Electricity

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 = $\frac{\text{amount of electrons flowing through the cross-section of the wire}}{\text{time taken}}$

Or, I = Q/t

Where, *I* → amount of current

Q → amount of electrons flowing through a cross-section

t → time taken

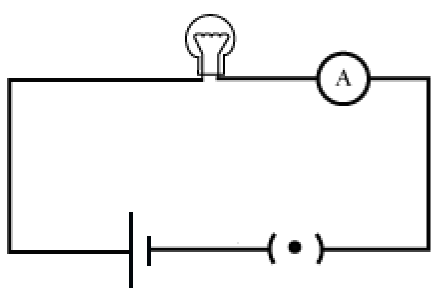
The SI unit of current (*I*) is taken as ampere (A), named after the great physicist, Andre Marie Ampere (1775 − 1836).

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.



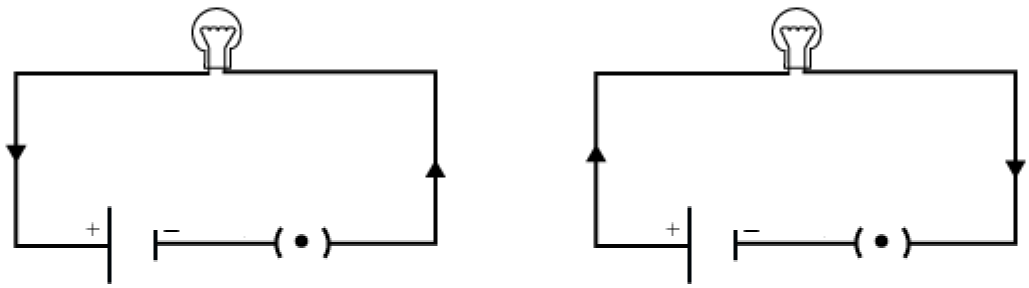
The smaller units of current are expressed in millliampere (mA) and micro ampere (μA). The relation between them is given by:

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

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.**

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

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.**

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

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

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

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

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

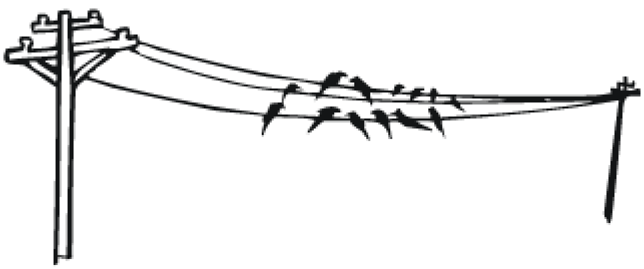
Hence, we can define potential difference between two points as 1 J of work that is required to move 1 C of charge between two points.

- 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?

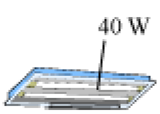
Birds sitting on live wires do not get electrocuted.

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 Power and Energy

We use electricity to run various electrical appliances such as bulbs, tube lights, refrigerators, electric heaters etc. in our homes. **Do you think all these home appliances consume an equal amount of electricity at a given time?**

No, the amount of electricity consumed by an electrical appliance depends on the power rated on that appliance. For example, for 220 V potential supply, a tube light of rated power 40 W draws 0.18 A of current, whereas a bulb of rated power 100 W draws 0.45 A of current.



How can you determine the rate of consumption of energy by a given appliance?

Electric power

Electric power is defined as the rate of consumption of energy or simply the rate of doing work.

i.e., power (P) = $\dfrac{\text{work done } (W)}{\text{Time } (t)}$ ……………. (i)

The work done by current (I) when it flows in a potential (V) for time (t) can be given by

$W = VIt$ ………………….. (ii)

⇒ Power, $(P) = \frac{VIt}{t} = VI$

∴ Electric power or $P = VI$

The SI unit of power is watts (W).

Also, the energy dissipated or consumed by an electric appliance per unit time is given by

$$\frac{H}{t} = I^2 R$$

It is also an equation for electric power.

i.e., $P = I^2R$

Now, according to Ohm's law

$$\Rightarrow V = IR$$

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

If we substitute the value of I in the equation of power, we get

$$P = \left(\frac{V}{R}\right)^2 R = \frac{V^2}{R}$$

Hence, we get the expression for electric power as

Where, 1 W = 1 V × 1 A = 1 V A

$$P = VI = I^2 R = \frac{V^2}{R}$$

1 watt is defined as the power consumed by an electrical circuit that carries a current of 1 ampere, when it is operated at a potential difference of 1 volt.

- Since Watt is a very small unit, we define a larger unit of power as **kilowatt** (kW). Thus,

$$1\ kW = 1000\ W$$

For practical purposes, we define kilowatt hour (kWh) as 'unit' where,

1 unit = 1 kWh = 1000 W × 1 hour

= 1000 W × 3600 s

= 36 × 10^5 Ws

= 3.6 × 10^6 J

1 kWh is also the commercial unit of electric energy.

Note that electricity is a flow of electrons and nothing else. Hence, power stations only make the electrons flow through conducting wires for which they charge us. They do not create or generate the electrons.

Prepare a list of electrical appliances commonly used in homes. Note down the respective watts rated on them. Now, try to calculate the amount of current drawn by respective appliances for a constant voltage of 220 V. Complete the table and discuss the result with your friends.

Electrical appliance	Rated power	Current drawn
Audio player	100 W	0.45 A
Fan	60 W	…..
TV	120 W	…..
Refrigerator	160 W	…..
Electric heater	1000 W	…..

Example:

(i) The amount of current drawn by an immersion water heater is 6.8 A. If the heater is operated on 200 V of potential difference, calculate its power.

Solution:

Given that,

Potential difference, V = 200 V

Current drawn, I = 6.8 A

By definition of electric power, we know that

$P = VI$

Hence, P = 200 V × 6.8 A

= 1360 W

Hence, power of the given immersion heater is 1360 W.

(ii) What is the monthly cost of energy to operate the given immersion water heater 3 hours/day at Rs 5.00 per unit?

Solution:

Power of the heater is 1360 W.

Energy consumed by it per day = 1360 W × $\frac{3 \text{ hours}}{1 \text{day}}$

Hence, energy consumed by it in 30 days = 1360 W × $\frac{3 \text{ hours}}{1 \text{day}}$ × 30 days

= 122400 W

= 122.4 kWh

= 122.4 units

Now, the cost of energy for one unit is Rs 5.00

∴ Cost of energy for 122.4 units will be 5 × 122.4 = 612

Hence, the monthly cost of energy of the heater is Rs 612.

What is the amount of energy consumed by the given water heater in one month?

Power Transmission and Distribution

Electricity produced in a power station is transmitted for industrial and domestic uses with the help of transformers, transmission wires, towers, etc.

After generating electricity, a power transformer is used, at heavy load, for its transmission. The power transmission transformer is usually large in size.

At the initial stage of power transmission, a step-up transformer is used to increase the voltage of electricity.

Transmission loss

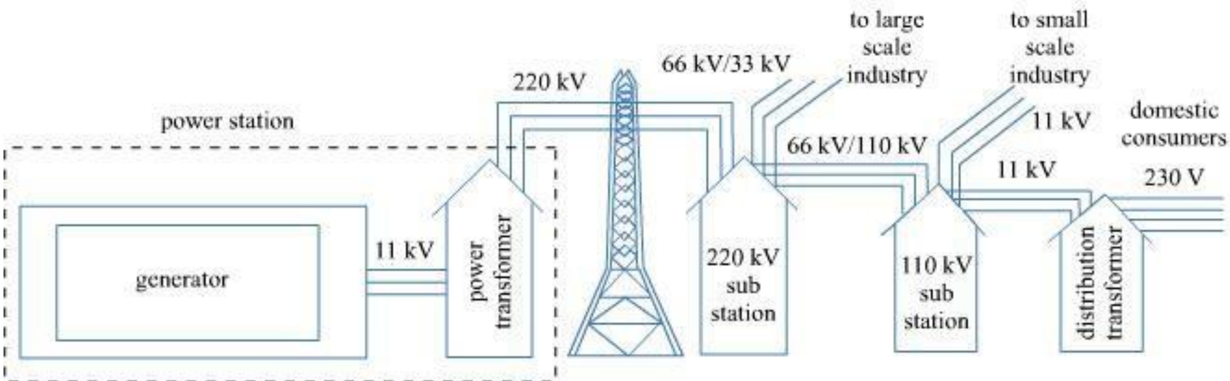
Energy loss in the form of heat, during the transmission of electricity, is minimal when the electricity is transmitted at a high voltage for a given power. This is because at high voltage, current flowing through the wire is minimal.

In an electric line, energy is lost in the form of heat. This loss is known as **transmission loss**. Heat developed in the electric lines is given by $H = I^2Rt$

And electric power is given by $P = V \times I$

If voltage is larger, current is smaller for the same power. Hence, the energy loss is less.

That is why a step-up transformer is used at the initial stage of transmission network.



Different stages of power distribution

Heat loss in the transmission network depends on the following three factors:

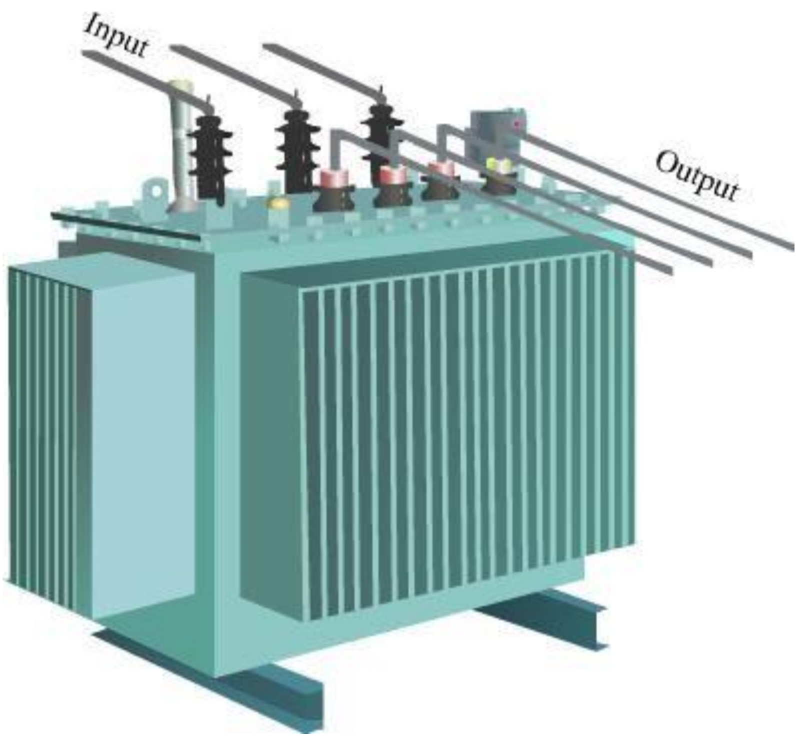
(i) Magnitude of the electric current flowing through the wires

(ii) Resistance of the wires

(iii) Time for which current is flowing

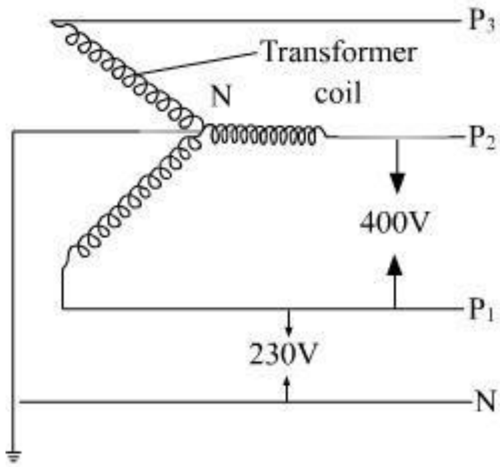
Star connection

At the last stage of transmission, a distribution transformer is used for the distribution of electricity at low voltage. This voltage is lesser than 33 kilo volts for industrial purposes and around 220v for domestic purposes. The size of a distribution transformer is smaller than a power transmission transformer.



Four lines come out of the distribution transformer. Let us see how these lines come out.

Wires are connected in star mode connection in the secondary coil of the distribution transformer as shown in the figure.

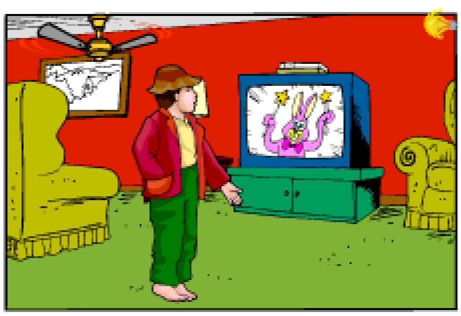


Star connection

We get four lines out of the distribution transformer; three phase lines (P_1,P_2 and P_3) and one neutral line(N). Each phase has the same frequency but different voltages.

From this distribution system, we can see that P_1 and N line are used for the domestic purpose.

Domestic Electric Circuit



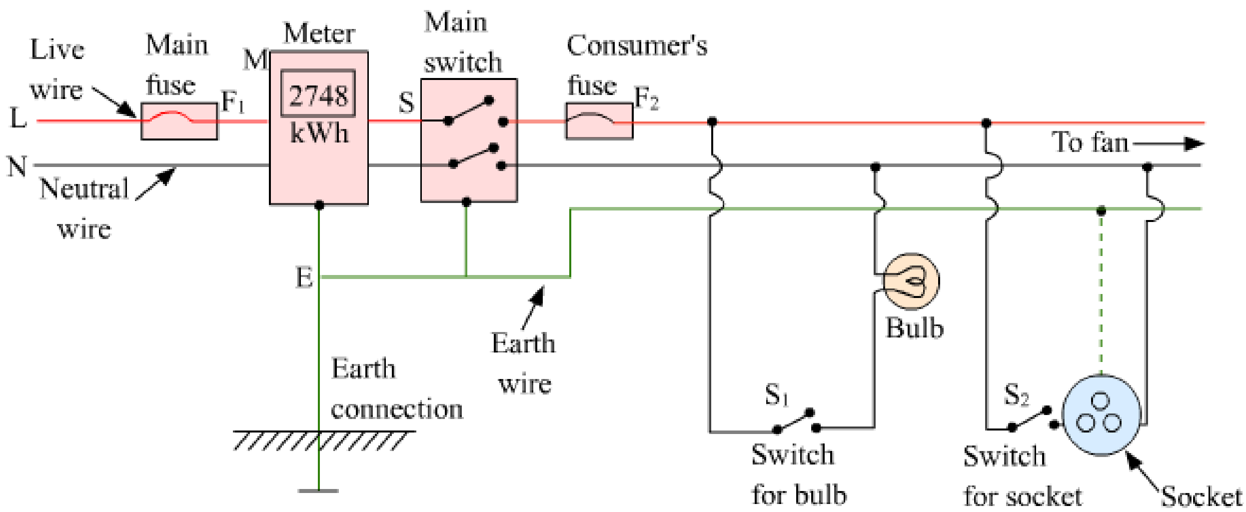
Vikram has read in his science book that electricity reaches our homes, schools, factories etc. through thick aluminum and copper wires. The supply voltage is 220 V.

He has scrutinized some electrical appliances such as bulbs, heaters, and refrigerators in his house and found that they all operate at 220 V. **He wonders how these appliances run simultaneously with only 220 V supply voltage.**

Vikram's confusion can be sorted out by understanding the concept of domestic electrical circuits.

Domestic wiring

Electricity is transferred to our homes through a pair of insulated copper or aluminum wires. This pair consists of a red color wire (called **live wire, L),** and a black color wire (called **neutral wire, N).** In addition to these wires, a green color wire known as the **Earth wire, E** is also connected with the circuit. In India, 220 V potential is supplied through live wire, while neutral wire has ground potential of zero volts.



In the above diagram, the pair of wires L and N first enter the main box, which is placed outside the house. From here, live wire L goes into the main fuse F_1 having a high rating of about 50 A.

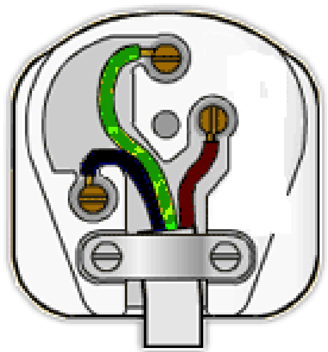
Then, both wires enter the electricity meter that records the electricity consumed in units, where 1 unit = 1 kWh = 3.6×10^6 J. The wires then go to the main switch, S. Electricity supplied to the house can be cut off using this switch.

The extensive use of electricity is due to the convenience and usefulness associated with this form of energy.

Domestic uses of electricity include lighting, heating, cooling and nowadays, even cooking. The electricity supply board usually provides alternating current at 220 V.

Alternating current consists of three phases or what we see as wires of three different colours.

1. Red wire is the live wire
2. Black wire is the neutral wire
3. Green wire is the earth wire



Here, the red and the black wires are called the supply wires, while the green wire is for safety.

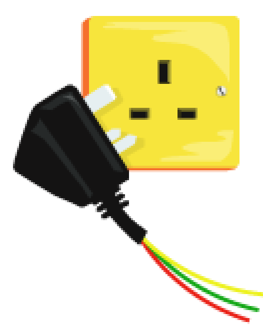
Why use the earth wire?

Earth wire is quite necessary in a household appliance. It causes a leaking current to flow harmlessly to the ground, thereby preventing the user of the appliance from getting an electric shock.

Importance of Earthing

We can receive an electric shock on touching a running appliance. This is caused by the leakage of current from the appliance. Earthing provides a safety measure against the electric shock, caused by the leakage of current. A third wire called the Earth wire (E) is also used in domestic wiring. This wire has green insulation over it. A copper plate connected to the main switch via the meter is connected at one end of this wire, E.

Sometimes, the insulation of a live wire burns due to excessive heating. A naked live wire may lead to an electrical shock. To protect the appliance against an electrical shock, its metallic case is connected with the Earth wire. Hence, a domestic socket is composed of three wires, namely the live wire, neutral wire, and Earth wire.



Open and Closed circuits

When the two ends of an electrical circuit are not connected, no current flows through the circuit. We say that the circuit is not complete and call it an open circuit. No current flows through the circuit in this situation.

On the other hand, when the two ends of an electrical circuit are connected and the circuit forms a closed loop, we call it a closed circuit.

Every circuit in ‘switched-off’ condition is an open circuit.

Switches: It is a device which is connected in the live wire so as to turn 'ON' or 'OFF' the current in the circuit.

Types of switches:

1) Single pole switch: A single pole switch is a simple switch which is used with an appliance to start or stop the flow of current in it. This switch only disconnects the live wire from the appliance.

2) Double pole switch: A double pole switch is a main switch in the distribution board, used to switch on or off the main supply. This switch disconnects both live and neutral wires simultaneously. We often use such switches in a staircase etc.

Why switch should always be connected in the live wire?

- If the switch, connected to live wire which is at high potential, is turned off, then the switch cuts the path of current to the appliances connected to the live wire.

  This is because, in this case, both the live and neutral wires connected to the ends of the appliances come at zero potential and hence does not allow current to flow in the circuit.

  Thus, if required, we can safely carry out repairs for our appliances as appliances in these case also are at zero potential.

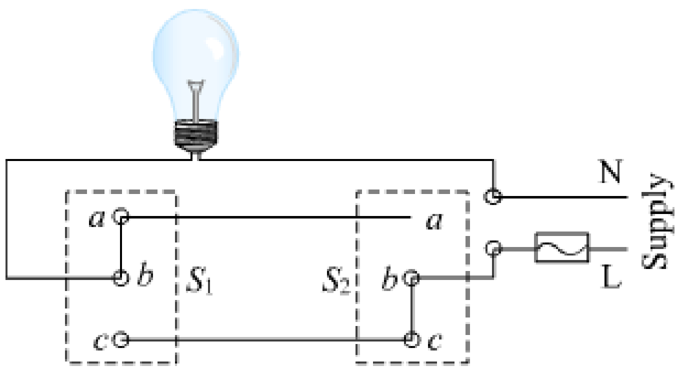
- But if the switch, connected to a neutral wire which remains at zero potential, is turned off, then also current will not flow through the appliances in this case as the circuit is not closed. But the live wire (or appliances) still remains at high potential in this case.

  So, it would becomes dangerous to carry out repairs in appliances as current would flow from the appliances to the person's body (body being at low potential).

Working of dual control switch/ double pole switch

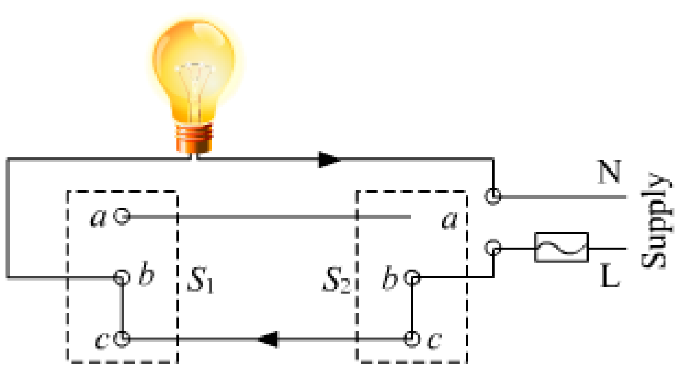
Two dual control switches S_1 and S_2 are connected at the top and bottom of the staircase, respectively. Now, the bulb connected to both the switches can be put on or off using any of the two switches.

Situation (a): In this situation, bulb does not glow as live wire connecting the point **c** of switch S_1 (in 'OFF' position) through point **b** and **c** of switch S_2 (in 'ON' position) is not making a complete circuit.



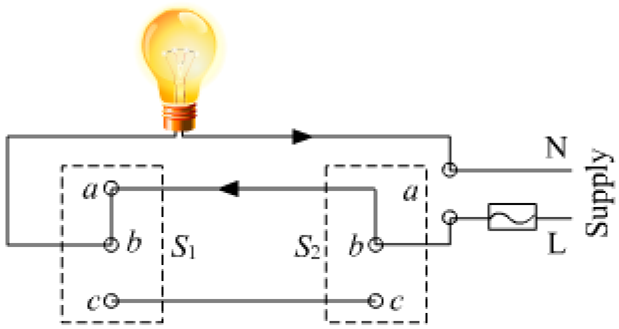
Bulb off

Situation (b): In this situation, switch S_1 is pressed 'ON' and switch S_2 is in same position (i.e. in 'ON' position). The live wire, which provides the current to point **c** of S_1 from point **b** and **c** of switch S_2 , now gets connected to point **b** of switch S_1. Hence, the circuit is complete and thus the current flows through the bulb and the bulb glows.



Bulb on through switch S_1

Situation (c): In this situation, switch S_1 (in 'OFF' position) will disconnect the path of the current from point **c** to **b** of switch S_1 but joins the point **a** to **b** of S_1 creating a new path for the current. Simultaneously, switch S_2 (in 'OFF' position) will disconnect point **c** from **b** and connect point **b** with **a** of switch S_2. Again the current flow from S_2 to S_1 through point **b** to **a** of S_2 to **a** to **b** of S_1. Hence, the bulb glows.



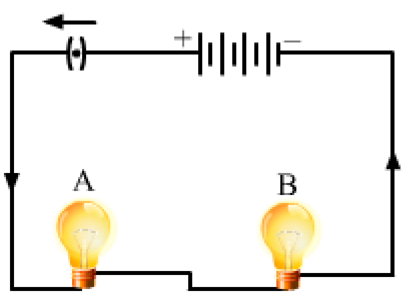
Bulb on through switch S_2

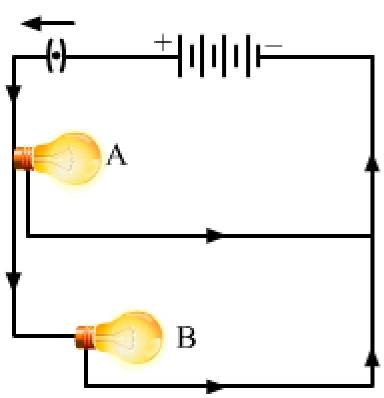
Series and Parallel circuits

Depending upon how the appliances are connected to each other, domestic electrical circuit can be of two types—parallel circuit and series circuit.

When the appliances are connected end-to-end one after another, the circuit is called **series circuit**.

When the appliances are connected parallel to each other between two points, the circuit is called **parallel circuit**.

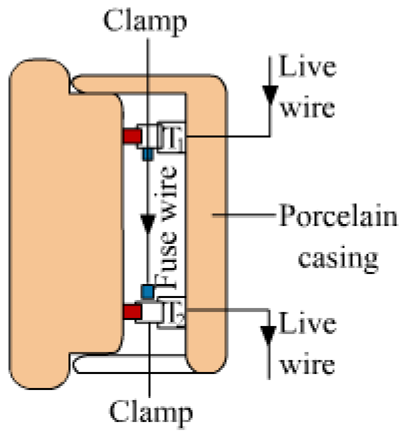




In domestic circuit, parallel circuit is always preferred over series circuit.

Electric fuse

An electric fuse is a safety device that protects the wiring against excessive heating caused by an excess supply of current. It melts when heavy current flows through the circuit, thereby causing the circuit to become open.



Characteristic of electric fuse

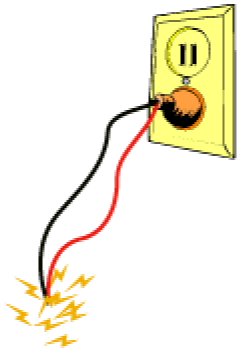
- Fuse wire has low melting point. It is generally made up of an alloy of lead and tin.
- Fuse wire is always connected in the series with the live wire. Its resistance is higher than that of the copper wires. So it gets heated up much faster than the copper wire when excessive current flows through it.
- Current rating of the fuse wire decides its thickness. More the current rating of the fuse wire, more will be its thickness.

Miniature circuit breaker (MCB)

An MCB is a device which functions as a fuse, but does not require replacement. MCB falls down to break the circuit when heavy amount of current flows through it. Once the fault is rectified, the MCB is reset.

Excessive flow of current can be caused by any of the following two cases:

I. Short circuiting

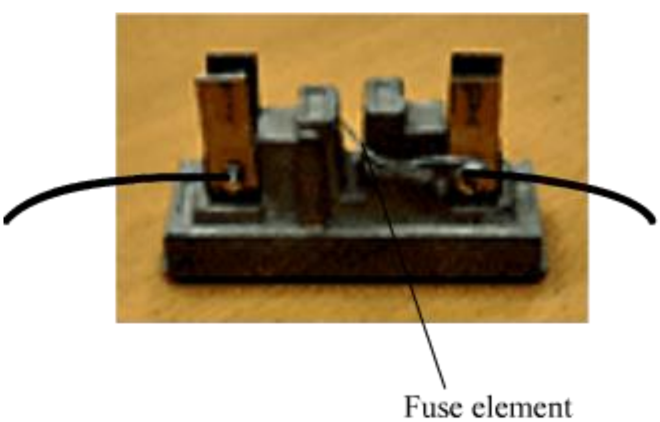


Short circuiting occurs when naked live and neutral wires touch each other. In such a case, the resistance of the circuit becomes very less. Now, according to Ohm's law, current is inversely proportional to resistance.

Thus, the lowering of resistance of the circuit raises the current to a significant amount. As a result, the wires become hot and a spark is caused by Joule's heating effect of current. This situation is known as short circuiting.

II. Overloading

A large amount of current is withdrawn from the circuit, when a large number of electrical appliances of high power-rating are switched on at the same time or connected in a single multi-plug. This situation is called overloading. It may even lead to a fire in the circuit.



To prevent any damage by short circuiting or over loading, an electric fuse (that consists of a low melting point wire) is used. The wiring of the circuit is made of low resistance copper wire of a certain thickness. This allows only a maximum amount of current to flow through it, which is called its **safe limit.**

If an amount of current flowing through a circuit exceeds its safe limit either caused by short circuiting or over loading, the excess heat caused by Joule's heating melts the wire. This results in the breaking of the circuit, thereby preventing the appliances from damage.

Depending on the thickness, fuse elements are rated as 1 A, 2 A, 3 A, 5 A, 10 A, 15 A, and so on. For example, a 10 A fuse element melts and breaks if the current exceeds its limit of 10 A.

Short circuiting and overloading are the major hazards related to electricity. There are various other hazards of electricity against which we should be cautious and should take precautions.

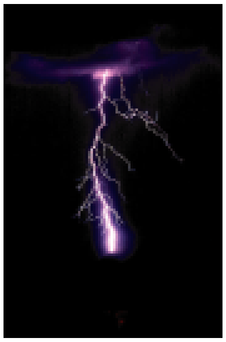
Precautions to be taken while using electricity:

- Never touch switches with wet hands.
- Ensure all electrical appliances are properly earthed.
- Ensure MCB, fuse and switch are connected to live wire.
- Never repair an appliance while in use.
- The wiring used must be properly insulated.

Electrical Charge

Why is it advised to stay away from an electric plug, fitted loosely in the socket?

This is because a loosely fitted electric plug can produce sparks. These sparks can harm the human body, if it comes in contact with it.



Electric sparks can be found in nature too. They are present on a large scale and are more harmful. Lightning is a natural phenomenon. However, it is destructive as it is a result of electric sparks.

The sparks produced by lighting can be dangerous, since they are caused due to an accumulation of a huge amount of charges. Also, the sparks produced are widespread.

If you take off your woollen sweater inside a dark room, you will be able to see sparks. These sparks occur due to the presence of electric charges.

Rubbing induces electrical charge

Comb dry hair with a plastic comb and bring it near small pieces of paper. **What do you observe?**

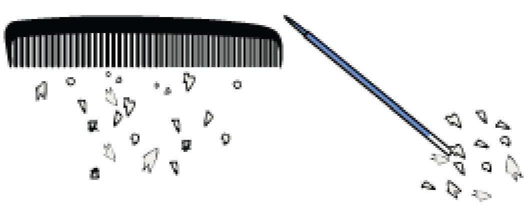
You will observe that the pieces of paper get attracted towards the comb.

What is the reason for this?

A small amount of electrical charge is acquired by the comb on rubbing it with dry hair. Thus, the comb becomes charged and attracts small pieces of paper.

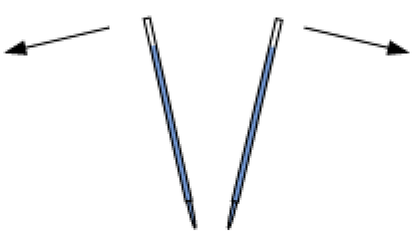
Rub various objects (such as a glass rod, plastic scale, and rubber tube) with different types of clothes (such as cotton, woollen, and silk). Now, bring these objects close to small pieces of paper. **Can you tell which objects are charged and which are not?**

Interaction between Charges



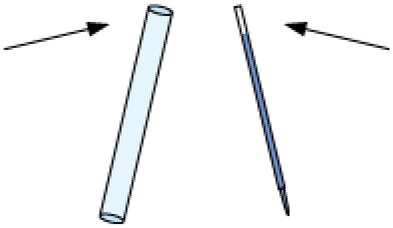
You know that a charged plastic comb attracts small pieces of paper. Similarly, when we rub a refill with a polythene bag and bring it close to the pieces of paper, we will see that the refill attracts the pieces of paper. Thus, we can say that both the comb and the refill acquire charge.

Bring two charged refills close to each other. **What do you observe?** You will observe that the refills repel each other.



Rub a glass rod with silk cloth. The glass rod will also get charged. **What do you**

observe when you bring the glass rod close to the charged refill? You will observe that the rod and the refill attract each other.



Can you explain these observations? These observations can be explained on the basis of **like** and **unlike** charges.

There are two kinds of charges existing in nature: **positive** charges and **negative** charges. As a convention, the charge carried by a plastic refill rubbed against a polythene bag is taken as negative. And the charge carried by a glass rod rubbed with silk is taken as positive. Different types of charges interact with each other according to the following rule:

Like charges repel and unlike charges attract.

Thus, the two refills carrying negative charges repel each other. Now, the refill and the glass rod carry opposite charges. Therefore, they are attracted towards each other.

Bring different charged objects near a charged glass rod and observe the interaction between them. **Can you identify the type of charge on an object by observing its interaction with the glass rod?** Now, bring each of these objects near a charged refill. **Are you able to guess correctly the type of interaction of these objects with the refill?**

Modern Theory of Electrification

You know that a glass rod gets charged when rubbed with a silk cloth. Do you know why this happens?

To explain the phenomenon of charging by rubbing, you must have the basic knowledge of atomic theory.

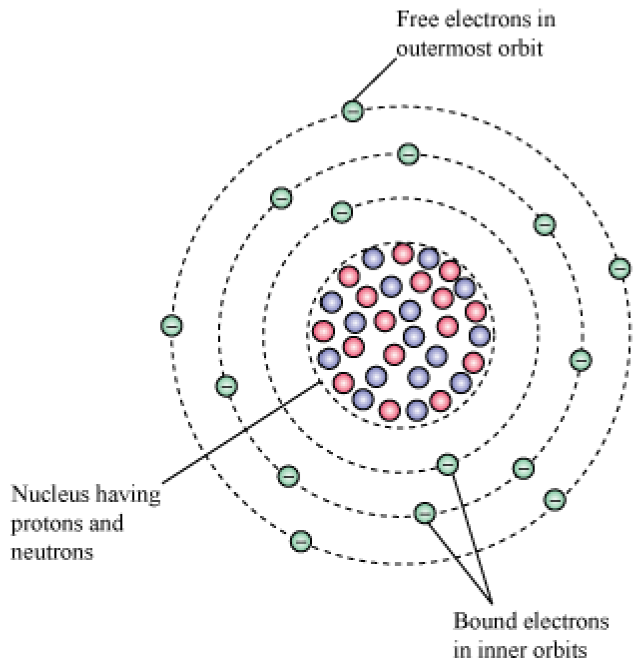
Atoms are the building blocks of all matter in the universe. An atom consists of three main particles.

Protons—positively charged particles

Neutrons—neutral particles

Electrons—negatively charged particles

Neutrons and protons are closely packed, forming the nucleolus, at the centre of an atom. Electrons revolve around the nucleolus in different orbits of different diameters.



Though an atom has charged particles, it is still electrically neutral. Why?

In an atom, the number of protons is equal to the number of electrons. Therefore, the total positive charge is equal to the total negative charge. Thus, on the whole, the atom is electrically neutral.

Valence Electrons

Electrons present in the outermost orbit are called **valence electrons**. These electrons are loosely bound to the atom and can easily get free. It is these valence electrons that are responsible for electrification of a body. When two bodies are rubbed with each other, free electrons of one body get transferred to another body.

This leaves one body with extra electrons, thus acquiring negative charge, and the other body with deficiency of electrons because of which it gets charged positively. It is important to note here that in positive electrification, protons are not transferred from one body to another; rather it is the deficiency of electrons because of which a body acquires positive charge.

Glass Rod and Silk

When a glass rod is rubbed with a silk cloth, the valence electrons from the glass rod get transferred to the silk, thus making the glass rod positively charged and silk negatively charged. This in turn develops an attractive force between the two.

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?**

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.

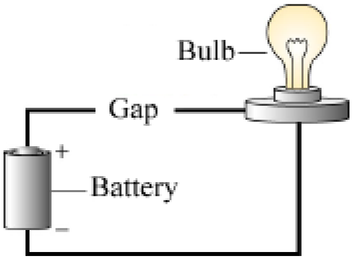
Electrical conductors	Electrical insulators

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

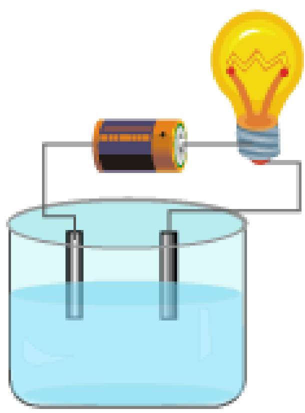


Construct a simple electrical circuit, as shown in the given figure.

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.

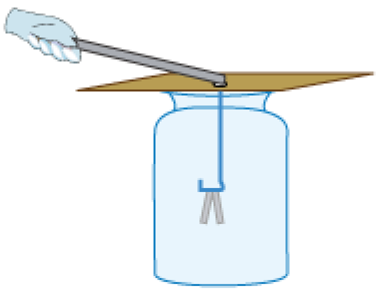
Hence, it can be concluded from this activity that ***impure water is a good conductor of electricity, while pure water is a good insulator of electricity.***

Charging by Conduction

In an electroscope, the charge carried by a charged object is transferred to the aluminium strips through a metal wire. Thus, we can say that charge can be transferred from one charged body to another.

However, charge can only be transferred through a good conductor of electricity. In the case of an electroscope, charge is transferred to the aluminum strips through a metal wire. Metal wires are good conductors of electricity. Thus, charge can pass through them.

Let us see if charge can be transferred through the human body. It is extremely dangerous to touch an object carrying a heavy charge. In order to test whether a charge can be transferred through the human body or not, let us perform a simple activity.



Touch a charged glass rod with the metal strip of an electroscope. You will observe that the aluminum strips are repelled by each other. Also, you will observe that they remain in that position even after removing the glass rod. Now, touch the metal strip with your hand. **What do you observe?**

You will observe that the aluminum strips collapse to their original position as soon as you touch the metal wire.

Why does this happen? The charge carried by the aluminum strips is transferred to our body, which in turn is transferred to the ground, i.e., the charge carried by the aluminum strips is transferred to the Earth through our body. Thus, you see that the human body is a good conductor of electricity.

The transfer of charge to the Earth is known as Earthing or grounding.
Removing a charge from a charged body is known as discharging.

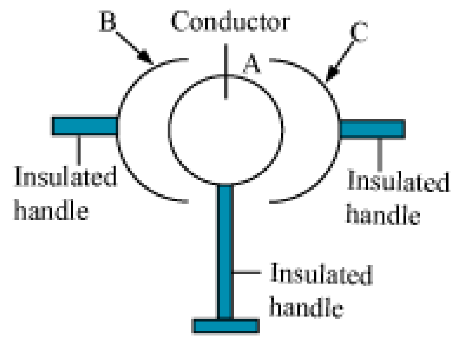
Buildings are provided with earthing so that in case of leakage of an electrical charge, people inside the building are not affected, and the charge is transferred to the ground safely.

When electrically charged, the charges on a conductor, whether solid or hollow, reside on the outer surface of the conductor.

Let us perform few experiments to see how charges are distributed on a conductor.

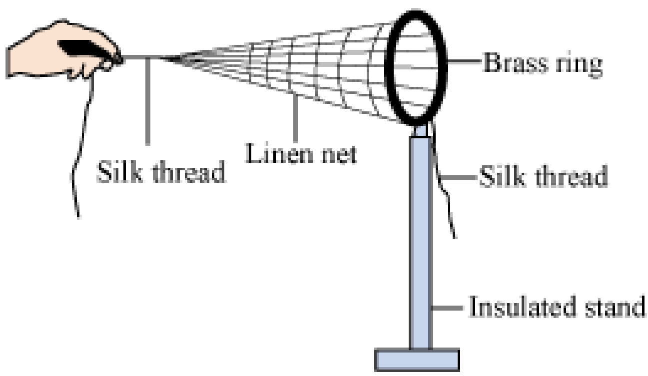
Biot's Experiment

A is a spherical conductor and **B** and **C** are two hemispherical conductors with handles such that **B** and **C** can just fit on sphere **A**. When **A** is electrically charged, we cover it up with **B** and **C**. After some time, we detach **B** and **C** from **A**. Now, if we test all of them, then we will observe that the hemispheres **B** and **C** are charged, but sphere **A** is neutral. Why does this happen?



When **B** and **C** are attached to **A**, the whole system acts similar to a single conductor. As electric charges only reside on the outer surface of a conductor, all the charges from **A** get transferred to the outer surfaces of **B** and **C**. Therefore, on detaching from **A,** only the hemispheres **B** and **C** contain charges whereas **A** becomes neutral.

Faraday's Butterfly-Net Experiment



Apparatus

- Butterfly net made of linen
- Brass ring mounted on the butterfly net
- Insulated stand supporting the brass ring
- Silk thread fixed on the pointed side of the net such that it extends on both sides

Working

First the net is charged by a glass rod. Then, the presence of the charges is tested on the inner as well as on the outer surface of the net with the help of a proof plane and gold leaf electroscope. It is observed that no charge is present on the inner surface of the net. All the charges are present on the outer surface only.

Then the thread is pulled, hence making the inner surface outer and the outer surface inner. The same experiment is repeated. Again, it is observed that the charges are present on the new outer surface.

Charges on a conductor are present only on the outer surface of the conductor. Therefore, charges are always found on the outer surface of the net and not in the inner surface.

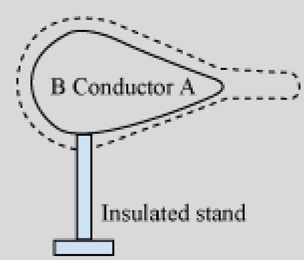
How Charges are Distributed on a Conductor

Do you think that charges are always evenly distributed on a conductor?

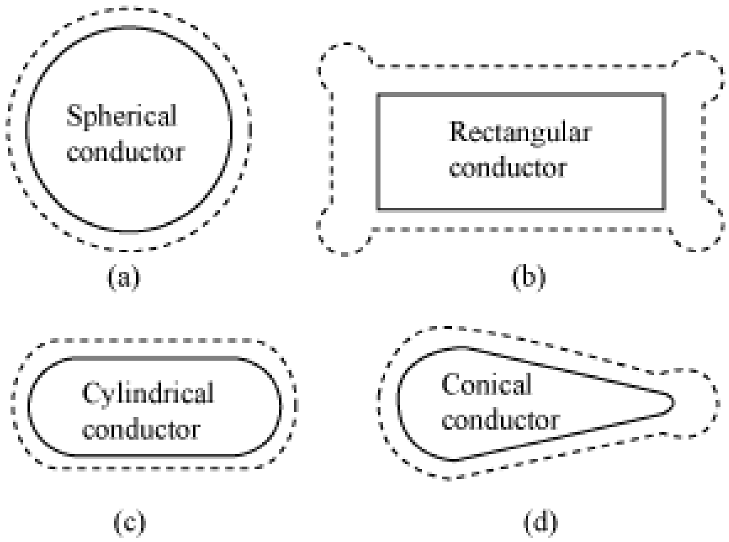
The answer is simple NO. Distribution of charges on a surface depends upon the shape of the conductor. It is observed that charges are densely packed on the pointed areas of a conducting surface or we can say that the density of charges is more on the pointed edges.

The charges present on a unit surface area of a substanceare called the **surface density of charges**.

Take an egg-shaped conductor. Charge it and test the amount of charges at different points on it by using a proof plane or electroscope. It is observed that surface charge density is the maximum at A and the least at B.



The distributions of charges on conductors of different shapes are shown in the following figures.

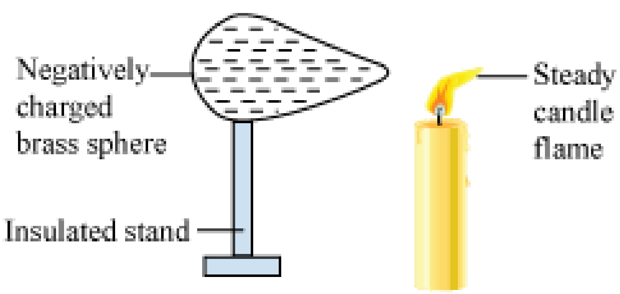


Leakage of Charge

Mount a conical conductor on an insulated stand. Charge the conductor with negative charges. Now, bring a candle near the pointed end of the conical conductor. You will observe that the flame of the candle bends away from the conductor. Why is it so?

It is so because the surface charge density of the pointed edge is very high. Hence, when the air molecules come in contact with the pointed end, they take away some electrons from the conductor and become negatively charged.

This is called the **leakage of charges.** These air molecules then lose the electrons to the neighbouring air molecules. The air molecules then repel each other, thus forming an electric wind, which bends the flame of the candle away from the pointed edge.

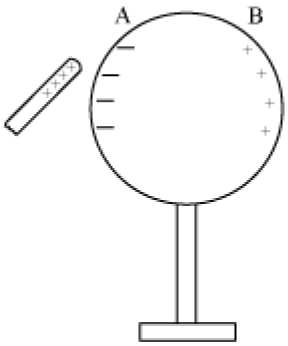


Charging by Induction

It is another method to charge a conductor. In this method the conductor to be charged is not touched with the charge body, but is kept near the it.

A conductor may be charged permanently by induction in the following steps.

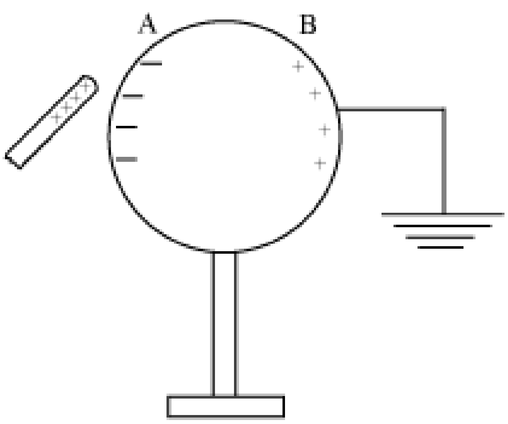
Step I



To charge a conductor AB negatively by induction, bring a positively charged glass rod close to it. The end A of the conductor becomes negatively charged while the far end B becomes positively charged.

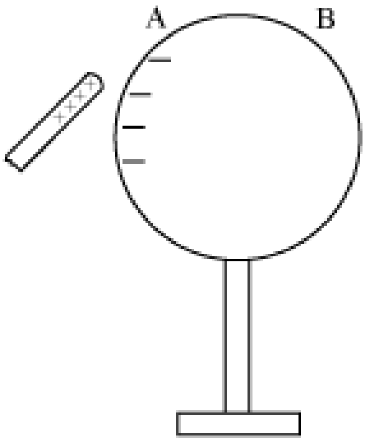
It happens so because when positively charged glass rod is brought near the conductor AB, it attracts the free electrons present in the conductor towards it. As a result, the electron accumulates at the near end A and therefore, this end becomes negatively charged and end B becomes deficient of electrons and acquires positive charge.

Step II



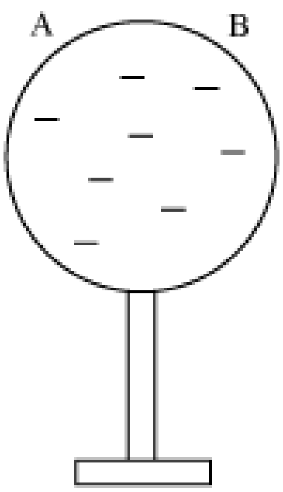
The conductor is now connected to the earth. The positive charges induced will disappear. The negative induced charge on end A of the conductor remains bound to it due to the attractive forces exerted by the positive glass rod.

Step III



The conductor is disconnected from the earth keeping the glass rod still in its position. End A of the conductor continues to hold the negative induced charge.

Step IV

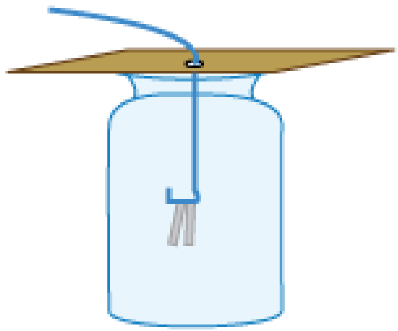


Finally, when the glass rod is removed, the negative induced charge on the near end spreads uniformly over the whole conductor.

Construction and Working of an Electroscope

You know that objects can be charged by rubbing. **Is it possible to detect whether an object is carrying a charge?**

Electroscope is an instrument that is used to detect electrical charge on a body.



How can you construct an electroscope?

It is a pretty simple device. Take an empty glass bottle and cover its mouth with a piece of cardboard. Pierce a hole at the centre of the cardboard and insert a thick metal wire curved at the end. Hang two small strips of aluminium foil of the same size on the curved end of the metal wire (as shown in the figure). This is an electroscope.

Therefore, you see that an electroscope is used to detect whether an object is carrying a charge or not. However, it cannot detect the type of charge (positive or negative) carried by an object.

The pith-ball electroscope and the gold-leaf electroscope are two classical types of electroscopes.

Lightening

You know that lightning is a large electrical spark in nature. Lightning usually occurs during thunderstorms. You can see bright streaks of light in the sky known as **lightning**.

Let us see how lightning occurs.

Some key points you should remember:

- In general, air is a poor conductor of electricity.
- Lightning only occurs when accumulation of charges becomes so high that air cannot resist the flow of charges.

The electrical discharge that causes lightning may take place between two clouds or between a cloud and the Earth.

Lightning Conductor

Projecting objects such as trees, poles and tall buildings are more likely to be striked by lightning. A lightning conductor is an instrument which is used to protect tall buildings from being striked by the lightning.

It is a long metal rod that runs from the top to bottom along the outer wall of the building. The lower end of the conductoris connected to a metal plate which is burried deep under the ground. If the lightning strikes, the conductor provides the path for the charge to pass directly to the ground without harming the building.

Safety measures during lightning strikes

Following are some safety measures to be followed during a thunderstorm when lightning strikes.

If outdoor:

1. Avoid taking shelter under trees.
2. Avoid being near to any kind of metal objects which may include metal wires, fences, machinery and power appliances.
3. Take shelter inside a fully enclosed car with all the windows shut.

If indoor:

1. Turn off all the electrical appliances such as television and refrigerator.