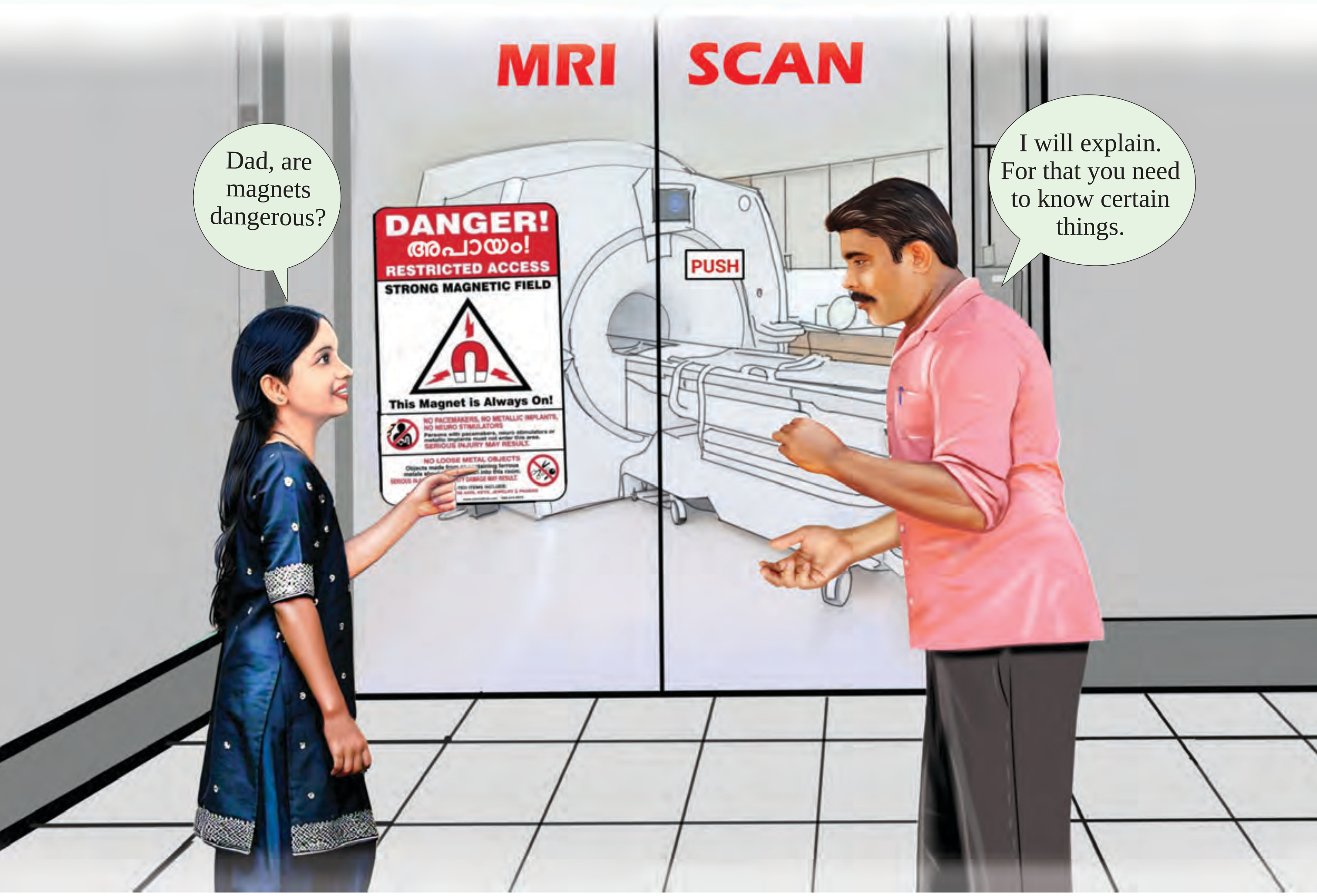
4 Magnetic Effect of Electric Current



Have you also had similar doubts?

Let's do some activities.

Take a pivoted magnetic needle. Bring a piece of wood near to it.

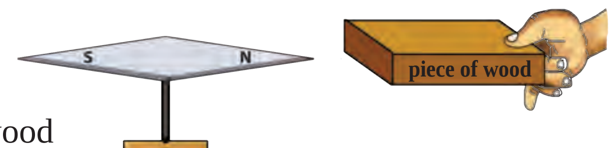


Fig. 4.1

- What do you observe?
  The magnetic needle (deflects / doesn’t deflect)
- Bring a bar magnet near the magnetic needle instead of the wooden piece. What do you observe?

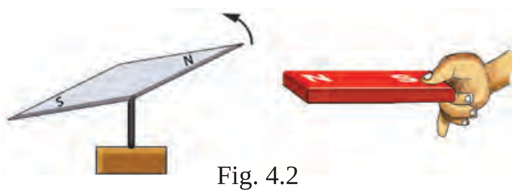


Fig. 4.2

PhET→ Magnets and Compass

- What is the reason?

Isn't the magnetic needle deflected because of the attraction and repulsion between the two magnetic poles?

You have now understood that if another magnetic field is created near the magnetic needle, the magnetic needle will deflect.

Don’t you know that there is a magnetic field around a magnet?

There are many magnetic field lines (flux lines) within a magnetic field. These imaginary lines are used only to visualise the magnetic field.

- Using a magnetic compass, draw the magnetic flux lines around a bar magnet in your science diary.

Compare your drawing with the given figure.

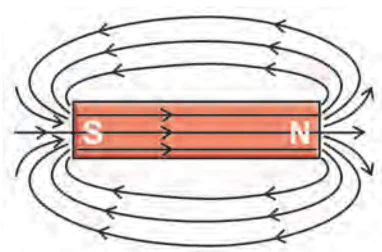


Fig. 4.3

- What is the direction of the magnetic flux lines surrounding a magnet?
- What is its direction inside the magnet?

Can we create a magnetic field without using permanent magnets?

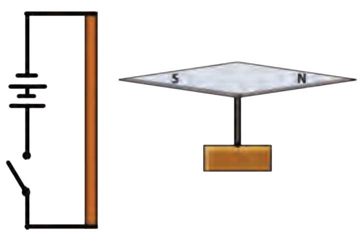


Fig. 4.4

Current Carrying Conductor and Magnetic Field

Make a circuit as shown in figure 4.4 using a conducting rod, connecting wires, a 9 V cell and a bell switch. Bring it near a pivoted magnetic needle.

- When the bell switch is off, what is the direction of the magnetic needle?
- Now turn on the bell switch. What do you observe?
- Why did the magnetic needle deflect now?

Now we can understand that a magnetic field is formed around a current carrying conductor.

A magnetic field is formed around a current carrying conductor. This magnetic field can exert a force on a magnetic needle. This is the magnetic effect of electricity.

Does the direction of deflection of the magnetic needle depend on the direction of the current?

Arrange a circuit as shown in figure 4.5 in such a way that the conducting rod AB is above the pivoted magnetic needle, parallel and close to it.

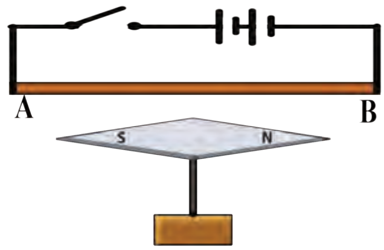
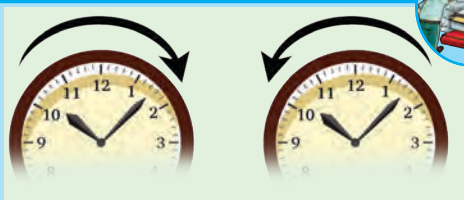


Fig. 4.5

- What do you observe when the bell switch is turned on?
- In which direction does the north pole of the magnetic needle deflect when viewed from above?

  (clockwise direction / anticlockwise direction)

Haven't we learned that a magnetic field can exert a force on a magnetic needle? In the previous experiment, the force necessary to move the magnetic needle is created by the magnetic fields. Isn't this magnetic field due to the current passing through the conductor?



Clockwise direction | **Anticlockwise direction**

The clockwise direction is the direction in which the hands of a clock move. The anticlockwise direction is the direction opposite to it.

Reverse the direction of the current. Now isn't the magnetic needle deflecting in the opposite direction?

- What could be the reason? Write down your inference.

Isn't this because the direction of the magnetic field around the conductor has reversed?

- In figure 4.5, which direction does the north pole of the magnetic needle deflect, when the current is from A to B?

  (clockwise direction / anticlockwise direction)
- What is the direction, if the current is from B to A?

  (clockwise direction / anticlockwise direction)

Repeat the experiment by placing the conductor below the magnetic needle.

- When the current is from A to B, in which direction does the north pole of the magnetic needle deflect?
  (clockwise direction / anticlockwise direction)

Hans Christian Oersted
Lifetime : 1777-1851
Birthplace : Denmark

Hans Christian Oersted was a Danish scientist. In 1820 he conducted an experiment that demonstrated the relationship between electricity and magnetism. These experiments laid the foundation for advancements in the field of electricity. The CGS unit of intensity of the magnetic field is named oersted in honour of him.

- What is the direction, if the current is from B to A?

  (clockwise direction / anticlockwise direction)

Through this experiment, the scientist Hans Christian Oersted discovered that a magnetic field is formed around a current carrying conductor.

Can we find out the direction of the magnetic field around a current carrying conductor?

Let's do an experiment to understand the relationship between the direction of the current and the deflection of the magnetic needle.

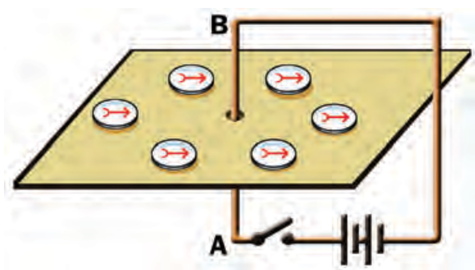


Fig. 4.6

Pass a copper wire through a cardboard and arrange it perpendicular to the surface of the cardboard as shown in the figure.

Connect the copper wire in series with a 9V battery and a bell switch. Arrange small magnetic compasses in a circular shape around the copper wire on the cardboard as shown in the figure. Turn on the bell switch. Observe the direction of deflection of the north pole of the magnetic needle.

- When the current is from A to B, in which direction does the north pole of each magnetic needle deflect?

  (clockwise / anticlockwise)

Observing the magnetic compasses mark the north poles of the magnetic needles on the cardboard.

After removing the magnetic compasses from the cardboard, draw the magnetic field lines and mark their direction.

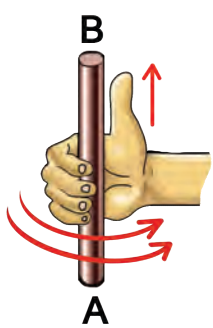


Fig. 4.7

- What is the direction of the magnetic field now?

  (clockwise / anticlockwise)

Now, imagine holding the current carrying conductor AB with your right hand so that your thumb points in the direction of the current.

- Compare the direction indicated by the tips of your fingers curling around the conductor with the direction of the magnetic field. Aren't they the same? Write down your findings in the science diary.

This method of finding the direction of the magnetic field around a current carrying conductor is known as the right hand thumb rule.

Right Hand Thumb Rule

Imagine holding a conductor with your right hand in such a way that the thumb points in the direction of the electric current, the fingers curled around the conductor will indicate the direction of the magnetic field.

Ampere's Swimming Rule

Ampere's swimming rule can also be used to find the direction of the magnetic field around a current carrying conductor. Imagine a person swimming in the direction of the electric current, looking at the magnetic needle, as shown in the figure. The north pole of the magnetic needle will deflect towards the left side of the person.

Let's do another activity (Fig. 4.8).

Make two holes in a cardboard. Pass a copper wire through these holes and make a loop. Arrange half of the loop above the cardboard and half below as shown in the figure. Place magnetic compasses near the holes through which the copper wire passes. Connect the loop of wire to a battery and a bell switch.

- Turn on the bell switch. What do you observe?

Find the direction of the magnetic field at points A and B by observing the magnetic compasses.

- In which direction does the current flow in the part of the coil that faces you?

  (clockwise direction / anticlockwise direction)
- In this case, what is the direction of the flux lines?

  (into the coil / out of the coil)
- What happens to the magnetic field if the bell switch is turned off?

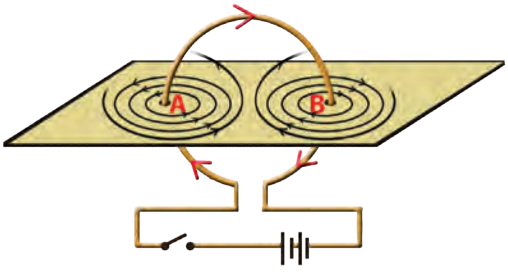


Fig. 4.8

If the current in the coil is clockwise, the direction of the flux lines will be inward into the coil. If the current is anticlockwise, the direction of the flux lines will be outward.

Haven't you noticed that there was no magnetic force when there was no current in the circuit? From this, we can understand that the magnetic force obtained from the coil is temporary (only when there is current).

Is there a way to increase the magnetic strength associated with a coil of wire?

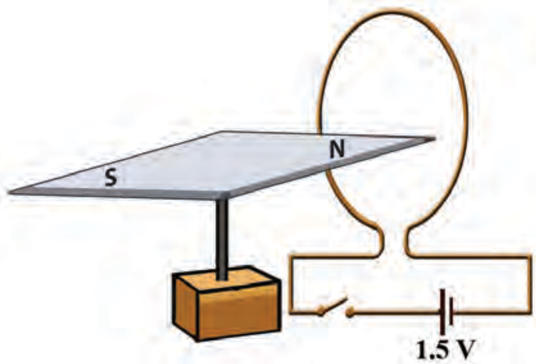


Fig. 4.9

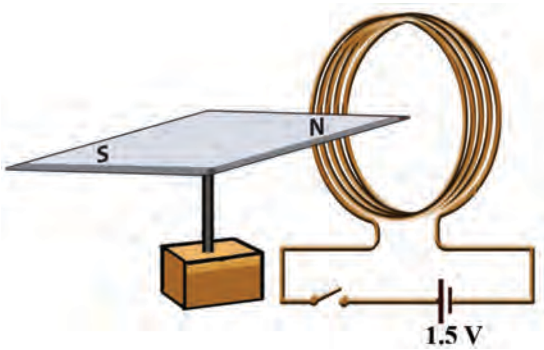


Fig. 4.10

Connect a coil of wire to a battery and a bell switch. Hold the coil near one end of a pivoted magnetic needle.

- Turn on the bell switch. What do you observe?

Now increase the number of turns of the coil and hold it near the magnetic needle. Pass the same current through it.

- What change do you observe in the deflection of the magnetic needle?
- What change has occurred in the magnetic strength?

Then, replace the 1.5 V cell with a 3 V battery and pass the current.

- Now, has the deflection of the magnetic needle increased or decreased?
- If so, write down the factors that affect the strength or intensity of the magnetic field around a coil of wire.

  ➢ Number of turns of the conductor

  ➢

When the number of turns of the conductor increased, both the magnetic strength and the magnetic flux increased, but the flux produced by a single turn of the conductor did not increase.

How can we utilize the magnetic effect of electric current using coils of wire?

Solenoid

Take a PVC pipe of length 10 cm and diameter 4 cm (1.5 inch). Wind 2 m insulated copper wire of gauge 26 around it. Remove the copper coil from the PVC pipe without deforming the coil. What is the shape of the coil now? Doesn't it look like a spring [Fig.4.11(a)]? An insulated conductor wound in a spiral shape is a solenoid. The centres of all the turns lie on the same straight line.

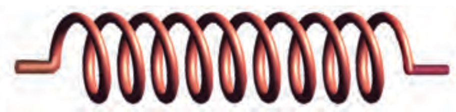


Fig. 4.11 (a)

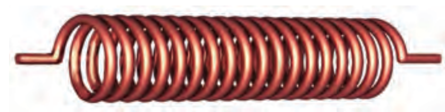


Fig. 4.11 (b)

Similarly, prepare another solenoid of the same length as the first one by winding 4 m of insulated copper wire on the same PVC pipe [Fig. 4.11 (b)].

Arrange magnetic compasses around the first solenoid. Connect the solenoid to a 9 V battery and a bell switch (Fig. 4.12).

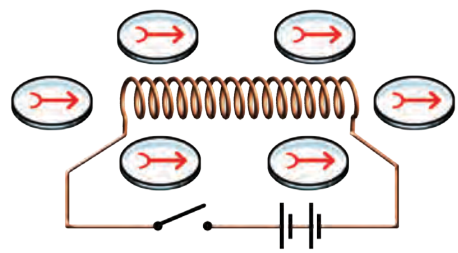


Fig. 4.12

What do you observe when you turn on the bell switch?

Repeat the experiment using the second solenoid.

- Now, what do you observe? (the deflection increases / decreases)
- What is the reason?
- Increase the current through the solenoid. What about the deflection of the magnetic compasses?

  (increased / decreased)

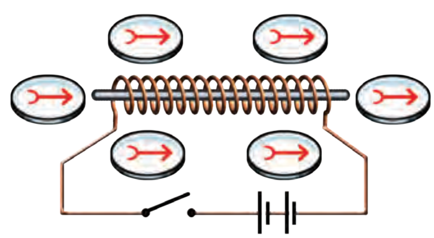


Fig. 4.13

- Place a piece of soft iron as the core of the solenoid. Turn on the bell switch (Fig. 4.13). What do you observe?
- Place a soft iron core with a larger area of cross section. Turn on the bell switch. What do you observe? (Fig. 4.14)

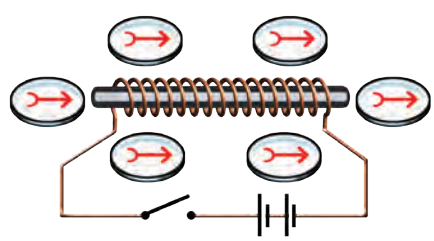


Fig. 4.14

Observe the magnetic compasses at the ends of the solenoid and determine the polarity at each end.

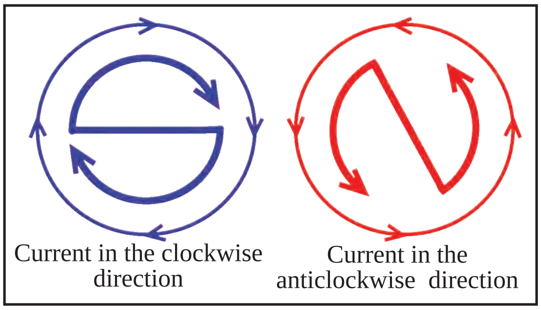


Fig. 4.15

- If the current flows in clockwise direction at one end of the solenoid, what will be the polarity at that end?

  (south pole / north pole)
- What about the end in which the current is in anticlockwise direction?

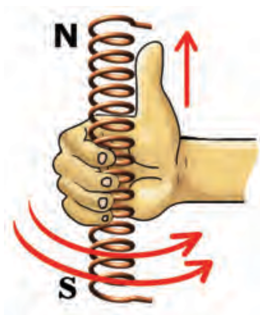


Fig. 4.16

Imagine holding a solenoid with your right hand. When your fingers curl around in the direction of the current, isn't your thumb pointing towards the north pole of that solenoid?

If you hold a current carrying solenoid with your right hand in such a way that your four fingers curl the coils in the direction of the current, the thumb points towards the north pole of the solenoid.

The solenoid utilizes magnetic effect of electricity for practical purposes.

PhET→ Magnets and Electromagnets

Based on the activities conducted so far, write down the factors that influence the magnetic strength of a current carrying solenoid.

- The number of turns of the conductor per unit length.
-

Electromagnets are devices that create magnetic field using electricity.

Explain how a strong electromagnet can be made.

Are there similarities between the magnetic field around a bar magnet and that around a current carrying solenoid?

Sprinkle iron filings on an acrylic sheet placed over a bar magnet and observe.

Compare it with figure 4.17 (a) and record your inferences in the science diary.

Now sprinkle iron filings on an acrylic sheet placed on top of a current carrying solenoid [Fig. 4.17 (b)].

- What do you observe?

- Haven't you understood that the magnetic field lines around a bar magnet and a solenoid are alike?

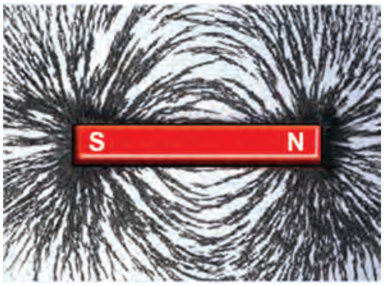


Fig. 4.17 (a)

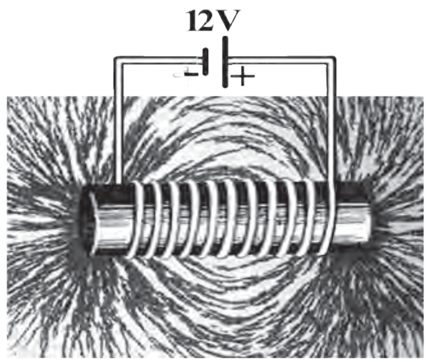


Fig. 4.17 (b)

Complete table 4.1 by comparing the stability of magnetic field, polarity, and the possibility of change in magnetic strength etc., of a bar magnet and a current carrying solenoid.

Bar magnet	Current carrying solenoid
Magnetism is permanent	
	Magnetic strength can be varied.
Polarity cannot be changed	

Table 4.1

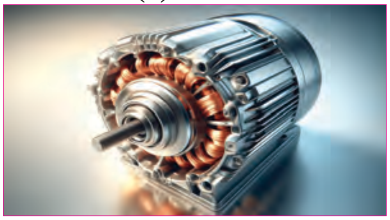
- If the strength of the electromagnets is significantly increased, won't they attract surrounding magnetic materials strongly?

Observe situations in (Fig. 4.18) where strong magnetic fields are used.

Cranes using electromagnets
(a)

Maglev train
(b)

MRI scanner
(c)



Electric motor
(d)

Fig. 4.18

Very strong electromagnetic fields are used in MRI (Magnetic Resonance Imaging) scanning. We know that patients are asked to remove all ornaments (made of metal) before undergoing an MRI scan. Since the magnetic field of the MRI scanner is very strong, magnetic materials are strongly attracted and may cause accidents. The presence of other metals reduces the accuracy of the scanning report. Now haven't you understood the indication of the image seen at the beginning of this unit? If there is a magnetic shielding made of iron sheets (as in an electric motor), the magnetic flux neither flows out nor causes any accidents.

The figures of current carrying conducting loops are given below. Which figures give the correct representation of the magnetic polarity of the end you are facing?

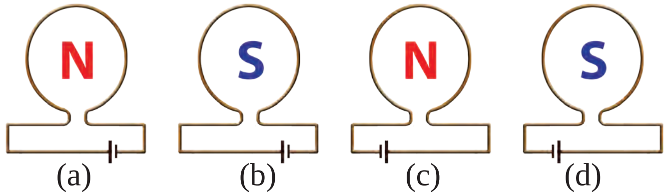


Fig. 4.19

Observe figure 4.20.

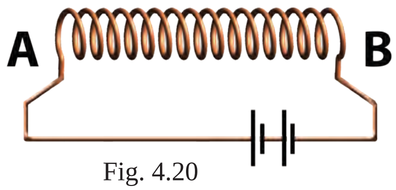


Fig. 4.20

(a) What is the magnetic polarity of end A?

(b) What is the magnetic polarity of end B?

Electric Motor

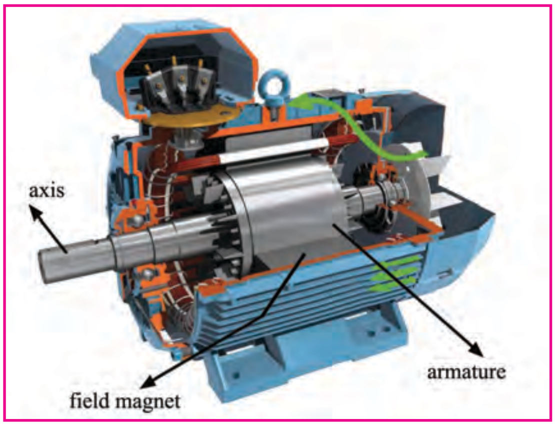


Fig. 4.21

Observe figure 4.21. This is a picture of an electric motor. Don't you see many coils? You know that a magnetic field is created when electricity flows through the coils of wire.

How does the motor work when the switch is turned on?

Let's see how forces are experienced by a current carrying conductor in a magnetic field.

Place a reasonably sized ring magnet on a table with the north pole facing upwards. Place a thin acrylic sheet on top of it. Take two copper wire pieces of length 20 cm each (gauge 16) with its insulation removed. Place them parallel to each other on the sheet above the magnet. Place another piece of copper wire (AB) across on top of them as shown in the figure. Connect the positive terminal of a 12V battery through a bell switch to one of the parallel copper wires. Connect the end of the second copper wire to the negative terminal of the battery.

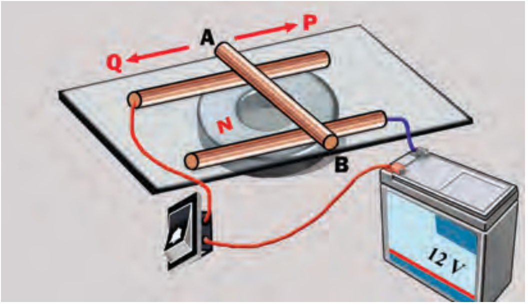


Fig. 4.22

- What do you observe when the switch is turned on?
- Note in which direction the copper wire AB moved.
  (towards Q / towards P)
- Repeat the experiment by reversing the polarity of the battery. In which direction does the copper wire move?
  (towards Q / towards P)
- Repeat the experiment by placing the south pole of the magnet facing upwards. Repeat the experiment by reversing the polarity of the battery. What do you observe?
- What do you observe if the polarity of the magnet and the direction of the current are reversed together?
- What could be the reason for the conductor AB moving in the same direction as before? Write it down in your science diary.

If the direction of the current or the magnetic field is reversed, the direction of motion of the conductor will be reversed.

If the direction of the current and the magnetic field are reversed together, the conductor will move in the same direction as before.

What are the factors that influence the direction of the force experienced by the conductor?

- Direction of electric current
-

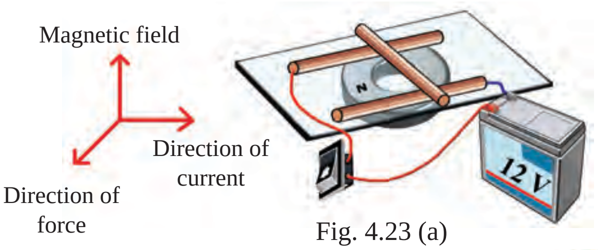


Fig. 4.23 (a)

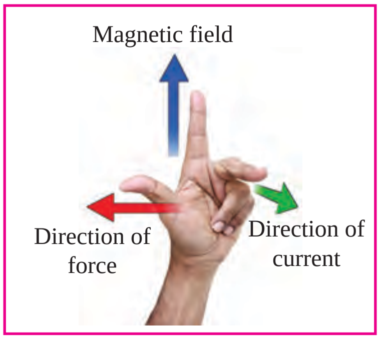


Fig. 4.23 (b)

- In this experiment, in which way are the directions of the electric current and the magnetic field arranged?

  (perpendicular to each other / parallel to each other)

Point the first finger of your left hand in the direction of the magnetic field and the second finger in the direction of the electric current through the conductor.

- Now, isn't the force experienced by the conductor in the direction indicated by the thumb?

Didn't you understand that the direction of the magnetic field, the direction of the electric current, and the direction of motion of the conductor are mutually perpendicular?

The direction of the force experienced by a current carrying conductor placed in a magnetic field, the direction of the magnetic field and the direction of the electric current are mutually perpendicular. This relationship was discovered by John Ambrose Fleming. Fleming's left hand rule is useful to find the direction of motion of a conductor in devices that utilise the magnetic effect of electricity.

Fleming's Left Hand Rule

Hold the thumb, first finger, and second finger of your left hand perpendicular to each other. If the **F**irst finger points in the direction of the magnetic field and the se**C**ond finger in the direction of the electric current, then the thu**M**b will indicate the direction of the force experienced by the conductor.

While using Fleming's left hand rule to find the direction of motion of a conductor, it will be easier to first confirm the direction of the magnetic field with the first finger.

How does an electric motor work?

Let's do some activities to understand the parts and working of an electric motor. For this, we need cardboard, insulated copper wire, a 9 V battery, a ring magnet, two safety pins, and a conducting wire. Wrap the insulated copper wire around a PVC pipe to make a coil. Make sure that both ends of the coil extend slightly outwards. Remove the insulation at both ends. Arrange the coil, ring magnet and battery as shown in figure 4.24. Make sure that the plane of the coil is parallel to the surface of the cardboard.

- What do you observe when the switch is turned on?
- Why does the coil rotate very fast?

Discuss on the basis of Fleming's left hand rule and write your inference in the science diary.

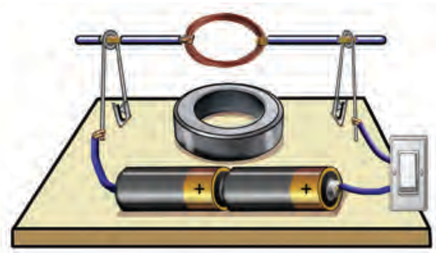


Fig. 4.24

Motor Principle

A current carrying conductor which is free to move, placed in a magnetic field, exhibits a tendency to deflect. This is motor principle.

Motors in electrical appliances like fans and mixies work on this principle.

Observe the schematic diagram of an electric motor (Fig. 4.25).

- Which are the main parts of an electric motor?

N, S → Magnetic poles   PQ → Axis of rotation R_1, R_2 → Split rings

ABCD → Armature B_1, B_2 → Graphite brushes

The armature is made by winding insulated copper wire over a soft iron core of suitable shape. It is firmly attached to the axis PQ. The armature can rotate freely about this axis.

From figure 4.25, you can understand the direction of the current through the armature. Is the direction of the current on sides AB and CD the same, relative to the direction of the magnetic field? You have understood that the direction of the magnetic field is from the north pole to the south pole. Is the force experienced on the side AB and that on the side CD in the same direction? Find out based on Fleming's left hand rule and write it down.

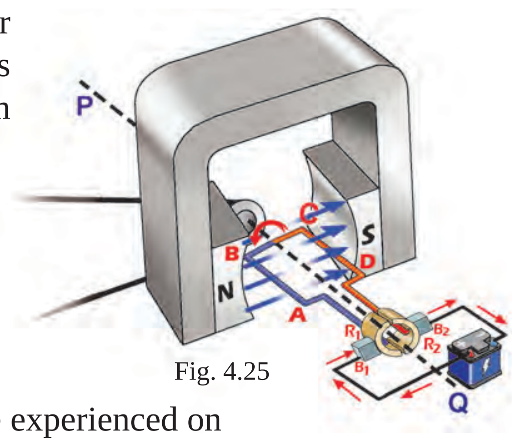


Fig. 4.25

- Direction of the force experienced on side AB (upward / downward)

BLDC Motor (BrushLess Direct Current Motor)

Unlike ordinary DC motors BLDC motors operate without brushes and split rings. Instead of the brushes and rings rubbing against the rotating armature, an electronic switch is used to change the direction of the current as required. Induction motors are used in ordinary fans. Fans using BLDC motors reduce electricity consumption up to 60%. Hence BLDC fans are known as energy saving fans.

- Direction of the force experienced on the side CD is

  (upward / downward)
- What is the effect produced on the armature by the forces experienced on sides AB and CD?

Thus, an electric motor is a device that converts electric energy into mechanical energy based on the motor principle. Isn't the force experienced in opposite directions on the sides AB and CD?

Even though the direction of the magnetic field does not change, the force is experienced on sides AB and CD in opposite directions. Isn't this because the direction of the current is opposite in AB and CD?

Let's see how this is made possible after half rotation (180°).

This is made possible by the special arrangement of brushes and split rings.

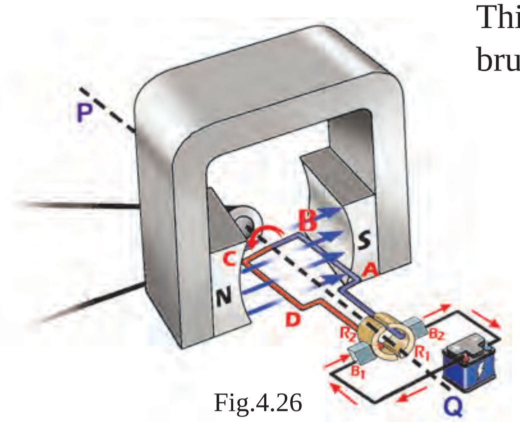


Fig.4.26

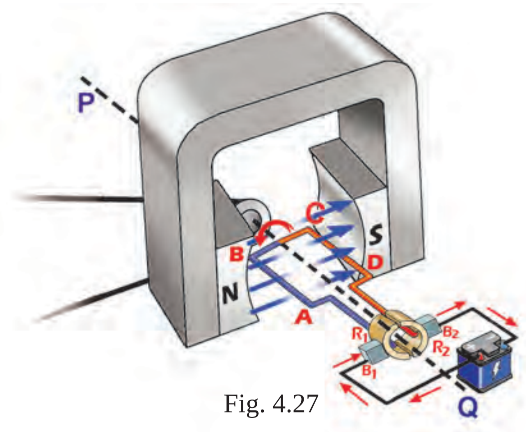


Fig. 4.27

- Just before the armature starts rotating (Fig. 4.25), aren't the contacts between the brushes and the split rings B_1R_1 and B_2R_2?
- When the armature completes half rotation (Fig. 4.26), how are the contacts between the brushes and the rings?

  B_1R_2, ...
- When the armature completes one rotation, how are the contacts between the brushes and the rings (Fig. 4.27)?
- At the beginning of rotation (Fig. 4.25), what is the direction of the current through the side AB near the north pole?

  A→B / B →A
- What about side CD near the south pole?

When half rotation is completed (Fig. 4.26), isn't the side CD that comes in front of the north pole?

- What is the direction of the current?

  C→D / D →C

- What is the direction of the current through the side AB that comes in front of the south pole?
- When sides AB and CD reach in front of the north pole, the direction of the current is always

  inwards / outwards
- And when sides AB and CD reach in front of the south pole, what will be its direction?

Thus, the direction of the current is the same in the parts of the armature that reach in front of the magnetic poles. Hence the armature rotates continuously in the same direction.

The split ring commutator is the mechanism used to change the direction of the current through AB and CD after each half rotation.

Are there any other devices that operate based on the motor principle?

Moving Coil Loudspeaker

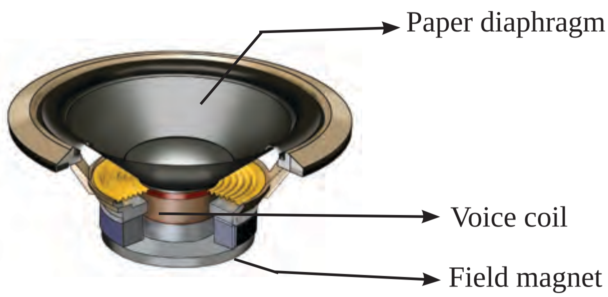


Fig. 4.28 (a)

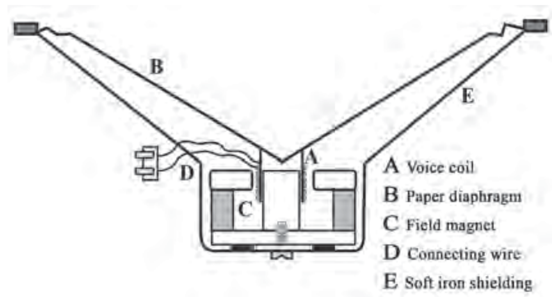


Fig. 4.28 (b)

- What are the main parts of this device?
- Where is the voice coil situated?
- From where do the audio signals (electric signals) reach the voice coil?
- To which part is the diaphragm connected?
- What happens when audio signals pass through the voice coil?
- What happens to the diaphragm?
- What is the energy conversion taking place in this device?

The electric signals (audio signals) received from a microphone are amplified using an amplifier. These audio signals are then passed through a voice coil, which is placed in a magnetic field. The coil experiences a force and vibrates because the coil carrying the electric current is placed in a magnetic field. This vibration causes the diaphragm to vibrate, thus reproducing the sound.

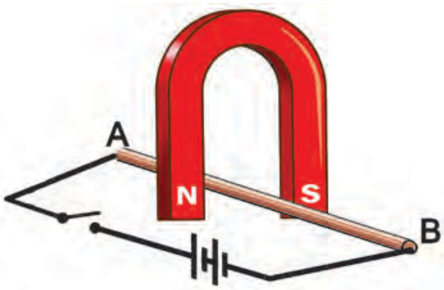


Fig. 4.29

In figure 4.29, AB is a conducting rod that is free to move.

(a) When the bell switch is turned on, in which direction will the metal rod AB move?

b) What should be done to keep the direction of motion of the rod unchanged while changing the direction of the current?

What is the energy conversion that takes place in a moving coil loudspeaker?

Name two devices that work on the principle of a motor.

Let's Assess

1. A conducting wire AB is bent into a loop as shown in the figure. A battery is connected to the ends of the conductor.
   a) When the switch is turned on, find the direction of the magnetic field around the conductor at points A and B.
   b) State the law used for this.
   c) Explain how to find the direction of the magnetic field in a conducting loop.

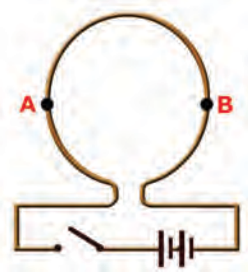


Fig. 4.30

2. The direction of the magnetic field around a current carrying conductor AB is marked. Find the direction of the electric current through the conductor and state the law that supports this.

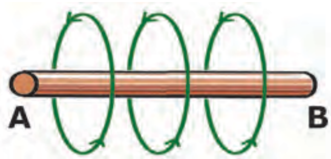


Fig. 4.31

3. Choose the correct statement regarding the magnetic polarity of a current carrying solenoid and write it down

   a) If the current in one end of the solenoid is clockwise, then that end is north pole.
   b) If the current in one end of the solenoid is clockwise, then that end is south pole.
   c) If the current in one end of the solenoid is anticlockwise, then that end is south pole.
   d) None of the above.

4. Observe the diagram.

   a) Identify the device shown in the diagram.
   b) To rotate the armature in a clockwise direction, which terminal of the battery should be connected to the point X?
   c) What is the necessity of using a split ring commutator in this device?

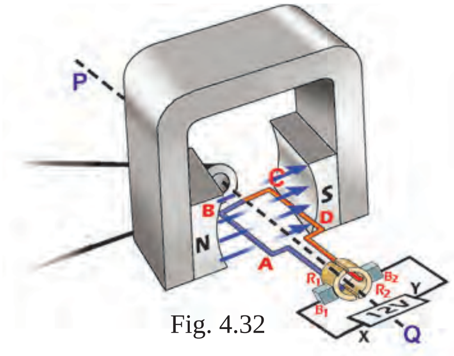


Fig. 4.32

5. What is the function of the diaphragm in a moving coil loudspeaker?

   a) To amplify sound signals.
   b) To convert mechanical energy into sound waves.
   c) To separate high frequency sound signals.
   d) To increase the strength of the magnetic field.

6. A conductor is held above and parallel to a magnetic needle.

   a) What causes the magnetic needle to deflect when the switch is turned on?
   b) Suggest two ways to reverse the direction of this deflection.

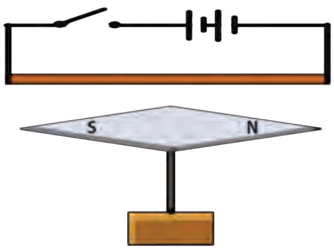
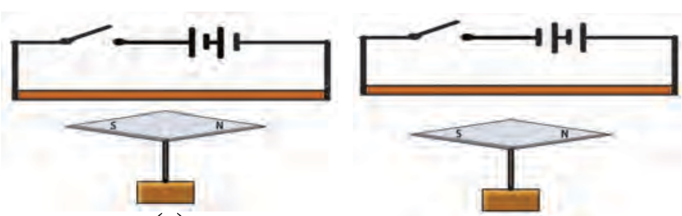


Fig. 4.33

7. Observe the diagrams [Fig. 4.34 (a), (b)].

   a) In both cases, does the north pole of the magnetic needle deflect clockwise or anticlockwise, when the switch is turned on?
   b) Justify your answer.


(a) Fig. 4.34 (b)

8. AB is a copper wire. An acrylic sheet is kept above the south pole of a magnet. Two copper wires are placed above the sheet in such a way that they are parallel. A battery and a switch are connected to the wires. AB is placed above them.

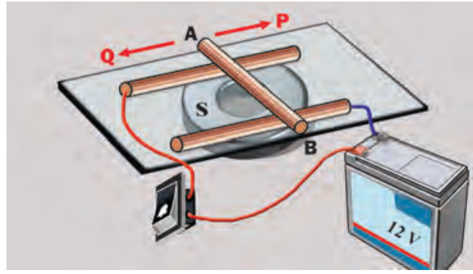


Fig. 4.35

   a) In which direction will the copper wire roll when the switch is turned on?

      (towards Q / towards P)

   b) What happens if the direction of the current is reversed?

9. Observe figure 4.36.

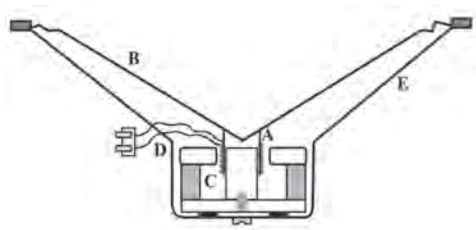


Fig. 4.36

   a) Identify the device shown in the schematic diagram.

   b) What is its working principle?

   c) What is the energy conversion taking place in this device?

   d) Name the labelled parts.

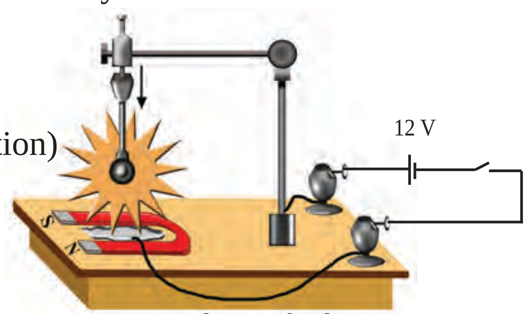
   e) Name another device that works on the same principle.

10. A wooden block contains mercury between the north and south poles. A freely rotating toothed wheel is in contact with the mercury. When an electric current is passed through the wheel,

   a) in which direction is the wheel rotating?

      (clockwise direction / anti clockwise direction)

   b) Justify your answer.



Barlow's wheel

Fig 4.37

Extended activities

1. Construct and operate a device to prove the principle of a motor using two permanent magnets, a piece of copper wire, conducting wires, and a cell.
2. Dismantle a scrap loudspeaker. Identify its parts and arrange them on a paper with labels. Explain why the voice coil in it is very thin.