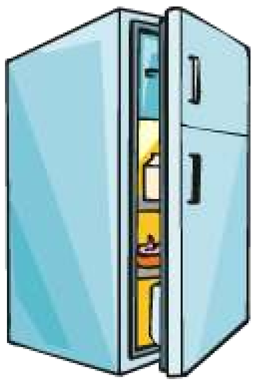
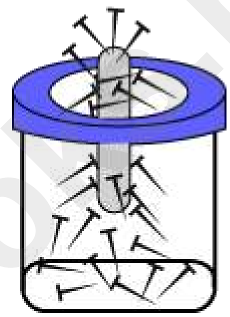
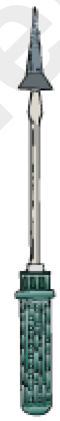
Electricity and Magnetism

Magnet - An Introduction

You are familiar with the fact that magnets have a variety of applications in our daily lives. Magnets are used in refrigerator doors, in junkyards, as pin holders, in screwdrivers, etc.



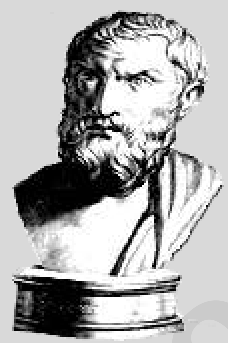
A question that can arise in our minds is how magnet was discovered. In this section, we will tell you an interesting story about the accidental discovery of magnet.

Around 2,000 B.C., a shepherd named **Magnes** lived in an area named **Magnesia** (situated in Northern Greece). He used to take his herd of sheep to graze in the nearby mountains. He used to control his herd with a long stick that had an iron tip. Also, a few iron nails were fixed to his shoes.

It is said that one day while he was herding his sheep, he observed that his shoes and the tip of the stick were stuck to a large black-coloured rock. It was very difficult for him to move on that black rock. Later, this rock and similar rocks were named **magnetite** (after either his name or that of the place). Magnetite has the property to attract objects made up of iron. The substances that can attract iron are now known as **magnets**.

Do You Know:

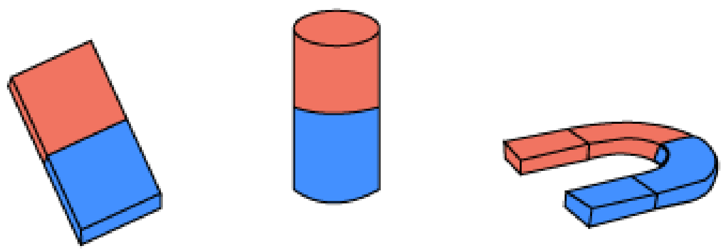
Lucretius was the first person who wrote magical stories about magnets around the first century BC.



Magnetite is the natural magnet. It is found in the form of rocks. Sometimes, magnetite is found in large quantities in beach sand. It is also found in the brain of bees, some birds, and in humans

With the passage of time, people learned to make magnets from iron pieces. These magnets are known as **artificial magnets**. Like natural magnets, these artificial magnets can also attract iron objects.

With the help of modern technology, artificial magnets having different shapes (for example, bar magnets, cylindrical magnets, and horseshoe magnets, spherical magnets) are also made.



a) Bar magnet b) Cylindrical magnet c) Horseshoe magnet

Remember, all the magnets, natural or artificial, always have two poles know as North-Pole (N) and South-Pole (S).

Let us have some fun with a magnet.

Find more on the discovery of magnets from this video

Properties of a Magnet

Attractive Property

Attach a magnet to one end of a long stick. Now, hold the stick and drag the other end (the one having the magnet attached to it) on the soil present in areas such as your garden, backyard, playground, and school. You will find that some soil particles stick to the magnet.

When you observe these small particles carefully, you will see that they are iron filings. Make a table listing the amount of iron filings present in the soil at different locations. **Where do you find the greatest amount of iron filings?**

Naina has a box in which she keeps all the materials that are required during stitching such as spools of thread, wool, buttons, needles, and small bits of cloth. She is not able to find the needle in her box. **What is the easiest way to find the lost needle?**

Refrigerator stickers: Have you seen stickers that remain attached to the surface of refrigerators? These stickers have magnets attached to them. **Why do the stickers stick to the door of a refrigerator?**

Refrigerators are made up of magnetic material (iron). Hence, stickers having magnets stick to refrigerators.

From the given examples, you can easily make out the most important property of a magnet—**a magnet attracts objects made up of iron**. **This is called attractive property of magnet.** Apart from iron, the other materials that a magnet attracts are nickel, cobalt.

Identifying Directions Using a Magnet

Ramdin is a fisherman who often sails in the sea to catch fish. He always carries a marked magnet to help him in identifying the directions. **How does this magnet help him in locating the correct direction?**

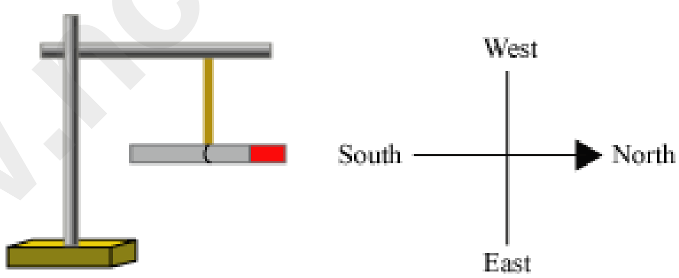
Do you know that **a bar magnet, when suspended freely, always comes to rest in the North-South direction.** You can confirm this fact by suspending a marked magnet by a thread. Notice the direction pointed by its marked end when it comes to rest.

Marking a bar magnet using the position of the sun

Stand on your roof with your face toward the sun in the morning. Since you are facing the East, your left hand will be toward the North and your right hand will be toward the South. Suspend a bar magnet and allow it to rotate freely. When it comes to rest, mark the end that points toward your left with red ink. Hence, your magnet becomes a **marked magnet**. The marked end of the magnet will indicate the North direction when suspended freely with a thread.

Identifying the four directions

To identify the four directions using your marked magnet (the marked end points toward the North), suspend the marked magnet with a thread, and wait until it comes to rest. The marked end will point toward the North, while the unmarked end will point toward the South, as shown in the given figure.



The magnet helps Ramdin in identifying the directions because when suspended freely, a magnet always aligns itself in the North-South direction.

In the making and working of a magnetic compass, the property of the North-South alignment of a magnetic needle is used.

In ancient times, sea travellers used to identify the directions with the help of marked bar magnets suspended by threads.

Rajeev’s teacher gives him two identical, red-coloured needles. His teacher tells him that one is a magnetised needle, while the other is an ordinary iron needle and asks him to identify the magnetised one. How can Rajeev do so?

Magnetic compass

A simple magnetic compass

With the help of a magnetic compass, you can know the directions at a particular place. The red end of the needle indicates the North direction. Rotate the compass in such a way that its red end directly points to the letter ‘N’ of the compass. Now, observe all the four alphabets marked on the compass. These letters indicate the four directions at that particular place, in the same order.

Take a bar magnet and label its ends as **A** and **B**. **How would you determine which letter is on the north pole of this magnet?**

A bar magnet

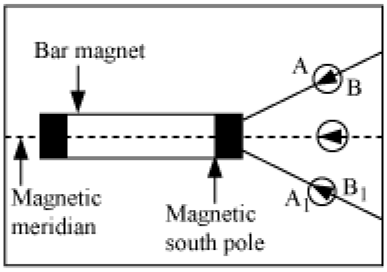
Do You Know:

A Chinese emperor named Hoang Ti had a specially designed chariot having a statue of a lady fixed on it. The statue, which could freely rotate about an axis, had an extended arm to show the direction.

It was said that the extended arm of the lady always pointed toward the South when it came to rest. In this way, the emperor could locate his way when he was at a new place.

Why did the extended arm of the lady always point toward the South?

Magnetic Poles



- Take a white sheet of paper and fix it on a wooden drawing board.
- In the middle of the white sheet, draw a straight line.
- Place a magnetic compass needle on the drawing board and turn the board in clockwise or anticlockwise direction to align the needle with the line drawn on drawing board.

At this point, the drawing board is said to be in magnetic meridian.

- Place a bar magnet instead of the magnetic needle such that its axis coincides with the line on the paper.
- Mark the outline of the magnet.
- Place the compass needle near one end of the bar magnet.

As the action of the earth's field is ineffective along the magnetic meridian, the compass needle will not show any deflection because of the earth's magnetic field. The compass needle is only attracted by the nearest pole of the magnet at this position.

- Mark the two ends of the needle by two dots as shown in the figure.
- Now, change the position of the compass needle and repeat the whole process for the new position of the needle. Take two such marks by placing the compass at two different places.
- Join the two marks by straight lines.
- You will see that the straight lines meet near the end of the magnet.
- It is this point of intersection that indicates the exact position of the magnetic pole of the bar magnet.

Try to find out the exact position of the other pole of the magnet.

The length between the two poles is called the effective length of the magnet. It is observed that the effective length of a magnet is 0.84 times the length of the real magnet.

So, have you found the answer to the question – **why a magnetic compass always aligns itself along the North-South direction**?

So far you have learned that *opposite poles of magnets attract each other whereas like poles of magnets repel each other.*

The answer to the question lies in this property of a magnet.

A magnetic compass works on this principle because the earth is considered as a huge bar magnet with its North and South poles aligned along the geographical South and North Poles respectively.

Hence, the North pole of the magnetized needle in a magnetic compass is attracted towards earth's geographic North Pole and the South pole of the magnetized needle is attracted towards earth's geographic South Pole. Hence, the magnetized needle of a magnetic compass always aligns itself along the North-South direction.

Some interesting facts:

- Did you know that the only repulsive force that you have studied about is the magnetic force?
- Repulsion is considered the sure way for testing magnets. Do you know why?

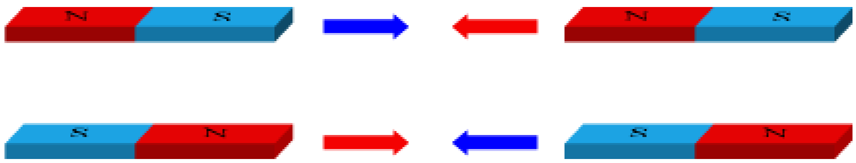
Magic trick

Pooja goes to a village fair. There, she sees a magic trick in which a frog is made to hover magically over a table defying earth's gravity. Pooja observes that the magician had slipped a magnet below the table and this made the frog rise in the air. **What made the frog rise in the air in the presence of the magnet?**

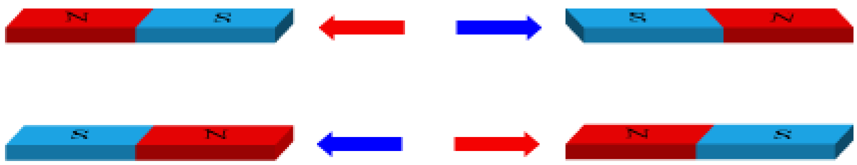
The frog behaves like a magnet. Hence, it is repelled by the permanent magnet placed below the table.

Like poles repel each other and unlike poles attract each other

- When north pole of one magnet is brought near to south pole of another magnet, we will observe that the poles will attract each other. Thus, we can say unlike poles of magnets attract each other.



- When two north poles or two south poles of magnets are brought close to each other, we will observe that the poles will repel each other. Hence, we can say like poles of magnets repel each other.



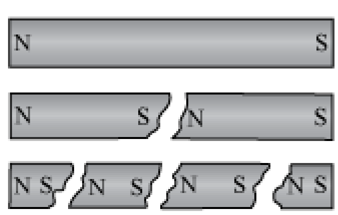
Repulsion is the sure test for a magnet

A magnet can either attract or repel another magnet, depending upon the type of poles. However, a magnet will always attract an un-magnetised magnetic material. Hence, attraction can take place for both but repulsion will take place only with a magnet. Hence, repulsion is a surer way of differentiating between an un-magnetised magnetic material and a magnet.

Magnetic poles always occur in pairs

Niraj has a bar magnet. He breaks it into two pieces. He then brings the broken ends of the pieces close to each other. To his surprise, the broken ends attract each other. Again he brings the broken end of one piece to the smooth end of the other piece. This time he observes that the pieces repel each other. **Can you explain why this happens?**

This is because **magnetic poles always occur in pair** i.e., you cannot separate a single pole of a magnet by breaking it into pieces. **When you break a bar magnet, each piece of the broken magnet behaves similar to a separate bar magnet.** Therefore, every piece will have one North Pole and one South Pole in it.



Characteristics of Magnetic Field Lines

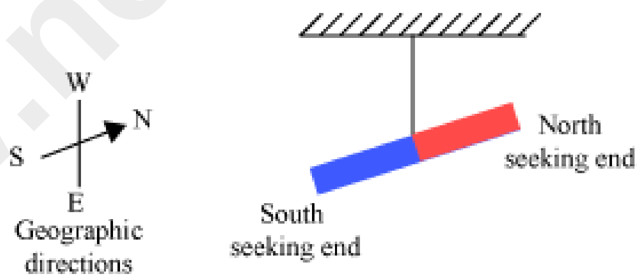
Construct a simple circuit with open ends M and N. Take a thick conducting wire of aluminium and connect it between the open ends. Now, place a magnetic compass near the aluminium wire and note the position of the compass needle. Now, close the switch to allow the current to flow through the wire and notice the deflection in the needle.

It can be concluded from this activity that electric current flowing through aluminium wire has produced a magnetic force that is exerted on the compass needle resulting in its deflection. **Can we say that a magnetic field is related to an electric current?**

Hans Christian Oersted (1777-1851) was the first scientist to observe that a compass needle gets deflected when placed near a current carrying conductor. By this, he concluded that electricity and magnetism are related to each other and called it electromagnetism.

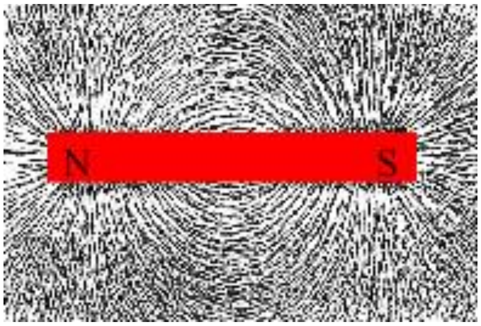
Magnetic lines of force (magnetic force)

You know that a bar magnet can repel or attract another magnet depending on the nature of poles of the other two magnets that are facing each other. When a bar magnet is suspended by thread, its one end always points towards the geographic North Pole, called **magnetic North Pole** and the other end always points towards the geographic South Pole, called **magnetic South Pole** of the magnet.



Like poles repel and unlike poles attract each other.

Take a drawing cardboard and sprinkle some iron filings on it. Notice the position of the iron filings as a whole. Now, take a bar magnet and slowly bring it below the cardboard. You will observe that the iron filings tend to attract towards the magnet.



It is observed that most of the iron filings align themselves at poles. **What does the pattern represent?** It represents that the magnet exerts a force around its body with a stronger force near the two poles. A magnet produces a magnetic field, which can be detected by the force exerted on the iron filings. The regular pattern of the iron filings on the board represents the lines of magnetic field or lines of magnetic force called **magnetic lines**.

How to determine the shapes of magnetic field lines of a bar magnet?

To understand the process, let us see this animation

Do you know the direction of a magnetic field inside the magnet?

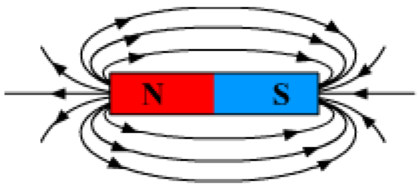
Inside the magnet, magnetic field lines run from the South Pole to the North Pole where they emerge out. Therefore, we can say that magnetic field lines make closed curves.

- The region where magnetic field lines are crowded has relatively greater strength. Hence, in a magnet, strength of the regions near the poles is greater than other regions.
- It should be noted that a compass needle cannot point in two directions when placed at a point near the magnet. This means that no two magnetic field lines cross each other at a point.

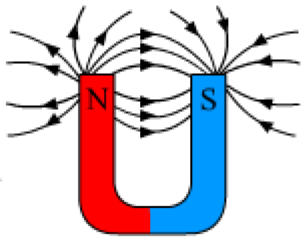
Characteristics of magnetic field lines

1. Magnetic field lines emanate from the North Pole and terminate at the South Pole of a magnet. (Outside the magnet)
2. The degree of closeness of magnetic field lines represents the relative strength of the magnet.
3. No two field lines can intersect each other.

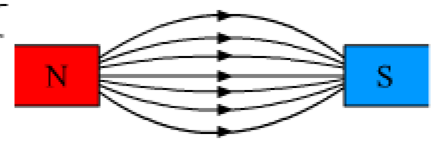
Non-uniform magnetic field due to stronger magnets



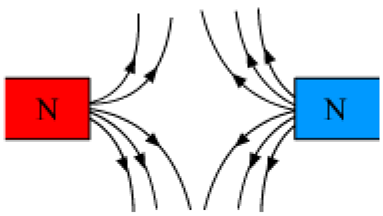
Magnetic field lines
due to a bar magent



Magnetic field lines
due to a horse
shoe magnet



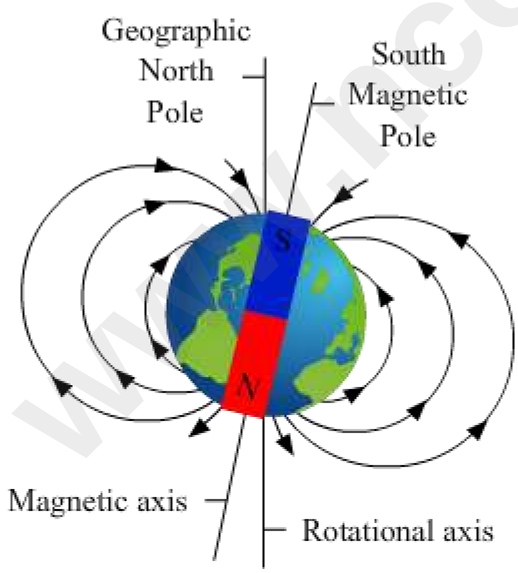
Magnetic field lines
due to two unlike
poles facing each other



Magnetic field lines due to
two like poles facing
each other

Magnetic field lines of the Earth

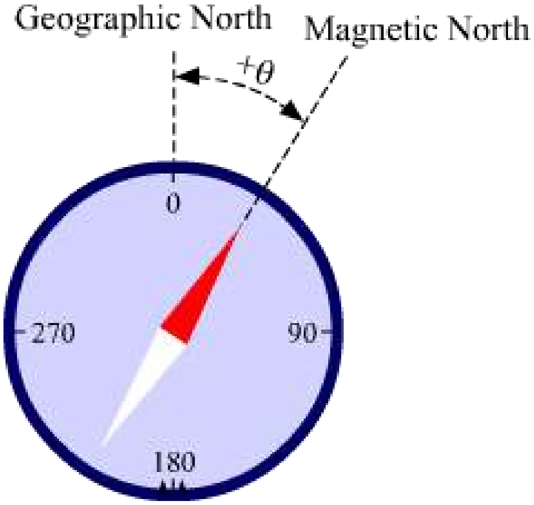
The Earth is treated as magnetic because it is assumed that a huge bar magnet is buried within its interior with the magnetic North Pole near the geographic South Pole, and the magnetic South Pole near the geographic North Pole respectively.



Since magnetic field lines originate from the magnetic North Pole and end at the magnetic South Pole, the Earth's magnetic field lines originate from its geographic South Pole and end at its geographic North Pole respectively.

The magnetic poles of the Earth continuously change their position with time i.e., the magnetic North Pole becomes the magnetic South Pole and vice-versa. This phenomenon of flipping of poles is known as **magnetic reversal**. It is assumed by scientists that the Earth's magnetic field has undergone 170 such reversals in the past 100 millions years.

We have learnt that when a magnetic compass is suspended freely, it aligns itself in geographic North-South direction. But in actual, the North pole of the magnetic needle is not exactly along the geographic North. This is depicted in the figure below.



Thus, the angle of the horizontal plane between the geographic North (true North) and the magnetic North as shown in the above figure is known as **magnetic declination**. The magnetic declination varies with time and place.

- If magnetic North is towards East of true North, declination is taken positive.
- If magnetic North is towards West of true North, declination is taken negative.

Permanent Magnets and Electromagnets

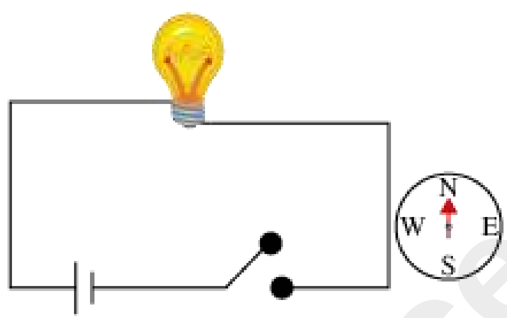
Amar watches his father fix an electric bell in their new house. He wonders **how a bell produces such a loud sound when its switch is pressed on**.

In this section, we will learn about the construction and working of an electric bell.

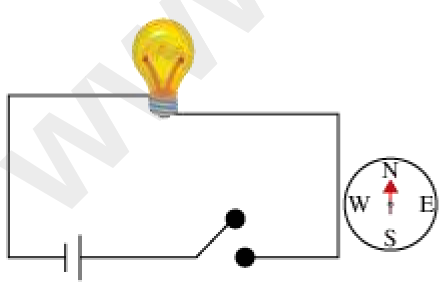
An electric bell works on the principle of electromagnetism.

Hans Christian Oersted (1777-1851) was one of the greatest physicists of his time. Until 1820, it was believed that only natural magnets were able to possess magnetism. In 1820, Oersted suggested that a wire behaves similar to a magnet when an electric current passes through it. He was the first scientist to demonstrate the magnetic effect of current.

Now, if you switch off the current in the previous experiment, then what would you expect to observe? **Would the needle return to its previous position? If yes, then why?**



You will observe that the needle returns to its original position. This happens because the wire carries no current when the switch is off. Hence, the phenomenon of the magnetic effect of current does not apply here.



Reverse the terminals of the cell by reversing the cell and bring the compass near the circuit again, as shown in the given figure.

Switch on the current in the circuit and observe the deflection in the compass needle. **Does the needle deflect in the same direction as in the previous case?**

You will observe that the needle is deflected in a direction opposite to that in the earlier case. This happens because the direction of current in the wire is opposite to that in the earlier case.

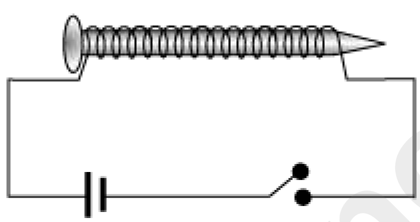
The direction of deflection of a compass needle depends on the direction of the current flowing in the wire.

The phenomenon of the magnetic effect of current is used in various fields in our day-to-day life. One such use of the magnetic effect of current is illustrated below.

Puneet visited a junkyard on a school education trip. In the junkyard, he saw the arm of a crane, with a large magnet at its bottom, move over a heap of junk and collect objects made of iron. The magnet used in a junkyard crane is not a natural or a **permanent magnet**. It is a **temporary magnet**, which is called an **electromagnet**. As its name suggests, its magnetic nature depends on the presence of an electric current.

Construction of an electromagnet

Take a long piece of insulated copper wire and an iron nail. The wire must be insulated i.e., it must be covered by plastic in order to prevent short-circuiting, which is caused by the contact of wires. Make a coil from this wire by winding it around the iron nail. Now, construct an electric circuit that consists of a cell, a switch, and the two ends of the coil, as shown in the given circuit diagram.

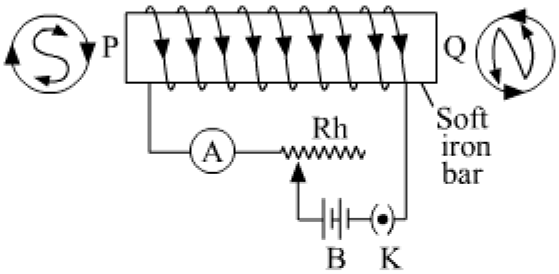


After constructing the electric circuit, switch on the current in the coil by closing the switch and bring a paper clip near one end of the nail. **What do you observe? Does the paper clip get attracted towards the end of the nail and get attached to it?**

When the switch is ON, the nail in the circuit behaves like a magnet. When a magnetic material such as an iron nail is placed within a current-carrying coil, it behaves like a magnet called **electromagnet**.

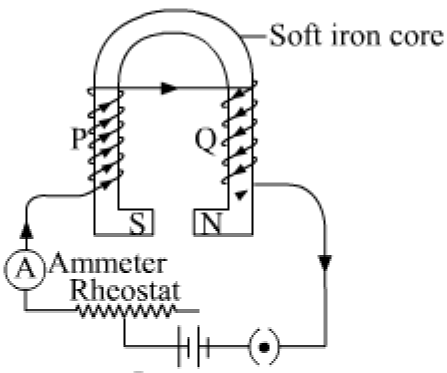
Types of an electromagnet

- **Bar-shaped or I-shaped electromagnet:** To create such an electromagnet, a thin insulated copper wire is wound in a form of a solenoid on a soft iron bar. When current passes through this wire, the bar starts behaving like an electro magnet.



I-shaped electromagnet

- **Horse-shoe or U-shaped electromagnet:** This electromagnet is constructed when a thin insulated copper wire is spirally wound on the arms of the horse-shoe shaped soft iron core. The wire is wound in such a way that when the winding is seen from both the ends, they appear to be in opposite sense on the two arms.



Horse-shoe electro-magnet

What will happen to the paper clip when you open the switch? Will it remain attached to the nail?

- **A magnetic material will act as an electromagnet till the time current continues to pass through it.**
- **When the current stops flowing, the material loses all its magnetic properties and behaves like a normal material.**

The principle of electromagnetism is used in various devices such as electric bell, electric fan, etc.

The strength of an electromagnet depends on the

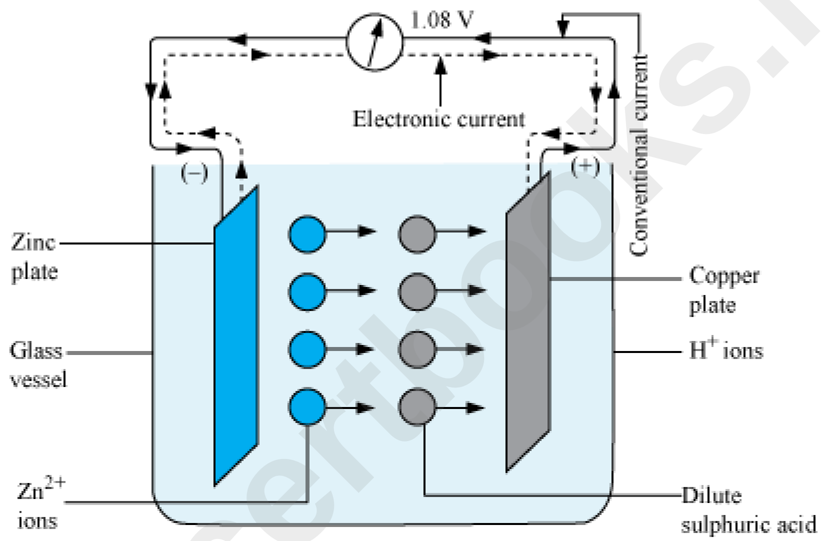
- total number of turns in the coil of wire
- strength of the current in the coil
- characteristics of the magnetic material over which the wire is wound

Construction of Electric Cells, Electric Bulbs, and Electric Switches

We use many electrical appliances which work only when electricity flows through them. Electricity is the flow of electric charges when the negative and positive terminals of an electric cell are connected by a certain substance. Let us see the construction of an electric cell.

Construction of an Electric Cell

A simple cell consists of a vessel with two metal rods or plates, known as electrodes, and a chemical substance known as electrolyte.



The chemical energy stored in a cell converts into electrical energy when current is drawn from the cell. A very commonly used cell is a dry cell which cannot be recharged once all its stored energy is consumed.

When all the chemicals stored inside it are used, the cell stops generating electricity. Hence, we have to replace the cell with a new one. This type of cell is known as primary cell.

An electric cell generates a very small amount of electricity. However, this electricity is sufficient for the working of many small electrical devices. Some common devices that use electricity from cells are clocks, videogames, wristwatches, etc.

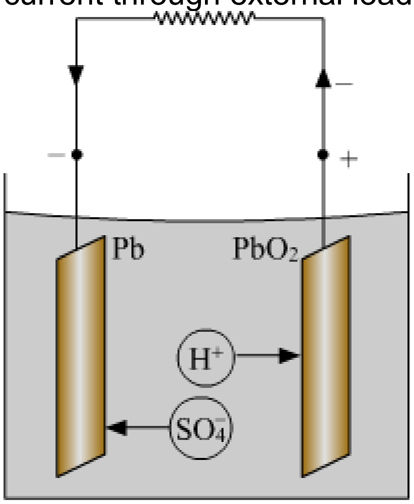
There are other types of cells existing which do not need to be replaced even if the stored chemicals get used up completely. These cells are called secondary cells and can be recharged using electricity. One of the examples of secondary cell is lead-acid cell. Let us understand its construction and how it works.

Lead-Acid Cell

It consists of two electrodes made of lead (Pb) and lead-oxide (PbO_2). Both the electrodes are dipped in dilute sulphuric acid (H_2SO_4). An external load, such as bulb, is connected between the ends of the electrodes.

The dilute acid has both positive (H+) and negative ions (SO_4^{2-}). Now, due to reactions between the components of the cell, the positive ions flow towards the lead-oxide electrode and negative ions towards lead electrode.

Thus, electric charges are produced on both the electrodes which result in the flow of current through external load.



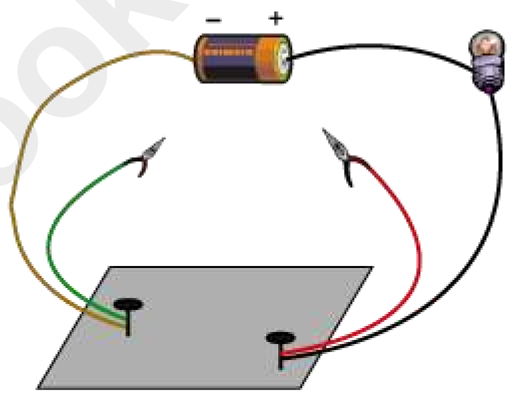
Another example of secondary cell is nickle-cadmium (Ni-Cd) cell. These are portable; thus are used in different handy electronic gadgets.

Try to locate the filament and the terminals in a torch bulb.	
Some interesting facts: **The current flowing in a filament raises its temperature up to 3,000°C. This generates a large amount of heat and is responsible for the glowing of a light bulb.** **The length of the tungsten filament in a light bulb is about 2 meters.**	

Switching devices

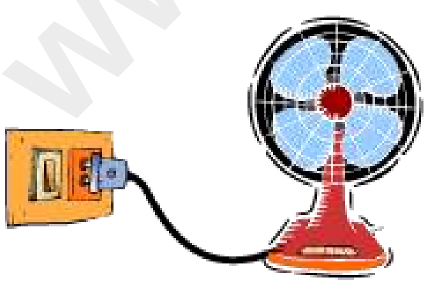
A switch is an electric device that is used to either complete or break an electric circuit. It has two positions 'ON' and 'OFF'. At ON position, the circuit is complete and the circuit breaks when the switch is at OFF position.

You can understand the working of a switch by designing your own switch and circuit.

List some common home appliances that have inbuilt switches.	
Complete the given circuit using the clips so that the bulb glows. Label the direction of the current flowing through it.	 An electric circuit with switch

A practical switch

You can make an electric table fan work by switching on the switch connected to the socket board. On switching it on, the switch allows current to flow through it and through the fan. This makes the fan work.

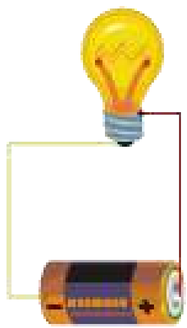


Construction of Torch

You are given a bulb, two connecting wires, and a cell. **Can you join these components in such a way so that the bulb will start emitting light?**

Let us find out how to do so.

You have already learned so many things through animation. Let us put them in words.



Simple electric circuit

Simple Electric Circuit

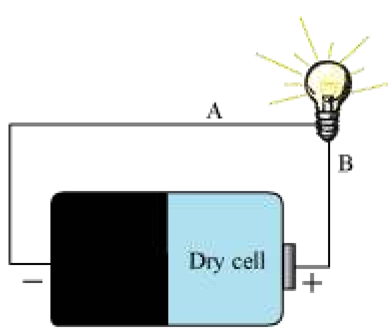
An **electric circuit** is a closed loop consisting of an electricity-producing device (such as a cell) and an electric device (such as a bulb). These are connected to each other using wires, as shown in the given figure.

- You know that the bulb emits light when current flows through its filament.
- It is important to understand the importance of a simple electrical circuit. We use electrical instruments such as TV, fridge, etc. in our daily life. A simple electrical circuit acts as the basic reference to understand these relatively complex circuits.

Do you know that current flows in a circuit because of the flow of charged particles, known as "electrons"?

Closed Circuit

Let us take a dry cell attached with a bulb as shown in the figure.



The bulb is connected to the dry cell by a copper wire. When the copper wire is connected to both the terminals of the cell, electrons start flowing, resulting in a flow of current in the wire. When the current flows through the bulb, the filament of the bulb offers resistance to the electrons, thus converting electrical energy into heat energy and resulting in the glowing of the bulb. This circuit is called closed circuit.

The circuit in which current after starting from the positive terminal of a cell returns to the negative terminal of it, without any break, through a closed loop is called closed circuit.

Open Circuit

Now, take out the wire from one terminal of the bulb. In this situation, current does not have the closed path to return to the negative terminal of the cell. Hence, the bulb does not glow. This is called an open circuit.

This circuit where the current does not have a closed path to complete the circuit is called an open circuit.

Electric circuit of a torch

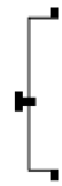
A torch is a practical example of a simple electric circuit. It is an electric device that emits light. It consists of a bulb, electric cells, a switch, a reflector, and a cylindrical shape casing.

Function of each component of a torch

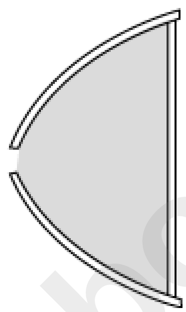
- **Bulb:** The bulb emits light when electric current flows through its filament.

- **Electric cell:** The cell is an electricity-producing device. The required current for the filament of the bulb is supplied by it.

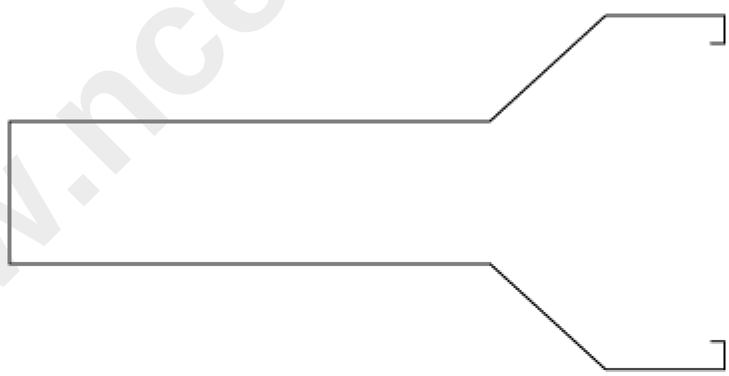
- **Switch:** The switch is used to complete and break the circuit inside the torch. In simple words, it is used to turn the torch on and off.



- **Reflector:** The reflector is a curved, silvered mirror. It is used to focus the light in a particular direction.



- **Casing:** The casing is used to provide covering for the basic components of the torch for protection and safe handling.



Construct your own torch by inverting the terminals of the cells. Does the bulb glow?

Electrical Symbols

Ranveer felt that it was absurd to draw the diagrams of different components of an electrical circuit. His friend Kailash told him a convenient way of drawing these components.

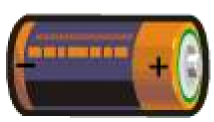
He suggested Ranveer to draw the symbolic representations of these components. Ranveer wanted to know **what these symbolic representations of common components are.**

An electric circuit consists of various electrical components such as a source, a device (a bulb), a switch, connecting wires, etc. The symbols of these components must be used to represent an electric circuit on paper. Hence, symbols play a very important role in the construction of electric circuits.

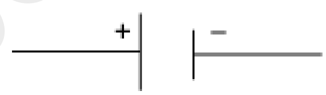
Description of Symbols

Electric cell

Its symbol has two parallel lines: one is longer than the other and they are separated by a small distance. Since electric cells have two terminals, the longer line represents the positive terminal, while the shorter one represents the negative terminal, as shown in the given figure.



Electric cell

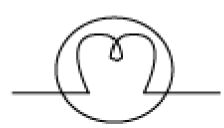


Symbolic representation

Electric bulb

Its symbol consists of a small section of spiral wire that is enclosed within a circle. Its two terminals are represented by two straight lines, as shown in the given figure.

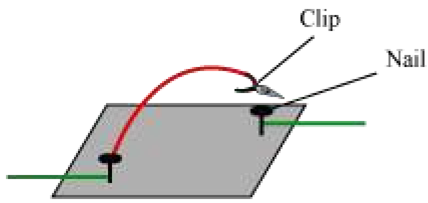
Electric bulb



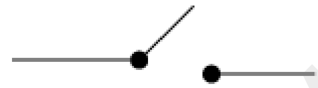
Symbolic representation

Switch in 'OFF' position

A switch has a clip that can be attached to another terminal. If the clip is not attached to the terminal, then the switch is in the 'OFF' position, as shown in the given figure.

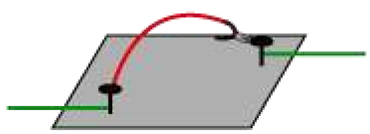


Switch in 'OFF' position


Symbolic representation

Switch in 'ON' position

If the clip has been attached to the other terminal, then it is in the 'ON' position as shown in the given figure.


Switch in 'ON' position


Symbolic representation

Wire

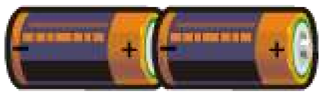
Wires connect each component to make an electric circuit.


Wire

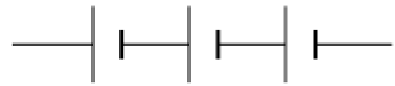
Symbolic representation

Battery

A battery is a combination of two or more cells connected in a line. Its symbol can be drawn by connecting the longer line of the symbol of one cell to the shorter line of the other cell, as shown in the given figure.

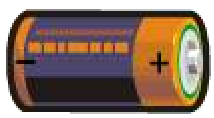
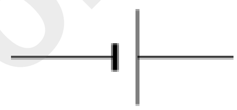
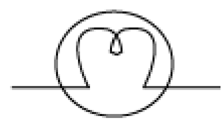
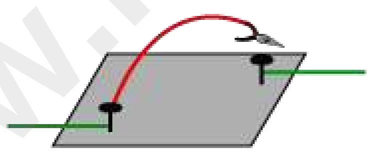
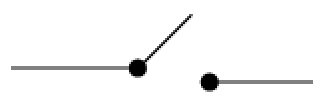
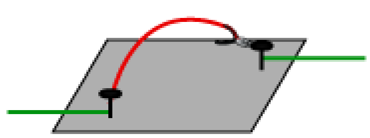


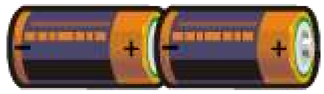
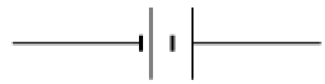
Battery



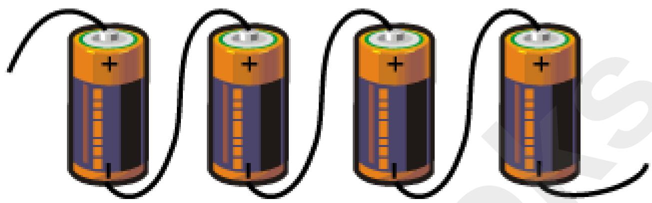
Symbolic representation

The above discussion on the symbolic representation of electric circuits can be summarized in a tabular form as

S. No.	Electric component	Symbolic representation
1.		
2.		
3.		
4.		
5.		

6.		

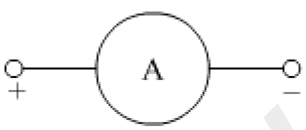
Many household devices such as radios, electric toys, remote controls, etc. use a combination of cells. However, some devices use batteries in which cells are placed side by side, as shown in the given figure.



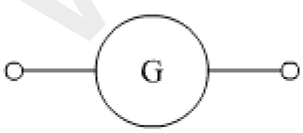
A combination of four cells

Some more instruments and their symbols used in an electric circuit

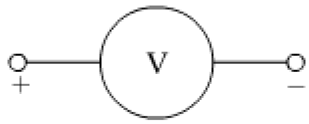
Ammeter: It is an instrument used to measure electric current in an electric circuit. It is always connected in series with other electrical components so that the entire current passes through it. It is symbolically represented by letter A.



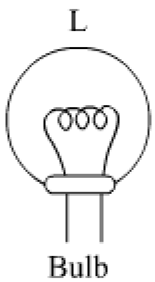
Galvanometer: This instrument detects very weak current in an electric circuit or is used to know the direction of flow of current in a circuit. It is connected in the same manner as an ammeter is connected in a circuit. It is symbolically represented by letter G.



Voltmeter: It is an instrument used to measure the potential difference between any two points in an electric circuit. It is always connected in parallel to the flow of current. It is symbolically represented by letter V.



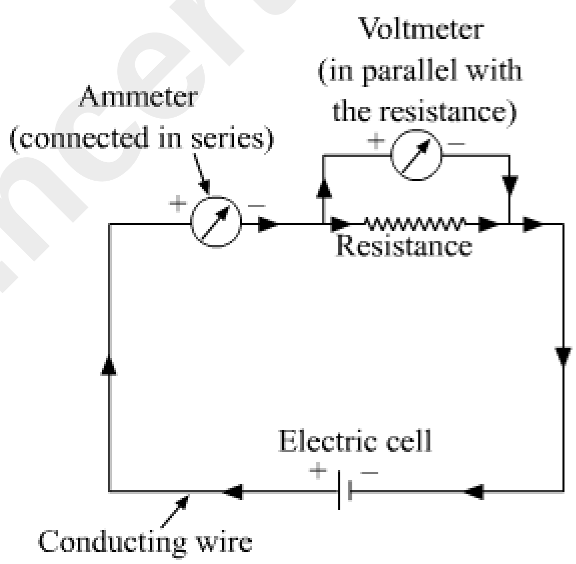
Load: It is any another appliance connected in an electric circuit. It can be a resistance, a bulb, a heated etc. or a combination of electric appliances. Symbolically, it is represented by letter L.



Can you draw the symbolic representation of the battery used in a torch?

Electric Circuit

An unbroken path or line that makes electrical current flow possible through conducting wires connected to other resistances is known as an electric circuit. The figure below shows different components in an electrical circuit.



Electrical circuit

Circuit Diagrams

How do you construct an electric circuit?

You should follow some **precautions** while handling electric devices and circuits.

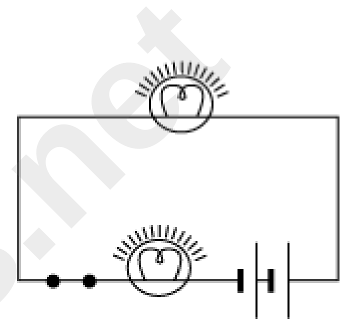
•Do not touch any device when it is connected to the mains

•Do not use the mains as the source of energy while constructing a simple circuit

•Do not use your teeth to peel the wires

Collect two bulbs, a switch, a battery that consist of two cells, and a piece of electric wire of sufficient length. Cut the wire in four pieces with the help of a wire cutter. Connect the two terminals of the battery with both bulbs using two pieces of wires. Connect the switch with the terminals of both bulbs using the two remaining pieces of wires.

[Note: You can refer to the given circuit diagram]

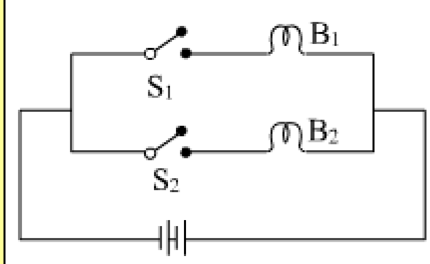


Keep the switch in the 'ON' position. **Do both bulbs glow simultaneously?** If the filament of one bulb is broken, then **what will happen to the other bulb?** Will the circuit become **incomplete?** Will the current still flow in the circuit? **Is a circuit with a broken filament similar to the circuit in which the switch is in the 'OFF' position?**

The circuit is complete in the 'ON' position. Hence, current passes through both the bulbs and they glow simultaneously. If the filament of one bulb is broken, then the circuit becomes incomplete and the other bulb does not glow. Therefore, this situation is similar to that of a circuit in which the switch is in the 'OFF' position.

Such circuits where the appliances in connection operates simultaneously once the switch is closed are known as series circuits. In series circuit, the working of each appliance is dependent on each other.

Now using two bulbs, two switch, battery that consist of two cells, and six pieces of electric wires of sufficient length, construct a circuit as shown in the figure.



The circuit will be complete for both the bulbs when both the switches are closed. Hence, current passes through both the bulbs and they glow simultaneously.

Now, if S_1 is opened, the circuit for bulb B_1 breaks whereas for B_2, it still remains complete. Thus, current flows through bulb B_2 and it glows. Similarly, the bulb B_1 glows even if S_2 is opened.
Now, if the filament of one bulb is broken, then the circuit becomes incomplete for that bulb only and hence it stops glowing. But the circuit is still complete for the other bulb. Therefore, the current still flows through it keeping it in the glowing state.

Such circuits where the working of each appliance is independent of each other are known as parallel circuits.

Construct an electrical circuit consisting of a cell, a switch, and a bulb in such a way that the bulb does not glow.

Electric Current

Electricity requires a link to flow from cells. Do you know how electricity flows through an electrical circuit? What constitutes a current in the circuit?

Electric charge

The distribution of charge in a body is measured in coulombs. The quantization of charge requires that a charge on a body always remain the integral multiple of charges in an electron. Therefore, we have the relation

$Q = ne$

Where, Q is the charge on the body

n is the number of electrons

e is the charge on electrons (1.6×10^{-19})

The SI unit of electric charge is coulomb, denoted by the letter ‘C’.

Number of electrons in 1 C of charge

Total charge possessed by one electron = 1.6×10^{-19} C

i.e., 1 electron = 1.6×10^{-19} C

$\Rightarrow$ 1 C = $\frac{1}{1.6\times10^{-19}}$ electrons

Or, 1 C = 6.25×10^{18} electrons

Hence, we can say that one coulomb of electric charge contains 6.25×10^{18} electrons.

Electric current (Flow of charges)

The directed flow of negative charges (i.e. electrons) through a wire is called an electric current. A current is said to be flowing if a closed link has been provided for the electrons. This link is called the electric circuit. An electric circuit provides a continuous path for the electrons to flow, and hence constitute an electric current.

The magnitude of an electric current is defined as the amount of electrons passing through a cross-sectional area of the wire within a given interval of time.

i.e., Current = $\dfrac{\text{amount of electrons flowing through the cross-section of the wire}}{\text{time taken}}$

Or, $I = \frac{Q}{t}$

Where, I → amount of current

Q → amount of electrons flowing through a cross-section

t → time taken

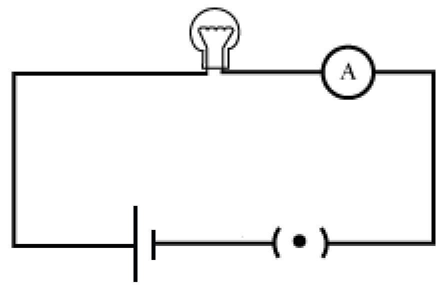
The SI unit of current (I) is taken as ampere (A), named after the great physicist, Andre Marie Ampere (1775 − 1836).

Since, the SI unit of charge is coulomb (C) and that of time is second (s), we define 1 ampere (A) as,

$$1\ \text{A} = \frac{1\ \text{C}}{1\ \text{s}}$$

i.e., 1 ampere is 1 coulomb of charge flowing through a conductor in one second.

An Ammeter is used to measure the amount of current flowing in a circuit. The ammeter is always connected besides the electric components of a circuit.

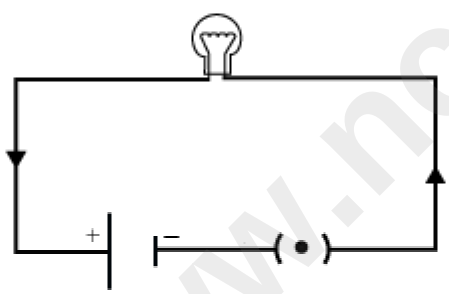


The smaller units of current are expressed in millliampere (mA) and micro ampere (μA). The relation between them is given by:

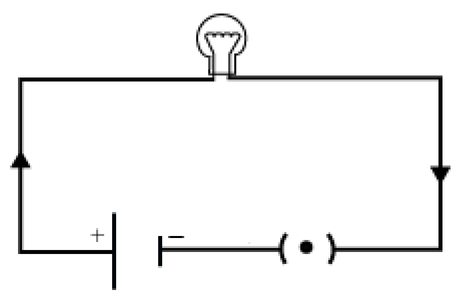
$1\ mA = 10^{-3} A$, and $1 \mu A = 10^{-6}\ A$

Direction of the electric current

It is well known that current is the flow of negatively charged particles i.e. electrons. Since like charges repel each other and unlike charges attract each other, the negative terminal of the cell pushes the electrons, and the positive terminal attracts them. Hence, the electrons flow from the negative terminal of the battery to the positive terminal via the electric components such as the bulb placed between them.



Direction of flow of electrons



Direction of flow of current

Conventionally, the direction of an electric current is taken as opposite to the direction of an electric charge. Hence, electric current flows from the positive terminal to the negative terminal via the bulb.

What makes the electrons, and hence the current to flow in a circuit?

It is the difference in potential that tends to push the electrons across the circuit, which in turn is responsible for the flow of current.

You know that potential difference between two points can be compared with the difference between the water levels in two connected containers.

In the same way, the flow of electric current can be compared with the flow of water between the water columns. Water always flows from higher level to lower level. Similarly, electric current always flows from high potential to low potential.

Do you know how the flow of electric current occurs?

The answer is very simple. The flow of electric current occurs because of the flow of charged particles. In metallic conductors, the charged particles are electrons. Therefore, we can say that the flow of electric current is nothing but a flow of electrons.

The Direction of Electric Current

By convention, we consider the direction of electric current to be the same as the direction of flow of positively charged particles. As electric current in a conductor is the flow of electrons, which are negatively charged particles, **the direction of flow of current is opposite to the direction of flow of electrons.**

Amount of Electric Current

By now, we know that electric current is the flow of charged particles in a conductor. Therefore, the amount of current is also related to the amount of charge. The amount of electric current in a conductor is the flow of total charge per unit time.

$$\text{Electric current } (I) = \frac{\text{Total charge flowing } (Q)}{\text{Total time } (t)}$$

The unit of electric current is ampere (A). It is defined as the flow of one coulomb of charge in one second.

That is, $1\ \text{A} = \frac{1\ \text{C}}{1\ \text{s}}$

Conductors and Insulators

Switches, electrical plugs, wires, and sockets should be made up of materials that allow electricity to pass through them. However, electrical wires, plug tops, switches, and other parts of electrical appliances are covered with rubber and plastic so that a person does not get an electric shock. **How are these two kinds of materials different from each other?**

Precautions while working with electricity

While working with electric appliances or any electric circuit, you are advised to use a screwdriver instead of using your hand. **Have you ever wondered why?**

Let us see what is special about a screwdriver that makes it suitable for working with electrical appliances.

In absence of a screwdriver, you are advised to wear rubber gloves or slippers while working with electricity. **Do you know why?**

It is because rubber does not allow electric current to pass through it. We will not get an electric shock when we touch appliances carrying electricity if we are wearing rubber gloves. If we touch any appliance carrying electricity with naked hands, then we may get an electric shock.

Wet hands

You are advised not to operate electrical appliances with wet hands or when there is water on the surface of an electrical appliance. The reason behind this is that water allows electricity to pass through it.

Though pure water, i.e., distilled water does **not** allow electricity to pass through it, the presence of salts and other impurities turns it into an electrical conductor.

Hence, if you touch any appliance carrying electricity with wet hands, there is a huge risk of getting electrocuted.

You can see many materials around you. Some of them allow electricity to pass through them, while others do not. Therefore, you can classify them into two categories, i.e., ***electrical conductors*** and ***electrical insulators***. This classification is explained below.

Electrical conductors	Electrical insulators
Electricity can pass through certain materials. These materials are known as electrical conductors.	Electricity cannot pass through certain materials. These materials are known as electrical insulators.
All metals (for example, aluminium, copper, iron, and steel) are good conductors of electricity. Therefore, electrical wires are made up of metals such as aluminium and copper.	Few examples of good electrical insulators are plastic, wood, glass, and rubber. Therefore, plastic or rubber is often used to cover electrical wires.

The given table lists a few common objects/materials as electrical conductors and insulators.

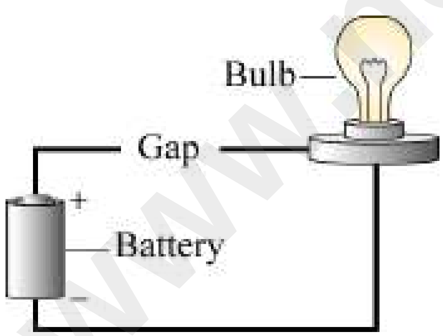
Material/Object	Flow of electricity through it	Electrical Conductor or Insulator
Key	Allows	Conductor
Glass	Does not allow	Insulator
Iron nail	Allows	Conductor
Plastic pen	Does not allow	Insulator
Eraser	Does not allow	Insulator
Coin	Allows	Conductor
Chalk	Does not allow	Insulator
Thermocol	Does not allow	Insulator

Conductor or Insulator

Construct a simple electrical circuit, as shown in the given figure.

Collect samples of different types of materials such as a coin, a cork, rubber, glass, paper, a key, a pin, a plastic scale, a wooden block, a pencil lead, candle wax, etc.

Now, insert each of these samples into the gap in the electrical circuit and observe if the bulb glows. Complete the following classification table.



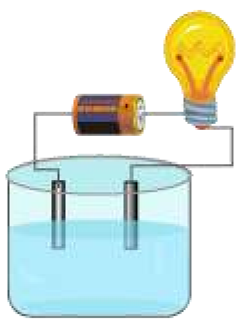
Sample	Does the bulb glow?	Electrical Conductor or Insulator
Coin	Yes	Conductor
Cork	No	Insulator

Is water a good conductor of electricity?

Let us try to find the answer to this question. Construct a circuit, as shown in the given figure.

Now, fill the beaker with distilled water and observe the bulb.
Does the bulb glow?

No, it will not glow as pure water or distilled water is an electrical insulator.



Now, mix some salt in the water.

Does the bulb glow?

Yes, the bulb will glow as impure water is a good conductor of electricity.

Hence, it can be concluded from this activity that ***impure water is a good conductor of electricity, while pure water is a good insulator of electricity.***