6 Magnetism

You may have noticed that when you shake a pin holder, many of the pins stick to the opening, as shown in Figure 6.1(b). This is because a magnetic ring holds them there. Pin holders and the colourful plastic stickers used to attach slips of paper to the wall of a refrigerator are common examples of the use of magnets in our daily lives. Magnetic stickers usually have a small button-shaped magnet at the back.

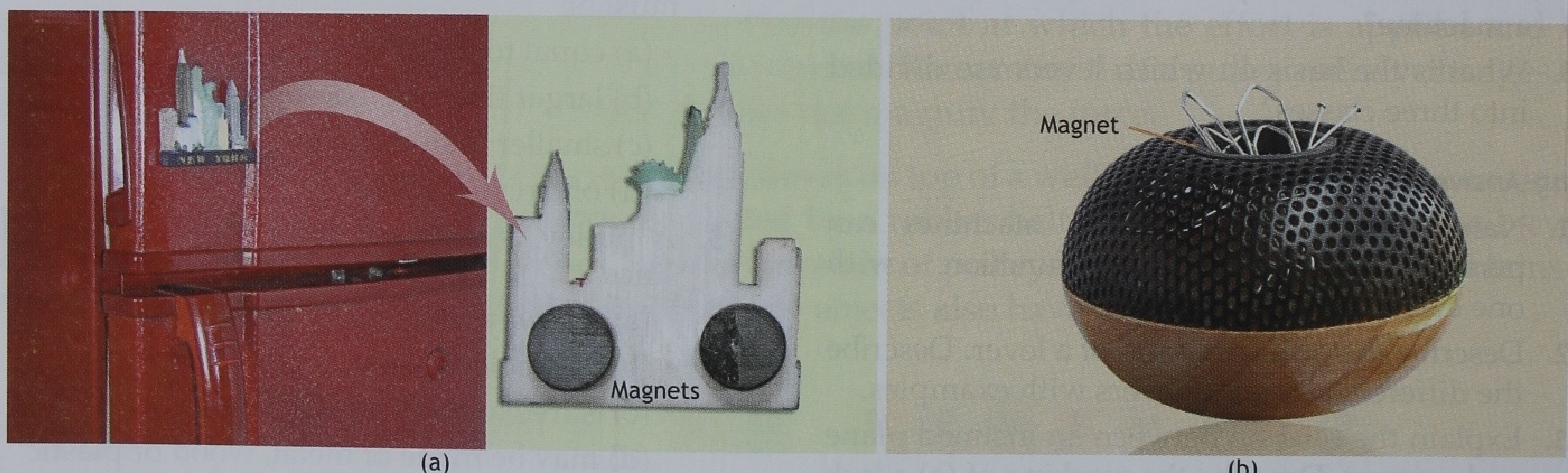


Fig. 6.1 (a) Magnetic stickers and (b) pin holders are common examples of the use of magnets in our daily lives.

As early as 800 BC, the ancient Greeks probably knew that magnetite, an iron ore mined in the province of Magnesia, attracted iron. The philosopher–scientist Thales of Miletus, who lived nearby, may have been the first Greek to study magnetism. The term 'magnet' was derived either from Magnesia, or from Magnes, the name of the shepherd who supposedly discovered magnetism when the iron tip of his stick and the nails of his shoes stuck to some rocks containing magnetite.

Magnetic Materials

Only some natural substances show magnetic properties. These are called magnetic materials, and include the elements iron, cobalt and nickel and many of their compounds.

ACTIVITY Bring a magnet close to objects such as pens, pencils, pins, clips, coins, containers, utensils and common tools. The objects that are attracted by the magnet are made of magnetic materials, while the others are nonmagnetic.

Many of us are used to thinking that all magnets are made of iron, and that magnets attract all objects made of iron. Neither of these beliefs is fully correct. Many magnets do not contain any iron at all. They are made of alloys (mixtures) of cobalt, nickel and other elements. One such alloy of aluminium, nickel and cobalt is called alnico. Other magnetic materials called ferrites also do not contain iron.

In the activity described earlier, you may have noticed that a magnet does not attract utensils made of stainless steel. Thus, stainless steel is not a magnetic material, although it contains a large proportion of iron.

MAGNETS AND THEIR PROPERTIES

An object which attracts other objects made of magnetic materials is called a magnet. The properties of magnets and the manner in which they interact with each other and with other objects made of magnetic materials is collectively called magnetism. As we shall learn later, magnetism also includes those effects of electric currents, which are similar to and closely linked with the properties of magnets. Magnets are available in different shapes, sizes and strengths at stores for scientific supplies, hobby shops and some toy shops. The common shapes are shown in Figure 6.2.

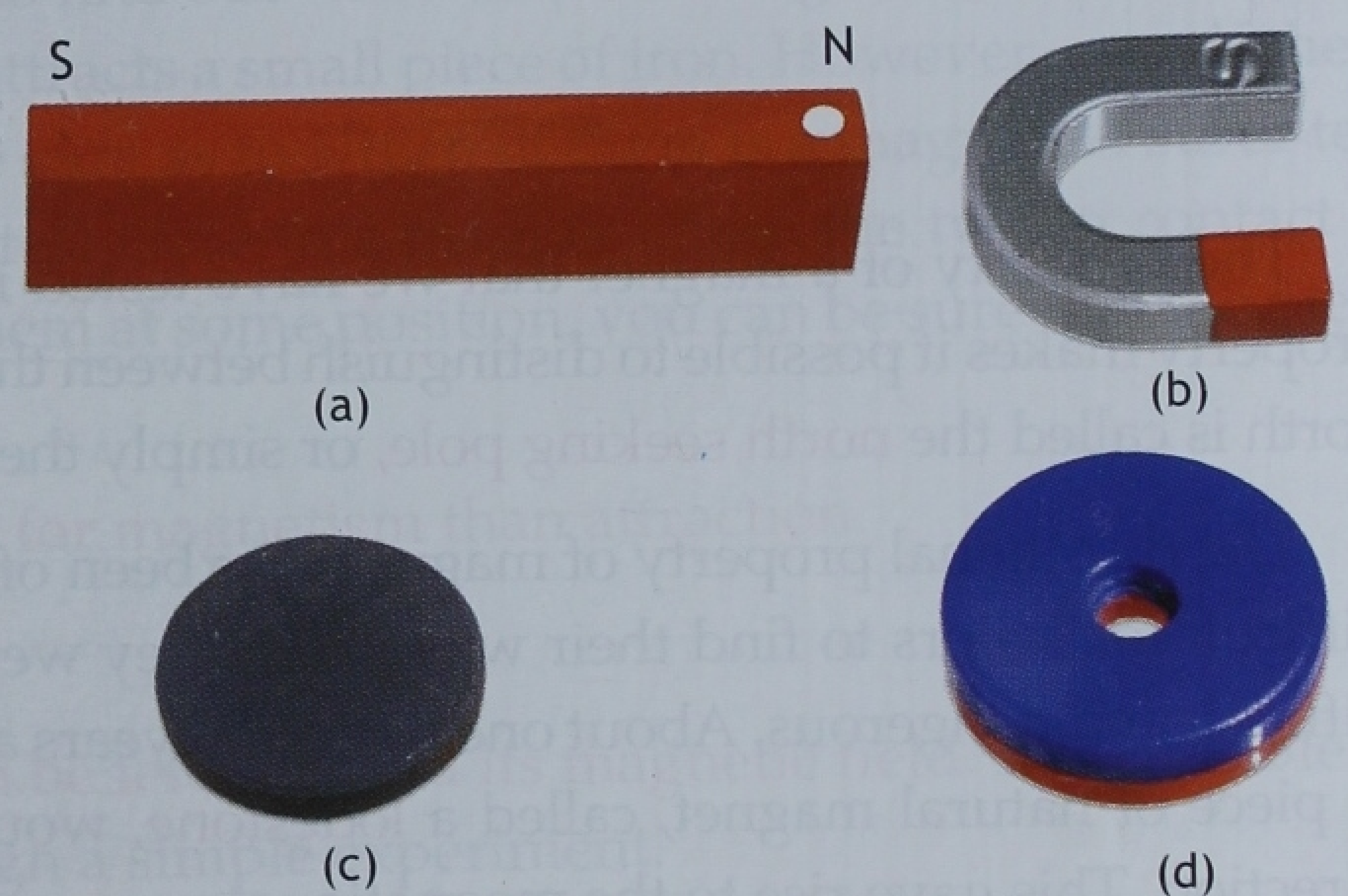


Fig. 6.2 (a) Bar magnet, (b) horseshoe magnet, (c) disc magnet and (d) ring magnet

Poles of a Magnet

ACTIVITY Spread some iron filings on a sheet of paper or board. Place a bar magnet on this and move it around. Alternatively, sprinkle iron filings over a bar magnet, pick up the magnet and tap it gently a few times. You will find that the iron filings stick mostly to the ends of the magnet.

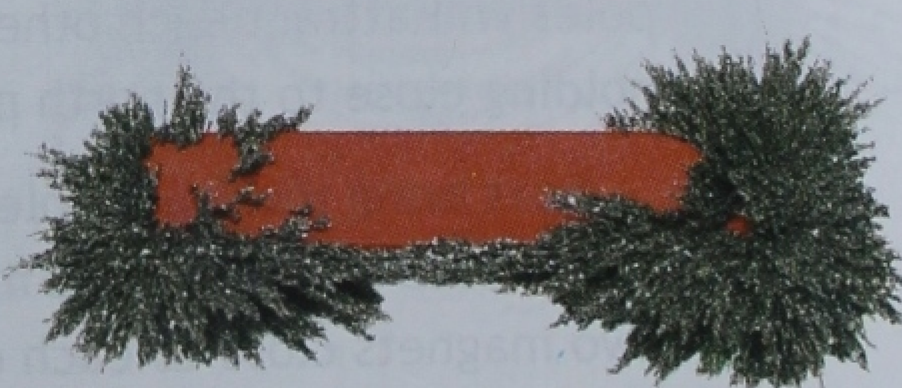


Fig. 6.3 Iron filings are attracted mostly by the two ends of a bar magnet.

This activity shows that a magnet's property of attracting iron is maximum at its two ends and almost nil elsewhere. It is, in fact, possible to identify two points near the ends of a magnet where all its magnetic properties appear to be concentrated. These two points are called the poles of a magnet. They lie slightly inside the two ends. The distance between them is approximately 0.85 times the length of the magnet.

You may have wondered at the unusual shape of a horseshoe magnet. The advantage of the shape is that the two poles lie next to each other. Hence, their combined attractive power can act on the same object.

Directional Property of a Magnet

ACTIVITY Suspend a bar magnet from a fixed support such that it remains horizontal and can rotate freely, as shown in Figure 6.4. You will find that after some time it comes to rest along the north–south direction. Make a chalk mark on the end that is pointing towards the north. Disturb the position of the magnet and then allow it to come to rest. You will find that the magnet again lies along the north–south direction, with the marked end pointing north. Repeat the activity a few times.

Fig. 6.4 A magnet which can rotate freely comes to rest along the north–south direction.

The property of a magnet that we have tested in this activity is called its directional property. This property makes it possible to distinguish between the two poles of a magnet. The pole which points to the north is called the north seeking pole, or simply the north pole. The other pole is called the south pole.

The directional property of magnets has been of great importance in history. In ancient times, it was difficult for sailors to find their way when they were far away from land. This made long sea voyages difficult and dangerous. About one thousand years ago, natural magnets began to be used for navigation. A piece of natural magnet, called a lodestone, would be suspended on board a ship to find the north direction. This gave rise to the magnetic compass, which is used even today to find the direction.

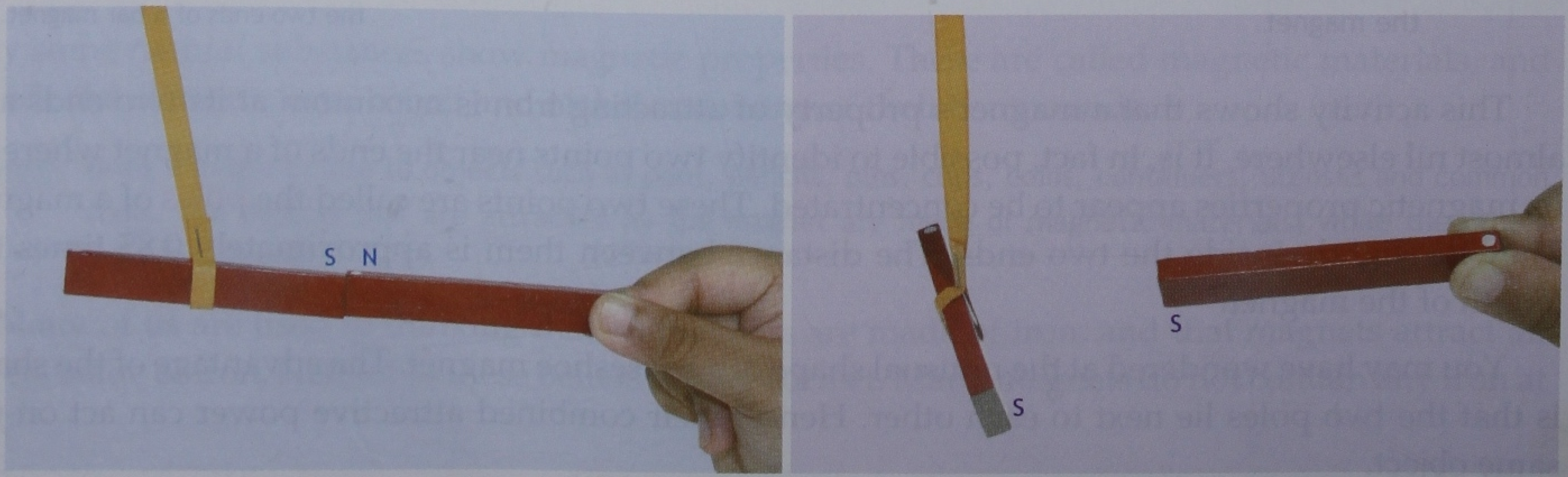
Forces between Magnets

Any two magnets exert forces on each other. This can be seen with the help of a few simple experiments.

ACTIVITY Use a paper strip to hang a magnet. Bring the north pole of another magnet close to its south pole. The two poles will attract each other. The same thing will happen if you bring the south pole of the magnet you are holding close to the north pole of the suspended magnet.

Next bring the south pole of the magnet you are holding close to the south pole of the suspended magnet. In this case the suspended magnet will move away. The same thing will happen if you bring the north poles of two magnets close to each other.

Fig. 6.5 When two magnets are brought near each other, they either attract or repel each other.



It is possible to draw the following conclusions from these observations.

1. Magnets exert forces on each other.
2. These forces may be attractive, i.e., tending to pull the magnets towards each other, or repulsive, i.e., tending to push the magnets away from each other.
3. Like poles repel each other. This means two north poles try to push each other away and two south poles try to push each other away.
4. Unlike poles attract each other. This means a north pole and a south pole attract each other.

Test for a magnet

Suppose you have a piece of metal and you want to find out whether it is a magnet. It would appear that you can do this easily by checking whether it attracts a small piece of iron. However, even if there is some attraction between the two, you cannot be sure as to which of them is a magnet. A surer test would be to take the piece of metal you want to test close to a magnet. Place the two in contact in different positions. If there is repulsion between them at some position, you can be sure that the piece of metal you are testing is a magnet.

This is summarised as repulsion is a surer test for magnetism than attraction.

Magnetic Field

The region around a magnet, where its effects can be felt, is called its magnetic field. It is possible to get some idea about the nature of this field through a simple experiment.

ACTIVITY Sprinkle some iron filings uniformly on a thin sheet of glass or transparent plastic. Place the sheet carefully on top of a bar magnet and tap it a few times. The iron filings will arrange themselves as shown in Figure 6.6. This provides something like a photograph of the magnetic field.

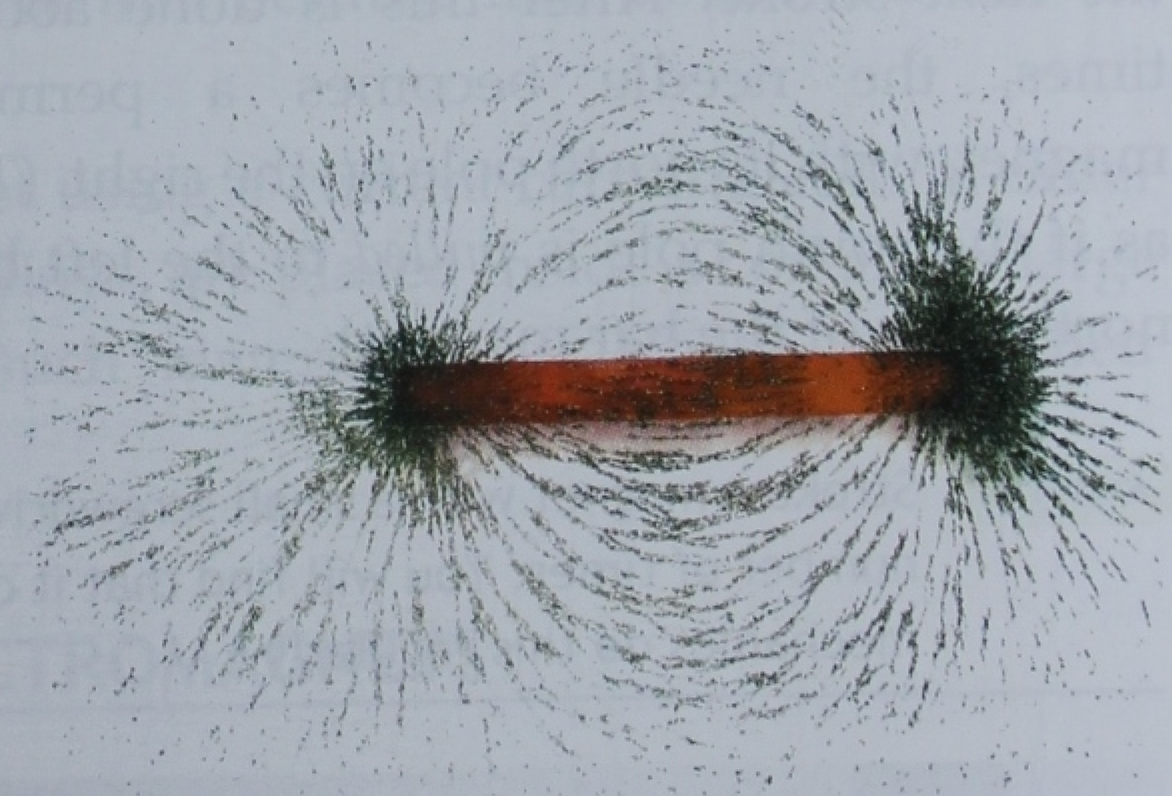


Fig. 6.6 The magnetic field created by a bar magnet

Magnetic Induction

Normally pieces of iron, such as paper clips and pins, do not attract each other. However, if a bar magnet is brought close to them, they get attached to each other to form a chain. Why does this happen?

When a piece of magnetic material comes close to a magnet, temporary magnetic poles are created at its ends. Therefore, it becomes a magnet for the time being. This process by which a piece of magnetic material starts behaving like a magnet when it is brought close to a magnet is called magnetic induction. In Figure 6.7, a south pole is created or induced at the end of the clip touching the north pole of the magnet. The attraction between these opposite poles is what we see as the attraction

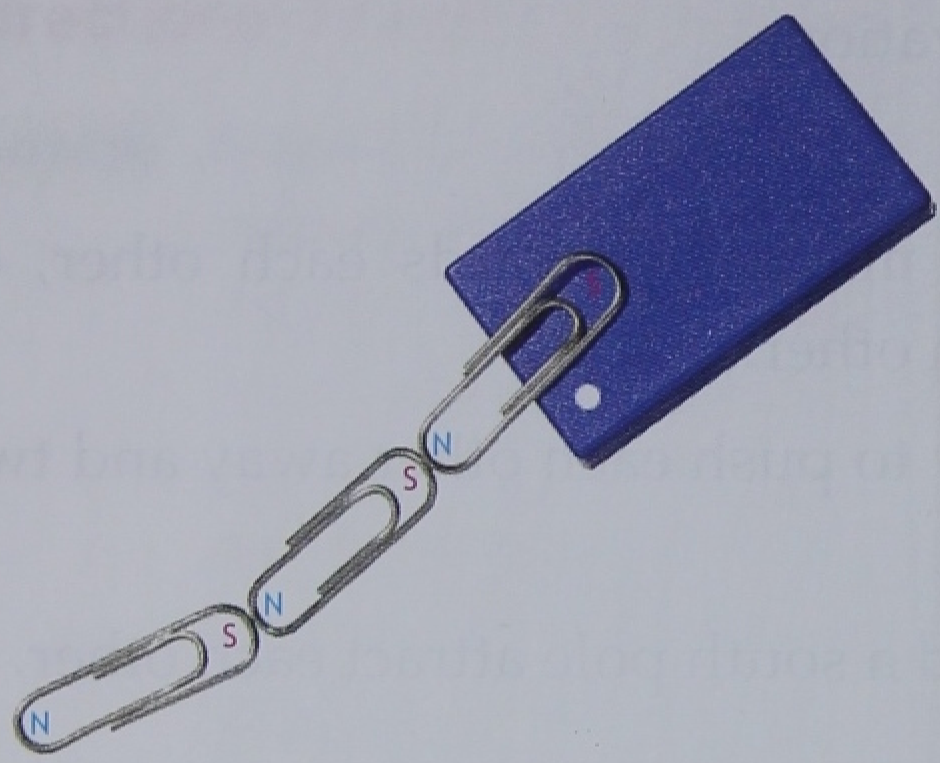


Fig. 6.7 Temporary magnetic poles are induced at the ends of the clips.

between the magnet and the clip. The same process is repeated in the other clips. We can now say that in the process of attraction of a piece of magnetic material by a magnet, induction precedes (comes before) attraction.

The effects of magnetic induction can be either temporary or permanent. In the example we have discussed, they are temporary. The clips behave as small magnets only as long as they are in contact with the magnet. They lose this property when they are separated from the magnet.

Magnetisation by induction

It is possible to create permanent magnets using the process of magnetic induction. The method is shown in Figure 6.8. A steel needle is repeatedly *stroked* by the north pole of a bar magnet. This means the magnet is moved in only one direction (in this case from right to left) when it is in contact with the needle. It is then lifted and taken to its initial position for the next stroke. After this is done about 30 times, the needle becomes a permanent magnet, with its north pole on the right. (This is as if the south pole is *pulled* to the left by the north pole of the bar magnet)

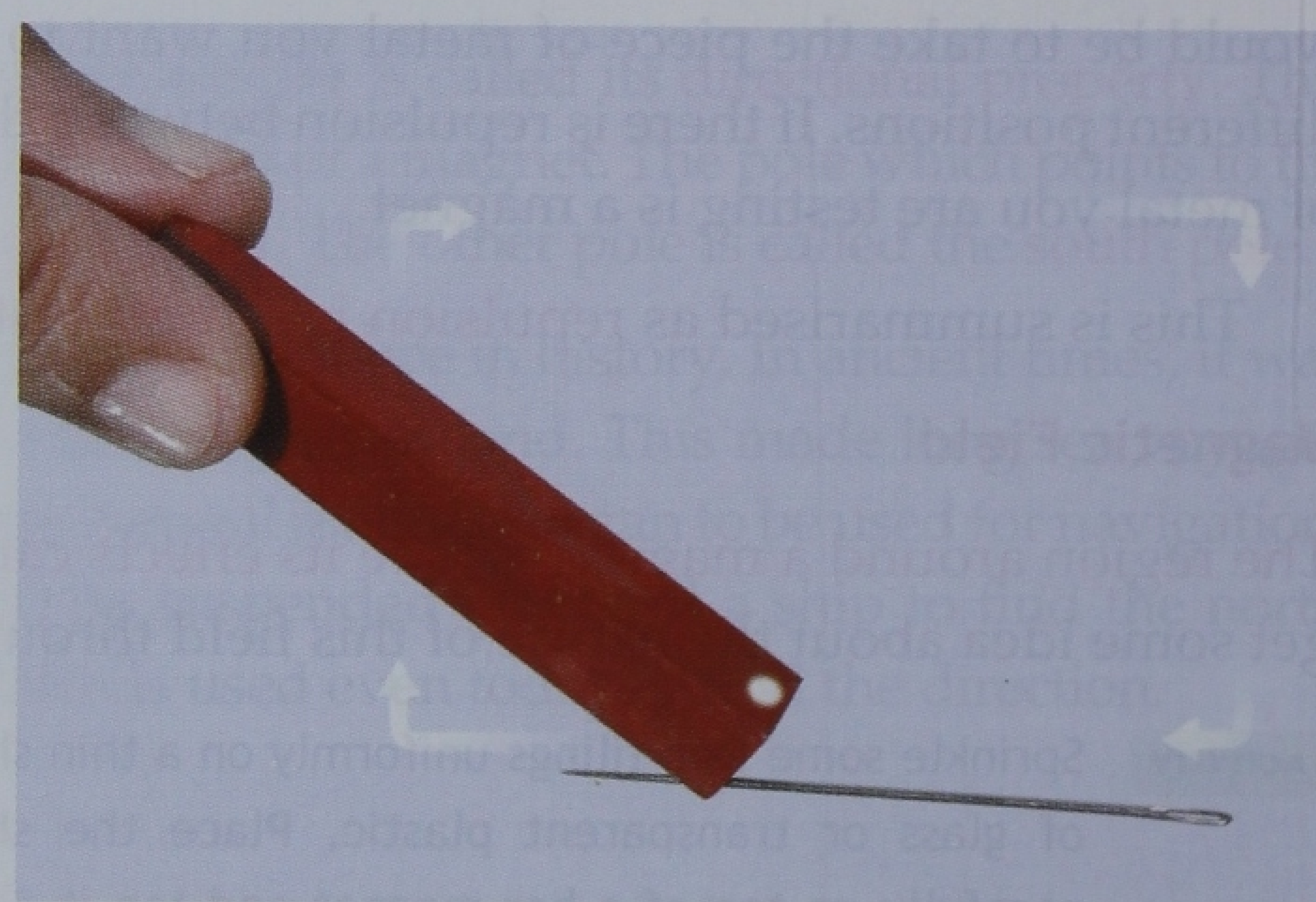


Fig. 6.8 A steel needle can be magnetised by stroking it with a permanent magnet.

ACTIVITY Stroke a magnet with a small screwdriver (the ring magnet at the base of an old speaker will do quite well) a number of times. You will find that it can now pick up steel screws, which is quite convenient. Radio and TV mechanics do this regularly.

ELECTROMAGNET

It is possible to make a magnet by using an electric current. Such a device is called an electromagnet. You will learn later that electricity and magnetism are very closely linked.

ACTIVITY Cut a piece from a used gel-pen refill. Wind about 2 m of enamelled wire around it to make a coil, as shown in Figure 6.9(a). Push an iron nail into the tube. Scrape off the enamel from the free ends of the coil. Connect them to a cell with the help of sticking tape. As current flows through the coil, the nail will behave as a magnet. It will attract small iron objects such as pins and clips. If you disconnect the cell, current will no longer flow through the coil, and the nail will stop acting as a magnet. This is the principle of the electromagnet.

Remove the nail from the tube and insert a pin partially into the tube, as shown in Figure 6.9(b). The pin will get drawn into the tube when you connect the coil to the cell.

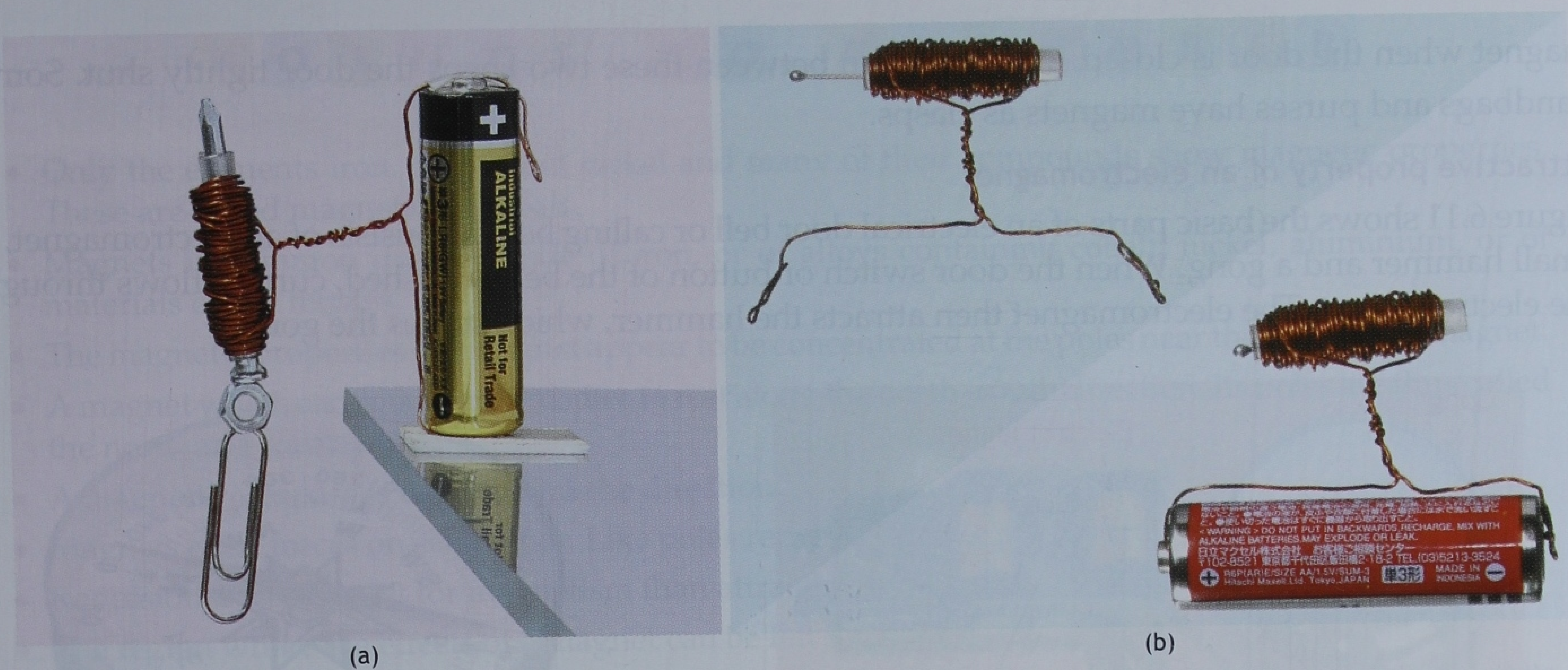


Fig. 6.9 (a) The electromagnet attracts iron objects when current flows through it. (b) The coil draws in a pin when current flows through it.

Three things related to an electromagnet need to be mentioned here.

1. The coil behaves like a magnet even when the nail is taken out. This shows that the magnetism of an electromagnet is due to the current flowing through it. The piece of iron placed inside the coil is called the core of the electromagnet. It only strengthens the electromagnet.
2. An electromagnet is a temporary magnet. It does not remain a magnet when the current is switched off. The core of an electromagnet is made of iron because iron does not retain its magnetism once the current is switched off.
3. However, it is possible to make a permanent magnet using a current-carrying coil. In order to do this, certain materials, such as steel or special alloys, are placed inside a coil and a large current is passed through the coil. Unlike iron, such materials are able to retain their magnetism permanently.

USES OF MAGNETS AND ELECTROMAGNETS

We have discussed the attractive and directional properties of magnets, and the temporary and permanent natures of electromagnets and magnets. Let us briefly study some of their uses.

Attractive property of permanent magnets

We have already seen that pin holders and magnetic stickers have small magnets. Magnets are also used as catches in cupboards. A small but reasonably powerful permanent magnet is fitted just inside the opening of the cupboard. A small flat piece of iron fixed to the door just touches the

Fig. 6.10 A magnetic door closer

magnet when the door is closed. The attraction between these two keeps the door tightly shut. Some handbags and purses have magnets as clasps.

Attractive property of an electromagnet

Figure 6.11 shows the basic parts of an electrical door bell or calling bell. It consists of an electromagnet, a small hammer and a gong. When the door switch or button of the bell is pushed, current flows through the electromagnet. The electromagnet then attracts the hammer, which strikes the gong.

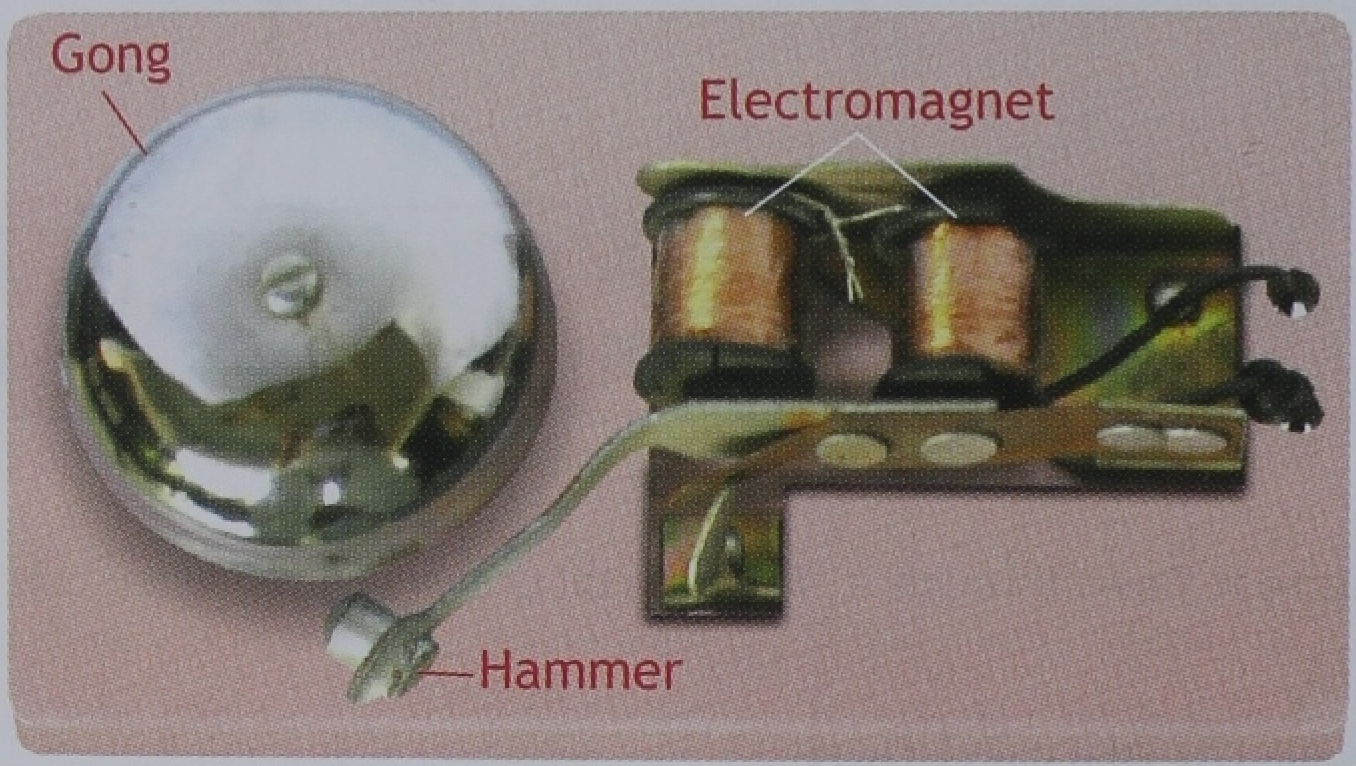


Fig. 6.11 An electric bell

Fig. 6.12 A compass

Directional property of permanent magnets

As we have discussed earlier, the magnetic compass makes use of the directional property of a permanent magnet. It has a horizontal magnetic needle fitted inside a case with a transparent top. The needle can move freely and always comes to rest in the north–south direction. Usually, a horizontal circular card is attached to the needle. This card has the directions marked on it for convenience.

CARE OF MAGNETS

We have learnt that magnets may be temporary or permanent. However, even permanent magnets may lose their magnetic properties under certain conditions and, therefore, need some care.

Keepers

A permanent magnet, such as a bar magnet or a horseshoe magnet, can get demagnetised, or lose its magnetism, if the poles are left open. This can be prevented to a large extent by putting each north pole in contact with a south pole of the same strength through a small piece of iron. The pieces of iron used for this purpose are called (magnetic) keepers.

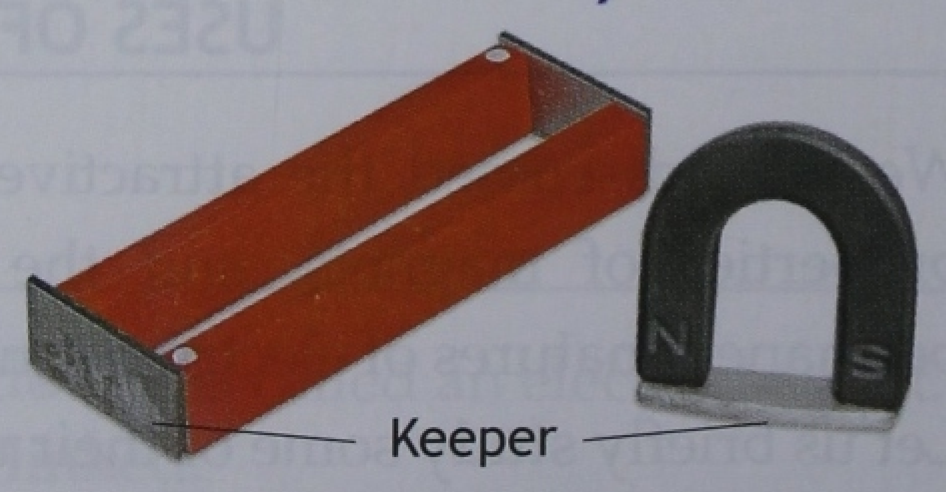


Fig. 6.13 Magnetic keepers protect a magnet.

A single keeper is placed between the poles of a horseshoe magnet. Two keepers are used to protect a pair of bar magnets. The two bar magnets are placed with their north and south poles in opposite directions.

Damage to magnets

Permanent magnets can be damaged if they are exposed to heat, hammered or dropped from a height. Hence, although a permanent magnet appears to be quite sturdy, it has to be handled with some care.

POINTS TO REMEMBER

- Only the elements iron, cobalt and nickel and many of their compounds show magnetic properties. These are called magnetic materials.
- Magnets in common use are made of iron, or of alloys containing cobalt, nickel, aluminium, or of materials called ferrites.
- The magnetic properties of a magnet appear to be concentrated at the poles near the ends of the magnet.
- A magnet which can rotate freely comes to rest along the north–south direction. Its poles are thus called the north and south poles.
- A magnetic compass is used to find the direction.
- Magnets exert forces on each other. Like poles repel and unlike poles attract each other.
- Repulsion is a surer test for magnetism than attraction.
- The region where the effects of a magnet can be felt is called its magnetic field.
- When a piece of magnetic material comes close to a magnet, temporary magnetic poles are created at its ends. This is called magnetic induction. Induction precedes attraction.
- A magnet created by an electric current is called an electromagnet.
- If an iron nail is placed inside a coil, it will behave as a magnet only as long as an electric current flows through the coil. Iron does not retain its magnetism when the current is switched off.
- Permanent magnets can be made by placing a piece of steel or certain special alloys inside a coil through which a large current is passed.
- Pin holders, magnetic stickers and magnetic door closers use the attractive property of magnets.
- Electric bells use the attractive property of electromagnets.
- A compass uses the directional property of a permanent magnet.
- A permanent magnet tends to lose its magnetism gradually. This can be prevented to a large extent by using magnetic keepers.
- Permanent magnets can be damaged by heating, hammering or if they are dropped from a height.

EXERCISE

Short-Answer Questions

1. State two possible origins of the term 'magnetism'.
2. Name three elements that are magnetic materials.
3. How is magnetism of help in navigation?
4. What is the basic difference between the magnetic properties of iron and steel?
5. State two ways in which a magnet can get demagnetised rapidly.
6. State one advantage of the shape of a horseshoe magnet.

Long-Answer Questions

1. What is a magnet? What is meant by
   (a) magnetic materials, and
   (b) magnetic fields?
2. Why is repulsion a surer test of magnetism than attraction? Describe one application of the attractive property of magnets.
3. What is magnetic induction? Describe in detail how a steel needle can be magnetised by induction.
4. Explain the directional property of magnets. How do the poles of a magnet get their names? Describe one application of this property.
5. Describe a simple experiment by which we can get an idea about the shape of the magnetic field produced by a bar magnet. Make a sketch of the field.
6. What is an electromagnet? How is it different from a permanent magnet? Describe one application of an electromagnet.

7. How can a magnet lose its magnetism? How should magnets be stored so that they do not lose their magnetism gradually?

Objective Questions

Choose the correct option.

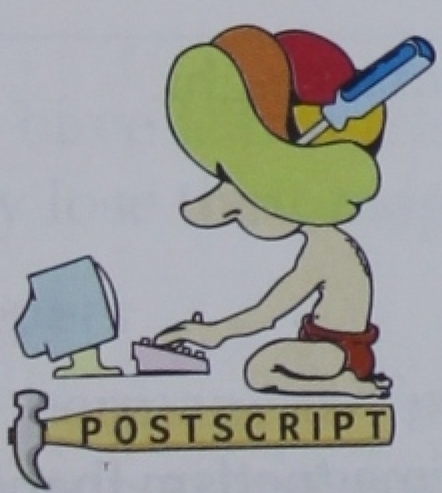
1. Which of the following is not a magnetic material?
   (a) Iron (b) Nickel
   (c) Cobalt (d) Stainless steel
2. Which of the following best describes the field due to a magnet?
   (a) The region where its effects are felt
   (b) The two regions close to its poles
   (c) The region between its poles
   (d) The region where it aligns itself along the north–south direction
3. Which of the following materials is best suited as the core of an electromagnet?
   (a) Steel (b) Iron
   (c) Alnico (d) Magnetite
4. Which of the following materials is best suited for making magnetic keepers?
   (a) Steel (b) Iron
   (c) Alnico (d) Wood
5. When the north pole of a bar magnet picks up an iron nail, which of the following are induced in the nail?
   (a) North poles
   (b) South poles
   (c) A north pole and south pole
   (d) None of these

Fill in the blanks.

1. Magnetism was first discovered in ....
2. ...... is a surer test of magnetism than attraction.
3. ...... precedes attraction in magnetism.
4. A compass uses the ...... property of a magnet.
5. A door bell uses the attractive property of ....

Write true or false.

1. A single keeper can protect a horseshoe magnet but not a bar magnet.
2. An electromagnet is a permanent magnet.
3. A permanent magnet can lose its magnetism with time.
4. Magnetic induction occurs when a piece of magnetic material comes near a magnet.
5. Ferrites are alloys of iron.



Making a Compass

You will need a needle, a piece of cork or rubber and a plastic bowl. Magnetise a needle and pass it through a piece of cork or rubber. Pour some water into the bowl and let the needle float in the water. When the needle comes to rest, it will point in the north–south direction.

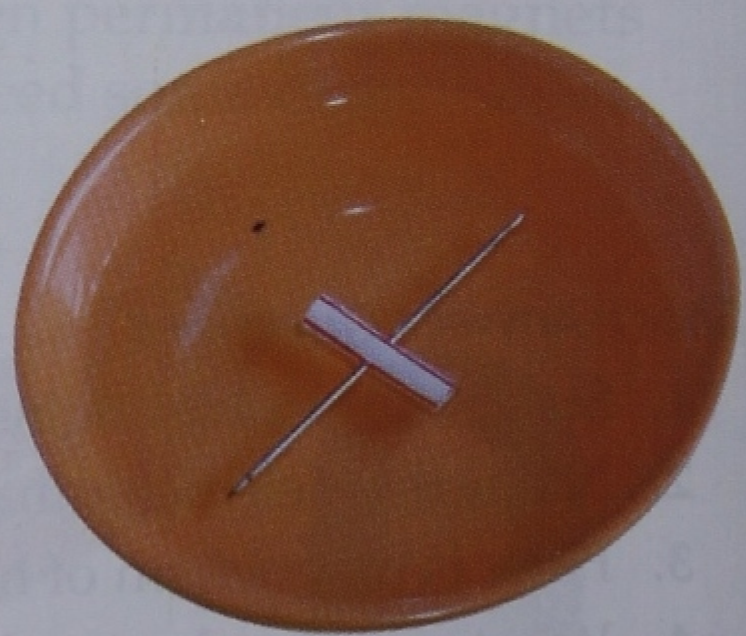


Fig. 6.14