Current Electricity

Electric Potential

So, by now you must have understood electric potential and potential difference.

Let us define these two for you −

- **Electric potential of a point in an electric field is defined as the work to be done to move a unit positive charge from infinity to that point.**
- **Potential difference between two given points in an electric field is defined as the amount of work to be done to move a unit positive charge from one point to the other.**

Potential difference (V) = $\dfrac{\text{Work done } (W)}{\text{Amount of charge moved } (Q)}$

$$\boxed{V = \frac{W}{Q}}$$

Do you know?

The SI unit of electric potential is volt (V), named after the great physicist, Alessandro Volta (1745−1827).

A chemical reaction within a cell develops a difference in potential between both its terminals. When a cell is connected to a circuit, the potential difference causes the charge to flow and hence, the current is flowing through the circuit.

If we substitute the SI units of work done [i.e., Joule (J)] and charge [i.e., coulomb (C)] in the following relation, we get

$V = \dfrac{W}{Q}$

$\Rightarrow 1\text{ V} = \dfrac{1\text{ J}}{1\text{ C}}$

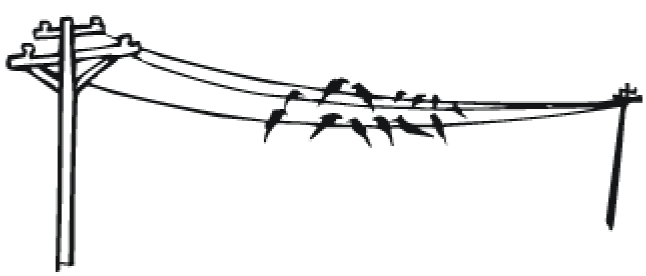
Hence, we can define potential difference between two points as 1 J of work that is required to move 1 C of charge between two points.

The potential difference between two points is measured with the help of a voltmeter. For this purpose, it is connected across the points from where the potential is to be measured.

Do you know?

We can get an electric shock if we touch a naked live wire.

Electric current tends to flow due to the potential difference that exists between the Earth and a wire (as the wire acquires a positive value). Therefore, when we touch a naked live wire, our body provides the current a bridge or link to flow from high potential (wire) to zero potential (Earth) via our body. This flow results in an electric shock, which can prove to be fatal.



Do you know?

Birds sitting on live wires do not get electrocuted.

Potential difference is a must for current to flow. Birds do not get electrocuted while sitting on live transmission wires because their bodies do not provide a bridge or link for the electrons to flow. The potential of a bird's body is zero before coming in touch with a wire. When a bird sits on a wire, its body potential rises and becomes equal to the potential of the wire. If a person standing on the ground touches the bird, then both will get an electric shock. This is because the person's body would provide a link for the electrons to pass on to the Earth.

Electric Cell

We know that charge flows from higher potential to lower potential, till the equipotential condition is reached. When two conductors at different potentials are connected through a metal wire, charge starts flowing from higher potential to lower potential. This flow of charges is called electric current. The amount of electric current is defined as the total flow of charge per unit time.

Flow of current between two conductors is not permanent; the conductors reach at the same potential quickly and the current stops flowing. To have a continuous supply of current, we must maintain a constant potential difference between the conductors all the time. To maintain a steady flow of current, i.e. to maintain a constant potential difference, we use electric cell.

Electric Cell

An electric cell is a device used for maintaining permanent potential difference with the simplest arrangement between the conductors. Its job is to simply bring electrons already in the conductors in motion.

There are two types of electric cells:

- **Primary Cell** − In a primary cell, chemical energy is directly converted to electrical energy.

  For example, simple voltaic cell, Leclanche cell

- **Secondary Cell**− In a secondary cell, electric energy is stored in the form of chemical energy, which is converted into electric energy on demand.

  For example, lead acid cell, Ni−Cd cell

Electromotive Force (*emf*)

When current drawn from a cell is zero, the circuit is said to be an open circuit. In an open circuit, the potential difference between the two terminals of a cell is called **electromotive force**.

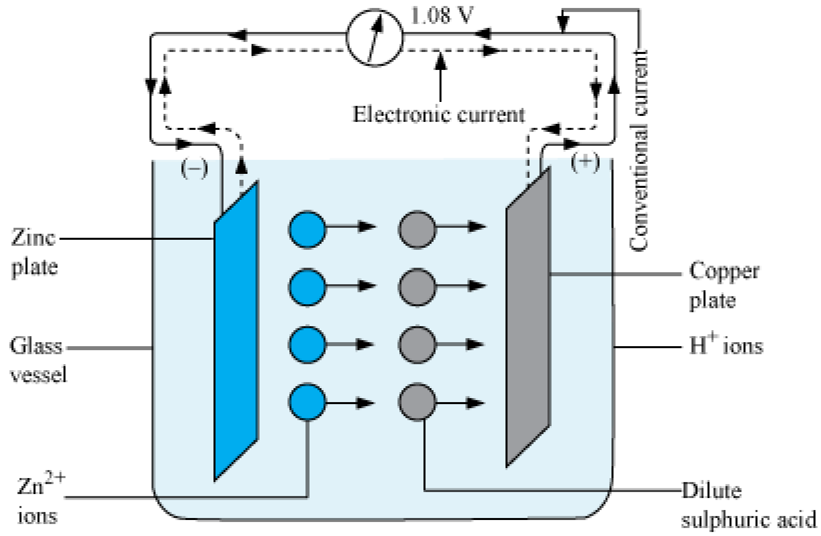
Emf of a cell depends on the following factors:

- Materials of plates used in the cell
- Nature of electrolyte used

Emf remains constant even if the shapes or sizes of the plates of a cell are changed.

Simple Voltaic Cell

A simple electric cell was invented in 1800 by Alessandro Volta. It was the first device capable of maintaining a constant potential difference between two plates with chemical energy. The cell was named Voltaic Cell after the inventor.



Construction: It consists of two metallic plates of copper and zinc. Each plate is attached with a brass terminal.

The plates are placed in a glass vessel with the terminals connected to a voltmeter through insulated copper wires.

The voltmeter records a potential difference of 1.10 volts, when sulphuric acid is poured into the container.

It was assumed by Volta that the copper plate acted as the positive terminal and the zinc as the negative, and the current flew externally from copper to zinc.

Theory: Ionisation potential of zinc is −0.76 volts and ionisation potential of copper is 0.34 volts.

As ionisation potential of copper is more than that of zinc, zinc is more electropositive than copper.

Sulphuric acid (H_2SO_4) is used as an electrolyte in the ionised state.

$H_2SO_4 \leftrightarrow 2H^+ + SO_4^{2-}$

When the zinc plate comes in contact with hydrogen ions (H^+), hydrogen ions, being more electropositive, ionise zinc to form zinc ions and free electrons.

$Zn \rightarrow Zn^{2+} + 2e^-$

The free electrons move out in the external circuit towards the copper plate as they take the passage of least resistance. However, the zinc ions enter in the dilute sulphuric acid.

Since Zn^{2+} ions are positively charged, they repulse hydrogen ions and hydrogen ions crowd up at the copper plate.

Copper in turn starts losing electrons to hydrogen ions, which form nascent hydrogen.

$2H^+ + 2e^- \rightarrow 2H$

This nascent hydrogen combines to form molecular hydrogen.

$2H \rightarrow H_2$

The above reactions show how free electron or charge drifts from zinc plate to copper plate in the external circuit. Therefore, it is deduced that electron flows from zinc to copper.

However, by convention, we say that current flows from copper to zinc, when actually free electrons flow from zinc to copper.

Emf between zinc and copper = 0.34 − (−0.76) = 1.10 V

Drawback of this cell is that it cannot give current for more than 10 minutes as it has serious defects such as local action and polarisation.

Electrical Symbols

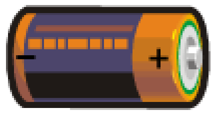
Ranveer felt that it was absurd to draw the diagrams of different components of an electrical circuit. His friend Kailash told him a convenient way of drawing these components. He suggested Ranveer to draw the symbolic representations of these components. Ranveer wanted to know **what these symbolic 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.

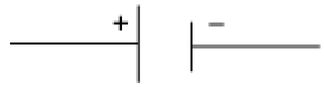
Description of Symbols

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

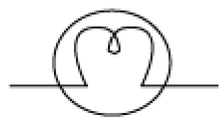


Symbolic representation

Electric bulb

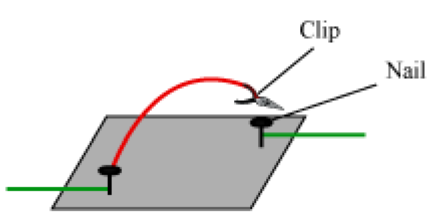
Its symbol consists of a small section of spiral wire that is enclosed within a circle. Its two terminals are represented by two straight lines, as shown in the given figure.


Electric bulb


Symbolic representation

Switch in 'OFF' position

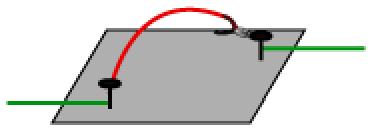
A switch has a clip that can be attached to another terminal. If the clip is not attached to the terminal, then the switch is in the 'OFF' position, as shown in the given figure.



Switch in 'OFF' position

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

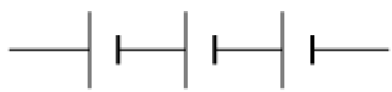
Wires connect each component to make an electric circuit.

Wire

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.

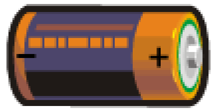
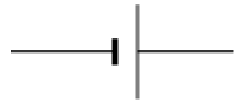
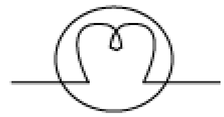
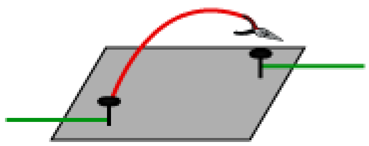
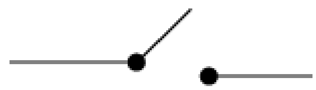
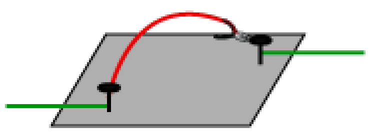
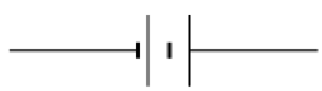
Battery



Symbolic representation

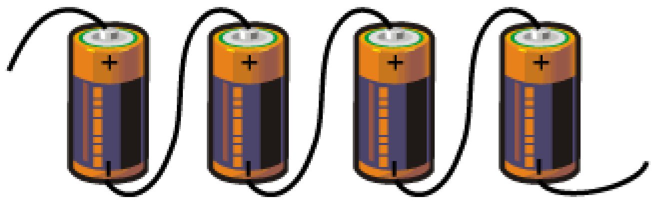
The above discussion on the symbolic representation of electric circuits can be summarized in a tabular form as

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.

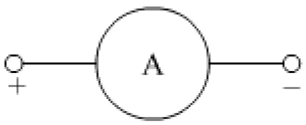
However, some devices use batteries in which cells are placed side by side, as shown in the given figure.



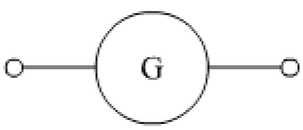
A combination of four cells

Some more instruments and their symbols used in an electric circuit

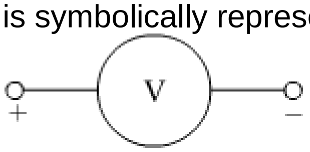
Ammeter: It is an instrument used to measure electric current in an electric circuit. It is always connected in series with other electrical components so that the entire current passes through it. It is symbolically represented by letter A.



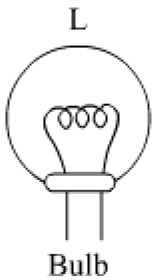
Galvanometer: This instrument detects very weak current in an electric circuit or is used to know the direction of flow of current in a circuit. It is connected in the same manner as an ammeter is connected in a circuit. It is symbolically represented by letter G.



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.

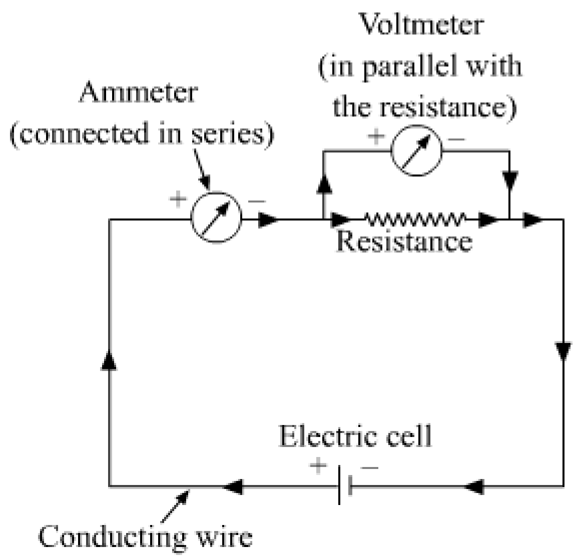


Load: It is any another appliance connected in an electric circuit. It can be a resistance, a bulb,a heated etc. or a combination of electric appliances. Symbolically, it is represented by letter L.



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

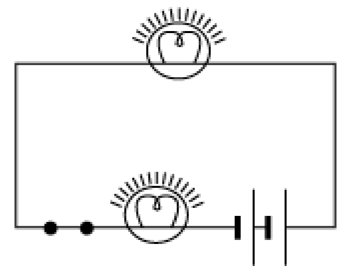
How do you construct an electric circuit?

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

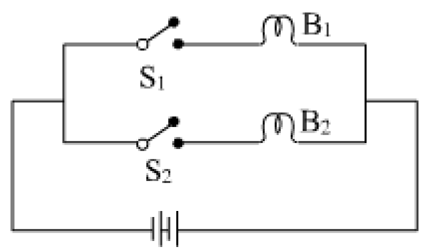
•Do not use your teeth to peel the wires

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

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

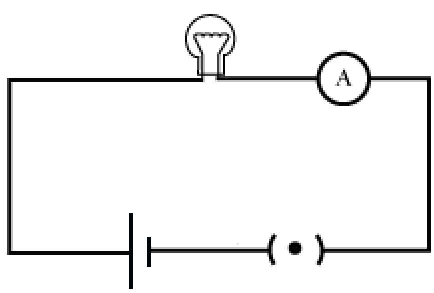
The SI unit of current (*I*) is taken as ampere (A), named after the great physicist, Andre Marie Ampere (1775 − 1836).

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

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

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.



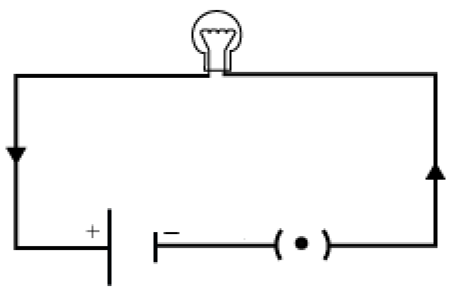
The smaller units of current are expressed in millliampere (mA) and micro ampere (µA). The relation between them is given by:

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

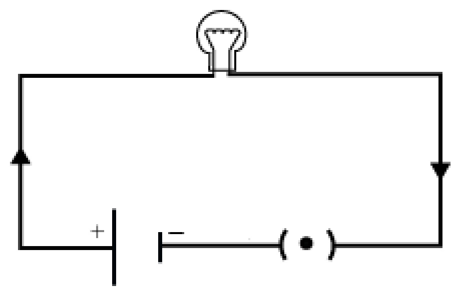
Direction of the electric current

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.**

Let us now understand how electric current flows.

Amount of Electric Current

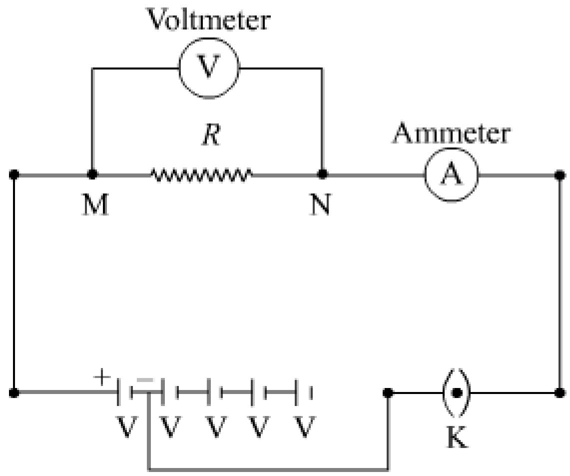
By now, we know that electric current is the flow of charged particles in a conductor. Therefore, the amount of current is also related to the amount of charge. The amount of electric current in a conductor is the flow of total charge per unit time.

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

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

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

Ohm's Law



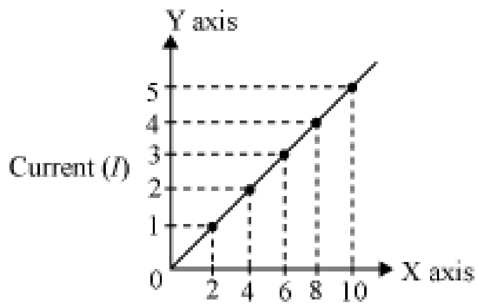
Construct a simple electric circuit using a battery having 5 cells of equal potential V, a resistor of resistance R, and a switch. Connect a voltmeter and an ammeter across and along the resistor respectively (as shown in the given figure).

Make sure that initially the circuit is connected with only one cell. Now, switch on the circuit and measure the readings in both the ammeter and the voltmeter. Note these readings in the table given below.

Now, connect the circuit with two cells and measure the readings in the voltmeter and the ammeter. Repeat the process using three, four, and five cells respectively and note the readings in each case. An example is tabulated below.

Number of cells	**Potential difference between M and N**	**Current flowing in circuit (A)**
1	2	1
2	4	2
3	6	3
4	8	4
5	10	5

Now, plot a graph between the potential difference and the current for these five readings. Draw the potential difference on *x*-axis and current on *y*- axis. You will observe that the graph between the two quantities comes out to be a straight line. **What is the significance of this straight line?**



I - *V* Characteristics

You know that current is a flow of electric charge. These charges flow from one point to another when a potential difference exists between the two points. **How do we relate potential difference with current?**

If you calculate the ratio VIVI for all five cases, then you will get the same value approximately. This implies that the ratio VIVI is constant. It does not depend on the number of cells used in the circuit. Hence, we can say that the **potential difference (*V*) is directly proportional to current (*I*). Thus,**

V ∝ I

This relation is known as Ohm's law.

According to this law, under constant physical condition i.e. constant temperature, pressure etc. the applied potential difference is directly proportional to the current flowing in the circuit.

Or, $V = RI$

Where R is a constant of proportionality called resistance of the resistor, it tends to resist the flow of charge through a conducting wire**.** Its SI unit is **Ohm (Ω)**.

Thus, we can write Ohm's law as

$$I = \frac{V}{R}$$

Hence, according to Ohm's law, current is

1. Directly proportional to potential difference.
2. Inversely proportional to resistance.

If the potential difference is doubled (keeping resistance the same), current will also get doubled. On the other hand, if resistance is doubled (keeping potential difference the same), current will reduce to half.

Ohmic resistors:

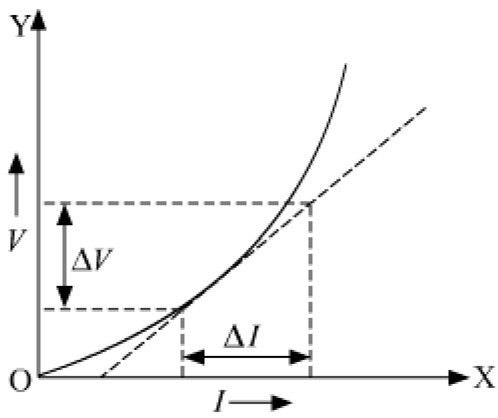
Conductors which follow the ohm's law at constant temperature are called ohmic resistors. Examples: All metallic conductors (Copper, Aluminium, silver etc.), copper sulphate solution with copper electrodes, and dilute sulphuric acid, etc.

A straight line graph passing through the origin is obtained between potential difference *V* and current *I* for such resistors. This means that the ratio of *V* and *I* i.e. *R* is constant for all values of *V* or *I*.

Non-ohmic resistors:

Conductors which do not follow the ohm's law are called non-ohmic resistors. Examples: LED, solar cell, junction diode, transistor, bulb filament etc.

A non-linear graph is obtained between potential difference *V* and current *I* for such resistors. This means the ratio of V and I i.e. *R* does not remains constant for such resistors.



V vs *I* for non-ohmic conductors

Example:

In an electrical circuit, what is the resistance offered by a bulb to a flow of charge if the ammeter and the voltmeter show a reading of 2 A and 12 V respectively?

Solution:

Given that,

Potential difference, *V* = 12 V

And current, I = 2 A

According to Ohm's law, potential difference

$V = IR$

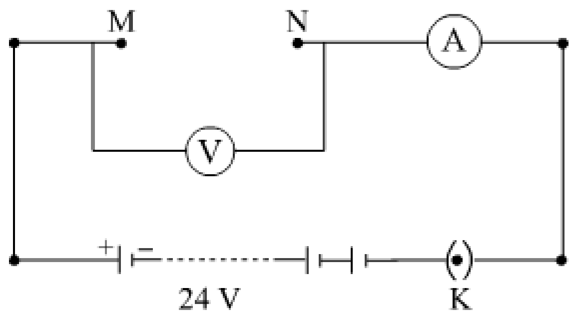
Or, $R = \frac{V}{I}$

$\therefore R = \frac{12\ \text{V}}{2\ \text{A}} = 6\ \Omega$

Hence, 6 Ω resistance is offered by the bulb to the flowing charge.

Example:

In the given electric circuit, the potential of the battery is 24 V.



When a copper wire is connected between points M and N, the ammeter reads 5 A, whereas when a chromium wire of the same length and thickness is connected between points M and N, the ammeter reads 2 A. **Can you tell which wire offers greater resistance to the flow of charges?**

Solution:

Given that,

potential difference for both the wires, V = 24 V

For Copper wire:

Current, I = 5 A

On applying Ohm's law, we get

$\Rightarrow V = IR$

Or, $R = \frac{V}{I}$

$\therefore R_{cu} = \frac{24\ \text{V}}{5\ \text{A}} = 4.8\ \Omega$

For Chromium wire:

Current, I = 2 A

On applying Ohm's law, we get

$V = IR$

Or, $R = \frac{V}{I}$

$\therefore R_{cr} = \frac{24\ \text{V}}{2\ \text{A}} = 12\ \Omega$

Since, R_{cr} is greater than R_{cu}, chromium wire will offer greater resistance in comparison to copper wire. Hence, Ohm's law shows that chromium wire is a poor conductor of electricity as compared to copper wire.

Electric Resistance and Electron Drift

We know that good conductors have free electrons on their surfaces. These electrons move randomly in all directions in a conductor, such that there is no net flow of electrons in a particular direction.

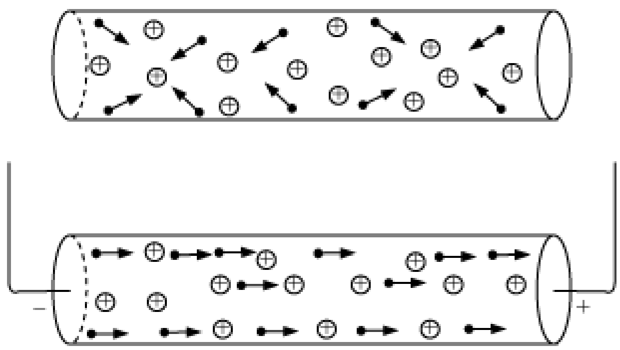
Hence, no current flows in a conductor till some external potential difference is not applied. Now, the question is what happens in a conductor when an external potential is applied to it? To understand this, we first need to know how free electrons move in a conductor.

There are a few assumptions we make to understand the microscopic view of the movement of free electrons. These are—

Electrons are free to move anywhere in a conductor. This can easily be understood by the fact that the force exerted by the protons on the free electrons is very small.

As the sizes of the electrons are very small as compared to those of the atoms, we also assume that electrons do not collide with one another, but only collide with the atoms of a metal. Thus, electrons change directions continuously.

So, when we apply an external field, electrons drift very slowly in one particular direction by slightly modifying their random motion. Electrons do not start moving in a straight line in a particular direction when external potential difference is applied. Their movement is still random. It is just that there is a net displacement of electrons in the direction opposite to that of the field. For the sake of simplicity, the electrons in the following figure are shown to be drifting in only one particular direction.



The motion of electrons continues to be random even after an external field is applied because they keep colliding with the other atoms. Hence, we can conclude that these collisions slow down the passage of current, or we can also say:

‘The more the number of collisions, the more is the resistance offered by a conductor.’

Electric resistance can be defined as the obstruction or opposition to the drifting electrons.

Electric resistance completely depends on the nature of a conductor.

Units of Resistance:

Resistance is measured in ohms (Ω).

If a current of 1 amp flows through a conductor, when its ends are maintained at a potential difference of 1 V, then the conductor is said to have a resistance of 1 Ω.

Factors Affecting Resistance of a Conductor

Do you know why it is advisable to use thick conducting wires in wiring?

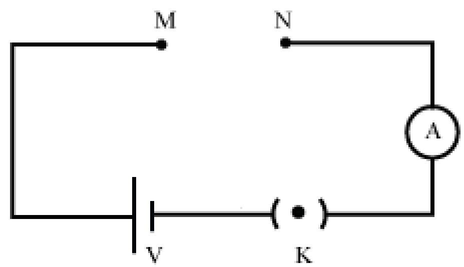
This is related to the amount of resistance offered by wires used in circuits. We know that resistance is a natural tendency of the conductors to oppose the flow of electric charge from it. Hence, it causes a loss of electricity and should be minimised. This can be achieved by using thick conducting wires.

Here, we will discuss the different factors on which resistance of a conductor depends.

Factors that affect resistance

Construct an open circuit with open ends M and N (as shown in the figure). Take six pieces of wire with dimensions as given below.

Case (i) Copper wire → of length MN of the given cross-section.
Case (ii) Copper wire → of length greater than MN having the same cross-section.
Case (iii) Copper wire → of length less than MN having the same cross section.
Case (iv) Copper wire → of length MN but a comparatively thicker cross-section.
Case (v) Copper wire → of length MN but comparatively a thinner cross-section.
Case (vi) Chromium wire → of length MN and of same cross-section as in case (i).



Connect copper wire of case (i) between the open points M and N, and note the readings in the ammeter. The reading will give you the amount of current flowing through the copper wire.

Similarly, connect wire of case (ii) and note the reading in the ammeter. Repeat the process with the remaining four wires and make a table of your readings in each case. Scrutinize the readings and compare them with the dimensions of the wire. **Does the current depend on the length, cross-section, and nature of the material used?**

You will notice that the amount of current that flows through wire in case (i) is greater than that flowing through wire in case (ii). **What does this mean?** This means that a long wire offers greater resistance in comparison to a short wire. Also, resistance decreases with an increase in the cross-sectional area.

Similarly, if you allow the current to flow in each wire for a relatively longer period, you will find that there is a decrease in current. Hence, from this activity we can say that resistance of a conductor depends on the following:

I. Length of the conductor

II. Cross-sectional area of the conductor

III. Temperature of the conductor

IV. Nature of the material used

Symbol of resistor

I. length of the wire

Resistance is directly proportional to the length of the conductor i.e.

R ∝ l

Where, *l* → length of the conductor

II. Cross-section of the conductor

Resistance is inversely proportional to the area of cross-section of the conductor i.e.

$$R \propto \frac{1}{A}$$

A → area of cross-section

- Since conductors have a circular cross-section, the area of cross-section is directly proportional to the square of the radius of the cross-section i.e.

$$R \propto \frac{1}{r^2}$$

r → radius of the cross-section

When the diameter of a conductor is made double, its resistance becomes one fourth.

Thus, we can write,

R ∝ l/A

Or,

$$R = \rho \frac{l}{A}$$

Where, ρ is the proportionality constant, called the **electrical resistivity** of the material of the conductor. It is also known as specific resistance.

The resistivity or specific resistance of a substance is equal to its resistance, if it has a unit length and unit cross-sectional area.

The SI unit of resistivity is Ω m (Ohm-meter).

- Resistivity is the characteristic property of a material. It only depends on the nature of the material and not its dimensions. This is one of the major differences between resistance and resistivity. But like resistance, resistivity also varies with temperature.

Conductivity

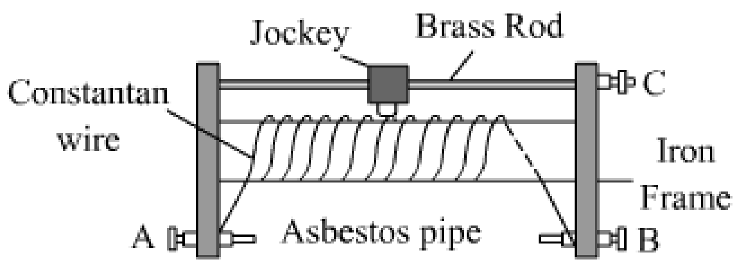
The reciprocal of resistivity is known as conductivity. Its SI unit is ohm^{-1}metre−1 or $\Omega^{-1}m^{-1}$ or siemen metre^{-1}.

$$\sigma = \frac{1}{\rho} = \frac{l}{Ra}$$

Rheostat or variable resistance:

It is a device used in an electric circuit by which we can continously change the resistance of the circuit. It does this by varying the length of the resistance wire used in circuit.

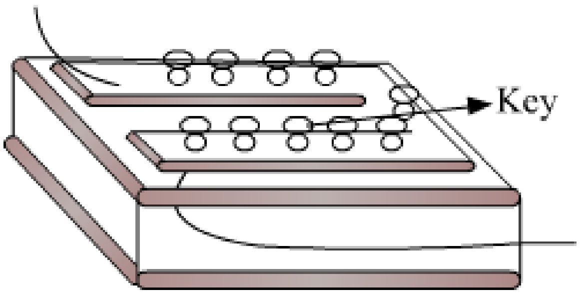
Graphic



Rheostat

Resistance box

It is a box consisting of several resistances of different values connected in series. As per the circuit requirement, resistance of any desired value can be achieved by removing or inserting the key from the box.



Resistance box

III Temperature of the conductor

Experimentally, it is found that resistance of a conductor increases with the temperature and vice-versa. But resistance of alloys such as nichrome, constantan etc. is only slightly affected by temperature. Hence, alloys are better suited in electrical circuits.

Semiconductors

Germanium and silicon offer resistance lying between the resistances of conductors and insulators. Hence, these are called semiconductors. **Their resistivity decreases with temperature, in contrast to conductors and alloys**.

Semiconductors have great importance because their conducting properties change with temperature, impurity, concentration etc.

IV Nature of the material

In the above activity, you will notice that the reading in the ammeter for wire in case (i) is greater than the reading for wire in case (vi).

This means that a copper wire offers less resistance than a chromium wire of the same length and cross-sectional area, on the nature of the material used.

Hence, it can be deduced that the resistance of a conductor depends on the nature of the material used.

The following table shows the resistivity of some materials at 20 °C.

Category	**Material**	**Resistivity (in Ω m)**
Conductors	Silver	1.60×10^{-8}

	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.48×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	184×10^{-8}
Alloys	Manganin (Cu – Mn – Ni)	44×10^{-8}
	Constantan (Cu – Ni)	49×10^{-8}
	Nichrome (Ni – Cr – Mn – Fe)	100×10^{-8}

Semiconductors	Germanium	0.6
	Silicon	2300
Insulators	Glass	$10^{10} – 10^{14}$
	Paper	10^{12}
	Hard rubber	$10^{13} – 10^{16}$
	Diamond	$10^{12} – 10^{13}$
	Ebonite	$10^{15} – 10^{17}$

Interesting Fact:

Superconductivity

The phenomenon of superconductivity was discovered by K. Onnes in 1911. He discovered that the resistance of mercury fell abruptly to zero on lowering its temperature below 4.2 K. This means that if a current is passed through a superconducting wire it will continue to flow forever!

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.

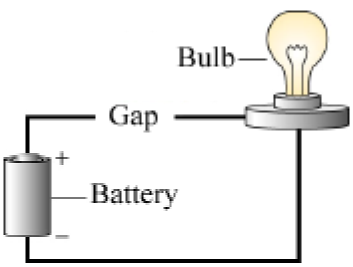
Electrical conductors	Electrical insulators
Electricity can pass through certain materials. These materials are known as electrical conductors.	Electricity cannot pass through certain materials. These materials are known as electrical insulators.
All metals (for example, aluminium, copper, iron, and 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

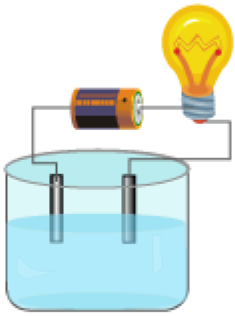
Construct a simple electrical circuit, as shown in the given figure.



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.***