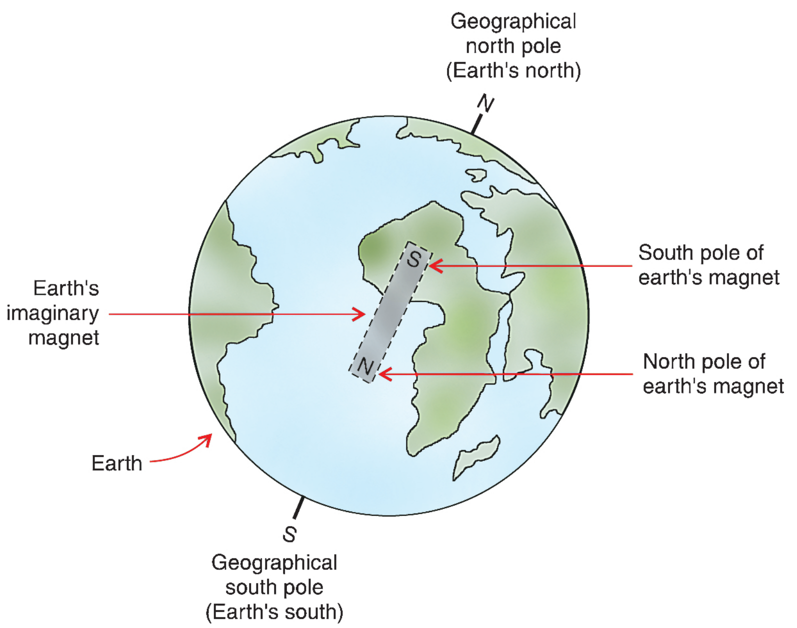



**Figure 9.** The earth's magnetism is due to an imaginary bar magnet buried at its centre. The S pole of earth's magnet is towards its north; and the N pole of earth's magnet is towards its south.

The south pole of earth's magnet is in the geographical north because it attracts the north pole of the suspended magnet. Similarly, the north pole of earth's magnet is in the geographical south because it attracts the south pole of the suspended magnet. Thus, there is a magnetic S-pole near the geographical north, and a magnetic N-pole near the geographical south. The positions of the earth's magnetic poles are not well defined on the globe, they are spread over an area. The axis of earth's magnet and the geographical axis do not coincide with each other. **The axis of earth's magnetic field is inclined at an angle of about 15° with the geographical axis.** Due to this a freely suspended magnet (or magnetic needle) makes an angle of about 15° with the geographical axis and points only approximately in the north-south directions at a place. In other words, a freely suspended magnet does not show exact geographical north and south because the magnetic axis and geographical axis of the earth do not coincide. It is now believed that **the earth's magnetism is due to the magnetic effect of current (which is flowing in the liquid core at the centre of the earth). Thus, earth is a huge electromagnet.** Before we go further and discuss the magnetic effect of current in detail, **please answer the following questions :**

## Very Short Answer Type Questions

**1.** State any two properties of magnetic field lines.

**2.** What are the two ways in which you can trace the magnetic field pattern of a bar magnet ?

**3.** You are given the magnetic field pattern of a magnet. How will you find out from it where the magnetic field is the strongest ?

**4.** State whether the following statement is true or false :
The axis of earth's imaginary magnet and the geographical axis coincide with each other.

**5.** Why does a compass needle get deflected when brought near a bar magnet ?

**6.** Where do the manufacturers use a magnetic strip in the refrigerator ? Why is this magnetic strip used ?

**7.** Fill in the following blanks with suitable words :
(*a*) Magnetic field lines leave the..........pole of a bar magnet and enter at its........pole.
(*b*) The earth's magnetic field is rather like that of a ......... magnet with its........pole in the northern hemisphere.

## Short Answer Type Questions

**8.** Draw a diagram to show the magnetic field lines around a bar magnet.

**9.** What is a magnetic field ? How can the direction of magnetic field lines at a place be determined ?

**10.** Explain why, two magnetic field lines do not intersect each other.

**11.** When an electric current is passed through any wire, a magnetic field is produced around it. Then why an electric iron connecting cable does not attract nearby iron objects when electric current is switched on through it ?

## Long Answer Type Question

**12.** (*a*) Define magnetic field lines. Describe an activity to draw a magnetic field line outside a bar magnet from one pole to another pole.
(*b*) Explain why, a freely suspended magnet always points in the north-south direction.

## Multiple Choice Questions (MCQs)

**13.** A strong bar magnet is placed vertically above a horizontal wooden board. The magnetic lines of force will be :
(*a*) only in horizontal plane around the magnet
(*b*) only in vertical plane around the magnet
(*c*) in horizontal as well as in vertical planes around the magnet
(*d*) in all the planes around the magnet

**14.** The magnetic field lines produced by a bar magnet :
(*a*) originate from the south pole and end at its north pole
(*b*) originate from the north pole and end at its east pole
(*c*) originate from the north pole and end at its south pole
(*d*) originate from the south pole and end at its west pole

**15.** Which of the following is not attracted by a magnet ?
(*a*) steel (*b*) cobalt (*c*) brass (*d*) nickel

**16.** The magnetic field lines :
(*a*) intersect at right angles to one another
(*b*) intersect at an angle of 45° to each other
(*c*) do not cross one another
(*d*) cross at an angle of 60° to one another

**17.** The north pole of earth's magnet is in the :
(*a*) geographical south (*b*) geographical east
(*c*) geographical west (*d*) geographical north

**18.** The axis of earth's magnetic field is inclined with the geographical axis at an angle of about :
(*a*) 5° (*b*) 15° (*c*) 25° (*d*) 35°

**19.** The shape of the earth's magnetic field resembles that of an imaginary :
(*a*) U-shaped magnet (*b*) Straight conductor carrying current
(*c*) Current-carrying circular coil (*d*) Bar magnet

**20.** A magnet attracts :
(*a*) plastics (*b*) any metal (*c*) aluminium (*d*) iron and steel

**21.** A plotting compass is placed near the south pole of a bar magnet. The pointer of plotting compass will :
(*a*) point away from the south pole (*b*) point parallel to the south pole
(*c*) point towards the south pole (*d*) point at right angles to the south pole

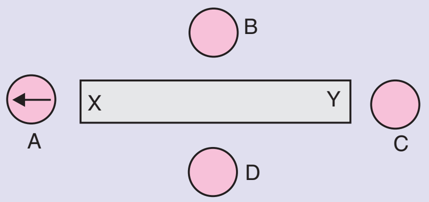
**22.** The metallic pointer of a plotting compass gets deflected only when it is placed near a bar magnet because the pointer has :
(*a*) electromagnetism (*b*) permanent magnetism
(*c*) induced magnetism (*d*) ferromagnetism

**23.** Which of the following statements is incorrect regarding magnetic field lines ?
(*a*) The direction of magnetic field at a point is taken to be the direction in which the north pole of a magnetic compass needle points.
(*b*) Magnetic field lines are closed curves
(*c*) If magnetic field lines are parallel and equidistant, they represent zero field strength
(*d*) Relative strength of magnetic field is shown by the degree of closeness of the field lines

## Questions Based on High Order Thinking Skills (HOTS)

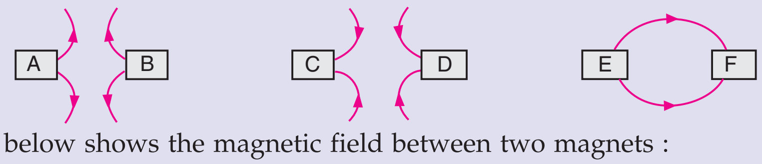
**24.** Copy the figure given below which shows a plotting compass and a magnet. Label the N pole of the magnet and draw the field line on which the compass lies.

**25.** (*a*) The diagram shows a bar magnet surrounded by four plotting compasses. Copy the diagram and mark in it the direction of the compass needle for each of the cases B, C and D.

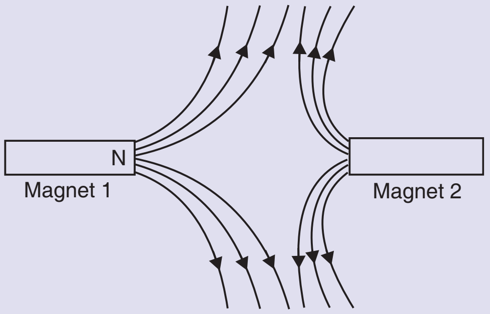



(*b*) Which is the north pole, X or Y ?

**26.** The three diagrams in the following figure show the lines of force (field lines) between the poles of two magnets. Identify the poles A, B, C, D, E and F.




**27.** The figure given below shows the magnetic field between two magnets :

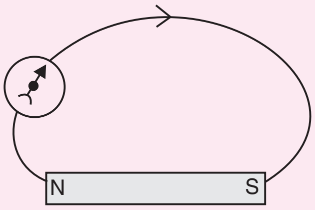


(*i*) Copy the diagram and label the other poles of the magnets.
(*ii*) Which is the weaker magnet ?

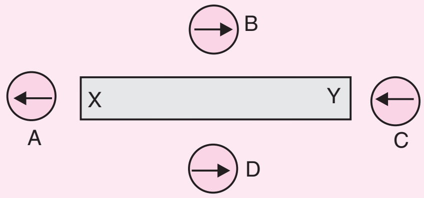
**ANSWERS**

**4.** False **7.** (*a*) north ; south (*b*) bar ; south **13.** (*d*) **14.** (*c*) **15.** (*c*) **16.** (*c*) **17.** (*a*) **18.** (*b*)
**19.** (*d*) **20.** (*d*) **21.** (*c*) **22.** (*b*) **23.** (*c*)

**24.**




**25**(*a*)




(*b*) X

**26.** A = N ; B = N ; C = S, D = S ; E = N, F = S **27.** (*i*) S—N ; N—S (*ii*) Magnet 2

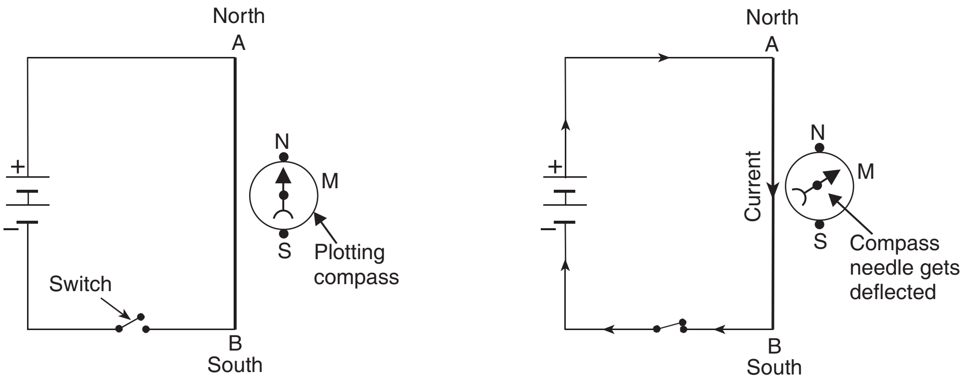
## MAGNETIC EFFECT OF CURRENT (OR ELECTROMAGNETISM)

The magnetic effect of current was discovered by Oersted in 1820. Oersted found that a wire carrying a current was able to deflect a compass needle. Now, the compass needle is a tiny magnet which can be deflected only by a magnetic field. Since a current carrying wire was able to deflect a compass needle, it was concluded that **a current flowing in a wire always gives rise to a magnetic field around it.** The importance of magnetic effect of current lies in the fact that it gives rise to *mechanical forces*. The electric motor, electric generator, telephone and radio, all utilize the magnetic effect of current. The magnetic effect of current is also called electromagnetism which means electricity produces magnetism.

### Experiment to Demonstrate the Magnetic Effect of Current

We will now describe Oersted's experiment to show that a current carrying wire produces a magnetic field around it. We take a thick insulated copper wire and fix it in such a way that the portion *AB* of the wire is in the north-south direction as shown in Figure 10(*a*). A plotting compass *M* is placed under the wire *AB*. The two ends of the wire are connected to a battery through a switch. When no current is flowing in the wire *AB*, the compass needle is parallel to the wire *AB* and points in the usual north-south direction [Figure 10(*a*)].






(*a*) (*b*)

**Figure 10.** Experiment to show that an electric current produces a magnetic effect.

Let us pass the electric current through wire *AB* by pressing the switch. On passing the current we find that compass needle is deflected from its north-south position as shown in Figure 10(*b*). And when the current is switched off, the compass needle returns to its original position. We know that a freely pivoted compass needle always sets itself in the north-south direction. It deflects from its usual north-south direction only when it is acted upon by another magnetic field. So, **the deflection of compass needle by the current-carrying wire in the above experiment shows that an electric current produces a magnetic field around it.** It is this magnetic field which deflects the compass needle placed near the current-carrying wire.

If we reverse the direction of electric current flowing in the wire *AB* by reversing the battery connections, we will find that the compass needle is deflected in the *opposite* direction. This shows that when we reverse the direction of electric current flowing in the wire, then the direction of magnetic field produced by it is also reversed.

**A concealed current-carrying conductor can be located due to the magnetic effect of current by using a plotting compass.** For example, if a plotting compass is moved on a wall, its needle will show deflection at the place where current-carrying wire is concealed.

## Magnetic Field Patterns Produced by Current-Carrying Conductors Having Different Shapes

The pattern of magnetic field (or shape of magnetic field lines) produced by a current-carrying conductor depends on its shape. Different magnetic field patterns are produced by current-carrying conductors having different shapes. We will now study the magnetic field patterns produced by :

(*i*) a straight conductor (or straight wire) carrying current,
(*ii*) a circular loop (or circular wire) carrying current, and
(*iii*) a solenoid (long coil of wire) carrying current.

We will discuss all these cases, one by one. Let us start with the straight current-carrying conductor.

## 1. Magnetic Field Pattern due to Straight Current-Carrying Conductor (Straight Current-Carrying Wire)

**The magnetic field lines around a straight conductor (straight wire) carrying current are concentric circles whose centres lie on the wire** (Figure 11). In Figure 11, we have a straight vertical wire (or conductor) *AB* which passes through a horizontal cardboard sheet *C*. The ends of the wire *AB* are connected to a battery through a switch. When current is passed through wire *AB*, it produces a magnetic field around it. This magnetic field has magnetic field lines around the wire *AB* which can be shown by sprinkling iron filings on the cardboard *C*. The iron filings get magnetised. And on tapping the cardboard sheet, the iron filings arrange themselves in circles around the wire showing that **the magnetic field lines are circular in nature.** A small plotting compass *M* placed on the cardboard indicates the direction of the magnetic field. When current in the wire flows in the *upward* direction (as shown in Figure 11), then the lines of magnetic field are in the *anticlockwise* direction. If the direction of current in the wire is reversed, the direction of magnetic field lines also gets reversed.

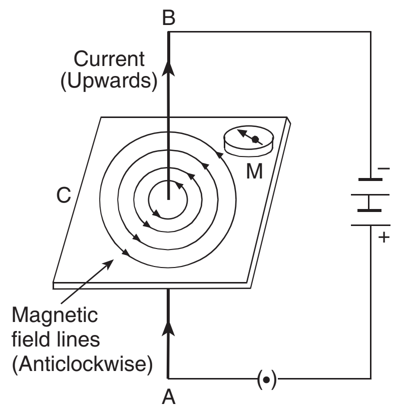



**Figure 11.** Magnetic field pattern due to a straight current-carrying wire.

It has been shown by experiments that **the magnitude of magnetic field produced by a straight current-carrying wire at a given point is : (*i*) directly proportional to the current passing in the wire, and (*ii*) inversely proportional to the distance of that point from the wire.** So, greater the current in the wire, stronger will be the magnetic field produced. And greater the distance of a point from the current-carrying wire, weaker will be the magnetic field produced at that point. In fact, as we move away from a current-carrying straight wire, the concentric circles around it representing magnetic field lines, become larger and larger indicating the decreasing strength of the magnetic field.

## Direction of Magnetic Field Produced by Straight Current-Carrying Conductor (Straight Current-Carrying Wire)

If the direction of current is known, then the direction of magnetic field produced by a straight wire carrying current can be obtained by using Maxwell's right-hand thumb rule. According to Maxwell's right-hand thumb rule : **Imagine that you are grasping (or holding) the current-carrying wire in your right**

**hand so that your thumb points in the direction of current, then the direction in which your fingers encircle the wire will give the direction of magnetic field lines around the wire.** Figure 12 shows a straight current-carrying wire *AB* in which the current is flowing vertically upwards from *A* to *B*. To find out the direction of magnetic field lines produced by this current, we imagine the wire *AB* to be held in our right hand as shown in Figure 12 so that our thumb points in the direction of current towards *B*. Now, the direction in which our fingers are folded gives the direction of magnetic field lines. In this case our fingers are folded in the anticlockwise direction, so the direction of magnetic field (or magnetic field lines) is also in the anticlockwise direction (as shown by the circle drawn at the top of the wire).

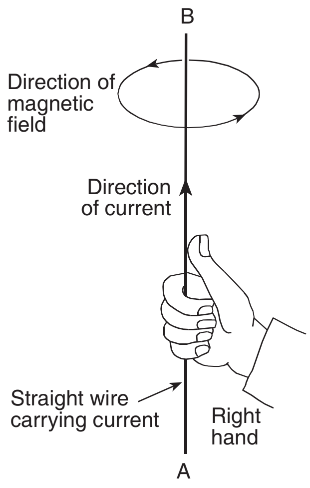



**Figure 12.** Right-hand thumb rule to find the direction of magnetic field.

Maxwell's right-hand thumb rule is also known as Maxwell's corkscrew rule (Corkscrew is a device for pulling corks from bottles, and consists of a spiral metal rod and a handle). According to Maxwell's corkscrew rule : *Imagine driving a corkscrew in the direction of current, then the direction in which we turn its handle is the direction of magnetic field (or magnetic field lines).* The corkscrew rule is illustrated in Figure 13. In Figure 13, the direction of current is vertically downwards. Now, if we imagine driving the corkscrew downwards in the direction of current, then the handle of corkscrew is to be turned in the clockwise direction. So, the direction of magnetic field (or magnetic field lines) will also be in the clockwise direction. This example is *opposite* to the one we considered in right-hand thumb rule given above. Thus, when electric current flows vertically *upwards* the direction of magnetic field produced is *anticlockwise.* On the other hand, when electric current flows vertically *downwards* then the direction of magnetic field is *clockwise.*

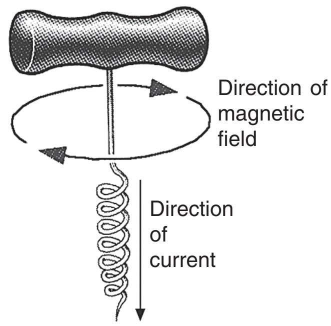



**Figure 13.** Maxwell's corkscrew rule to find the direction of magnetic field.

## 2. Magnetic Field Pattern due to a Circular Loop (or Circular Wire) Carrying Current

We know that when current is passed through a straight wire, a magnetic field is produced around it. It has been found that the magnetic effect of current increases if instead of using a straight wire, the wire is converted into a circular loop (as shown in Figure 14). In Figure 14, a circular loop (or circular wire) is fixed to a thin cardboard sheet *T*. When a current is passed through the circular loop of wire, a magnetic field is produced around it. The pattern of magnetic field due to a current-carrying circular loop (or circular wire) is shown in Figure 14. The magnetic field lines are *circular* near the current-carrying loop. As we move away, the concentric circles representing magnetic field lines become bigger and bigger. At the centre of the circular loop, the magnetic field lines are *straight* (see point *M* in Figure 14). By applying right-hand thumb rule, it can be seen that each segment of circular loop carrying current produces magnetic field lines in the same direction within the loop. At the centre of the circular loop, all the magnetic field lines are in the same direction and aid each other, due to which the strength of magnetic field increases.

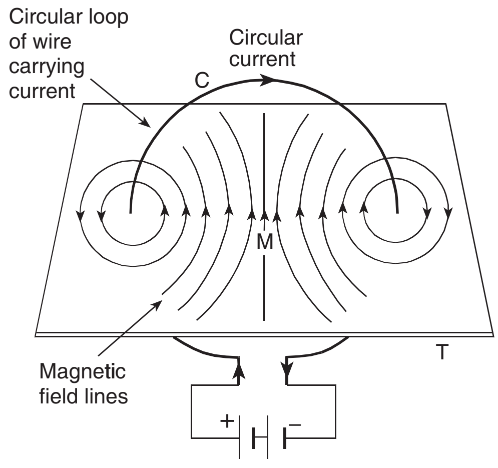



**Figure 14.** Magnetic field lines due to circular loop (or circular wire) carrying current.

The magnitude of magnetic field produced by a current-carrying circular loop (or circular wire) at its centre is :

(*i*) directly proportional to the current passing through the circular loop (or circular wire), and (*ii*) inversely proportional to the radius of circular loop (or circular wire).

In this discussion we have considered the magnetic field produced by a circular loop (or circular wire) which consists of only 'one turn' of the wire. The strength of magnetic field can be increased by taking a circular coil consisting of a number of turns of insulated copper wire closely wound together. 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. We can now say that : The strength of magnetic field produced by a circular coil carrying current is directly proportional to both, number of turns (*n*) and current (*I*); but inversely proportional to its radius (*r*). Thus, the strength of magnetic field produced by a current-carrying circular coil can be increased : (*i*) by increasing the number of turns of wire in the coil, (*ii*) by increasing the current flowing through the coil, and (*iii*) by decreasing the radius of the coil.

## Clock Face Rule

A current-carrying circular wire (or loop) behaves like a thin disc magnet whose one face is a north pole and the other face is a south pole. The polarity (north or south) of the two faces of a current-carrying circular coil (or loop) can be determined by using the clock face rule given below.

According to Clock face rule, look at one face of a circular wire (or coil) through which a current is passing :

(*i*) if the current around the face of circular wire (or coil) flows in the *Clockwise direction*, then that face of the circular wire (or coil) will be *South pole* (S-pole).

(*ii*) if the current around the face of circular wire (or coil) flows in the *Anticlockwise direction*, then that face of circular wire (or coil) will be a *North pole* (N-pole)

For example, in Figure 15(*a*), the current in a face of the circular wire is flowing in the Clockwise direction, so this face of current-carrying circular wire will behave as a South magnetic pole (or S-pole). On the other hand, in Figure 15(*b*) the current in the face of the circular wire is flowing in the Anticlockwise direction, so this face of current-carrying circular wire will behave as a North magnetic pole (or N-pole).


(*a*) The direction of current in this face of circular wire is Clockwise, so this face of circular wire carrying current will act as a South magnetic pole (S-pole)

(*b*) The direction of current in this face of circular wire is Anticlockwise, so this face of circular wire carrying current will act as a North magnetic pole (or N-pole)

**Figure 15.**

Please note that **if the direction of current in the front face of a circular wire is clockwise, then the direction of current in the back face of this circular wire will be anticlockwise (and vice versa)**. This means that the front face of this current-carrying circular wire will be a south pole but its back face will be a north pole. For example, the direction of current in the front face of current-carrying circular wire shown in Figure 14 is clockwise, so the front face of this current-carrying circular wire will be a south magnetic pole (S-pole). If, however, we view the current-carrying circular wire given in Figure 14 from back side, we will find that the direction of current flowing in the back face of this circular wire is anticlockwise. Due to this, the back face of this current-carrying circular wire will be a North magnetic pole (N-pole). The Clock face rule is also used in determining the polarities of the two faces (or two ends) of a current-carrying solenoid as well as an electromagnet.

## 3. Magnetic Field due to a Solenoid

**The solenoid is a long coil containing a large number of close turns of insulated copper wire.** Figure 16 shows a solenoid *SN* whose two ends are connected to a battery *B* through a switch *X*. When an electric current is passed through the solenoid, it produces a magnetic field around it. The magnetic field produced by a current carrying solenoid is shown in Figure 16. **The magnetic field produced by a current-carrying solenoid is similar to the magnetic field produced by a bar magnet.** Please note that the lines of magnetic field pass through the solenoid and return to the other end as shown in Figure 16. 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. If the strength of magnetic field is just the same in a region, it is said to be *uniform* magnetic field. Thus, the magnetic field is *uniform* inside a current-carrying solenoid. The uniform magnetic field inside the current-carrying solenoid has been represented by drawing parallel straight field lines (see Figure 16). Even the earth's magnetic field at a given place is *uniform* which consists of parallel straight field lines (which run roughly from south geographical pole to north geographical pole).

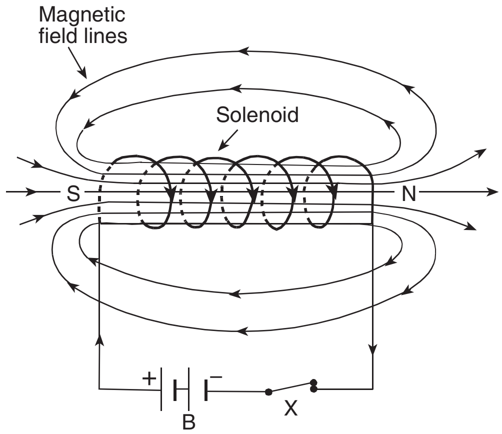



**Figure 16.** Magnetic field due to a current carrying solenoid is similar to that of a bar magnet.

One end of the current-carrying solenoid acts like a north-pole (N-pole) and the other end a south pole (S-pole). So, if a current-carrying solenoid is suspended freely, it will come to rest pointing in the north and south directions (just like a freely suspended bar magnet). We can determine the north and south poles of a current-carrying solenoid by using a bar magnet. This can be done as follows : We 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.

The strength of magnetic field produced by a current carrying solenoid depends on :

(*i*) **The number of turns in the solenoid.** Larger the number of turns in the solenoid, greater will be the magnetism produced.

(*ii*) **The strength of current in the solenoid.** Larger the current passed through solenoid, stronger will be the magnetic field produced.

(*iii*) **The nature of "core material" used in making solenoid.** The use of soft iron rod as core in a solenoid produces the strongest magnetism.



## Electromagnet

An electric current can be used for making temporary magnets known as electromagnets. **An electromagnet works on the magnetic effect of current.** Let us discuss it in detail. We have just studied that when current is passed through a long coil called solenoid, a magnetic field is produced. It has been found that if a soft iron rod called core is placed inside a solenoid, then the strength of magnetic field becomes very large because the iron core gets magnetised by induction. This combination of a solenoid and a soft iron core is called an electromagnet. Thus, **An electromagnet is a magnet consisting of a long coil of insulated copper wire wrapped around a soft iron core that is magnetised only when electric current is passed through the coil.** A simple electromagnet is shown in Figure 17. To make an electromagnet all that we have to do is to take a rod *NS* of soft iron and wind a coil *C* of insulated copper wire round it. When the two ends of the copper coil are connected to a battery, an electromagnet is formed (see Figure 17).

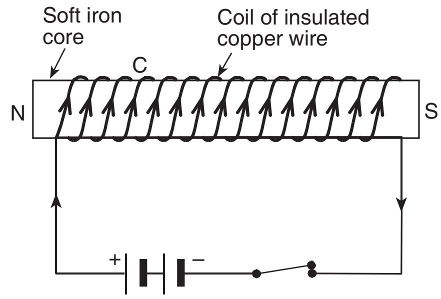


**Figure 17.** Electromagnet.

It should be noted that the solenoid containing soft iron core in it acts as a magnet only as long as the current is flowing in the solenoid. If we switch off the current in the solenoid, it no more behaves as a magnet. All the magnetism of the soft iron core disappears as soon as the current in the coil is switched off. A very important point to be noted is that it is the iron piece inside the coil which becomes a strong electromagnet on passing the current. **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.

**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 (see Figure 18).

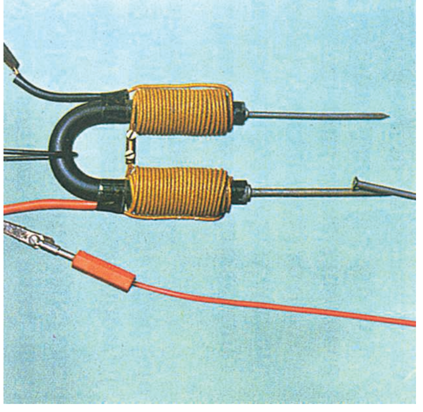


**Figure 18.** This is a U-shaped electromagnet with iron nails sticking to its two poles.

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.

We can determine the polarity of electromagnet shown in Figure 17 by using the clock face rule. If we view the electromagnet from its left end, we will see that the direction of current flowing in the coil is anticlockwise. So, the left end of this electromagnet will be North pole (N-pole). And if we view the electromagnet given in Figure 17 from its right end, we will see that the direction of current in its coil is clockwise. So, the right side end of this electromagnet is a South pole (S-pole). Some uses of electromagnets are shown in Figures 19 and 20.

**Figure 19.** In hospitals, doctors use an electromagnet to remove particles of iron or steel from a patient's eye.

**Figure 20.** This is a Maglev train (Magnetic leviation train) which does not need wheels. It floats above its track by strong magnetic forces produced by computer-controlled electromagnets.

**Differences Between a Bar Magnet (or Permanent Magnet) and an Electromagnet**

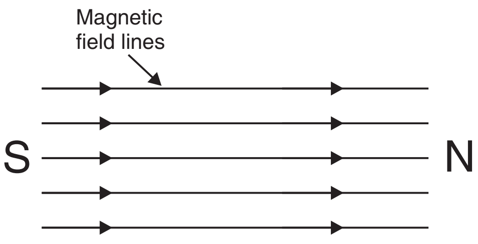
| *Bar magnet (or Permanent magnet)* | *Electromagnet* |
|---|---|
| 1. The bar magnet is a permanent magnet. | 1. An electromagnet is a temporary magnet. Its magnetism is only for the duration of current passing through it. So, the magnetism of an electromagnet can be switched on or switched off as desired. |
| 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 by changing the current passing through it. |
| 4. The (north-south) polarity of a permanent magnet is fixed and cannot be changed. | 4. The polarity of an electromagnet can be changed by changing the direction of current in its coil. |

Permanent magnets are usually made of alloys such as : Carbon steel, Chromium steel, Cobalt steel, Tungsten steel, and Alnico (Alnico is an alloy of aluminium, nickel, cobalt and iron). Permanent magnets of these alloys are much more strong than those made of ordinary steel. Such strong permanent magnets are used in microphones, loudspeakers, electric clocks, ammeters, voltmeters, speedometers, and many other devices. Let us solve one problem now.

**Sample Problem.** The magnetic field in a given region is uniform. Draw a diagram to represent it.

**(NCERT Book Question)**

**Answer.** A uniform magnetic field in a region is represented by drawing equidistant, parallel straight lines, all pointing in the same direction. For example, the uniform magnetic field which exists inside a current-carrying solenoid can be represented by parallel straight lines pointing from its S-pole to N-pole (as shown in Figure alongside).




The uniform magnetic field inside a current-carrying solenoid.

We are now in a position to **answer the following questions :**

## Very Short Answer Type Questions

1. Which effect of current can be utilised in detecting a current-carrying wire concealed in a wall ?
2. What conclusion do you get from the observation that a current-carrying wire deflects a compass needle placed near it ?

**3.** Name the scientist who discovered the magnetic effect of current.

**4.** State qualitatively the effect of inserting an iron core into a current-carrying solenoid.

**5.** Name the rule for finding the direction of magnetic field produced by a straight current-carrying conductor.

**6.** State the form of magnetic field lines around a straight current-carrying conductor.

**7.** What is the other name of Maxwell's right-hand thumb rule ?

**8.** State whether the following statement is true or false :
The magnetic field inside a long circular coil carrying current will be parallel straight lines.

**9.** What is the shape of a current-carrying conductor whose magnetic field pattern resembles that of a bar magnet ?

**10.** State three ways in which the strength of an electromagnet can be increased.

**11.** Fill in the following blanks with suitable words :

(*a*) The lines of.............round a straight current-carrying conductor are in the shape of............

(*b*) For a current-carrying solenoid, the magnetic field is like that of a..............

(*c*) The magnetic effect of a coil can be increased by increasing the number of............., increasing the ............, or inserting an.............core.

(*d*) If a coil is viewed from one end and the current flows in an anticlockwise direction, then this end is a.........pole.

(*e*) If a coil is viewed from one end, and the current flows in a clockwise direction, then this end is a ..... pole.

## Short Answer Type Questions

**12.** Describe how you will locate a current-carrying wire concealed in a wall.

**13.** Describe some experiment to show that the magnetic field is associated with an electric current.

**14.** (*a*) Draw a sketch to show the magnetic lines of force due to a current-carrying straight conductor.

(*b*) Name and state the rule to determine the direction of magnetic field around a straight current-carrying conductor.

**15.** State and explain Maxwell's right-hand thumb rule.

**16.** What is Maxwell's corkscrew rule ? For what purpose is it used ?

**17.** (*a*) Draw the magnetic lines of force due to a circular wire carrying current.

(*b*) What are the various ways in which the strength of magnetic field produced by a current-carrying circular coil can be increased ?

**18.** State and explain the Clock face rule for determining the polarities of a circular wire carrying current.

**19.** Name any two factors on which the strength of magnetic field produced by a current-carrying solenoid depends. How does it depend on these factors ?

**20.** (*a*) Draw a circuit diagram to show how a soft iron piece can be transformed into an electromagnet.

(*b*) Describe how an electromagnet could be used to separate copper from iron in a scrap yard.

**21.** (*a*) How does an electromagnet differ from a permanent magnet ?

(*b*) Name two devices in which electromagnets are used and two devices where permanent magnets are used.

## Long Answer Type Questions

**22.** (*a*) What is a solenoid ? Draw a sketch to show the magnetic field pattern produced by a current-carrying solenoid.

(*b*) Name the type of magnet with which the magnetic field pattern of a current-carrying solenoid resembles.

(*c*) What is the shape of field lines inside a current-carrying solenoid ? What does the pattern of field lines inside a current-carrying solenoid indicate ?

(*d*) List three ways in which the magnetic field strength of a current-carrying solenoid can be increased ?

(*e*) What type of core should be put inside a current-carrying solenoid to make an electromagnet ?

**23.** (*a*) What is an electromagnet ? Describe the construction and working of an electromagnet with the help of a labelled diagram.

(*b*) Explain why, an electromagnet is called a temporary magnet.

(*c*) Explain why, the core of an electromagnet should be of soft iron and not of steel.

(*d*) State the factors on which the strength of an electromagnet depends. How does it depend on these factors ?
(*e*) Write some of the important uses of electromagnets.

## Multiple Choice Questions (MCQs)

**24.** The strength of the magnetic field between the poles of an electromagnet would be unchanged if :
(*a*) current in the electromagnet winding were doubled
(*b*) direction of current in electromagnet winding were reversed
(*c*) distance between the poles of electromagnet were doubled
(*d*) material of the core of electromagnet were changed

**25.** The diagram given below represents magnetic field caused by a current-carrying conductor which is :

(*a*) a long straight wire (*b*) a circular coil
(*c*) a solenoid (*d*) a short straight wire

**26.** The magnetic field inside a long straight solenoid carrying current :
(*a*) is zero
(*b*) decreases as we move towards its end.
(*c*) increases as we move towards its end.
(*d*) is the same at all points.

**27.** Which of the following correctly describes the magnetic field near a long straight wire ?
(*a*) The field consists of straight lines perpendicular to the wire.
(*b*) The field consists of straight lines parallel to the wire.
(*c*) The field consists of radial lines originating from the wire.
(*d*) The field consists of concentric circles centred on the wire.

**28.** The north-south polarities of an electromagnet can be found easily by using :
(*a*) Fleming's right-hand rule (*b*) Fleming's left-hand rule
(*c*) Clock face rule (*d*) Left-hand thumb rule

**29.** The direction of current in the coil at one end of an electromagnet is clockwise. This end of the electromagnet will be :
(*a*) north pole (*b*) east pole (*c*) south pole (*d*) west pole

**30.** If the direction of electric current in a solenoid when viewed from a particular end is anticlockwise, then this end of solenoid will be :
(*a*) west pole (*b*) south pole (*c*) north pole (*d*) east pole

**31.** The most suitable material for making the core of an electromagnet is :
(*a*) soft iron (*b*) brass (*c*) aluminium (*d*) steel

**32.** The magnetic effect of current was discovered by :
(*a*) Maxwell (*b*) Fleming (*c*) Oersted (*d*) Faraday

**33.** A soft iron bar is inserted inside a current-carrying solenoid. The magnetic field inside the solenoid :
(*a*) will decrease (*b*) will increase
(*c*) will become zero (*d*) will remain the same

**34.** The magnetic field lines in the middle of the current-carrying solenoid are :
(*a*) circles (*b*) spirals
(*c*) parallel to the axis of the tube (*d*) perpendicular to the axis of the tube

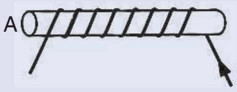
**35.** The front face of a circular wire carrying current behaves like a north pole. The direction of current in this face of the circular wire is :
(*a*) clockwise (*b*) downwards (*c*) anticlockwise (*d*) upwards

**36.** The back face of a circular loop of wire is found to be south magnetic pole. The direction of current in this face of the circular loop of wire will be :
(*a*) towards south (*b*) clockwise (*c*) anticlockwise (*d*) towards north

## Questions Based on High Order Thinking Skills (HOTS)

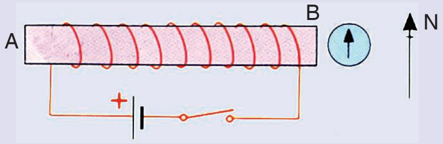
**37.** In the straight wire *A*, current is flowing in the vertically downward direction whereas in wire *B* the current is flowing in the vertically upward direction. What is the direction of magnetic field :
(*a*) in wire *A* ?
(*b*) in wire *B* ?
Name the rule which you have used to get the answer.

**38.** The figure shows a solenoid wound on a core of soft iron. Will the end A be a N pole or S pole when the current flows in the direction shown ?




**39.** A current-carrying straight wire is held in exactly vertical position. If the current passes through this wire in the vertically upward direction, what is the direction of magnetic field produced by it ? Name the rule used to find out the direction of magnetic field.

**40.** For the coil in the diagram below, when the switch is pressed :
(*a*) what is the polarity of end A ?
(*b*) which way will the compass point then ?




**41.** A current flows downwards in a wire that passes vertically through a table top. Will the magnetic field lines around it go clockwise or anticlockwise when viewed from above the table ?

**42.** The directions of current flowing in the coil of an electromagnet at its two ends X and Y are as shown below :


(*a*) What is the polarity of end X ?
(*b*) What is the polarity of end Y ?
(*c*) Name and state the rule which you have used to determine the polarities.

**43.** The magnetic field associated with a current-carrying straight conductor is in anticlockwise direction. If the conductor was held along the east-west direction, what will be the direction of current through it ? Name and state the rule applied to determine the direction of current ?

**44.** A current-carrying conductor is held in exactly vertical direction. In order to produce a clockwise magnetic field around the conductor, the current should be passed in the conductor :
(*a*) from top towards bottom (*b*) from left towards right
(*c*) from bottom towards top (*d*) from right towards left

**45.** A thick wire is hanging from a wooden table. An anticlockwise magnetic field is to be produced around the wire by passing current through this wire by using a battery. Which terminal of the battery should be connected to the :
(*a*) top end of wire ?
(*b*) bottom end of wire ?
Give reason for your choice.

## ANSWERS

**1.** Magnetic effect **4.** Magnetic field becomes very strong **8.** True **9.** Solenoid
**11.** (*a*) magnetic field ; concentric circles (*b*) bar magnet (*c*) turns ; current ; iron (*d*) north (*e*) south
**21.** (*b*) Electromagnets : Electric bell, Electric motors ; Permanent magnets : Refrigerator doors ; Toys

**22.** (*b*) Bar magnet **24.** (*b*) **25.** (*b*) **26.** (*d*) **27.** (*d*) **28.** (*c*) **29.** (*c*) **30.** (*c*) **31.** (*a*) **32.** (*c*) **33.** (*b*) **34.** (*c*) **35.** (*c*) **36.** (*b*) **37.** (*a*) Clockwise (*b*) Anticlockwise **38.** S-pole **39.** Anti-clockwise ; Right-hand thumb rule **40.** (*a*) S-pole (*b*) Away from the end B (→) (Because end B is a N-pole) **41.** Clockwise **42.** (*a*) S-pole (*b*) N-pole (*c*) Clock-face rule **43.** East to West **44.** (*a*) **45.** (*a*) Negative terminal (*b*) Positive terminal ; The current should be passed into wire upwards

## MAGNETISM IN HUMAN BEINGS

Extremely weak electric currents are produced in the human body by the movement of charged particles called ions. These are called ionic currents. Now, we have studied that whenever there is an electric current, a magnetic field is produced. So, when the weak ionic currents flow along the nerve cells, they produce magnetic field in our body. For example, when we try to touch something with our hand, our nerves carry electric impulse to the appropriate muscles. And this electric impulse creates a temporary magnetism in the 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 produced is quite significant are the heart and the brain.**

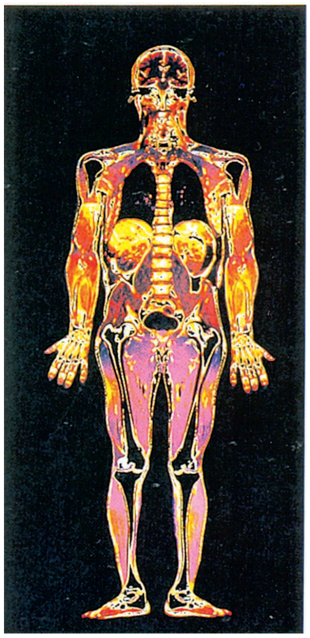


**Figure 21.** This picture showing the insides of the body was produced by using Magnetic Resonance Imaging (MRI).

The magnetism produced inside the human body (by the flow of ionic currents) forms the basis of a technique called Magnetic Resonance Imaging (MRI) which is used to obtain images (or pictures) of the internal parts of our body (see Figure 21). It is obvious that magnetism has an important use in medical diagnosis because, through MRI scans, it enables the doctors to see inside the body. For example, MRI can detect cancerous tissue inside the body of a person. Please note that the magnetism in human body is actually electromagnetism (which is produced by the flow of ionic currents inside the human body). Before we go further, and describe the force acting on a current-carrying conductor placed in a magnetic field, **please answer the following questions :**

### Very Short Answer Type Questions

1. What produces magnetism in the human body ?
2. Name one medical technique which is based on magnetism produced in human body. For what purpose is this technique used ?
3. Name two human body organs where magnetism produced is significant.
4. What is the full form of MRI ?
5. Name the technique by which doctors can produce pictures showing insides of the human body.
6. Name one technique which can detect cancerous tissue inside the body of a person.

## FORCE ON CURRENT-CARRYING CONDUCTOR PLACED IN A MAGNETIC FIELD

We have already described Oersted's experiment which shows that a current-carrying wire exerts a force on a compass needle and deflects it from its usual north-south position. Since a compass needle is actually a small freely pivoted magnet, we can also say that a current-carrying wire exerts a mechanical force on a magnet, and if the magnet is free to move, this force can produce a motion in the magnet. The reverse of this is also true, that is, **a magnet exerts a mechanical force on a current-carrying wire, and if the wire is free to move, this force can produce a motion in the wire** (see Figure 22). In fact, this result can be obtained by applying

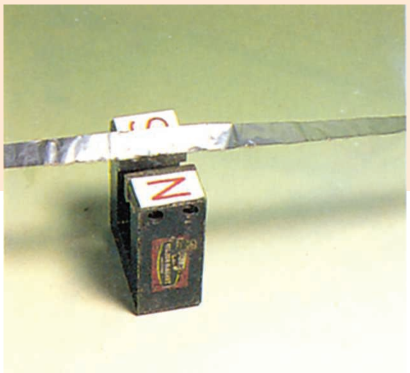



**Figure 22.** In this photograph we can see a piece of aluminium foil that has been fixed between the poles of a strong magnet. When a current is passed through the foil, it is pushed upwards, away from the magnet. It happens due to repulsion between the two magnetic fields : one from the magnet and one from current.

Newton's third law of motion according to which if a current-carrying wire exerts a force on a magnet, then the magnet will exert an *equal* and *opposite* force on the current carrying wire. In 1821, Faraday discovered that : **When a current-carrying conductor is placed in a magnetic field, a mechanical force is exerted on the conductor which can make the conductor move.** This is known as the motor principle and forms the basis of a large number of electrical devices like electric motor and moving coil galvanometer. We will now describe an experiment to demonstrate the force exerted by a magnet on a current-carrying wire and to show how the direction of force is related to the direction of current and the direction of magnetic field.

## Experiment to Demonstrate the Force Acting on a Current-Carrying Conductor Placed in a Magnetic Field : The Kicking Wire Experiment

A thick copper wire *AB* is suspended vertically from a support *T* by means of a flexible joint *J* (Figure 23). The lower end *B* of this wire is free to move between the poles of a U-shaped magnet *M*. The lower end *B* of the wire just touches the surface of mercury kept in a shallow vessel *V* so that it can move when a force acts on it. The positive terminal of a battery is connected to end *A* of the wire. The circuit is completed by dipping another wire from the negative terminal of the battery into the mercury pool as shown in Figure 23. We know that mercury is a liquid which is a good conductor of electricity, so the circuit is completed through mercury contained in the vessel *V*.

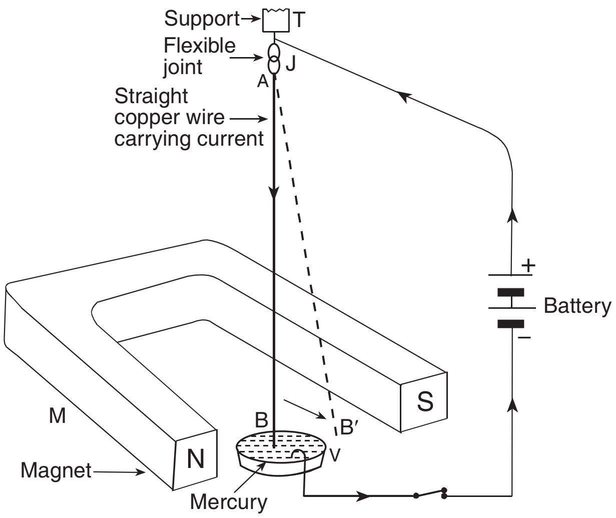



**Figure 23.** Experiment to demonstrate the force acting on a current-carrying wire (or conductor) *AB*, when placed in a magnetic field.

On pressing the switch, a current flows in the wire *AB* in the vertically downward direction. The wire *AB* is kicked in the forward direction (towards south) and its lower end *B* reaches the position *B*′, so that the wire comes to the new position *AB*′ as shown by dotted line in Figure 23. When the lower end *B* of the hanging wire comes forward to *B*′, its contact with the mercury surface is broken due to which the circuit breaks and current stops flowing in the wire *AB*. Since no current flows in the wire, no force acts on the wire in this position and it falls back to its original position. As soon as the wire falls back, its lower end again touches the mercury surface, current starts flowing in the wire and it is kicked again. This action is repeated as long as the current is passed in wire *AB*. It should be noted that the current-carrying wire is kicked forward because a force is exerted on it by the magnetic field of the U-shaped magnet. From this experiment we conclude that **when a current-carrying conductor is placed in a magnetic field, a mechanical force is exerted on the conductor which makes it move.**

In Figure 23, the current is flowing in the vertically downward direction and the direction of magnetic field is from left to right directed towards east, thus, the current carrying conductor is at right angles to the magnetic field. Now, we have just seen that the motion of the conductor is in the forward direction (towards south) which is at right angles to both, the direction of current and the direction of magnetic field. Since the direction of motion of the wire represents the direction of force acting on it, we can say that : **The direction of force acting on a current-carrying wire placed in a magnetic field is (*i*) perpendicular to the direction of current, and (*ii*) perpendicular to the direction of magnetic field.** In other words, we can say that the current, the magnetic field and the force, are at right angles to one another. It should be noted that **the maximum force is exerted on a current-carrying conductor only when it is *perpendicular* to the direction of magnetic field. No force acts on a current-carrying conductor when it is *parallel* to the magnetic field.**

If we reverse the direction of current in the wire *AB* so that it flows in the vertically upward direction from *B* to *A*, then the wire swings in the backward direction (towards north). This means that the direction of force on the current-carrying wire has been reversed. From this we conclude that **the direction of force on a current-carrying conductor placed in a magnetic field can be reversed by reversing the direction of current flowing in the conductor.** Keeping the direction of current unchanged, if we reverse the direction of magnetic field applied in Figure 23 by turning the magnet *M* so that its poles are reversed, even then the wire swings backwards showing that the direction of force acting on it has been reversed. Thus, **the direction of force on a current-carrying conductor placed in a magnetic field can also be reversed by reversing the direction of magnetic field.**

If the direction of *current* in a conductor and the direction of *magnetic* field (in which it is placed), are known, then the direction of *force* acting on the current-carrying conductor can be found out by using Fleming's left-hand rule. This is described below.

## Fleming's Left-Hand Rule for the Direction of Force

When a current carrying wire is placed in a magnetic field, a force is exerted on the wire. Fleming gave a simple rule to determine the direction of force acting on a current carrying wire placed in a magnetic field. This rule is known as Fleming's left-hand rule and it can be stated as follows. According to Fleming's left-hand rule : **Hold the forefinger, the centre finger and the thumb of your left hand at right angles to one another [as shown in Figure 24(*a*)]. Adjust your hand in such a way that the forefinger points in the direction of magnetic field and the centre finger points in the direction of current, then the direction in which thumb points, gives the direction of force acting on the conductor.** Since the conductor (say, a wire) moves along the direction in which the force acts on it, we can also say that the direction in which

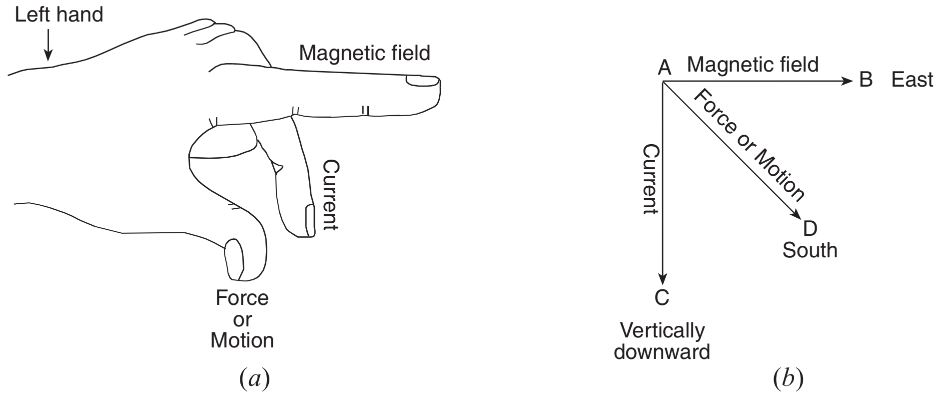



**Figure 24.** Diagrams to illustrate Fleming's left-hand rule.

the thumb points gives the direction of motion of the conductor. Thus, we can write Fleming's left-hand rule in another way as follows : *Hold the forefinger, the centre finger and the thumb of your left hand at right angles to one another. Adjust your hand in such a way that the forefinger points in the direction of magnetic field and the centre finger points in the direction of current in the conductor, then the direction in which the thumb points gives the direction of motion of the conductor.* To memorize Fleming's left-hand rule we should remember that the forefinger represents the (magnetic) field (both, forefinger and field, start with the same letter *f*), the centre finger represents current (both, centre and current start with letter *c*), and the thumb represents force or motion (both, thumb and motion contain the letter *m*). We will make the Fleming's left hand rule more clear by taking an example.

Suppose we have a vertical current-carrying wire or conductor placed in a magnetic field. Let the direction of magnetic field be from west to east as shown by arrow *AB* in Figure 24(*b*). Again suppose that the direction of current in the wire is vertically downwards as shown by arrow *AC*. Now, we want to find out the direction of force which will be exerted on this current-carrying wire. We will find out this direction by using Fleming's left-hand rule as follows : We stretch our left hand as shown in Figure 24(*a*) so that the forefinger, the centre finger and the thumb are perpendicular to one another. Since the direction of magnetic field is from west to east, so we point our forefinger from west to east direction to represent the magnetic field [Figure 24(*a*)]. Now, the current is flowing vertically downwards, so we point our centre finger vertically downwards to represent the direction of current. Now, let us look at the direction of our thumb. The thumb points in the forward direction towards south. This gives us the direction of force acting on the wire (or direction of motion of wire). So, the force acting on the current carrying wire will be in the south direction as shown by the arrow *AD* in Figure 24(*b*), and the wire will move in the south direction.

The devices which use current-carrying conductors and magnetic fields include electric motor, electric generator, microphone, loudspeakers, and current detecting and measuring instruments (such as ammeter and galvanometer, etc.)

Before we solve problems involving direction of current, direction of magnetic field and the direction of force by using Fleming's left-hand rule, we should keep the following points in mind :

(*i*) By convention, the direction of flow of positive charges is taken to be the direction of flow of current. So, the direction in which the positively charged particles such as protons or alpha particles, etc., move will be the direction of electric current.

(*ii*) The direction of electric current is, however, taken to be *opposite* to the direction of flow of negative charges (such as electrons). So, if we are given the direction of flow of electrons, then the direction of electric current will be taken as opposite to the direction of flow of electrons.

(*iii*) The direction of deflection of a current-carrying conductor (or a stream of positively charged particles or a stream of negatively charged particles like electrons) tells us the direction of force acting on it.

Let us solve some problems now.

**Sample Problem 1.** A stream of positively charged particles (alpha particles) moving towards west is deflected towards north by a magnetic field. The direction of magnetic field is :

(*a*) towards south (*b*) towards east

(*c*) downward (*d*) upward **(NCERT Book Question)**

**Solution.** Here the positively charged alpha particles are moving towards *west,* so the direction of current is towards *west.* The deflection is towards *north*, so the force is towards *north*. So, we are given that :

(*i*) direction of current is towards west, and

(*ii*) direction of force is towards north.

Let us now hold the forefinger, centre finger and thumb of our left-hand at right angles to one another. Adjust the hand in such a way that our centre finger points towards west (in the direction of current) and thumb points towards north (in the direction of force). Now, if we look at our forefinger, it will be pointing upward. Since the direction of forefinger gives the direction of magnetic field, therefore, the magnetic field is in the upward direction. So, the correct answer is : (*d*) upward.

**Sample Problem 2.** Think you are sitting in a chamber with your back to one wall. An electron beam moving horizontally from back wall towards the front wall is deflected by a strong magnetic field to your right side. What is the direction of magnetic field ? **(NCERT Book Question)**

**Solution.** Here the electron beam is moving from our back wall to the front wall, so the direction of current will be in the opposite direction, from front wall towards back wall or towards us. The direction of deflection (or force) is towards our right side. We now know two things :

(*i*) direction of current is from front towards us, and

(*ii*) direction of force is towards our right side.

Let us now hold the forefinger, centre finger and thumb of our left hand at right angles to one another. We now adjust the hand in such a way that our centre finger points towards us (in the direction of current) and thumb points towards right side (in the direction of force). Now, if we look at our forefinger, it will be pointing vertically downwards. Since the direction of forefinger gives the direction of magnetic field, therefore, the magnetic field is in the vertically *downward* direction.

## THE ELECTRIC MOTOR

**A motor is a device which converts electrical energy into mechanical energy.** Every motor has a shaft or spindle which rotates continuously when current is passed into it. The rotation of its shaft is used to


(*a*) This is an electric motor

(*b*) Washing machine uses an electric motor for its working

(*c*) Mixer and grinder has an electric motor in it

(*d*) Each wheel of this electric car is turned by an electric motor

**Figure 25.** Electric motor and some of its uses.

drive the various types of machines in homes and industry. Electric motor is used in electric fans, washing machines, refrigerators, mixer and grinder, electric cars and many, many other appliances (see Figure 25). A common electric motor works on direct current. So, it is also called D.C. motor, which means a "Direct Current motor". The electric motor which we are going to discuss now is actually a D.C. motor.

### Principle of a Motor

An electric motor utilises the magnetic effect of current. **A motor works on the principle that when a rectangular coil is placed in a magnetic field and current is passed through it, a force acts on the coil which rotates it continuously.** When the coil rotates, the shaft attached to it also rotates. In this way the electrical energy supplied to the motor is converted into the mechanical energy of rotation.

### Construction of a Motor

An electric motor consists of a rectangular coil *ABCD* of insulated copper wire, which is mounted between the curved poles of a horseshoe-type permanent magnet *M* in such a way that it can rotate freely between the poles N and S on a shaft (The shaft is a long cylindrical rotating rod at the centre of the coil which has not been shown in Figure 26 to keep the diagram simple). The sides *AB* and *CD* of the coil are kept perpendicular to the direction of magnetic field between the poles of the magnet. This is done so that the maximum magnetic force is exerted on the current-carrying sides *AB* and *CD* of the coil. **A device which reverses the direction of current through a circuit is called a commutator (or split ring)**. The two ends of the coil are soldered (or welded) permanently to the two half rings *X* and *Y* of a commutator. A commutator is a copper ring split into two parts *X* and *Y*, these two parts are insulated from one another and mounted on the shaft of the motor. End *A* of the coil is welded to part *X* of the commutator and end *D* of the coil is welded to part *Y* of the commutator. The commutator rings are mounted on the shaft of the coil and they also rotate when the coil rotates. As we will see later on, **the function of commutator rings is to reverse the direction of current flowing through the coil every time the coil just passes the vertical position during a revolution.** In other words, commutator rings reverse the direction of current flowing through the coil after every half rotation of the coil.

We cannot join the battery wires directly to the two commutator half rings to pass current into the coil because if we do so, then the connecting wires will get twisted when the coil rotates. So, to pass in electric current to the coil, we use two carbon strips *P* and *Q* known as brushes. The carbon brushes *P* and *Q* are fixed to the base of the motor and they press lightly against the two half rings of the commutator. The battery to supply current to the coil is connected to the two carbon brushes *P* and *Q* through a switch.

**The function of carbon brushes is to make contact with the rotating rings of the commutator and through them to supply current to the coil.** It should be noted that any one brush touches only one ring at a time, so that when the coil rotates, the two brushes will touch both the rings one by one.

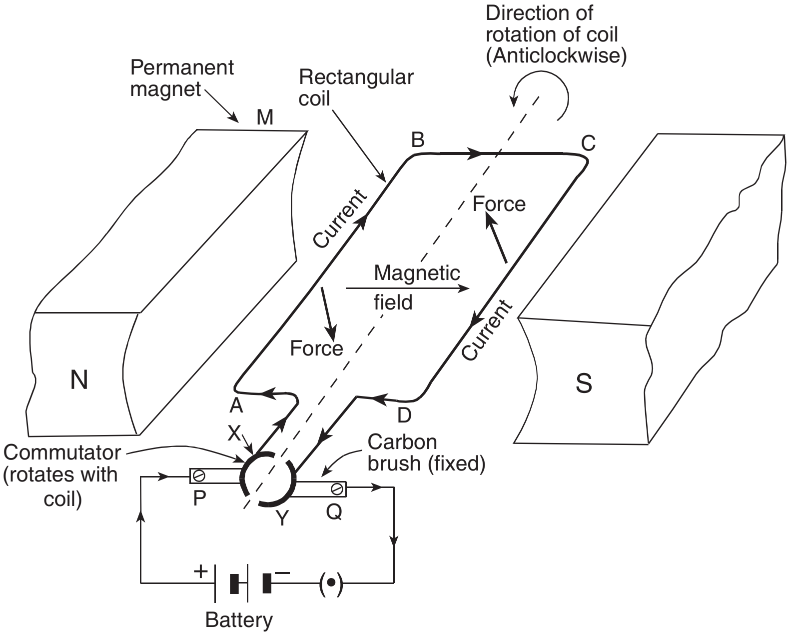



**Figure 26.** An electric motor.

## Working of a Motor

When an electric current is passed into the rectangular coil, this current produces a magnetic field around the coil. The magnetic field of the horseshoe-type magnet then interacts with the magnetic field of the current-carrying coil and causes the coil to rotate (or spin) continuously. The working of a motor will become more clear from the following discussion.

Suppose that initially the coil *ABCD* is in the horizontal position as shown in Figure 26. On pressing the switch, current from battery enters the coil through carbon brush *P* and commutator half ring *X*. The current flows in the direction *ABCD* and leaves via ring *Y* and brush *Q*.

(*i*) In the side *AB* of the rectangular coil *ABCD*, the direction of current is from *A* to *B* (see Figure 26). And in the side *CD* of the coil, the direction of current is from *C* to *D* (which is opposite to the direction of current in side *AB*). The direction of magnetic field is from N pole of the magnet to its S pole. By applying Fleming's left-hand rule to sides *AB* and *CD* of the coil we find that the force on side *AB* of the coil is in the downward direction whereas the force on side *CD* of the coil is in the upward direction. Due to this the side *AB* of the coil is pushed down and side *CD* of the coil is pushed up. This makes the coil *ABCD* rotate in the anticlockwise direction (see Figure 26).

(*ii*) While rotating, when the coil reaches vertical position, then the brushes *P* and *Q* will touch the gap between the two commutator rings and current to the coil is cut off. Though the current to the coil is cut off when it is in the exact vertical position, the coil does not stop rotating because it has already gained momentum due to which it goes beyond the vertical position.

(*iii*) After half rotation, when the coil goes beyond vertical position, the side *CD* of the coil comes on the left side whereas side *AB* of the coil comes to the right side, and the two commutator half rings automatically change contact from one brush to the other. So, after half rotation of the coil, the commutator half ring *Y* makes contact with brush *P* whereas the commutator half ring *X* makes contact with brush *Q* (see Figure 26). This reverses the direction of current in the coil. The reversal of direction of current reverses the direction of forces acting on the sides *AB* and *CD* of the coil. The side *CD* of the coil is now on the left side with a downward force on it whereas the side *AB* is now on the right side with an upward force on it. Due to this the side *CD* of the coil is pushed down and the side *AB* of coil is pushed up. This makes the coil rotate anticlockwise by another half rotation.

(*iv*) The reversing of current in the coil is repeated after every half rotation due to which the coil (and its shaft) continue to rotate as long as current from the battery is passed through it. The rotating shaft of electric motor can drive a large number of machines which are connected to it.

It should be noted that the current flowing in the other two sides, *AD* and *BC* of the rectangular coil is parallel to the direction of magnetic field, so no force acts on the sides *AD* and *BC* of the coil.

We have just described the construction and working of a simple electric motor. **In commercial motors :**

(*a*) the coil is wound on a soft iron core. The soft iron core becomes magnetised and increases the strength of magnetic field. This makes the motor more powerful. The assembly of soft iron core and coil is called an armature.

(*b*) the coil contains a large number of turns of the insulated copper wire.

(*c*) a powerful electromagnet is used in place of permanent magnet.

All these features together help in increasing the power of commercial electric motors.

We are now in a position to **answer the following questions :**

## Very Short Answer Type Questions

**1.** What happens when a current-carrying conductor is placed in a magnetic field ?

**2.** When is the force experienced by a current-carrying conductor placed in a magnetic field largest ?

**3.** In a statement of Fleming's left-hand rule, what do the following represent ?

(*a*) direction of centre finger.

(*b*) direction of forefinger.

(*c*) direction of thumb.

**4.** Name one device which works on the magnetic effect of current.

**5.** Name the device which converts electrical energy into mechanical energy.

**6.** A motor converts one form of energy into another. Name the two forms.

**7.** State whether the following statement is true or false :

An electric motor converts mechanical energy into electrical energy.

**8.** For Fleming's left-hand rule, write down the three things that are 90° to each other, and next to each one write down the finger or thumb that represents it.

**9.** Name the device which is used to reverse the direction of current in the coil of a motor.

**10.** What is the other name of the split ring used in an electric motor ?

**11.** What is the function of a commutator in an electric motor ?

**12.** Of what substance are the brushes of an electric motor made ?

**13.** Of what substance is the core of the coil of an electric motor made ?

**14.** In an electric motor, which of the following remains fixed and which rotates with the coil ?

Commutator ; Brush

**15.** What is the role of the split ring in an electric motor ?

**16.** Fill in the following blanks with suitable words :

(*a*) Fleming's Rule for the motor effect uses the............... hand.

(*b*) A motor contains a kind of switch called a ............ which reverses the current every half............ .

## Short Answer Type Questions

**17.** (*a*) A current-carrying conductor is placed perpendicularly in a magnetic field. Name the rule which can be used to find the direction of force acting on the conductor.

(*b*) State two ways to increase the force on a current-carrying conductor in a magnetic field.

(*c*) Name one device whose working depends on the force exerted on a current-carrying coil placed in a magnetic field.

**18.** State Fleming's left-hand rule. Explain it with the help of labelled diagrams.

**19.** What is the principle of an electric motor ? Name some of the devices in which electric motors are used.

**20.** (*a*) In a d.c. motor, why must the current to the coil be reversed twice during each rotation ?

(*b*) What device reverses the current ?

**21.** (*a*) State what would happen to the direction of rotation of a motor if :

(*i*) the current were reversed

(*ii*) the magnetic field were reversed

(*iii*) both current and magnetic field were reversed simultaneously.

(*b*) In what ways can a motor be made more powerful ?

## Long Answer Type Question

**22.** (*a*) What is an electric motor ? With the help of a labelled diagram, describe the working of a simple electric motor.

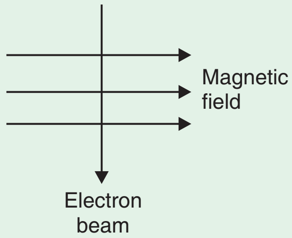
(*b*) What are the special features of commercial electric motors ?

## Multiple Choice Questions (MCQs)

**23.** In an electric motor, the direction of current in the coil changes once in each :

(*a*) two rotations (*b*) one rotation (*c*) half rotation (*d*) one-fourth rotation

**24.** An electron beam enters a magnetic field at right angles to it as shown in the Figure.




The direction of force acting on the electron beam will be :

(*a*) to the left (*b*) to the right (*c*) into the page (*d*) out of the page

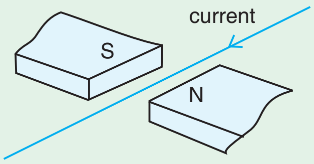
**25.** The force experienced by a current-carrying conductor placed in a magnetic field is the largest when the angle between the conductor and the magnetic field is :

(*a*) 45° (*b*) 60° (*c*) 90° (*d*) 180°

**26.** The force exerted on a current-carrying wire placed in a magnetic field is zero when the angle between the wire and the direction of magnetic field is :

(*a*) 45° (*b*) 60° (*c*) 90° (*d*) 180°

**27.** A current flows in a wire running between the S and N poles of a magnet lying horizontally as shown in Figure below :




The force on the wire due to the magnet is directed :

(*a*) from N to S (*b*) from S to N (*c*) vertically downwards (*d*) vertically upwards

**28.** An electric motor is a device which transforms :

(*a*) mechanical energy to electrical energy

(*b*) heat energy to electrical energy

(*c*) electrical energy to heat energy only

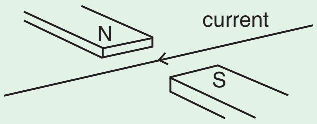
(*d*) electrical energy to mechanical energy

**29.** A magnetic field exerts no force on :

(*a*) an electric charge moving perpendicular to its direction (*b*) an unmagnetised iron bar

(*c*) a stationary electric charge (*d*) a magnet

**30.** A horizontal wire carries a current as shown in Figure below between magnetic poles N and S :



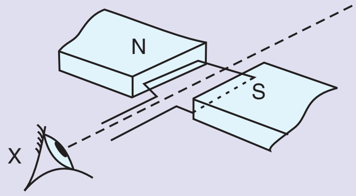

Is the direction of the force on the wire due to the magnet :

(*a*) in the direction of the current (*b*) vertically downwards

(*c*) opposite to the current direction (*d*) vertically upwards

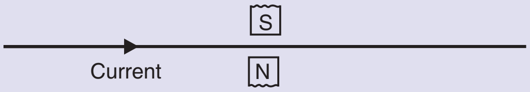
## Questions Based on High Order Thinking Skills (HOTS)

**31.** In the simple electric motor of figure given below, the coil rotates anticlockwise as seen by the eye from the position X when current flows in the coil.



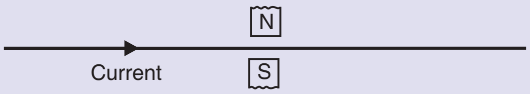

Is the current flowing clockwise or anticlockwise around the coil when viewed from above ?

**32.** Which way does the wire in the diagram below tend to move ?



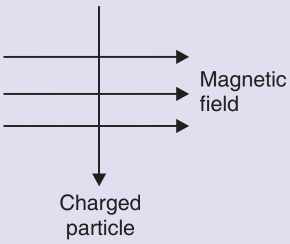

**33.** If the current in a wire is flowing in the vertically downward direction and a magnetic field is applied from west to east, what is the direction of force on the wire ?

**34.** Which way does the wire in the diagram below tend to move ?




**35.** What is the force on a current-carrying wire that is parallel to a magnetic field ? Give reason for your answer.

**36.** A charged particle enters at right angles into a uniform magnetic field as shown :




What should be the nature of charge on the particle if it begins to move in a direction pointing vertically out of the page due to its interaction with the magnetic field ?

## ANSWERS

**2.** When the current-carrying conductor is at right angles to the magnetic field **6.** Electrical energy to Mechanical energy **7.** False **14.** Remains fixed : Brush ; Rotates with the coil : Commutator **16.** (*a*) left (*b*) commutator; rotation; **17.** (c) Electric motor **21.** (*a*) (*i*) Direction of rotation would be reversed (*ii*) Direction of rotation would be reversed (*iii*) Direction of rotation would remain unchanged **23.** (*c*) **24.** (*c*) **25.** (*c*) **26.** (*d*) **27.** (*c*) **28.** (*d*) **29.** (*c*) **30.** (*d*) **31.** Clockwise **32.** Upward (out of the page) **33.** South **34.** Downward (into the page) **35.** Nil **36.** Positive charge

## ELECTROMAGNETIC INDUCTION : ELECTRICITY FROM MAGNETISM

We have already studied that an electric current can produce magnetism. The reverse of this is also true. That is, magnetism (or magnets) can produce electric current. **The production of electricity from magnetism is called electromagnetic induction.** For example, when a straight wire is moved up and down rapidly between the two poles of a horseshoe magnet, then an electric current is produced in the wire. This is an example of electromagnetic induction. Again, if a bar magnet is moved in and out of a coil of wire, even then an electric current is produced in the coil. This is also an example of electromagnetic induction.

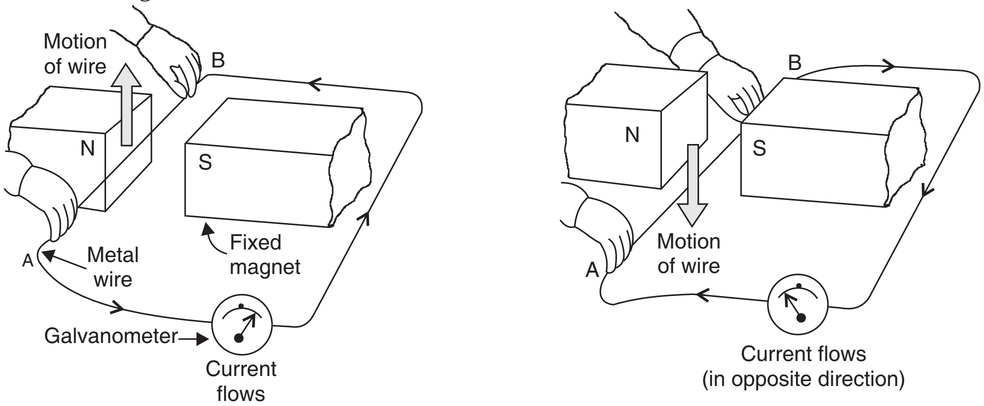
The current produced by moving a straight wire in a magnetic field (or by moving a magnet in a coil) is called *induced current.* The phenomenon of electromagnetic induction was discovered by a British scientist Michael Faraday and an American scientist Joseph Henry independently in 1831. **The process of electromagnetic induction has led to the construction of generators for producing electricity at power stations.** Before we describe experiments to demonstrate the phenomenon of electromagnetic induction, we should know something about the galvanometer which we will be using now.

**Figure 27.** Singers rely on induced currents in a microphone.

**A galvanometer is an instrument which can detect the presence of electric current in a circuit.** It is connected in series with the circuit. When no current is flowing through a galvanometer, its pointer is at the zero mark (in the centre of semi-circular scale). When an electric current passes through the galvanometer, then its pointer deflects (or moves) either to the left side of zero mark or to the right side of the zero mark, depending on the direction of current. We will describe the experiments now.

### 1. To Demonstrate Electromagnetic Induction by Using a Straight Wire and a Horseshoe–Type Magnet

In Figure 28(*a*), we have a straight wire *AB* held between the poles N and S of a horseshoe magnet (which is a U-shaped magnet). The two ends of wire are connected to a current-detecting instrument called galvanometer. When the wire *AB* is held standstill between the poles of the horseshoe magnet, then there is no deflection in the galvanometer pointer. This shows that no current is produced in the wire when it is held stationary in the magnetic field.




(*a*) As the wire *AB* is moved up through the magnetic field, a current is produced in it

(*b*) When the wire *AB* is moved down in the magnetic field, even then current is produced in it (but in the opposite direction)

**Figure 28.** Experiment to demonstrate electromagnetic induction. A current is induced in the wire when it is moved up or down between the poles of the magnet.

1. Let us move the wire *AB upwards* rapidly between the poles of the horseshoe magnet [see Figure 28(*a*)]. When the wire is moved up, there is a deflection in the galvanometer pointer showing that a current is produced in the wire *AB* momentarily which causes the deflection in galvanometer [see Figure 28(*a*)]. The deflection lasts only while the wire is in motion. Thus, *as the wire is moved up through the magnetic field, an electric current is produced in it.*

2. We now move the wire *AB downwards* rapidly between the poles of the horseshoe magnet [see Figure 28(*b*)]. When the wire is moved down, the galvanometer pointer again shows a deflection, but in the opposite direction (to the left side) [see Figure 28(*b*)]. This means that *when the wire is moved down in the magnetic field, even then an electric current is produced in it.* But when the direction of movement of wire is reversed (from up to down), then the direction of current produced in the wire is also reversed.

If we move the wire *AB* up and down continuously between the poles of the horse-shoe magnet, then a continuous electric current will be produced in the wire. But the direction of this electric current will change rapidly as the direction of movement of the wire changes. This is because when the wire moves up, then the current in it will flow in one direction but when the wire moves down, then the current in it will flow in opposite direction. We will see the pointer of galvanometer move to and fro rapidly as the current in the wire changes direction of flow continuously. The electric current produced in the wire (which changes direction continuously) is called alternating current or a.c.

The above experiment shows that when the direction of motion of wire in the magnetic field is reversed, then the direction of induced current is also reversed. Please note that the direction of induced current in the wire can also be reversed by reversing the positions of the poles of the magnet which means that **the direction of induced current can also be reversed by reversing the direction of magnetic field.** We will now discuss why the movement of a wire in the magnetic field produces an electric current in the wire.

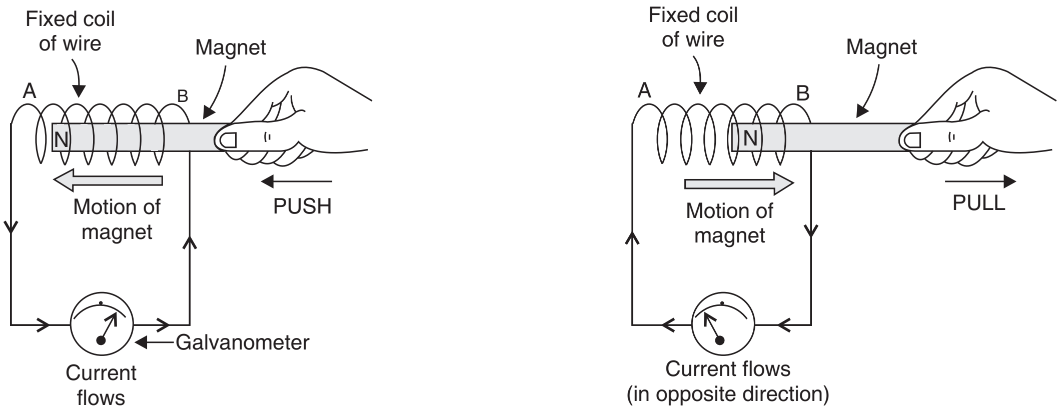
When a wire is moved in a magnetic field between the poles of a magnet, then the free electrons present in the wire experience a force. This force makes the electrons move along the wire. And the movement of these electrons produces current in the wire. We are spending energy (from our body) in moving the wire up and down in the magnetic field. So, it is the energy spent by us in moving the wire in the magnetic field which is getting converted into electrical energy in the wire and producing an electric current in the wire. Thus, **the movement of a wire in a magnetic field can produce electric current.** So, we can generate electricity by moving a wire continuously in the magnetic field between the poles of a magnet. This principle is used in producing electricity through generators. **A generator uses the movement (or rotation) of a rectangular coil of wire between the poles of a horseshoe magnet to produce an electric current (or electricity).** Thus, the phenomenon of electromagnetic induction is used in the production of electricity by a generator.

In the above experiment we have seen that **when a wire is moved between the poles of a fixed magnet, then an electric current is produced in the wire.** The reverse of this is also true. That is, **if a wire (in the form of a coil) is kept fixed but a magnet is moved inside it, even then a current is produced in the coil of wire**. This point will become more clear from the following experiment.

## 2. To Demonstrate Electromagnetic Induction by Using a Coil and a Bar Magnet

In Figure 29(*a*), we have a fixed coil of wire *AB*. The two ends of the coil are connected to a current-detecting instrument called galvanometer. Now, when a bar magnet is held standstill inside the hollow coil of wire, then there is no deflection in the galvanometer pointer showing that no electric current is produced in the coil of wire when the magnet is held stationary in it.

When a bar magnet is moved quickly into a fixed coil of wire *AB*, then a current is produced in the coil. This current causes a deflection in the galvanometer pointer [see Figure 29(*a*)]. Similarly, when the magnet is moved out quickly from inside the coil, even then a current is produced in the coil [see Figure 29(*b*)]. This current also causes a deflection in the galvanometer pointer but in the opposite direction (showing that when the direction of movement of magnet changes, then the direction of current produced in the coil also changes). So, the current produced in this case is also alternating current or a.c.




(*a*) As a magnet is pushed into the fixed coil, a current is produced in the coil

(*b*) When the magnet is pulled out from the fixed coil, even then a current is produced in the coil (but in the opposite direction)

**Figure 29.** Another way of demonstrating electromagnetic induction. A current is induced in the coil when the magnet is moved in or out.

**The production of electric current by moving a magnet inside a fixed coil of wire is also a case of electromagnetic induction.** The concept of a fixed coil and a rotating magnet is used to produce electricity on large scale in big generators of power houses. Please note that **the condition necessary for the production of electric current by electromagnetic induction is that there must be a relative motion between the coil of wire and a magnet.** Out of the coil of wire and a magnet, one can remain fixed but the other has to rotate (or move).

After performing a large number of experiments, Faraday and Henry made the following observations about electromagnetic induction :

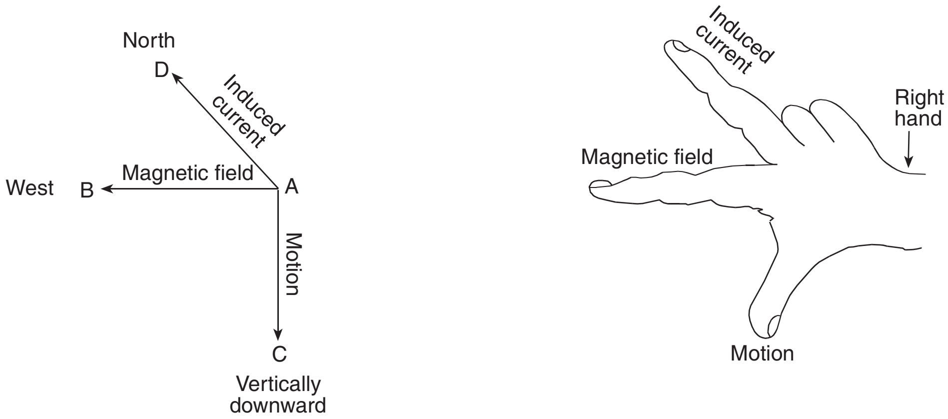
1. A current is induced in a coil when it is moved (or rotated) relative to a fixed magnet.
2. A current is also induced in a fixed coil when a magnet is moved (or rotated) relative to the fixed coil.
3. No current is induced in a coil when the coil and magnet both are stationary relative to one another.
4. When the direction of motion of coil (or magnet) is reversed, the direction of current induced in the coil also gets reversed.
5. The magnitude of current induced in the coil can be increased :
   (*a*) by winding the coil on a soft iron core,
   (*b*) by increasing the number of turns in the coil,
   (*c*) by increasing the strength of magnet, and
   (*d*) by increasing the speed of rotation of coil (or magnet).



## Fleming's Right-Hand Rule for the Direction of Induced Current

The direction of induced current produced in a straight conductor (or wire) moving in a magnetic field is given by Fleming's right-hand rule. According to Fleming's right-hand rule : **Hold the thumb, the forefinger and the centre finger of your right-hand at right angles to one another [as shown in Figure 30(*b*)]. Adjust your hand in such a way that forefinger points in the direction of magnetic field, and thumb points in the direction of motion of conductor, then the direction in which centre finger points, gives the direction of induced current in the conductor.**

Suppose the direction of magnetic field is directed from east to west as shown by arrow *AB* in Figure 30(*a*), and the direction of motion of conductor is vertically downwards, as shown by the arrow *AC* in Figure 30(*a*). Then to find out the direction of induced current in the conductor, we hold the thumb, the forefinger and centre finger of our right-hand mutually at right angles to one another. We adjust the right hand in such a way that the forefinger points from east to west (to represent the magnetic field), and the




(*a*) (*b*)

**Figure 30.** Diagrams to illustrate Fleming's right-hand rule for finding the direction of induced current in a conductor.

thumb points vertically downwards (to represent the direction of motion), then we will find that our centre finger points towards north [Figure 30(*b*)] and this gives the direction of induced current. Thus, the induced current in this case will be towards north as represented by arrow *AD* in Figure 30(*a*). Please note that Fleming's right-hand rule is also called dynamo rule.

## Direct Current and Alternating Current

Before we discuss the construction and working of an electric generator, it is necessary to know the meaning of direct current and alternating current. This is discussed below. **If the current flows in one direction only, it is called a direct current.** Direct current is written in short form as D.C. (or d.c.) The current which we get from a cell or a battery is direct current because it always flows in the same direction. The positive (+) and negative (–) polarity of a direct current is fixed. Some of the sources of direct current (or d.c.) are dry cell, dry cell battery, car battery and d.c. generator. **If the current reverses direction after equal intervals of time, it is called alternating current.** Alternating current is written in short form as A.C. (or a.c.). Most of the power stations in India generate alternating current. The alternating current produced in India reverses its direction every $\frac{1}{100}$ second. Thus, the positive (+) and negative (–) polarity of an alternating current is not fixed. Some of the sources which produce alternating current (or a.c.) are power house generators, car alternators and bicycle dynamos. An important advantage of alternating current (over direct current) is that **alternating current can be transmitted over long distances without much loss of**

(*a*) This is a very large power house generator. It produces alternating current (a.c.)

(*b*) Lamps and kettles can work with a.c. or d.c.

(*c*) Radios and televisions work only with d.c. (They have a device in them which converts a.c. supplied to them into d.c.).

**Figure 31.**

**electrical energy.** Both a.c. and d.c. can be used for lighting and heating purposes. But radios and televisions, etc., need a d.c. supply. The radios and televisions have a special device inside them which changes the a.c. supplied to them into d.c.

## ELECTRIC GENERATOR

The electric generator is a machine for producing electric current or electricity. **The electric generator converts mechanical energy into electrical energy.** A small generator is called a dynamo. For example, the small generator used on bicycles for lighting purposes is called a bicycle dynamo.

### Principle of Electric Generator

The electric generator is an application of electromagnetic induction. **The electric generator works on the principle that when a straight conductor is moved in a magnetic field, then current is induced in the conductor.** In an electric generator, a rectangular coil (having straight sides) is made to rotate rapidly in the magnetic field between the poles of a horseshoe-type magnet. When the coil rotates, it cuts the magnetic field lines due to which a current is produced in the coil.

Electric generators are of two types :

1. Alternating Current generator (A.C. generator), and
2. Direct Current generator (or D.C. generator).

Please note that A.C. generator is also written as a.c. generator and D.C. generator is also written as d.c. generator. We will now discuss both the types of electric generators, one by one. Let us start with the A.C. generator.

## A.C. GENERATOR

"A.C. generator" means "Alternating Current generator". That is, an A.C. generator produces alternating current, which reverses its direction continuously. A.C. generator is also known as an alternator. We will now describe the construction and working of an A.C. generator.

### Construction of an A.C. Generator

A simple A.C. generator consists of a rectangular coil *ABCD* which can be rotated rapidly between the poles N and S of a strong horseshoe-type permanent magnet *M* (see Figure 32). The coil is made of a large number of turns of insulated copper wire. The two ends *A* and *D* of the rectangular coil are connected to two circular pieces of copper metal called slip rings $R_1$ and $R_2$. As the slip rings $R_1$ and $R_2$ rotate with the coil, the two fixed pieces of carbon called carbon brushes, $B_1$ and $B_2$, keep contact with them. So, the current produced in the rotating coil can be tapped out through slip rings into the carbon brushes. The outer ends of carbon brushes are connected to a galvanometer to show the flow of current in the external circuit (which is produced by the generator).

### Working of an A.C. generator

Suppose that the generator coil *ABCD* is initially in the horizontal position (as shown in Figure 32). Again suppose that the coil *ABCD* is being rotated in the anticlockwise direction between the poles N and S of a horseshoe-type magnet by rotating its shaft.

(*i*) As the coil rotates in the anticlockwise direction, the side *AB* of the coil moves down cutting the magnetic field lines near the N-pole of the magnet, and side *CD* moves up, cutting the magnetic field lines near the S-pole of the magnet (see Figure 32). Due to this, induced current is produced in the sides *AB* and *CD* of the coil. On applying Fleming's right-hand rule to the sides *AB* and *CD* of the coil, we find that the currents are in the directions *B* to *A* and *D* to *C*. Thus, the induced currents in the two sides of the coil are in the same direction, and we get an effective induced current in the direction *BADC* (see Figure 32). Thus, in the first half revolution (or rotation) of coil, the current in the external circuit flows from brush $B_1$ to $B_2$.

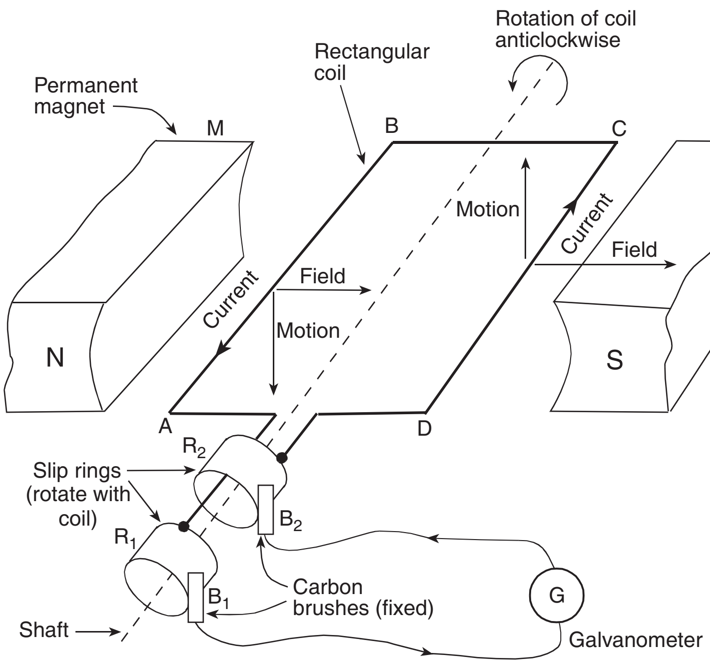



**Figure 32.** A.C. generator.

(*ii*) After half revolution, the sides *AB* and *CD* of the coil will interchange their positions. The side *AB* will come on the right hand side and side *CD* will come on the left side. So, after half a revolution, side *AB* starts moving up and side *CD* starts moving down. As a result of this, the direction of induced current in each side of the coil is reversed after half a revolution giving rise to the net induced current in the direction *CDAB* (of the reversed coil). The current in the external circuit now flows from brush $B_2$ to $B_1$.

Since the direction of induced current in the coil is reversed after half revolution so the polarity (positive and negative) of the two ends of the coil also changes after half revolution. The end of coil which was positive in the first half of revolution becomes negative in the second half. And the end which was negative in the first half revolution becomes positive in the second half of revolution. Thus, in 1 revolution of the coil, the current reverses its direction 2 times. In this way alternating current is produced in this generator.

**The alternating current (A.C.) produced in India has a frequency of 50 Hz.** That is, the coil is rotated at the rate of 50 revolutions per second. Since in 1 revolution of coil, the current reverses its direction 2 times, so in 50 revolutions of coil, the current reverses its direction $2 \times 50 = 100$ times. Thus, the A.C. supply in India reverses its direction 100 times in 1 second. Another way of saying this is that the alternating current produced in India reverses its direction every $\frac{1}{100}$ second. That is, each terminal of the coil is positive (+) for $\frac{1}{100}$ of a second and negative (–) for the next $\frac{1}{100}$ of a second. This process is repeated again and again with the result that there is actually no positive and negative in an A.C. generator.

**A.C. generators are used in power stations to generate electricity** which is supplied to our homes. These days most of the cars are fitted with small A.C. generators commonly known as alternators. The bicycle dynamos are very small A.C. generators.

We have just described a simple A.C. generator. In practical generators, the voltage (and the current) produced can be increased :

(*a*) by using a powerful electromagnet to make the magnetic field stronger in place of a permanent magnet.

(*b*) by winding the coil round a soft iron core to increase the strength of magnetic field.

(*c*) by using a coil with more turns.

(*d*) by rotating the coil faster.

(*e*) by using a coil with a larger area.

In power stations, huge A.C. generators (or alternators) are used to generate current for the A.C. mains which is supplied to homes, transport and industry. **The power house A.C. generators have a fixed set of coils arranged around a rotating electromagnet** (see Figure 33). Thus, in large power house generators, the *coils are stationary* and the *electromagnet rotates.* The big coils of a power house generator are kept stationary because they are very heavy and hence difficult to rotate. The electromagnet can, however, be rotated more easily. The shaft of electromagnet of a generator is connected to a turbine. When the turbine is turned by fast flowing water (or pressure of steam), then the electromagnet turns inside the coils and generator produces electricity.

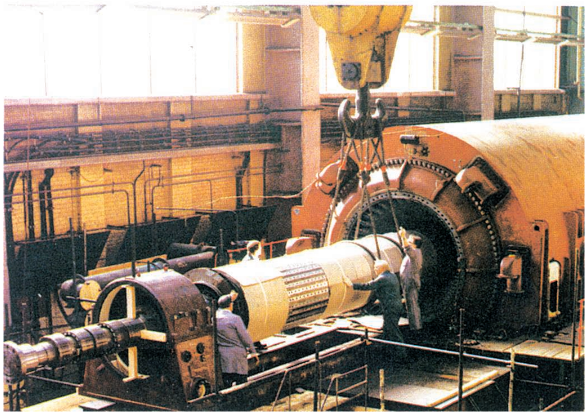


**Figure 33.** This power house generator produces electricity by rotating an electromagnet inside fixed coils of wire.

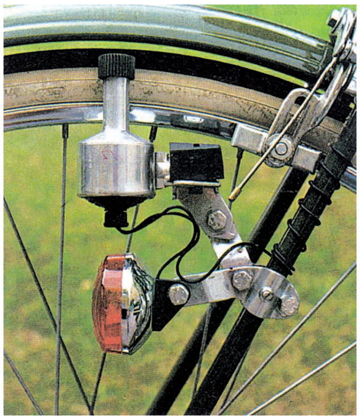


**Figure 34.** The bicycle dynamo in this picture also uses a rotating magnet inside a fixed coil of wire.

At Hydroelectric Power House, the generator is driven by the power of fast flowing water released from a dam across a river. In Thermal Power House, the generator is driven by the power of high pressure steam. The heat energy for making steam from water comes from burning coal, natural gas or oil. At Nuclear Power House, the heat energy for making steam comes from nuclear reactions taking place inside the nuclear reactor. The high pressure steam turns a turbine. The turbine turns the generator. And the generator converts mechanical energy (or kinetic energy) into electrical energy (or electricity). This electricity is then supplied to our homes.

## D.C. GENERATOR

We have just studied an A.C. generator which produces alternating current. In order to obtain direct current (which flows in one direction only), a D.C. generator is used. Actually, **if we replace the slip rings of an A.C. generator by a commutator, then it will become a D.C. generator.** Thus, in a D.C. generator, a split ring type commutator is used (like the one used in an electric motor). When the two half rings of commutator are connected to the two ends of the generator coil, then one carbon brush is at all times in contact with the coil arm moving down in the magnetic field while the other carbon brush always remains in contact with the coil arm moving up in the magnetic field. Due to this, the current in outer circuit always flows in one direction. So, it is direct current. A diagram of D.C. generator is given in Figure 35.

We can see from Figure 35 that *the only difference between a D.C. generator and an A.C. generator is in the way the two ends of the generator coil are linked to the outer circuit.* In a D.C. generator we connect the two ends of the coil to a *commutator* consisting of two half rings of copper. On the other hand, in an A.C. generator, we connect the two ends of the coil to two full rings of copper called *slip rings*. There is no commutator in an A.C. generator

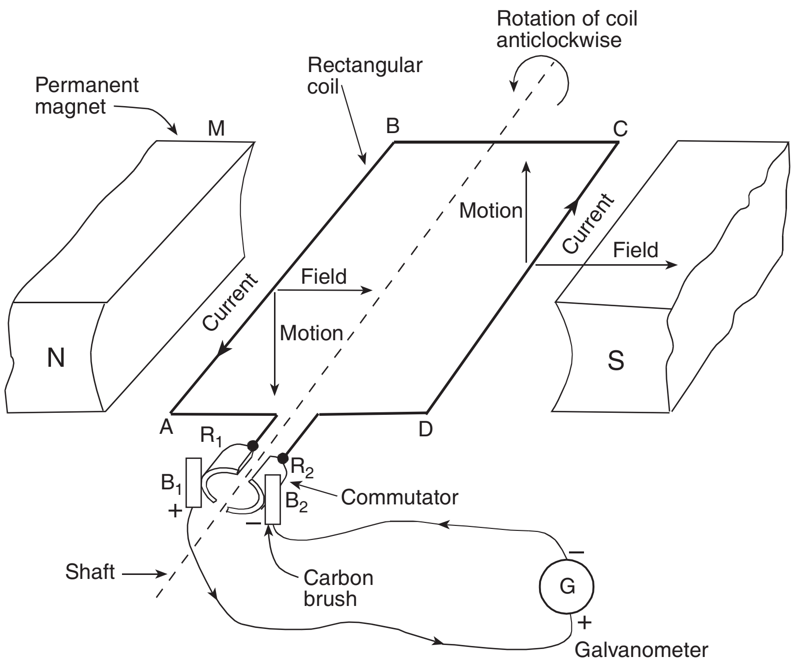



**Figure 35.** D.C. generator.



## Electromagnetic Induction Using Two Coils

So far we have learnt that electromagnetic induction can be brought about by moving a straight wire between the poles of a U-shaped magnet or by moving a bar magnet in a circular coil of wire. We will now study that electromagnetic induction can also be produced by using two coils. This is because **if current is changed in one coil, then current is induced in the other coil kept near it.** No relative motion of the coils is needed in this case. This will become more clear from the following discussion.

Two circular coils *A* and *B* are placed side by side, close to each other (see Figure 36). Coil *A* is connected to a battery and a switch *S* whereas coil *B* is connected to a galvanometer *G*.

(*i*) Let us pass current in coil *A* by pressing the switch. As soon as we pass current in coil *A*, the pointer of galvanometer attached to coil *B* shows a deflection, but quickly returns to zero position. This means that on switching on the current in coil *A*, an electric current is induced in coil *B* momentarily. If the current is now kept 'on' in coil *A*, nothing happens in the galvanometer of coil *B*.

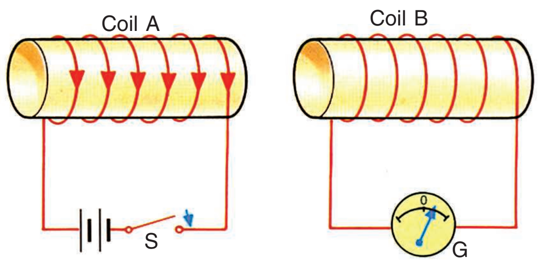



**Figure 36.** When the current in coil *A* is changed then a current is induced in coil *B*.

(*ii*) Let us now switch off the current in coil *A*. As soon as we switch off the current in coil *A*, the pointer of galvanometer attached to coil *B* again shows a momentary deflection, but on the opposite side. This means that on switching off current in coil *A*, an electric current is induced in coil *B* but in a direction opposite to that when the current was switched on.

(*iii*) If we keep on switching the current 'on and off' in coil *A* rapidly, then the galvanometer pointer will keep moving on both the sides of zero mark continuously, showing that a continuous current is induced in coil *B*. Since the current induced in coil *B* changes direction continuously, so it is an alternating current (or a.c.).

From this discussion we conclude that whenever the current in coil *A* is changing (starting or stopping) then an electric current is induced in the nearby coil *B*. Coil *A* which causes induction is called *primary* coil whereas coil *B* in which current is induced is known as *secondary* coil. A current is induced here even though the coils are *not moving* relative to each other. **We will now explain why a change in current in coil *A* induces current in coil *B*.**

(*i*) When we switch on current in coil *A*, it becomes an electromagnet and produces a magnetic field around coil *B*. The effect is just the same as pushing a magnet into coil *B*. So, an induced current flows in coil *B* for a moment. When the current in coil *A* becomes steady, its magnetic field also becomes steady and the current in coil *B* stops.

(*ii*) When we switch off the current in coil *A*, its magnetic field in coil *B* stops quickly. This effect is just the same as pulling a magnet quickly out of coil *B*. So, an induced current flows in coil *B* in the opposite direction.

Thus, the current is induced in coil *B* by the changing magnetic field in it when the current in coil *A* is 'switched on' or 'switched off'.

If the coil *A* is connected to alternating current (which keeps on changing), then a constant current will be induced in coil *B* whose magnitude will depend on the relative number of turns of wire in coil *A* and coil *B*. This fact is used in making transformers for stepping up (increasing) or stepping down (decreasing) the voltage of alternating current. These transformers are used at power stations and in a variety of electronic appliances such as radio sets and T.V. sets, etc. Let us solve some problems now.

**Sample Problem 1.** A coil of insulated copper wire is connected to a galvanometer. What will happen if a bar magnet is :

(*i*) pushed into the coil ?

(*ii*) held stationary inside the coil ?

(*iii*) withdrawn from inside the coil ? **(NCERT Book Question)**

**Solution.** (*i*) As a bar magnet is pushed into the coil, a momentary deflection is observed in the galvanometer indicating the production of a momentary current in the coil.

(*ii*) When the bar magnet is held stationary inside the coil, there is no deflection in galvanometer indicating that no current is produced in the coil.

(*iii*) When the bar magnet is withdrawn (or pulled out) from the coil, the deflection of galvanometer is in opposite direction showing the production of an opposite current.

**Sample Problem 2.** Explain why, the direction of induced current in the coil of an A.C. generator changes after every half revolution of the coil.

**Solution.** After every half revolution, each side of the generator coil starts moving in the opposite direction in the magnetic field. The side of the coil which was initially moving downwards in the magnetic field, after half revolution, it starts moving in opposite direction – upwards. Similarly, the side of coil which was initially moving upwards, after half revolution, it starts moving downwards. *Due to the change in the direction of motion of the two sides of the coil in the magnetic field after every half revolution, the direction of current produced in them also changes after every half revolution.*

Before we go further and describe the household electric circuits or domestic wiring, **please answer the following questions :**

### Very Short Answer Type Questions

**1.** Name the device which converts mechanical energy into electric energy.

**2.** Out of an A.C. generator and a D.C. generator :

(*a*) which one uses a commutator (split rings) ?

(*b*) which one uses slip rings ?

**3.** Name the phenomenon which is made use of in an electric generator.

**4.** Name the rule which gives the direction of induced current.

**5.** What condition is necessary for the production of current by electromagnetic induction ?

**6.** What type of generator is used at Power Stations ?

**7.** What change should be made in an a.c. generator so that it may become a d.c. generator ?

**8.** State whether the following statements are true or false :

(*a*) A generator works on the principle of electromagnetic induction.

(*b*) A motor works on the principle of electromagnetic induction.

**9.** What is the function of brushes in an electric generator ?

**10.** When a wire is moved up and down in a magnetic field, a current is induced in the wire. What is this phenomenon known as ?

**11.** When current is 'switched on' and 'switched off' in a coil, a current is induced in another coil kept near it. What is this phenomenon known as ?

**12.** What is the major difference between the simple alternator and most practical alternators ?

**13.** Why are Thermal Power Stations usually located near a river ?

**14.** List three sources of magnetic fields.

**15.** Complete the following sentence :

A generator with commutator produces...........current.

## Short Answer Type Questions

**16.** Two circular coils A and B are placed close to each other. If the current in coil A is changed, will some current be induced in the coil B ? Give reason for your answer.

**17.** (*a*) Explain the principle of an electric generator.

(*b*) State two ways in which the current induced in the coil of a generator could be increased.

**18.** (*a*) What is the difference between alternating current and direct current ?

(*b*) What type of current is given by (*i*) a dry cell, and (*ii*) a Power House generator ?

**19.** State and explain Fleming's right hand rule.

**20.** Name and state the rule to find the direction of :

(*a*) current induced in a coil due to its rotation in a magnetic field.

(*b*) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it.

**21.** (*a*) In what respect does the construction of an A.C. generator differ from that of a D.C. generator ?

(*b*) What normally drives the alternators in a Thermal Power Station ? What fuels can be used to heat water in the boiler ?

## Long Answer Type Questions

**22.** Draw the labelled diagram of an A.C. generator. With the help of this diagram, explain the construction and working of an A.C. generator.

**23.** (*a*) What do you understand by the term "electromagnetic induction"? Explain with the help of a diagram.

(*b*) Name one device which works on the phenomenon of electromagnetic induction.

(*c*) Describe different ways to induce current in a coil of wire.

**24.** (*a*) What do you understand by the terms 'direct current' and 'alternating current' ?

(*b*) Name some sources of direct current and some of alternating current.

(*c*) State an important advantage of alternating current over direct current.

(*d*) What is the frequency of A.C. supply in India ?

## Multiple Choice Questions (MCQs)

**25.** A rectangular coil of copper wire is rotated in a magnetic field. The direction of induced current changes once in each :

(*a*) two revolutions (*b*) one revolution

(*c*) half revolution (*d*) one-fourth revolution

**26.** The phenomenon of electromagnetic induction is :

(*a*) the process of charging a body.

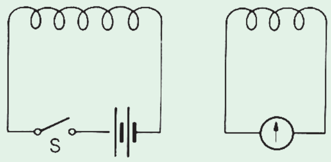
(*b*) the process of generating magnetic field due to a current passing through a coil.

(*c*) producing induced current in a coil due to relative motion between a magnet and the coil.
(*d*) the process of rotating a coil of an electric motor.

**27.** The device used for producing electric current is called a :
(*a*) generator (*b*) galvanometer (*c*) ammeter (*d*) motor

**28.** The essential difference between an AC generator and a DC generator is that :
(*a*) AC generator has an electromagnet while a DC generator has permanent magnet.
(*b*) DC generator will generate a higher voltage.
(*c*) AC generator will generate a higher voltage.
(*d*) AC generator has slip rings while the DC generator has a commutator.

**29.** When the switch S is closed in the figure given below, the pointer of the galvanometer moves to the right.




If S is kept closed, will the pointer :
(*a*) return to zero ?
(*b*) stay over on the right ?
(*c*) move to the left and stay there
(*d*) move to and fro until S is opened

**30.** Each one of the following changes will increase emf (or voltage) in a simple generator except :
(*a*) increasing the number of turns in the armature coil
(*b*) winding the coil on a soft iron armature
(*c*) increasing the size of the gap in which the armature turns
(*d*) increasing the speed of rotation

**31.** The north pole of a long bar magnet was pushed slowly into a short solenoid connected to a galvanometer. The magnet was held stationary for a few seconds with the north pole in the middle of the solenoid and then withdrawn rapidly. The maximum deflection of the galvanometer was observed when the magnet was :
(*a*) moving towards the solenoid (*b*) moving into solenoid
(*c*) at rest inside the solenoid (*d*) moving out of the solenoid

**32.** An electric generator converts :
(*a*) electrical energy into mechanical energy
(*b*) mechanical energy into heat energy
(*c*) electrical energy into chemical energy
(*d*) mechanical energy into electrical energy.

**33.** A d.c. generator is based on the principle of :
(*a*) electrochemical induction (*b*) electromagnetic induction
(*c*) magnetic effect of current (*d*) heating effect of current

**34.** An induced current is produced when a magnet is moved into a coil. The magnitude of induced current does not depend on :
(*a*) the speed with which the magnet is moved
(*b*) the number of turns of the coil
(*c*) the resistivity of the wire of the coil
(*d*) the strength of the magnet

**35.** The frequency of direct current (d.c.) is :
(*a*) 0 Hz (*b*) 50 Hz (*c*) 60 Hz (*d*) 100 Hz

**36.** The frequency of alternating current (a.c.) supply in India is :
(*a*) 0 Hz (*b*) 50 Hz (*c*) 60 Hz (*d*) 100 Hz

## Questions Based on High Order Thinking Skills (HOTS)

**37.** A coil is connected to a galvanometer. When the N-pole of a magnet is pushed into the coil, the galvanometer deflected to the right. What deflection, if any, is observed when :

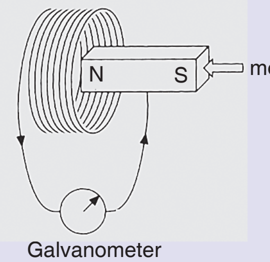
(*a*) the N-pole is removed ?

(*b*) the S-pole is inserted ?

(*c*) the magnet is at rest in the coil ?

State three ways of increasing the deflection on the galvanometer.

**38.** When the magnet shown in the diagram below is moving towards the coil, the galvanometer gives a reading to the right.



Galvanometer

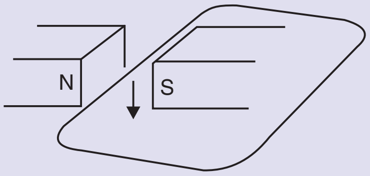
(*i*) What is the name of the effect being produced by the moving magnet ?

(*ii*) State what happens to the reading shown on the galvanometer when the magnet is moving away from the coil.

(*iii*) The original experiment is repeated. This time the magnet is moved towards the coil at a great speed. State two changes you would notice in the reading on the galvanometer.

**39.** If you hold a coil of wire next to a magnet, no current will flow in the coil. What else is needed to induce a current ?

**40.** The wire in Figure below is being moved downwards through the magnetic field so as to produce induced current.




What would be the effect of :

(*a*) moving the wire at a higher speed ?

(*b*) moving the wire upwards rather than downwards ?

(*c*) using a stronger magnet ?

(*d*) holding the wire still in the magnetic field ?

(*e*) moving the wire parallel to the magnetic field lines ?

**41.** Two coils A and B of insulated wire are kept close to each other. Coil A is connected to a galvanometer while coil B is connected to a battery through a key. What would happen if :

(*i*) a current is passed through coil B by plugging the key ?

(*ii*) the current is stopped by removing the plug from the key ?

Explain your answer mentioning the name of the phenomenon involved.

**42.** A portable radio has a built-in transformer so that it can work from the mains instead of batteries. Is this a step-up or step down transformer ?

## ANSWERS

**1.** Electric generator **2.** (*a*) D.C. generator (*b*) A.C. generator **3.** Electromagnetic induction **4.** Fleming's right-hand rule **6.** A.C. generator (or Alternator) **8.** (*a*) True (*b*) False **10.** Electromagnetic induction **11.** Electromagnetic induction **12.** Simple alternator : Magnet fixed and coil rotates ; Practical alternator : Coil fixed and magnet rotates **13.** To obtain water for making steam for turning turbines and for cooling spent steam to condense it back into hot water for making fresh steam

**14.** Permanent magnets ; Electromagnets ; Conductors carrying current (such as straight wire, circular coil and solenoid carrying current) **15.** direct **20.** (*a*) Fleming's right-hand rule (*b*) Fleming's left-hand rule **21.** (*b*) High pressure steam ; Coal ; Natural gas ; Oil **23.** (*b*) Electric generator **25.** (*c*) **26.** (*c*) **27.** (*a*) **28.** (*d*) **29.** (*a*) **30.** (*c*) **31.** (*d*) **32.** (*d*) **33.** (*b*) **34.** (*c*) **35.** (*a*) **36.** (*b*) **37.** (*a*) The galvanometer is deflected to the left (*b*) The galvanometer is deflected to the left (*c*) No deflection in galvanometer ; Increase the number of turns in the coil ; Use a stronger magnet ; Increase the speed with which magnet is pushed into the coil (or removed) **38.** (*i*) Electromagnetic induction (*ii*) Deflected to left (*iii*) Large deflection to right occurs more quickly **39.** Motion of the magnet into the coil (and out of the coil) **40.** (*a*) Current increased (*b*) Current reversed (*c*) Current increased (*d*) Current zero (*e*) Current zero **41.** (*i*) Galvanometer pointer moves to one side showing that a current is induced in the coil (*b*) Galvanometer pointer moves to the other side showing that the direction of induced current has been reversed ; Electromagnetic induction **42.** Step-down transformer (which reduces the voltage)

## DOMESTIC ELECTRIC CIRCUITS (OR DOMESTIC WIRING)

Electricity is generated at the power station. It is brought to our homes by two thick copper wires or aluminium wires fixed over tall electric poles (or by underground cables). From the electric pole situated in our street, two insulated wires *L* and *N* come to our house (see Figure 37). One of these wires is called *live wire* (read as *laa-ive* wire) and it is at a high potential of 220 volts whereas the other wire is called *neutral wire* and it is at the ground potential of zero volt. Thus, the potential difference between the live wire and the neutral wire in India is 220 – 0 = 220 volts. In Figure 37, *L* is the live wire and *N* is the neutral wire. The live wire has red insulation covering whereas neutral wire has black insulation covering. There is no harm if we touch the neutral wire but we will get an electric shock if, by chance, we touch the live wire.

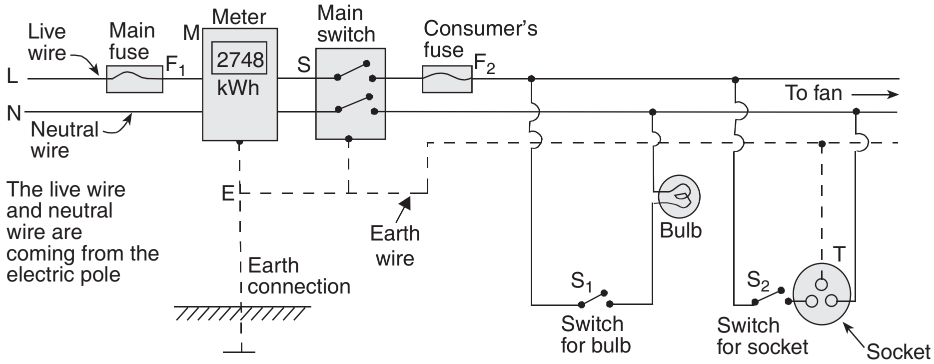



**Figure 37.** Diagram to show domestic electric wiring from electric pole to a room (In this diagram we have shown the wiring for an electric bulb and a three-pin socket only).

The two insulated wires *L* and *N*, coming from the electric pole, enter a box fitted just inside our house. In this box, a main fuse $F_1$ is put in the live wire. This fuse has a high rating of about 50 amperes. The two line wires then enter the electricity meter *M* which records the electrical energy consumed by us in the units of kilowatt-hours. The main fuse and the meter are both installed by the Electric Supply Department of our City.

The two wires coming out of the meter are connected to a main switch *S*. This main switch is to switch off the electricity supply when required so as to repair any faults in the internal wiring. After the main switch, there is another fuse $F_2$ in the live wire. This is called consumer's fuse. It is very important to note here that **usually there are two separate circuits in a house, the lighting circuit with a 5 A fuse and the power circuit with a 15 A fuse.** The lighting circuit is for running low power-rating devices such as electric bulbs, tube-lights, fans, radio, and TV, etc., which draw *small* current. On the other hand, power circuit is for running high power-rating devices such as electric iron, room heater, geyser, electric stove, refrigerator, etc., which draw *heavy* current. But to make things simple, we will describe only a lighting circuit with a 5 ampere fuse. **Each distribution circuit is provided with a separate fuse so that if a fault like short-circuiting occurs in one circuit, its corresponding fuse blows off but the other circuit remains unaffected.** Another point to remember is that the **various distribution circuits are connected in parallel** so that if a fault occurs in one circuit, its fuse will melt leaving the other circuit in operation. For example, the lighting circuit and power circuit in our home are in *parallel* so that if a short-circuit occurs in, say the power circuit, then the power-fuse will blow off but our lights will not go off because our lighting circuit will keep working.

Before we describe the wiring of our rooms, it is very important to note here that alongwith the live wire and the neutral wire, a third wire called earth wire also goes into our rooms. In Figure 37, the earth wire $E$ has been shown by dotted line. One end of the earth wire $E$ is connected to a copper plate and buried deep under the earth near the house (as shown in Figure 37) or at the nearest electric sub-station. The earth connection is first made to the electric meter and then to the main switch. This earth wire then goes into our room alongwith the live wire and the neutral wire. Please note that the earth wire up to the main switch of our house is usually an uncovered, thick copper wire having no plastic insulation over it. But the earth wire which goes from the main switch into our rooms is a copper wire having green insulation covering over it. Thus, **in order to distinguish between the live wire, neutral wire and earth wire, the wire having red plastic covering is made live wire, the wire having black plastic covering is made neutral wire, and the wire having green plastic covering is made earth wire.**

Now, three wires, live wire, neutral wire and the earth wire enter our room where we have to use an electric bulb, a fan and a three-pin socket for radio, and TV etc. We will now describe the internal wiring of a room. In a room, **all the electrical appliances like bulbs, fans and sockets, etc., are connected in parallel across the live wire and the neutral wire.** The main **advantage** of the parallel connection is that if one of the appliances is switched off, or gets fused, there is no effect on the other appliances and they keep on operating. Another **advantage** of the parallel circuits is that the same voltage of the mains line is available for all the electrical appliances. If, however, we connect the various electric bulbs in series, then if one bulb is switched off or gets fused then all other bulbs will also stop working because their electricity supply will be cut off. On the other hand, if the bulbs are connected in parallel, then switching on or off in a room has no effect on other bulbs in the same building. Moreover, if the various electric bulbs are connected in series, they will not get the same voltage (220 V) of the mains line. The bulbs connected in series will get lower voltage (than 220 V) and hence glow less brightly. All the bulbs connected in parallel will, however, get the same voltage (220 V) and hence glow brightly.

First of all we will describe the wiring for an electric bulb. One end of the bulb-holder is connected to the live wire through a switch $S_1$ and the other end of the bulb-holder is connected to the neutral wire (see Figure 37). When we press the switch $S_1$, the circuit for bulb gets completed and it lights up. We will now describe the wiring for a three-pin socket. One of the lower terminals of the socket $T$ is connected to the live wire through a switch $S_2$ and the second lower terminal is connected to the neutral wire. The upper terminal of the socket is connected to the earth wire (see Figure 37). Let us now describe the wiring for a fan. The live wire is connected to one terminal of the fan through a switch and a regulator. The neutral wire is connected to the other terminal of the fan. We have not shown the wiring for a fan in Figure 37. Please do it yourself.

It is obvious from the circuit given in Figure 37 that **all the electrical appliances are provided with separate switches.** It should be noted that **all the switches are put in the live wire,** so that when we switch off an electrical appliance (like an electric iron), then its connection with the live wire is cut off and there will be no danger of an electric shock if we touch the metal case of the electrical appliance. If , however, we put switches in the neutral wire, then the live wire will be in connection with the electrical appliance even when the switch is in the off position, and there is a danger of an electric shock.

## Earthing of Electrical Appliances

Sometime or the other we have received an electric shock from an electric iron or a room cooler. We will now discuss why we get the electric shock and how it can be prevented. In order to work an electrical appliance like an electric iron, electric kettle or a room cooler, we need two wires of the supply line, the live wire and the neutral wire. Sometimes, due to wear and tear or due to excessive heating, the plastic covering (or insulation) of the connecting wires gets removed or gets burnt and the live wire (which is at a high potential of 220 volts) becomes naked. This naked live wire may touch the metal case (or metal body) of the electrical appliance due to which the case becomes *live* and comes to the high voltage of 220 volts. If we happen to touch any part of this live appliance, a very high current flows through our body into the earth. Due to this high current flowing through our body, we get an electric shock (see Figure 38). It has been found that we do not get an electric shock if we are standing on a *wooden* plank. This is due to the fact that wood acts as an insulator and the circuit of current with earth does not get completed through our body.

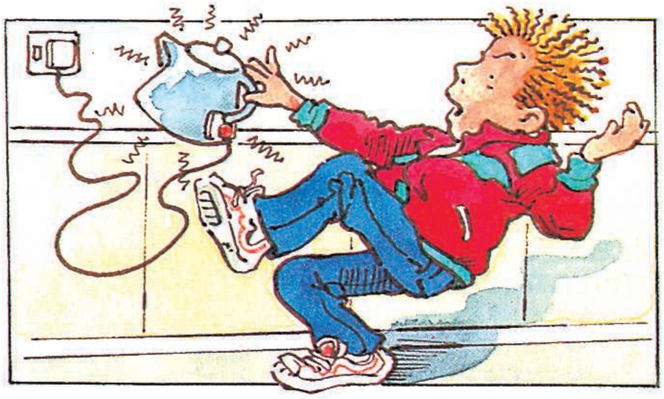


**Figure 38.** This electric kettle does not have a proper earth connection to its metal case. So, when touched, it gives an electric shock.

**To avoid the risk of electric shocks, the metal body of an electrical appliance is "earthed".** Earthing means to connect the metal case of electrical appliance to the earth (at zero potential) by means of a metal wire called "earth wire". In household circuits, we have three wires, the live wire, the neutral wire and the earth wire. One end of the earth wire is buried in the earth. We connect the earth wire to the metal case of the electrical appliance by using a three-pin plug. The metal casing of the appliance will now always remain at the zero potential of the earth. We say that the appliance has been earthed or grounded. Let us make it more clear with the help of a diagram. Figure 39 shows the earthing of an electric iron or press.

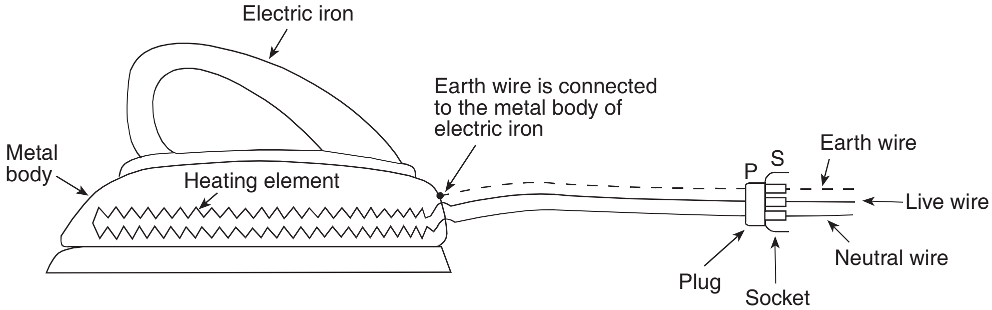



**Figure 39.** Diagram to show the connection of "earth wire" in an electric iron.

In Figure 39, the live wire and the neutral wire are connected to the two ends of the heating element whereas the earth wire is connected to the metal body of the electric iron. These three wires are connected to a three-pin plug *P*. The plug *P* is connected to a three-pin socket *S*. Let us see how the earth connection actually works.

If, by chance, the live wire touches the metal case of the electric iron (or any other appliance), which has been earthed, then the current passes directly to the earth through the earth wire. It does not need our body to pass the current and, therefore, we do not get an electric shock. Actually, a very heavy current flows through the earth wire and the fuse of household wiring blows out or melts. And it cuts off the power supply. In this way, earthing also saves the electrical appliance from damage due to excessive current. From the above discussion we conclude that **we earth the metallic body of an electrical appliance to save ourselves from electric shocks.** Thus, the earthing of electrical appliances is used as a safety measure. It should be noted that we give earth connections to only those electrical appliances which have metallic body, which draw heavy current, and which we are liable to touch. For example, electric iron, electric heater, room cooler and refrigerator, are all provided with earth connections. We, however, do not do earthing of an electric bulb or a tube-light because we hardly touch them when they are on. The metal casings of the switches are, however, earthed.

It should be noted that the connecting cable of an electrical appliance like an electric iron, electric kettle, water heater, room cooler or refrigerator contains three insulated copper wires of three different colours : red, black and green. **The red coloured wire is the live wire, the black wire is the neutral wire, whereas green wire is the earth wire** (see Figure 40).

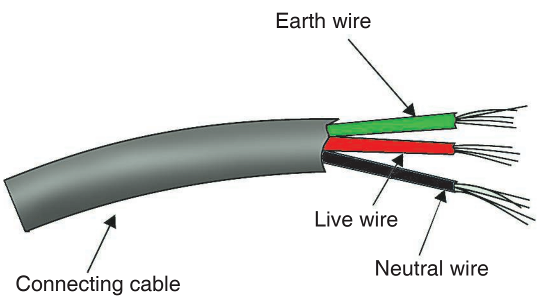



**Figure 40.** A three core connecting cable has three insulated copper wires in it. The red coloured wire is the live wire, the black wire is the neutral wire, whereas the green wire is the earth wire.

## Electric Fuse

The electric wires used in domestic wiring are made of copper metal because copper is a good conductor of electricity having very low resistance. Now, the copper wires chosen for household wiring are of such thickness so as to allow a certain maximum current to pass through them. If the current passing through wires exceeds this maximum value, the copper wires get over-heated and may even cause a fire. **An extremely large current can flow in domestic wiring under two circumstances : short circuiting and overloading.**

(*i*) **Short Circuiting.** If the plastic insulation of the live wire and neutral wire gets torn, then the two wires touch each other (see Figure 41). This **touching of the live wire and neutral wire directly is known as short circuit.** When the two wires touch each other, the resistance of the circuit so formed is very, very small. Since the resistance is very small, the current flowing through the wires becomes very large and heats the wires to a dangerously high temperature, and a fire may be started.

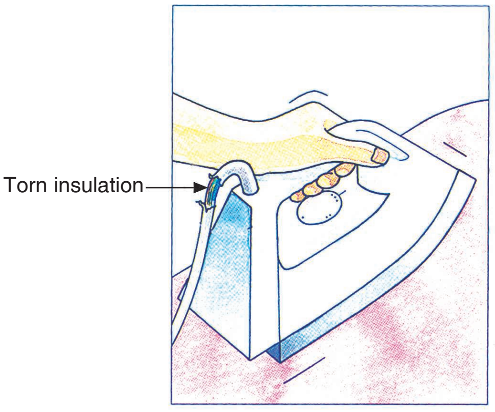



**Figure 41.** The insulation of connecting cable of this electric iron is getting torn. An electric short circuit is waiting to happen.

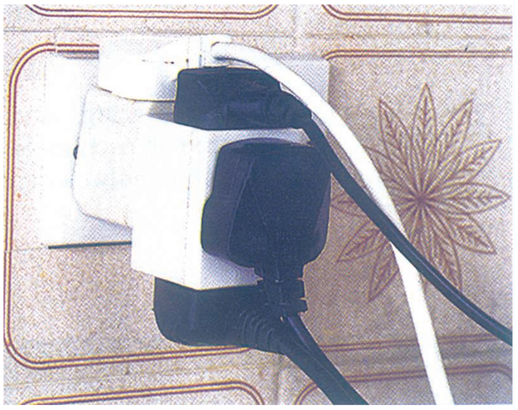


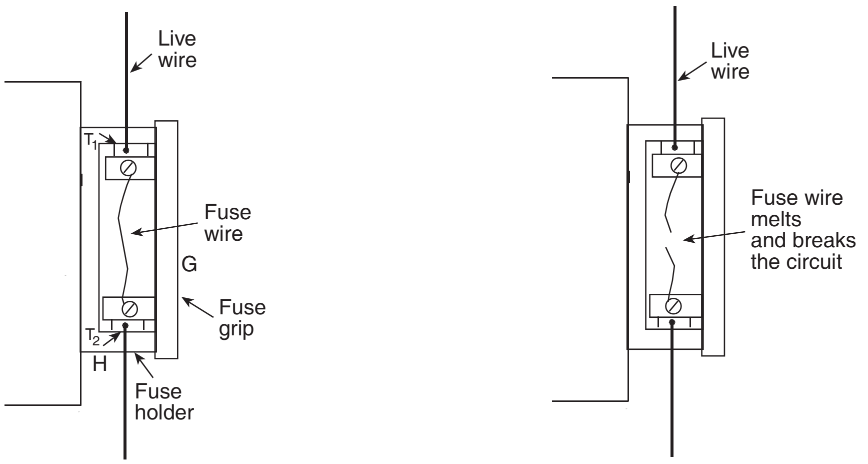
**Figure 42.** Too many appliances connected to a single socket. A case of overloading.

(*ii*) **Overloading.** The current flowing in domestic wiring at a particular time depends on the power ratings of the appliances being used. If too many electrical appliances of high power rating (like electric iron, water heater, air conditioner, etc.,) are switched on at the same time, they draw an extremely large current from the circuit. This is known as overloading the circuit. Overloading can also occur if too many appliances are connected to a single socket (see Figure 42). Now, due to an extremely large current flowing through them, the copper wires of household wiring get heated to a very high temperature and a fire may be started.

It is obvious that we should have some device which may disconnect the electricity supply when a short circuit or overloading occurs so that the electric fires are prevented in our homes. To avoid this danger of electric fires we use an electric fuse in the wiring. So, **when a building is wired, the wiring is protected by fuses**. We will now describe what a fuse is and how it works.

**A fuse is a safety device having a short length of a thin, tin-plated copper wire having low melting point, which melts and breaks the circuit if the current exceeds a safe value.** The thickness and length of the fuse wire depends on the maximum current allowed through the circuit. **An electric fuse works on the heating effect of current.** The fuse for protecting our domestic wiring is fitted just above our main switch on the switch board. **A fuse wire is connected in series in the electric circuits.**

The main fuse in domestic wiring consists of a porcelain fuse holder *H* having two brass terminals $T_1$ and $T_2$ in it [see Figure 43(*a*)]. This is connected in the live wire. The other part of the fuse is a removable fuse grip *G* which is also made of porcelain. The fuse grip has a fuse wire fixed in it. When fuse grip is inserted in the fuse holder as shown in Figure 43(*a*), then the circuit of our domestic wiring is completed. So, under normal circumstances when the current is within limit, the fuse wire is intact and electric current is available in our wiring.




(*a*) Under normal circumstances the fuse wire is intact and hence current flows in the circuit

(*b*) When excessive current flows in the circuit, the fuse wire gets heated too much, melts and breaks the circuit

**Figure 43.** Electric fuse.

When a short circuit takes place, or when overloading takes place, the current becomes large and heats the fuse wire too much. Since the melting point of fuse wire is much lower than copper wires, the fuse wire melts and breaks the circuit as shown in Figure 43(*b*). When the fuse wire breaks, electricity supply is automatically switched off before any damage can be done to the rest of the wiring (or the electrical appliances being used).

We will now give some important points about the fuse wire to be used in electrical circuits. First of all we should know why we use a *thin wire* as a fuse wire and not a *thick wire*. We use a thin wire in a fuse because it has a much greater resistance than the rest of connecting wires. Due to its high resistance, the heating effect of current will be much more in the fuse wire than anywhere else in the circuit. This will melt the fuse wire whereas other wiring will remain safe. We should not use a thick wire as a fuse wire because it will have a low resistance and hence it will not get heated to its melting point easily. The fuse wire is usually made from tin-plated copper wire having low melting point so that it may melt easily. **A pure copper wire cannot be used as a fuse wire** because it has a high melting point due to which it will not melt easily when a short circuit takes place.

**The fuse wire must have proper thickness which depends on the maximum current which the household wiring can safely carry.** The thickness of the fuse wire should be such that it is able to withstand only a little more current than drawn by the household circuit. Fuse wires are rated as 1 A, 2 A, 3 A, 5 A, 10 A, 13 A, 15 A, and so on. It is clear that a "10 ampere" fuse wire will be thicker than a "5 ampere" fuse wire. The fuse in the lighting and fans circuit of a small house is of 5 amperes rating which means that the fuse wire will melt if the current exceeds 5 amperes value. The fuse used in the power circuit of a small house for running electric iron, immersion heater, geyser and toaster, etc., having power of 1000 watts or more is of 15 A capacity. A blown fuse should be replaced only after the cause of excessive current flow has been found and removed. These days more and more houses are using 'Miniature Circuit Breakers' (MCBs) to protect the household wiring from the excessive flow of electric current through it (see Figure 44). If the current becomes too large, the miniature circuit breaker puts off a switch cutting off the electric supply. The MCB can be re-set when the fault has been corrected. Miniature circuit beaker (MCB) contains an electromagnet which, when the current exceeds the rated value of circuit breaker, becomes strong enough to separate a pair of contacts (by putting off a switch) and breaks the circuit. So, unlike fuses, MCBs do not work on heating effect of current. MCBs work on the magnetic effect of current.

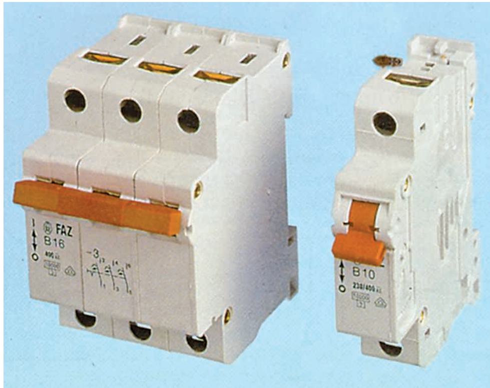
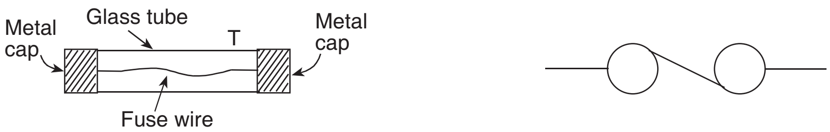


**Figure 44.** Miniature Circuit Breakers (MCBs) are now used in domestic wiring instead of fuses.

So far we have discussed the fuses which are put on the main switch-board in our houses to protect the whole wiring of the house. **Fuses are also used to protect the individual domestic electrical appliances from damage which may be caused due to excessive current flow through them** (see Figure 45). Costly electrical appliances like T.V. sets and refrigerators have their own fuses which protect them against damage by too much current. The fuse used for each electrical appliance should be slightly larger than the normal current drawn by it. For example, a T.V. set which normally takes less than 1 ampere of current should be fused at 2 amperes, and not, for example, at 10 amperes.


**Figure 45.** These are the cartridge fuses. They are used to protect the individual electrical appliances.

The fuse used in an electrical appliance is shown in Figure 46(*a*). It consists of a glass tube *T* having a thin fuse wire sealed inside it. The glass tube has two metal caps at its two ends. The two ends of the fuse wire are connected




(*a*) Diagram of the fuse used in electrical appliances

(*b*) Symbol of an electric fuse used in circuit diagrams

**Figure 46.**

to these metal caps. The metal caps are for connecting the fuse in the circuit in a suitably made bracket. In a circuit diagram, the electric fuse is represented by the symbol shown in Figure 46(*b*). We will now solve some problems based on electric fuse.

**Sample Problem 1.** An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect ? Explain. **(NCERT Book Question)**

**Solution.** We will first calculate the current drawn by this electric oven.

Now, Power, $P = 2$ kW

$= 2 \times 1000$ W

$= 2000$ W

Potential difference or Voltage, $V = 220$ V

And, Current drawn, $I = ?$ (To be calculated)

Now, Power, $P = V \times I$

So, $2000 = 220 \times I$

And Current drawn, $I = \frac{2000}{220}$

$= 9$ A

Now, the current drawn by this electric oven is 9 amperes which is very high but the fuse in this circuit is only of 5 ampere capacity. So, when a very high current of 9 A flows through the 5 A fuse, the fuse wire will get heated too much, melt and break the circuit, cutting off the power supply. Thus, when a 2 kW power rating electric oven is operated in a circuit having 5 A fuse, the fuse will blow off cutting off the power supply in this circuit.

**Sample Problem 2.** A circuit has a fuse of 5 A. What is the maximum number of 100 W (220 V) bulbs that can be safely used in the circuit ?

**Solution.** Suppose $x$ bulbs can be used safely.

Now, Power of 1 bulb = 100 W

So, Power of $x$ bulbs, $P = 100 \times x$ watts

Potential difference, $V = 220$ volts

Current, $I = 5$ amperes

Now, Power, $P = V \times I$

So, $100 \times x = 220 \times 5$

$$x = \frac{220 \times 5}{100}$$

$$x = 11$$

Thus, a maximum number of 11 bulbs can be used.

**Sample Problem 3.** What precautions should be taken to avoid overloading of domestic electric circuits ? **(NCERT Book Question)**

**Answer.** (*i*) Too many high power rating electrical appliances (such as electric iron, geyser, air conditioner, etc.) should not be switched on at the same time.

(*ii*) Too many electrical appliances should not be operated on a single socket.

**Sample Problem 4.** Name two safety measures commonly used in domestic electric circuits and appliances. **(NCERT Book Question)**

**Answer.** (*i*) Provision of electric fuse.

(*ii*) Earthing of metal bodies of electrical appliances.

## Hazards of Electricity (or Dangers of Electricity)

Though electricity is one of the most important and convenient form of energy but its improper use is associated with the following hazards or dangers :

1. If a person happens to touch a live electric wire, he gets a severe electric shock. In some cases, electric shock can even kill a person.
2. Short-circuiting due to damaged wiring or overloading of the circuit can cause electrical fire in a building.
3. The defects in the household wiring like loose connections and defective switches, sockets and plugs can cause sparking and lead to fires.

**Figure 47.** This man suffered a severe electric shock. A current passing through his hands caused heating which led to burns.

## Precautions in the Use of Electricity

To avoid the hazards like electric shocks or electric fires, we should observe the following precautions in the use of electricity :

1. If a person accidently touches a live electric wire or if an electric fire starts in the house, the main switch should be turned off at once so as to cut off the electricity supply. This will prevent the fire from spreading.

2. The person who happens to touch the live electric wire should be provided an insulated support of wood, plastic or rubber. We should never try to pull away the person who is in contact with the live wire, otherwise we will also get a shock.

3. All the electrical appliances like electric iron, cooler, and refrigerator, etc., should be given earth connections to save ourselves from the risk of electric shocks. Even if the earth connection is there, we should avoid touching the metal body of an electric appliance when it is on.

4. All the switches should be put in the live wire of the A.C. circuit, so that when the switch is turned off, the appliance gets disconnected from the live wire and there is no risk of electric shock.

5. We should never operate switches of electrical appliances with wet hands. The plugs should also not be inserted into sockets with wet hands (see Figure 48). This is because water conducts electricity to some extent, so touching the switches and sockets with wet hands can lead to electric shocks.

**Figure 48.** Never touch switches or sockets with wet hands.

6. The fuse should always be connected in the live wire of the circuit. The fuse wire should be of proper rating and material. We should never use a copper wire (connecting wire) as fuse wire because a copper wire has a very high current rating due to which a copper wire fuse cannot protect the wiring against short circuiting or overloading.

7. The household wiring should be done by using good quality wires having proper thickness and insulation. All the wire connections with switches, sockets and plugs should be tight, and all the wire joints should be covered with insulated adhesive tape. Defective switches, sockets and plugs should be replaced immediately.

8. We should avoid working on a live circuit for repairs, etc. If, however, it is necessary to handle a live circuit, then rubber gloves and rubber shoes must be put on, and we should stand on a dry wooden board. The electricians should wear rubber hand gloves and rubber shoes while working. The tools used for electrical repairs like testers, screw drivers, pincers, etc., should have properly insulated handles made of wood or bakelite plastic.

We are now in a position to **answer the following questions :**

### Very Short Answer Type Questions

1. What name is given to the device which automatically cuts off the electricity supply during short-circuiting in household wiring ?
2. What is the usual capacity of an electric fuse used (*i*) in the lighting circuit, and (*ii*) in the power circuit, of a small house ?
3. Give the symbol of an electric fuse used in circuit diagrams.
4. State whether the following statements are true or false :
   (*a*) A wire with a green insulation is usually the live wire.
   (*b*) A miniature circuit breaker (MCB) works on the heating effect of current.
5. Alongwith live wire and neutral wire, a third wire is also used in domestic electric wiring. What name is given to this third wire ?

**6.** List the colours of the three wires in the cable connected to the plug of an electric iron.

**7.** What is the electric potential of the neutral wire in a mains supply cable ?

**8.** If fuses of 250 mA, 500 mA, 1 A, 5 A and 10 A were available, which one would be the most suitable for protecting an amplifier rated at 240 V, 180 W ?

**9.** When does an electric short circuit occur ?

**10.** In which wire in an A.C. housing circuit is the switch introduced to operate the lights ?

**11.** In household circuits, is a fuse wire connected in series or in parallel ?

**12.** Usually three insulated wires of different colours are used in an electrical appliance. Name the three colours.

**13.** What is the usual colour of the insulation of : (*a*) live wire, (*b*) neutral wire, and (*c*) earth wire ?

**14.** What is the main purpose of earthing an electrical appliance ?

**15.** Give two reasons why different electrical appliances in a domestic circuit are connected in parallel.

**16.** How should the electric lamps in a building be connected so that the switching on or off in a room has no effect on other lamps in the same building ?

**17.** Fill in the following blanks with suitable words :

(*a*) A fuse should always be placed in the ............wire of a mains circuit.

(*b*) The earth wire should be connected to the.............of an appliance.

## Short Answer Type Questions

**18.** (*a*) Of what substance is the fuse wire made ? Why ?

(*b*) Explain why, a copper wire cannot be used as a fuse wire.

**19.** What type of electric fuse is used in electrical appliances like car stereos ? Explain with the help of a labelled diagram.

**20.** Distinguish between the terms 'overloading' and 'short-circuiting ' as used in domestic circuits.

**21.** (*a*) When does a fuse cut off current ? How does it do it ?

(*b*) What is the maximum number of 60 W bulbs that can be run from the mains supply of 220 volts if you do not want to overload a 5 A fuse ?

**22.** Explain the importance of using in a household electric circuit (*i*) fuse, and (*ii*) earthing wire.

**23.** (*a*) An electric iron is rated at 230 V, 750 W. Calculate (*i*) the maximum current, and (*ii*) the number of units of electricity it would use in 30 minutes.

(*b*) Which of the following fuse ratings would be suitable for this electric iron ?

1 A, 3 A, 5 A, 13 A

**24.** What is the function of an earth wire ? Why is it necessary to earth the metallic bodies of electrical appliances ?

**25.** (*a*) What current is taken by a 3 kW electric geyser working on 240 V mains ?

(*b*) What size fuse should be used in the geyser circuit ?

**26.** (*a*) Why are fuses fitted in the fuse box of a domestic electricity supply ?

(*b*) What device could be used in place of the fuses ?

## Long Answer Type Question

**27.** (*a*) Draw a labelled diagram to show the domestic electric wiring from an electric pole to a room. Give the wiring for a bulb and a three-pin socket only.

(*b*) State two hazards associated with the use of electricity.

(*c*) State the important precautions which should be observed in the use of electricity.

(*d*) What will you do if you see a person coming in contact with a live wire ?

(*e*) Explain why, electric switches should not be operated with wet hands.

## Multiple Choice Questions (MCQs)

**28.** At the time of short circuit, the current in the circuit :

(*a*) reduces substantially (*b*) does not change

(*c*) increases heavily (*d*) varies continuously

**29.** A 1.25 kW heater works on a 220 V mains supply. What current rating would a suitable fuse have ?

(*a*) 2 A (*b*) 5 A (*c*) 10 A (*d*) 13 A

**30.** The maximum number of 40 W tube-lights connected in parallel which can safely be run from a 240 V supply with a 5 A fuse is :
(*a*) 5 (*b*) 15 (*c*) 20 (*d*) 30

**31.** In normal use, a current of 3.5 A flows through a hair dryer. Choose a suitable fuse from the following :
(*a*) 3 A (*b*) 5 A (*c*) 10 A (*d*) 30 A

**32.** Which one of the following statements is not true ?
(*a*) In a house circuit, lamps are used in parallel.
(*b*) Switches, fuses and circuit breakers should be placed in the neutral wire
(*c*) An electric iron has its earth wire connected to the metal case to prevent the user receiving a shock
(*d*) When connecting a three-core cable to a 13 A three-pin plug, the red wire goes to the live pin.

**33.** A car headlamp of 48 W works on the car battery of 12 V. The correct fuse for the circuit of this car headlamp will be :
(*a*) 5 A (*b*) 10 A (*c*) 3 A (*d*) 13 A

**34.** A 3-pin mains plug is fitted to the cable for a 1 kW electric kettle to be used on a 250 V a.c. supply. Which of the following statement is not correct ?
(*a*) The fuse should be fitted in the live wire
(*b*) A 13 A fuse is the most appropriate value to use
(*c*) The neutral wire is coloured black
(*d*) The green wire should be connected to the earth pin.

**35.** A TV set consumes an electric power of 230 watts and runs on 230 volts mains supply. The correct fuse for this TV set is :
(*a*) 5 A (*b*) 3 A (*c*) 1 A (*d*) 2 A

**36.** Circuit Breaker Device which can be used in place of fuse in domestic electric wiring is called :
(*a*) CBD (*b*) DCB (*c*) MCD (*d*) MCB

**37.** An MCB which cuts off the electricity supply in case of short-circuiting or overloading works on the :
(*a*) chemical effect of current
(*b*) heating effect of current
(*c*) magnetic effect of current
(*d*) electroplating effect of current

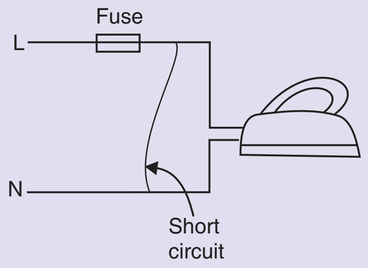
## Questions Based on High Order Thinking Skills (HOTS)

**38.** An air-conditioner of 3.2 kW power rating is connected to a domestic electric circuit having a current rating of 10 A. The voltage of power supply is 220 V. What will happen when this air-conditioner is switched on ? Explain your answer.

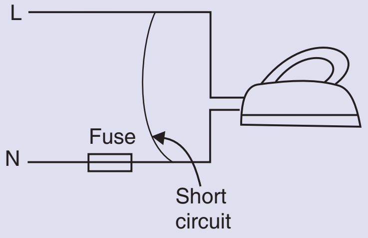
**39.** Three appliances are connected in parallel to the same source which provides a voltage of 220 V. A fuse connected to the source will blow if the current from the source exceeds 10 A. If the three appliances are rated at 60 W, 500 W and 1200 W at 220 V, will the fuse blow ?

**40.** A vacuum cleaner draws a current of 2 A from the mains supply.
(*a*) What is the appropriate value of the fuse to be fitted in its circuit ?
(*b*) What will happen if a 13 A fuse is fitted in its circuit ?

**41.** Which of the following circuits will still be dangerous even if the fuse blows off and electric iron stops working during a short circuit ?



(*A*)



(*B*)

**42.** An electric kettle rated as 1200 W at 220 V and a toaster rated at 1000 W at 220 V are both connected in parallel to a source of 220 V. If the fuse connected to the source blows when the current exceeds 9.0 A, can both appliances be used at the same time ? Illustrate your answer with calculations.

**43.** What is the main difference in the wiring of an electric bulb and a socket for using an electric iron in a domestic electric circuit ? What is the reason for this difference ?

**44.** (*a*) Explain why, it is more dangerous to touch the live wire of a mains supply rather than the neutral wire.
(*b*) Why is it safe for birds to sit on naked power lines fixed atop tall electric poles ?

**45.** A domestic lighting circuit has a fuse of 5 A. If the mains supply is at 230 V, calculate the maximum number of 36 W tube-lights that can be safely used in this circuit.

## ANSWERS

**1.** Electric fuse **2.** (*i*) 5 A (*ii*) 15 A **4.** (*a*) False (*b*) False **5.** Earth wire **7.** 0 volt **8.** 1 A **10.** Live wire **11.** In series **16.** In parallel **17.** (*a*) live (*b*) body **19.** Cartridge fuse **21.** (*b*) 18 bulbs **23.** (*a*) (*i*) 3.26 A (*ii*) 0.375 kWh (*b*) 5 A **25.** (*a*) 12.5 A (*b*) 13 A fuse **26.** (*b*) MCB **28.** (*c*) **29.** (*c*) **30.** (*d*) **31.** (*b*) **32.** (*b*) **33.** (*a*) **34.** (*b*) **35.** (*d*) **36.** (*d*) **37.** (*c*) **38.** Fuse will blow cutting off the power supply **39.** No **40.** (*a*) 3 A (*b*) A 13 A fuse could allow very high current to flow through the vacuum cleaner during short-circuiting or overloading which can damage the vacuum cleaner **41.** Circuit A is not dangerous after fuse blows because fuse is in live wire ; Circuit B is dangerous even if fuse blows because the fuse is in neutral wire **42.** No **43.** No earth connection for electric bulb ; Earth connection given to socket for electric iron **44.** (*a*) Live wire at high potential of 220 V; Neutral wire at ground potential of 0 V (*b*) Bird's body is not connected to the earth, so no current flows through bird's body into the earth **45.** 31 tube-lights