7 Magnetism and Electricity

You are already familiar with magnetic materials, the properties of magnets and some of their uses. You also know that a current-carrying conductor has magnetic properties. In this chapter, we will revise some of the things you know already and explore the link between magnetism and electricity.

MAGNETS AND THEIR PROPERTIES

A magnet is an object that attracts other objects made of magnetic materials. A permanent magnet is made by magnetising a piece of iron or some other magnetic material, such as alnico (an alloy of aluminium, nickel and cobalt).

The magnetic properties of a magnet are concentrated at two points near its ends called its poles. If a magnet is suspended in such a way that it can move freely, it always comes to rest with one of its poles pointing to the north. This pole is called the north-seeking pole or the north pole. The other pole is called the south-seeking pole or the south pole.

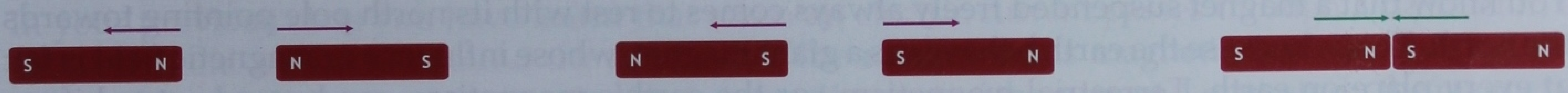


Fig. 7.1 Like poles repel, unlike poles attract.

Magnets exert forces on each other. If the south pole of one magnet is brought close to the north pole of another magnet, they will attract each other. If, on the other hand, two south poles or two north poles are brought near each other, they will be repelled. We say that like poles repel each other, while unlike poles attract each other.

Lines of Force

The region around a magnet where its effects can be felt is called its magnetic field. Although we cannot see this field, we can represent it by a set of curves called magnetic lines of force or simply lines of force. These lines of force are like a sketch or photograph of the magnetic field around a magnet.

ACTIVITY You may have done this in Class 6, but you can do it again to refresh your memory. Place a sheet of glass or transparent plastic over a bar magnet. Sprinkle some iron filings on the sheet and tap the sheet gently. The iron filings will arrange themselves in a pattern representing the lines of force around the magnet.

Fig. 7.2 (a) Lines of force around a bar magnet (b) Lines of force mapped by iron filings

Figure 7.2(a) shows the lines of force around a bar magnet. These are continuous curves, and have the following properties.

1. Each line of force starts from the north pole, goes to the south pole, and continues inside the magnet from the south pole to the north pole.
2. Two lines of force do not intersect each other.
3. The lines of force are closer together where the magnetic field is strong and wider apart where the field is weak.
4. The arrows show the direction in which magnetic force acts on a north pole placed in the magnetic field.

EARTH'S MAGNETIC FIELD

You know that a magnet suspended freely always comes to rest with its north pole pointing towards the north. This is because the earth behaves as a giant magnet, whose influence or magnetic field is felt at every place on earth. Terrestrial magnetism, or the earth's magnetism, can be understood if we imagine a giant magnet inside the earth, with its south pole near the geographic north pole and its

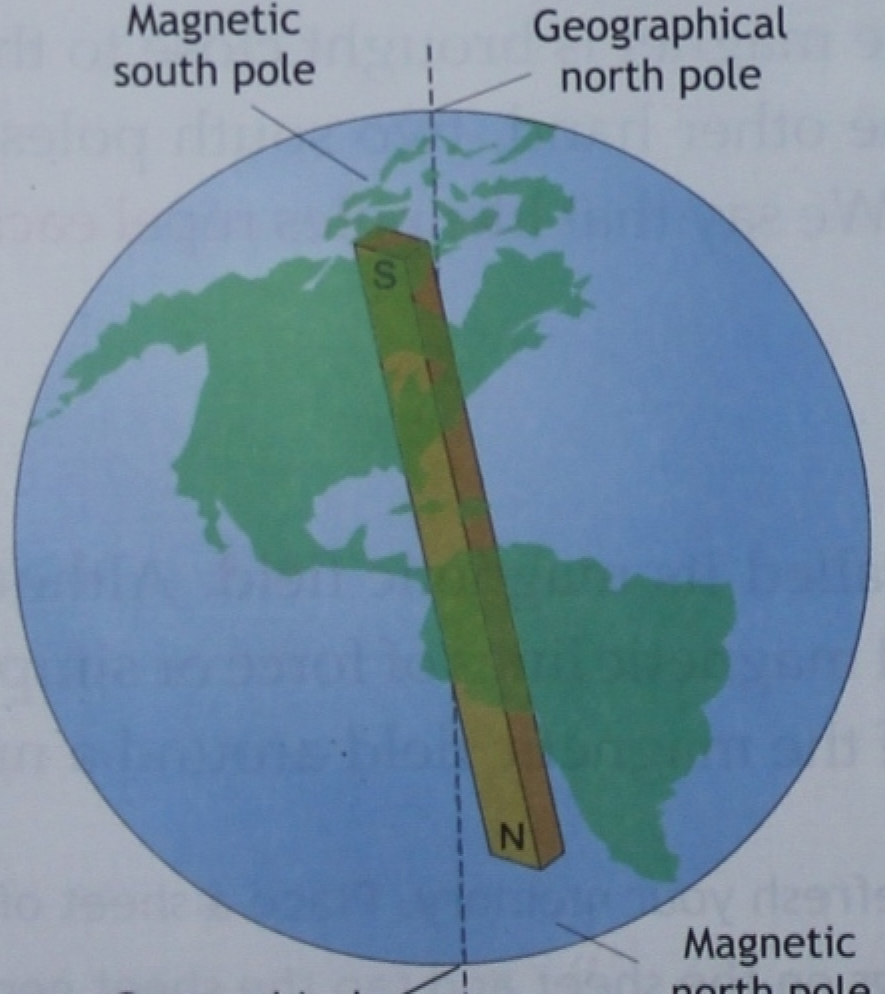


Fig. 7.3 The earth behaves as though there were a giant magnet inside it.

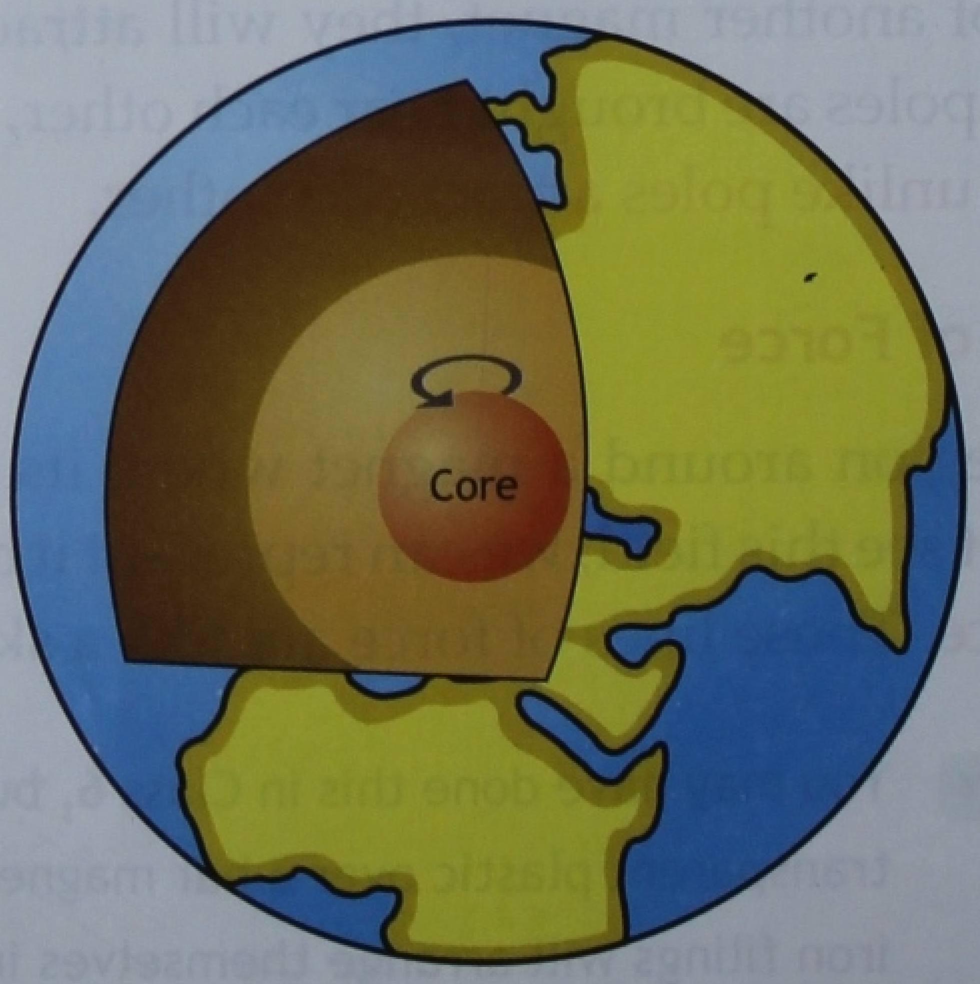


Fig. 7.4 Rotating charges inside the earth create the earth's magnetic field.

north pole near the geographic south pole. The 'earth magnet' would then make any freely suspended magnet align itself with its north pole pointing towards the geographic north, where the south pole of the earth magnet lies. This directional property of a magnet is used in the magnetic compass.

What causes terrestrial magnetism? Several processes are involved in this. First, the temperature deep inside the earth is so high that almost everything inside it is in a molten state. This molten material, containing a lot of iron, rotates with the earth, and as the layers move against each other, they get charged. These charges rotate along with the molten layers, giving rise to circular currents. You know that when a current flows through a coil, a magnetic field is created. Similarly, the circular currents inside the earth create a magnetic field.

Magnetic Compass

For many centuries, the magnetic compass has been used to find the direction on land or at sea. Its main part is a bar magnet, which is pivoted at its centre and can rotate freely in the horizontal plane. A long, light pointer is fixed to the magnet, and always comes to rest in the north–south direction. The pointer moves over a circular card fixed below the magnet. The directions are printed on this card, which usually has the angles 0° to 360° marked along its circumference. The entire arrangement is placed inside a flat, closed, circular box with a glass top.

Fig. 7.5 Magnetic compass

MAGNETIC EFFECT OF A CURRENT

In your previous class you have learnt that when an electric current passes through a conductor, a magnetic field is created around the conductor. The nature of this magnetic field depends on the shape of the conductor carrying current and on the direction of the current. Let us study the magnetic fields created around current-carrying conductors of different shapes.

Magnetic Field Due to a Straight Conductor

The magnetic field created by an electric current flowing through a straight conductor acts along concentric circles around it, as shown in Figure 7.6(a). There is a rule called the right-hand-thumb rule

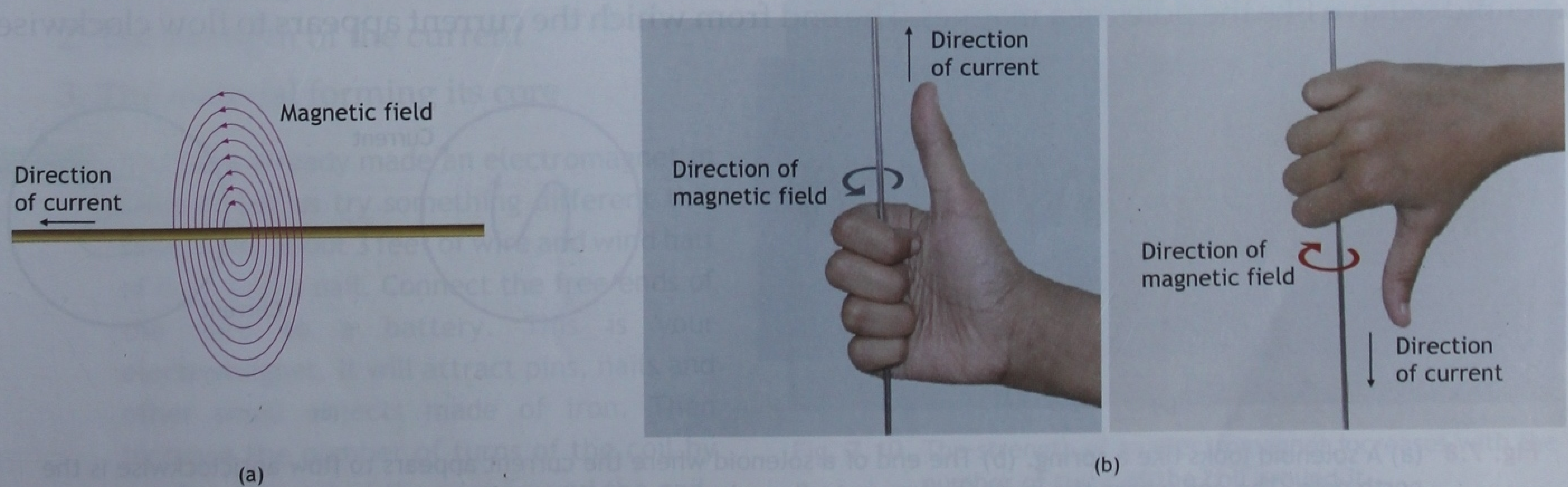


Fig. 7.6 (a) Magnetic field due to current flowing in a straight conductor (b) Right-hand-thumb rule

which helps one determine the direction of the magnetic field created by a straight conductor. According to this rule, if you grasp the conductor as shown in Figure 7.6(b), with the thumb pointing in the direction of the current, the magnetic field will act along the curved fingers, in a direction away from the palm and towards the fingertips. In the figure, when the thumb points *upwards*, the magnetic field acts *anticlockwise*. When the current flows *downwards*, the thumb points downwards and the magnetic field acts *clockwise*. There is another way of looking at this. If you look along a conductor and the current flowing in it is moving *away from you*, the magnetic field will act in the *clockwise* direction. If the current is flowing *towards you*, the magnetic field will act *anticlockwise*.

Magnetic Field Due to a Ring

When current flows through a ringlike conductor, the magnetic field created by it acts perpendicular to the plane of the ring, as shown in Figure 7.7. If the current flows *clockwise*, the magnetic field will be directed *into the ring*. If the current flows *anticlockwise*, the magnetic field will be directed *out of the ring*. You can also say that the magnetic field due to a clockwise current acts away from you, while the magnetic field due to an anticlockwise current acts towards you.

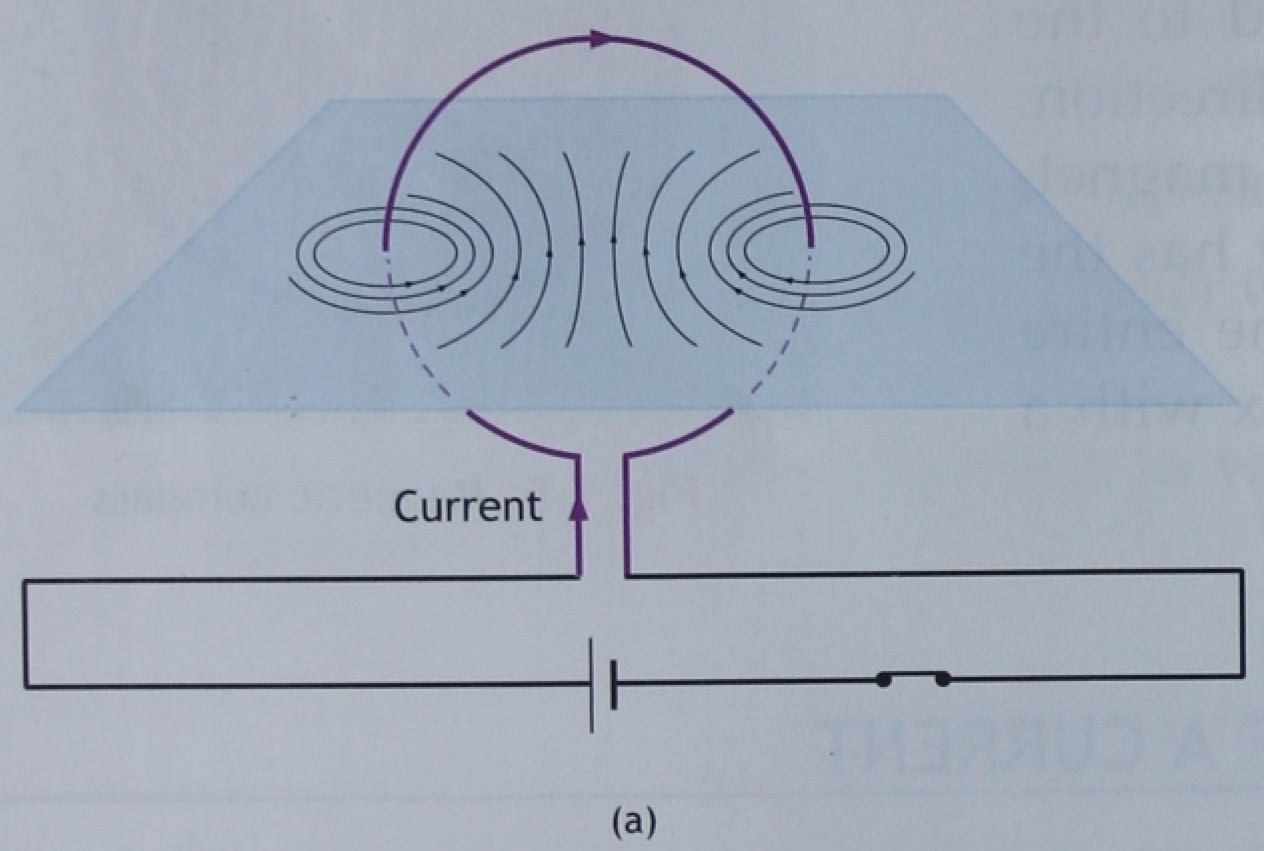


Fig. 7.7 (a) Magnetic field due to a clockwise current (b) Magnetic field due to an anticlockwise current

Solenoid

A solenoid is a coil of wire that looks somewhat like a spring. When current flows through a solenoid, each turn acts like a ring carrying the same current, and hence, creating the same magnetic field. The sum of these fields creates a strong and almost uniform magnetic field inside the solenoid. The result is that the solenoid acts as a magnet, and its magnetic field is like that of a bar magnet. The ends of a solenoid behave like the poles of a magnet. The end from which the current appears to flow clockwise

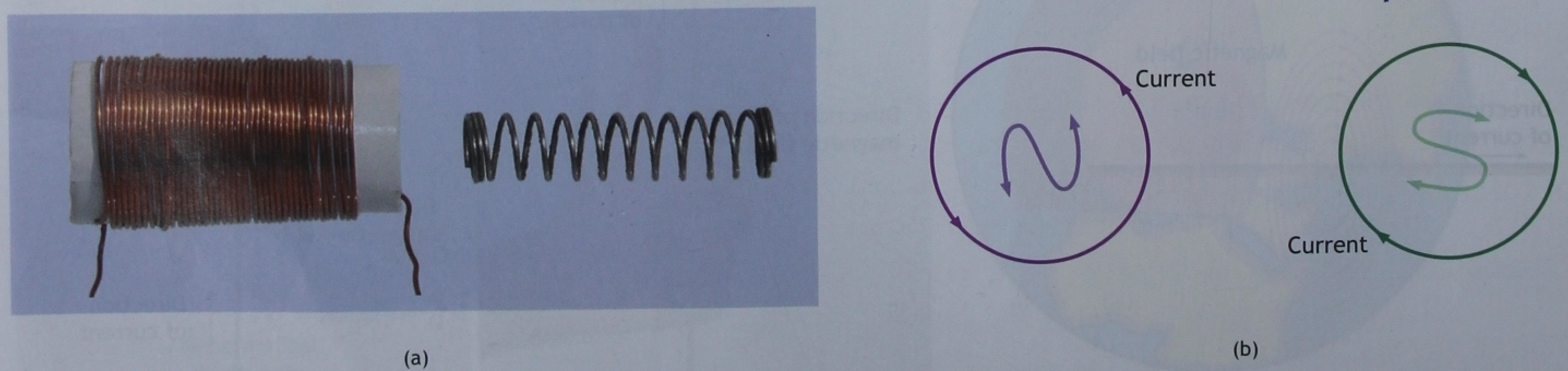


Fig. 7.8 (a) A solenoid looks like a spring. (b) The end of a solenoid where the current appears to flow anticlockwise is the north pole. The end where the current appears to flow clockwise in the south pole.

acts as the south pole. The end from which the current appears to flow anticlockwise acts as the north pole. Naturally, the poles of a solenoid get reversed if the direction of the current is reversed.

ACTIVITY To make a solenoid, wind about 2 feet of enamelled wire around a cardboard or plastic tube. You can wrap stiff paper around a pencil (AA) cell to make the tube. Wind the wire closely, with the turns touching each other. Use tape to hold the turns together. Scrape off the insulation from the free ends of the wire and connect them to a battery. Bring a compass near the two ends of the solenoid to check the polarity of the ends. Reverse the current in the solenoid by reversing the connections and bring the compass near the two ends again. Does the polarity of the ends change?

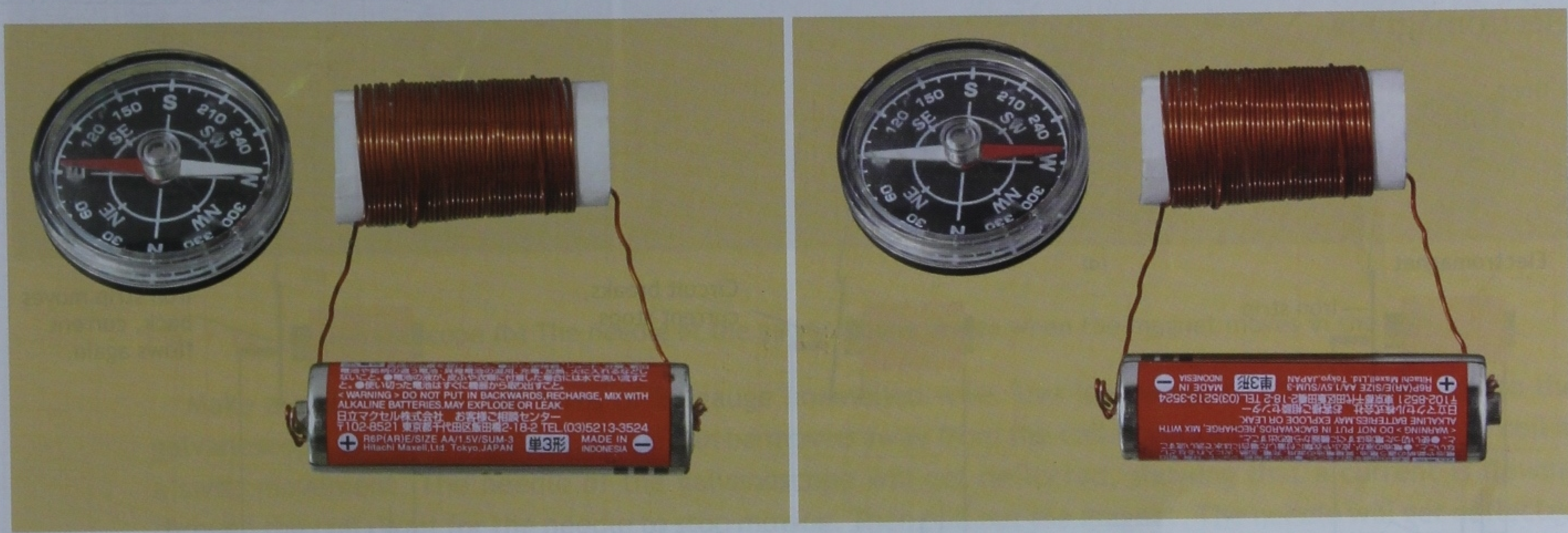


Fig. 7.9 Checking the polarity of the ends of a solenoid

Electromagnet

An electromagnet, as you have already learnt, is a magnet created by the flow of current through a coil. A solenoid also behaves as an electromagnet or a magnet created by the flow of current. The term 'electromagnet' is commonly used for a coil wound around a soft iron core.

The major difference between a permanent magnet and an electromagnet is that while the magnetic properties of a permanent magnet are 'fixed', those of an electromagnet can change. The poles of a permanent magnet are fixed, while the poles of an electromagnet (like the poles of a solenoid) depend on the direction of the current. The strength of an electromagnet depends on three things.

1. The number of turns of the coil per unit length
2. The strength of the current
3. The material forming its core

ACTIVITY You have already made an electromagnet in Class 6. Let us try something different this time. Take about 3 feet of wire and wind half of it around a nail. Connect the free ends of the wire to a battery. This is your electromagnet. It will attract pins, nails and other small objects made of iron. Then increase the number of turns of the coil by winding the rest of the wire around the nail.

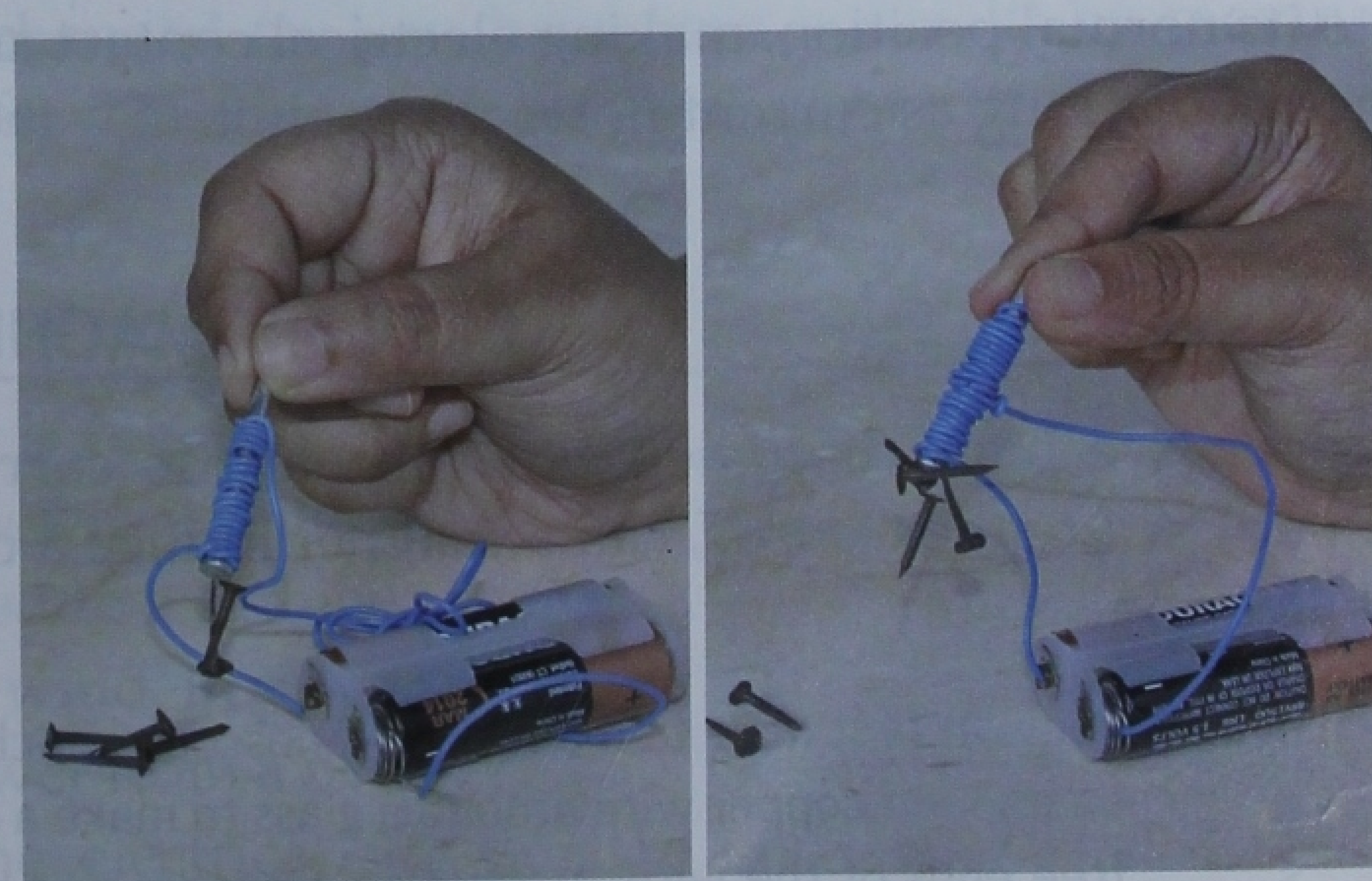


Fig. 7.10 The strength of an electromagnet increases with the number of turns of the coil around it.

This time the electromagnet will be able to pick up more nails. If you disconnect the battery, the electromagnet will lose its magnetism. If you decrease the current flowing through the electromagnet by connecting it to a single cell, its strength will decrease.

Uses of electromagnets

Electromagnets are used in many different ways in electrical circuits and appliances. In industry, electromagnets are used to lift and move scrap iron and to separate iron from other materials. Electrical circuits often use relays, which are switches operated by electromagnets. You have learnt in your previous class that these days MCBs are used instead of fuses. Some of these devices are electromagnets.

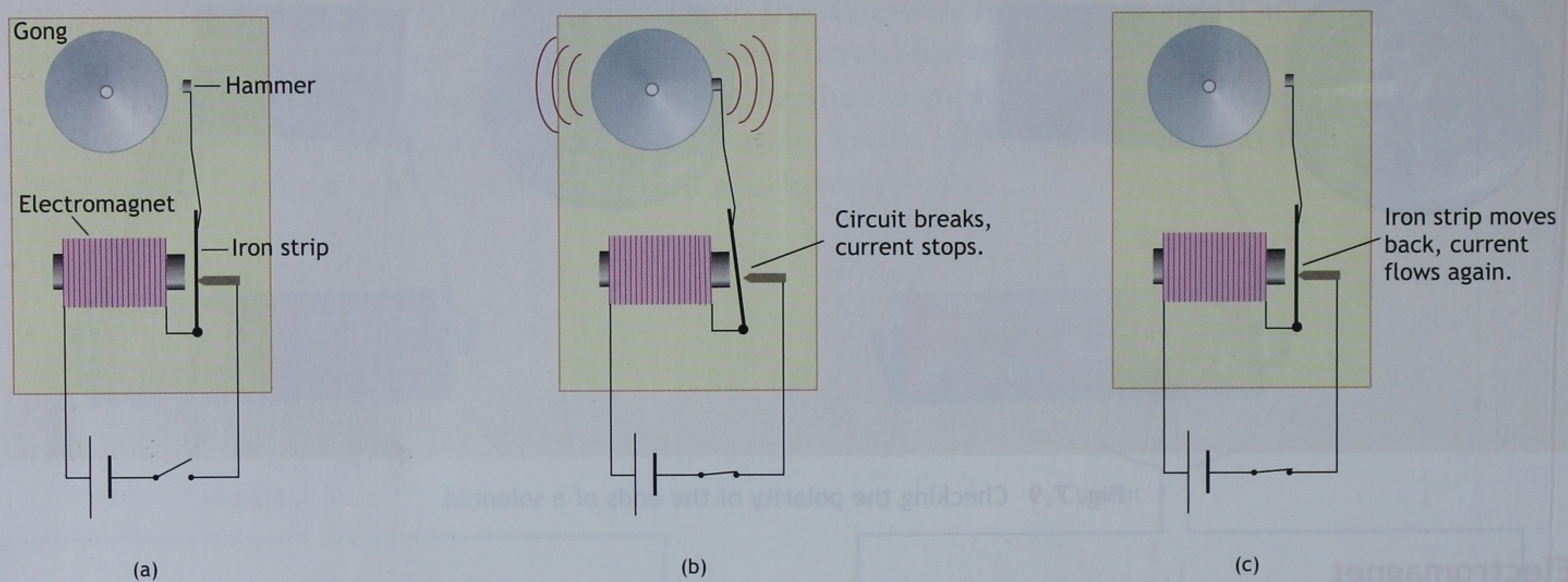


Fig. 7.11 (a) Electrical bell, and (b) breaking and (c) making the circuit of an electric bell

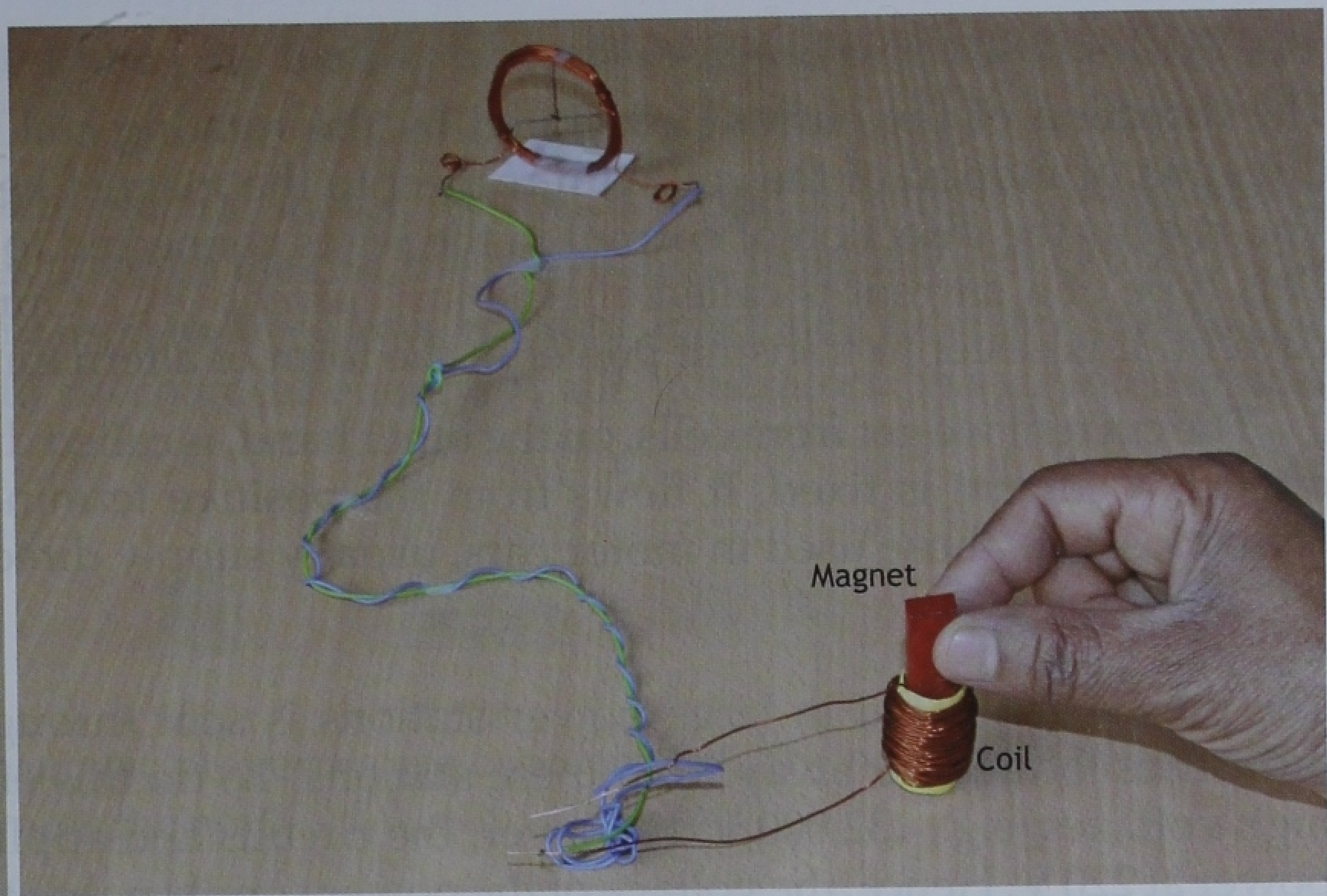
Electromagnets are also used in electric bells. The basic parts of an electric bell are (1) one or two coils with iron cores, (2) an iron strip, fixed at one end and with a small metal hammer at the other, (3) a metal gong which the hammer strikes, and (4) a make-and-break device attached to the iron strip. When current flows through the coils, they act as electromagnets and attract the iron strip. The hammer at the end of the strip then strikes the gong. This movement of the strip also breaks the contact at the make-and-break device, so that current stops flowing in the coils. The strip moves back to its normal position, making electrical contact and the process is repeated. Thus, the bell continues to ring as long as current flows through it.

ELECTROMAGNETIC INDUCTION

So far we have discussed how an electric current produces magnetism. Can the opposite also happen? In other words, can a magnet induce a current? The answer is 'Yes', as you will see in the following activity.

ACTIVITY You will first have to make a galvanoscope which can detect small currents. Wind about 10 feet of 28-gauge enamelled copper wire around a glass to make a coil. Tape the coil to a base. Scrape off the enamel from the free ends of the wire. Magnetise a needle and hang it from the top of the coil. The needle will point N–S. Turn the base to align the coil and the needle. If you now connect the galvanoscope to a cell, the needle will get deflected.

(a)



(b)

Fig. 7.12 (a) Galvanoscope (b) The needle of the galvanoscope moves when the magnet moves in the coil.

Make a coil of about 100 turns of 28-gauge enamelled wire. Use long wires to connect this coil to the galvanoscope so that the galvanoscope can be moved away from the coil. Insert a bar magnet into the coil in a swift movement. The needle of the galvanoscope will get deflected, showing that a current is flowing through the coil. Wait for the needle to stop moving. Then pull out the magnet. The needle will get deflected again. However, this time it will move in the opposite direction, showing that the direction of the current has changed. You can also change the direction of the current by changing the pole of the magnet that you insert into the coil.

Next move the coil over the magnet, instead of moving the magnet into and out of the coil. This will also produce a current.

So, we can conclude that a magnet can induce a current in a coil if either moves with respect to the other. A more scientific way of putting this is that when the magnetic flux linked with a circuit changes, an emf (or voltage) is induced in the circuit. You will learn about magnetic flux later. You could say that it is the magnetic field linked to a circuit. The term used to describe this phenomenon of a current being induced by a change in the flux linked with a circuit is electromagnetic induction. And the flux can be changed (as you have seen yourself) by moving a magnet near a coil or moving a coil near a magnet. This is essentially the way power is generated in a power station.

Electric Generator

In an electric generator, a coil mounted on a shaft is rotated between the poles of magnets. Electricity is induced in the coil as it rotates. The shaft of a generator in a power station is connected to a turbine. The blades of the turbine are moved by steam, water or wind. In a dynamo, used in a vehicle or the gensets used in homes, power from a petrol or diesel engine rotates the shaft. In a vehicle, the electrical power generated by the dynamo is supplied to the engine and utilised to charge the battery.

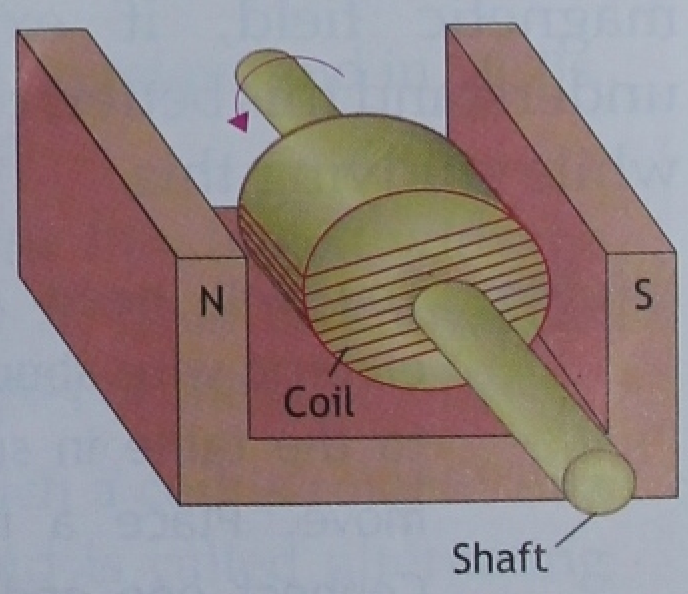


Fig. 7.13 Generator

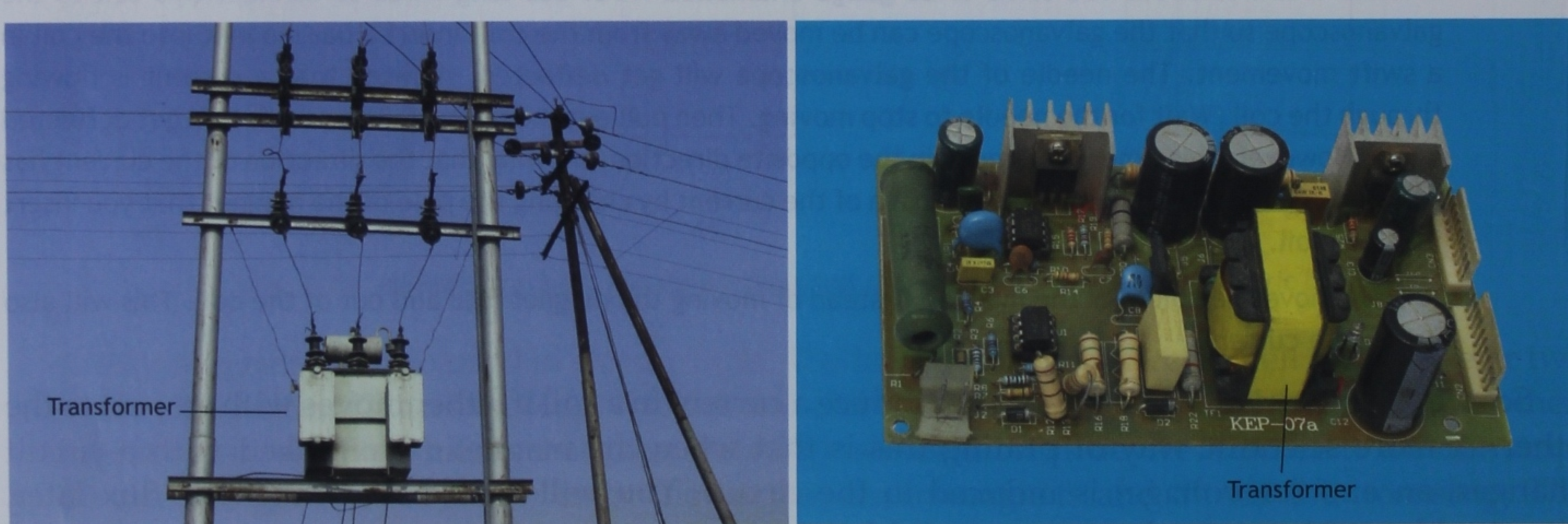
Alternating and Direct Currents

The direction of the current generated by the rotating coil in a generator keeps reversing, as the direction of motion of the coil with respect to the magnet keeps changing with every half rotation. This means the direction of current in the wires connected to the generator keeps reversing rapidly. This type of a current is called alternating current (AC). Our mains supply gives us an alternating current. It is easier to transmit power in the form of alternating current.

The current we get from cells, on the other hand, is called direct current (DC), because the direction of such a current is fixed. It flows from the positive terminal to the negative terminal of the cell. Dynamos, e.g., those used in motor cars, usually supply direct current.

Transformer

The power generated in large power stations is sent through power lines to towns, villages and industries located far away from these stations. To do this efficiently, power is transmitted at very high voltages, e.g., 132,000 V. However, the circuits and appliances we use at home are made to use power at 220 V. Hence, the voltage of the power supply needs to be decreased or stepped down before it enters our homes. This is done by a device called a transformer. Transformers are also used in electronic devices, such as televisions and music systems to decrease the voltage from 220 V to about 12 V. Some transformers are used to step up or increase the voltage.



(a) (b)

Fig. 7.14 (a) Power transformer (b) Transformer inside an electronic device

Electric Motor

In your previous class you have learnt that when a current-carrying conductor is placed in a magnetic field, it experiences a force. To understand this better, repeat the activity you did while studying this.

ACTIVITY You will need a cell, a magnet and an electric wire about 10 cm long. Tape the wire to the table in such a way that it is free to move. Place a magnet near it, as shown. Connect one end of the wire to one of the terminals of a cell. Then make the other end of

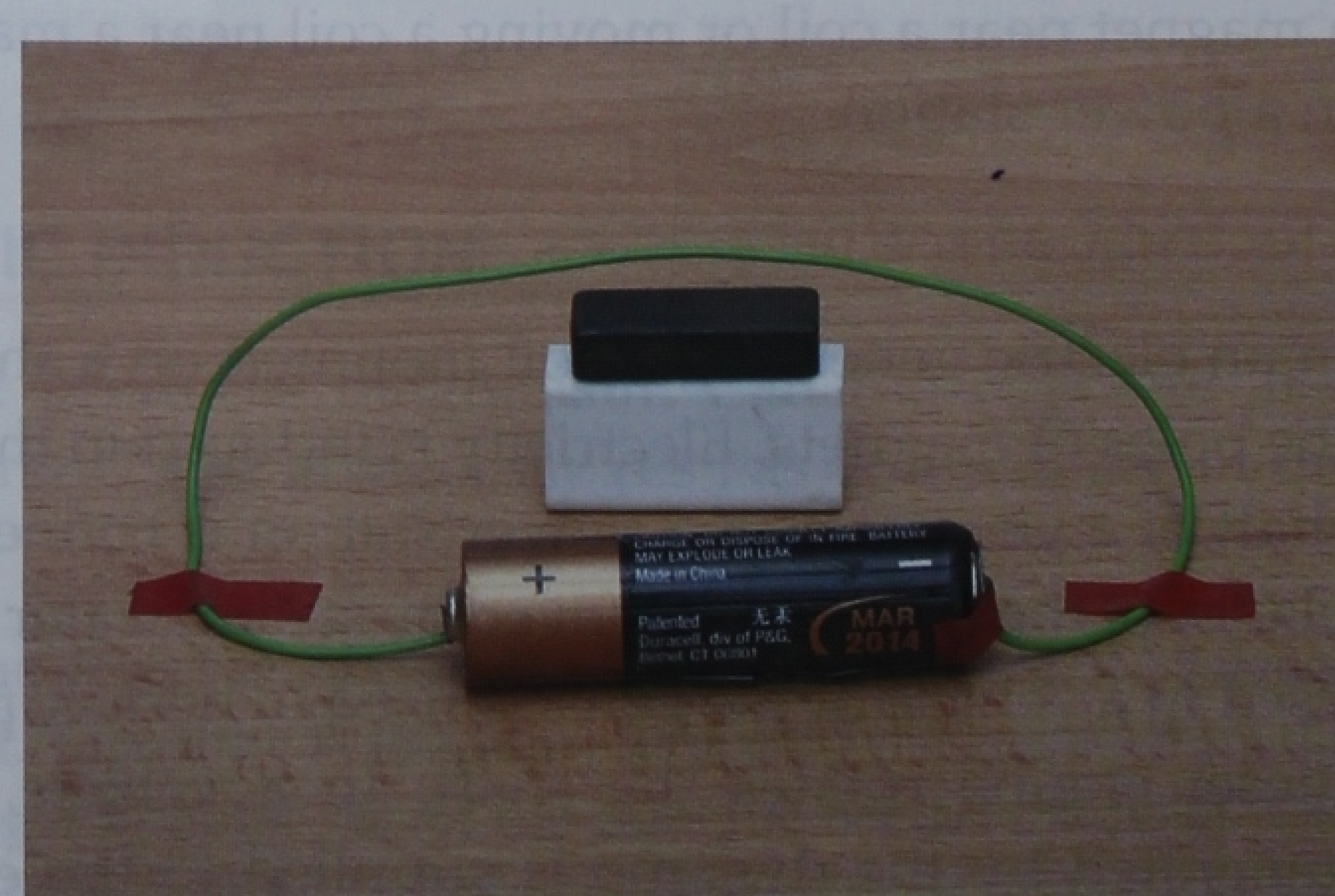


Fig. 7.15

the wire touch the other terminal of the cell. The wire will move every time it makes contact with the terminal.

This is essentially the principle of the electric motor, in which a coil of wire is placed inside magnets. When an electric current passes through the coil, the coil rotates. Thus, a device connected to the motor also rotates. Electric motors are used to drive fans, washing machines, food processors, and so on. They change electrical energy to mechanical energy, while generators change mechanical energy to electrical energy.

POINTS TO REMEMBER

- A magnet has two poles where its magnetic properties are concentrated. The north pole of a freely suspended magnet always points towards the north.
- Like poles repel while unlike poles attract.
- The region around a magnet where its effects can be felt is called its magnetic field. It can be represented by a number of continuous curves, called lines of force.
- Each line of force starts from the north pole, goes to the south pole and continues from the south pole to the north pole inside the magnet. Two lines of force do not intersect. The lines of force lie close to each other where the magnetic field is strong and are separated more widely where the field is weak.
- Rotating charges inside the earth create the earth's magnetic field. The earth acts as a giant magnet, with its south pole near the geographic north pole. Thus, a small bar magnet always aligns itself along the north–south direction. The magnetic compass works on this principle.
- Every electric current creates a magnetic field in its surroundings. The magnetic field due to a current in a straight conductor acts along circles with the conductor as axis. If current flows in the direction of the thumb, then the magnetic field acts along the curved fingers, acting away from the palm and towards the fingertips.
- When current flows in a ring, its magnetic field acts perpendicular to its plane, directed into the ring if this current flows clockwise and away from the ring if the current flows anticlockwise.
- A solenoid is a coil of wire somewhat like a spring. When current flows through a solenoid, the sum of the fields due to each ring creates an almost uniform magnetic field inside it. The field of a solenoid is similar to that of a bar magnet. The end of the solenoid from which the current appears to flow clockwise is the south pole of the solenoid.
- An electromagnet is a coil with a soft iron core. When a current flows through the coil, it acts as a magnet. The strength of an electromagnet depends on the number of turns per unit length, the current and the material at its core.
- Electromagnets are used to lift scrap iron, to separate iron from other materials, in relays and in MCBs. The electric bell also has an electromagnet.
- When a magnet is brought near a conducting ring or coil, it creates a magnetic flux linked with the coil. When the flux linked with a circuit changes, an emf is induced in it. This is known as electromagnetic induction. The flux can be changed by either moving the magnet or the coil.
- Electromagnetic induction is used to generate electricity in generators, in which a coil is rotated in a magnetic field. The current produced this way keeps changing direction and is called alternating current or AC.

- The electricity from any battery is DC, while we get AC from our mains supply.
- A dynamo is a small generator that supplies direct current.
- A transformer is a device that can increase or decrease the voltage.
- Electrical power is sent over long distances at very high voltage, e.g., 132,000 V. Transformers are used to decrease the voltage to 220 V before the supply enters our homes.
- An electric motor changes electrical energy to mechanical energy. It consists of a coil placed in a magnetic field. The coil rotates when a current flows through it.

EXERCISE

Short-Answer Questions

1. What causes the magnetic field of the earth?
2. Explain the thumb rule in relation to the magnetic field due to an electric current.
3. Describe the magnetic field inside a solenoid when current flows through it.
4. What is a dynamo? State one common use of a dynamo.
5. Describe the function of a transformer in brief.
6. How are electromagnets different from permanent magnets?
7. How is electrical power generated in a generator?

Long-Answer Questions

1. What are magnetic lines of force? Use a diagram to show the lines of force around a bar magnet.
2. Describe the construction of a magnetic compass. In what way has it been of use to mankind?
3. Describe the construction of an electromagnet. Mention some of its uses.
4. Distinguish between a dynamo and an electric motor. What are are the energy changes that can occur in them?
5. Distinguish between direct and alternating current, with examples.

Objective Questions

Choose the correct option.

1. Which of the following is not a property of magnetic lines of force?
   (a) Each line of force starts from a north pole and ends on a south pole.
   (b) Two lines of force do not intersect.
   (c) The lines of force lie close to each other in regions where the magnetic field is strong.
   (d) Each line of force is a continuous curve.
2. AC is used in preference to DC for mains power supply. Which of the following is the principal reason for this?
   (a) Transmission of electrical power is easier in the form of AC than DC.
   (b) It is cheaper to generate AC than to generate DC.
   (c) It is safer to use AC than to use DC.
   (d) More appliances can be used on AC than on DC.
3. Consider the statement "An electric current creates a magnetic field around itself."
   (a) This is always true.
   (b) This is true only for DC but not for AC.
   (c) This is true only for large currents.
   (d) This is true only for circular currents (currents flowing along a circular path).
4. The strength of an electromagnet does not depend on which of the following factors?
   (a) Its direction, i.e., north–south, east–west, etc.
   (b) The number of turns
   (c) The material of the core
   (d) The current flowing through it
5. The word 'alternating' in AC is used because the current
   (a) is an alternative to DC
   (b) alternates between high and low values
   (c) keeps reversing its direction
   (d) can be switched on and off alternately

Fill in the blanks.

1. Lines of force run from the south pole to the north pole ...... a magnet.

2. ...... charges inside the earth create the earth's magnetic field.
3. Electrical power is sent over long distances at ...... voltages.
4. We use electrical power at home at ...... V.
5. An electric motor changes ...... energy to ...... energy.

Write true or false.

1. A magnetic line of force is a closed curve.
2. There is a magnetic field at every place on the earth.
3. If current flows in the direction of the thumb of the right hand, the magnetic field acts along the curved fingers, acting away from the palm and towards the fingertips.
4. We can get both DC and AC directly from a battery.
5. An electric bell rings continuously because of the make-and-break arrangement.

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