# Electric Current and its Effects

## 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.**

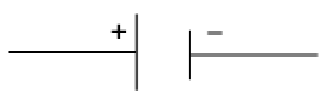
An electric circuit consists of various electrical components such as a source, a device (a bulb), a switch, connecting wires, etc. The symbols of these components must be used to represent an electric circuit on paper. Hence, symbols play a very important role in the construction of electric circuits.

## 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

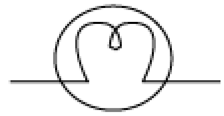



Symbolic representation

### 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.

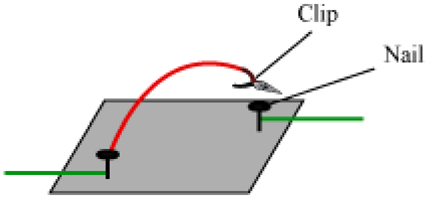
Electric bulb



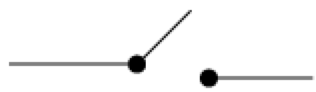
Symbolic representation

### 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.



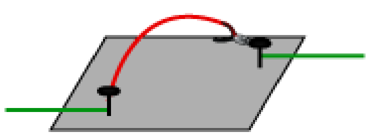

Switch in 'OFF' position



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

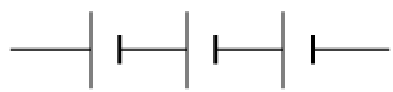


Symbolic representation

**Battery**

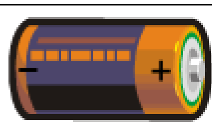
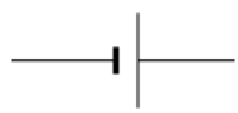
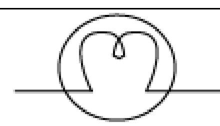
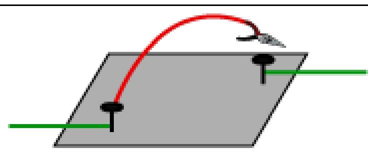
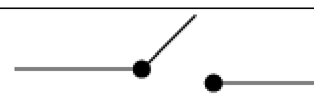
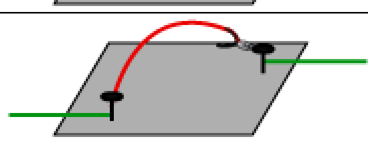
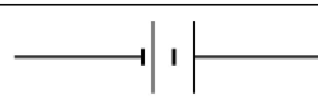
A battery is a combination of two or more cells connected in a line. Its symbol can be drawn by connecting the longer line of the symbol of one cell to the shorter line of the other cell, as shown in the given figure.

Battery

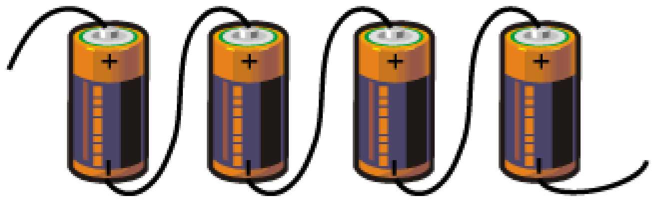


Symbolic representation

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.** |  |  |

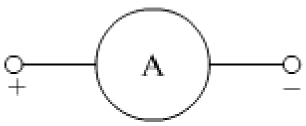
Many household devices such as radios, electric toys, remote controls, etc. use a combination of cells. However, some devices use batteries in which cells are placed side by side, as shown in the given figure.



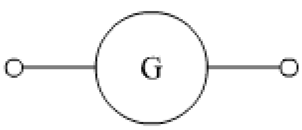

A combination of four cells

**Some more instruments and their symbols used in an electric circuit**

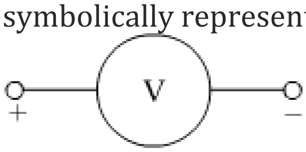
**Ammeter:** It is an instrument used to measure electric current in an electric circuit. It is always connected in series with other electrical components so that the entire current passes through it. It is symbolically represented by letter A.



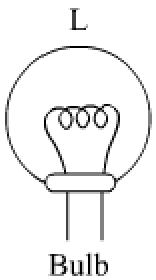

**Galvanometer:** This instrument detects very weak current in an electric circuit or is used to know the direction of flow of current in a circuit. It is connected in the same manner as an ammeter is connected in a circuit. It is symbolically represented by letter G.




**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.

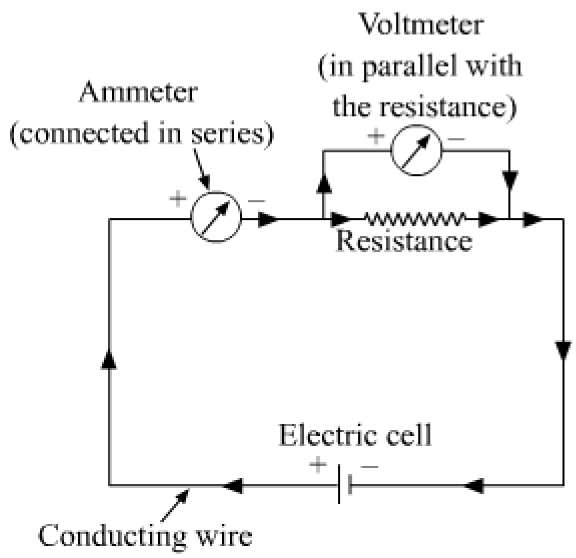



**Load:** It is any another appliance connected in an electric circuit. It can be a resistance, a bulb,a heated etc. or a combination of electric appliances. Symbolically, it is represented by letter L.




**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**

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

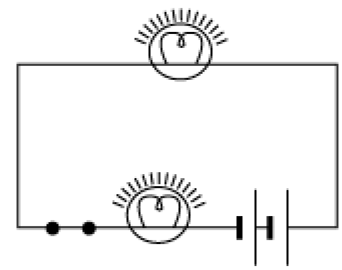
•Do not touch any device when it is connected to the mains

•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]**

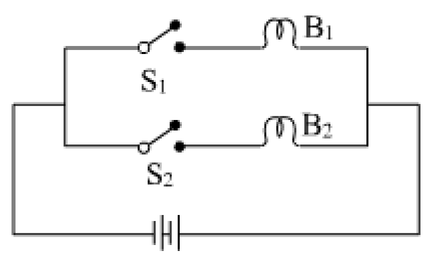


Keep the switch in the 'ON' position. **Do both bulbs glow simultaneously?** If the filament of one bulb is broken, then **what will happen to the other bulb?** Will the circuit become **incomplete?** Will the current still flow in the circuit? **Is a circuit with a broken filament similar to the circuit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

Heating Effect of Current

It is winter time. Dilip and his younger sister Meenakshi are studying in their room. A room heater has been kept to keep the temperature of the room above normal. This helps them bear the cold. Dilip has read in his science book that electricity is required for operating any electrical device. He wonders how a room heater can emit a large amount of heat.

The heater emits heat due to the conversion of electrical energy into heat energy. **This phenomenon is known as the heating effect of current**. Let us learn more about this effect.

A wire (say nichrome wire) becomes hot when electric current is allowed to flow through it for a relatively long time. This phenomenon is known as the **heating effect of electric current**.

**Joule's Heating**

We know that current begins to flow through a wire when it is connected with a source. All wires offer some resistance to the flow of current. To maintain a uniform supply of current, the source must expend its energy (because of which the source eventually gets exhausted). Part of this energy is used for maintaining the supply of current, while the rest is dissipated in the form of heat. This dissipated heat is responsible for the heating of the wire.

The heating effect is more prominent in wires of high resistance. For example, if we take nichrome and aluminium wires of equal length and cross sectional area, and pass an equal amount of current for the same time, we will observe that the nichrome wire gets more heated than the aluminium wire. This happens because nichrome offers more resistance to the flow of current than aluminium.

When a current ($I$) flows through a resistor of resistance ($R$) for time ($t$), the amount of heat produced ($H$) is given by

$$H = I^2Rt$$

This is called **Joule's law of heating.** This law suggests that the heat produced in a resistor is directly proportional to the

1. square of the current flowing through the resistor, i.e., $H \propto I^2$

2. resistance of the resistor, i.e., $H \propto R$

3. time for which the current flows through the resistor, i.e., $H \propto t$

Thus, we can infer from Joule's heating effect that an appliance offering more resistance to the flow of electrons releases more heat per unit time, keeping the potential of the source constant.

The Joule's law of heating can have other forms as H=V2Rt and H=VITH=V2Rt and H=VIT

**Example:** A room heater can offer a maximum resistance of 100 Ω when 5 A current flows through it for one minute. **What is the maximum amount of heat produced by the heater?**

**Solution:**

Current, $I$ = 5 A

Maximum resistance, $R$ = 100 Ω

Time, $t$ = 1 min

= 60 s

Using Joule's law of heating, the heat produced is given as $H = I^2Rt$

$\therefore H = (5)^2 \times 100 \times 60$

= 150000 J

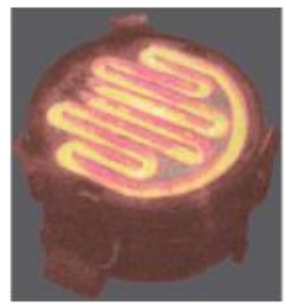
Hence, the room heater will produce a maximum of 150000 J of heat in one minute.

The heating effect of current is used in various heating appliances such as electric irons, room heaters, water heaters, hair dryers, geysers, etc. In all these devices, electrical energy is converted into heat energy, which is governed by **Joule's heating effect**.

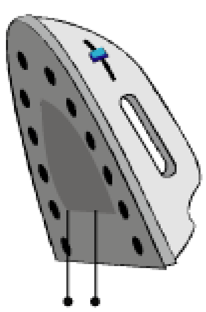
Let us learn about the functions of some heating devices.

**1. Electric heater**

An electric heater consists of a long coil of wire arranged on an insulating sheet, as shown in the given figure. When electric current is allowed to flow through this coil, it turns red hot because of the heating effect of current. As a result, it provides a specific amount of heat, which can be used for different purposes.



**2. Electric Iron**

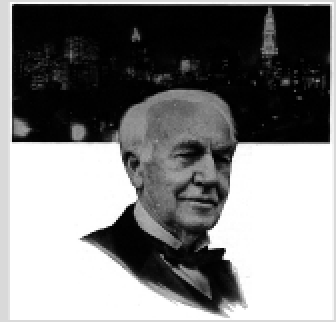


An electric iron consists of a thin metal plate that gets heated when electric current flows through it. This, in turn, heats the thick iron base of the device.

**3. Water heater**

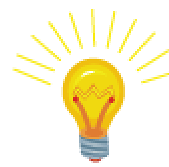
An electric water heater consists of a coil of wire that gets heated when electric current flows through it. This, in turn, heats the water in which the heater is completely immersed.

**Do You Know?**

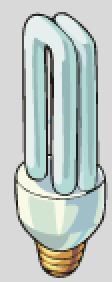
| | |
|---|---|
| **Edison and his bulb**<br><br>Thomas Alva Edison (1847–1931) was one of the greatest inventors in the history of science. He had one thousand inventions to his name besides the electric bulb. The bulb invented by him was comparatively long-lasting because he used a filament made of a metal having a high melting point. Now-a-days, tungsten filament is used in the electric bulb because it does not melt easily. |  |

**4. Electric bulb**

A bulb consists of a filament that radiates heat and light when current flows through it. The filament of a bulb is made of tungsten coil. The flow of current causes the filament of the bulb to heat up to an extremely high temperature such that it starts emitting light.



**Caution: Do not touch heating devices directly because they can cause your fingers to burn severely.**

| | |
|---|---|
| **All heating devices draw a large quantity of electricity to heat the respective appliances. However, bulbs are designed to emit light only. Hence, there is wastage of electricity in the form of heat. This wastage of electricity is reduced by replacing these electric bulbs by compact fluorescent lamps (CFLs). A CFL is shown in the given figure.** |  |

**List some heating devices that are being used in your home.**

Until now, we have discussed the uses of the heating effect of current in situations in which it is allowed to flow through special devices. However, what happens if a large amount of current suddenly flows through a normal wire?

In such an unfavourable situation, the wire becomes hot and eventually melts down. This can cause serious damage to the different circuit components connected to it. In order to avoid such a situation, a fuse element is joined along with the circuit.

**5. Electric fuse**

Electric fuses are devices used for the protection of expensive electric devices such as bulbs, TVs, fans, etc. A **fuse element** has a very low melting point. Hence, it melts quickly whenever there is a slight increase in the amount of current. As a result, the path of the current is broken. This protects the device from being damaged by the abrupt flow of current. The given figure shows a simple electric fuse that is commonly used in households.

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**.

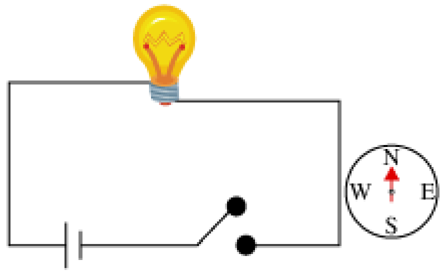
In this section, we will learn about the construction and working of an electric bell.

**An electric bell works on the principle of electromagnetism.**

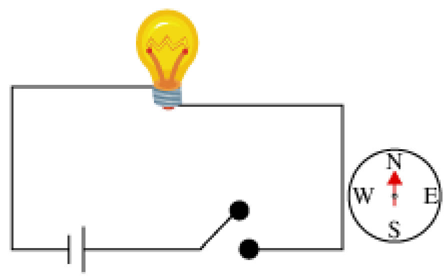
Let us show you the working of an electric bell.

**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.

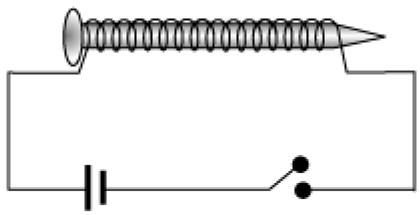
**The direction of deflection of a compass needle depends on the direction of the current flowing in the wire.**

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.

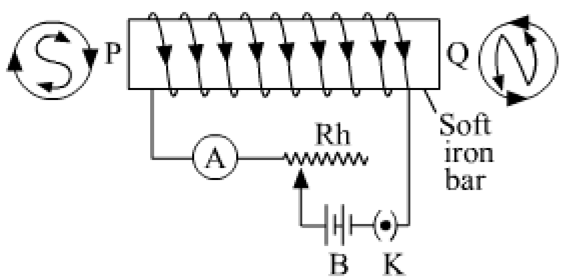


After constructing the electric circuit, switch on the current in the coil by closing the switch and bring a paper clip near one end of the nail. **What do you observe? Does the paper clip get attracted towards the end of the nail and get attached to it?**

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**.

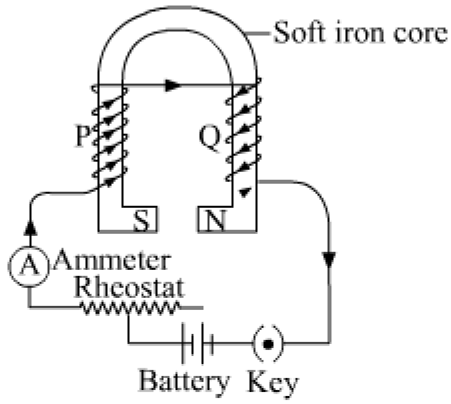
**Types of an electromagnet**

- **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 electromagnet.




*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