ELECTRICITY

Primary Cell – Simply Dry Cell:

A dry cell is a type of chemical cell commonly used in the common form batteries for many electrical appliances. It is a convenient source of electricity available in portable and compact form. It was developed in 1887 by Yei Sakizo of Japan.

Dry cells are normally used in small devices such as remote control for T.V., torch, camera and toys.

A dry cell is a portable form of a leclanche cell. It consists of zinc vessel which acts as a negative electrode or anode. The vessel contains a moist paste of saw dust saturated with a solution of ammonium chloride and zinc chloride.

The ammonium chloride acts as an electrolyte.

The purpose of zinc chloride is to maintain the moistness of the paste being highly hygroscopic. The carbon rod covered with a brass cap is placed in the middle of the vessel. It acts as positive electrode or cathode.

It is surrounded by a closely packed mixture of charcoal and manganese dioxide (MnO_2) in a muslin bag. Here MnO_2 acts as depolarizer. The zinc vessel is sealed at the top with pitch or shellac. A small hole is provided in it to allow the gases formed by the chemical action to escape. The chemical action inside the cell is the same as in leclanche cell.

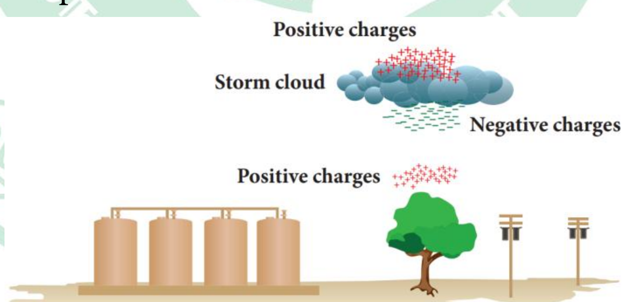
Lightning, Thunder and Earthing:

Getting a shock from a door knob after rubbing your foot on a carpet floor, results from discharge. Discharge occurs when electrons on the hand are quickly pulled to the positively charged doorknob. This movement of electrons, which is felt as a shock, causes the body to lose negative charge. Electric discharge takes place in a medium, mostly gases. Lightning is another example of discharge that takes place in clouds.

Lightning is produced by discharge of electricity from cloud to cloud or from cloud to ground. During thunderstorm air is moving upward rapidly. This air which moves rapidly, carries small ice crystals upward. At the same time, small water drops move downward. When they collide, ice crystals become positively charged and move upward and the water drops become negatively charged and move downward. So the upper part of the cloud is positively charged and the lower part of the cloud is negatively charged. When they come into contact, electrons in the water drops are attracted by the positive charges in the ice crystals. Thus, electricity is generated and lightning is seen.

Sometimes the lower part of the cloud which is negatively charged comes into contact with the positive charges accumulated near the mountains, trees and even people on the earth. This discharge produces lot of heat and sparks that results in what we see as lightning. Huge quantities of electricity are discharged in lightning flashes and temperatures of over 30,000°C or more can be reached. This extreme heating causes the air to expand explosively fast and then they contract. This expansion and contraction create a shock wave that turns into a booming sound wave, known as thunder.

Sometimes lightning may be seen before the thunder is heard. This is because the distance between the clouds and the surface is very long and the speed of light is more than the speed of sound.



Earthing:

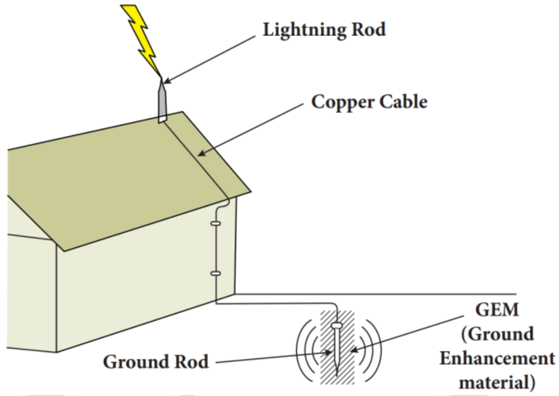
A safety measure devised to prevent people from getting shocked if the insulation inside electrical devices fails is called earthing. Electrical earthing can be defined as the process of transferring the discharge of electrical energy directly to the earth with the help of low-resistance wire.

We get electrical energy from different sources. Battery is one such source. We use it in wall clocks, cell phones etc. For the working of refrigerators, air conditioners, washing machines, televisions, laptops and water heaters we use domestic power supply. Usually an electric appliance such as a heater, an iron box, etc. are fitted with three wires namely live, neutral and earth. The earth wire is connected to the metallic body of the appliance. This is done to avoid accidental shock.

Suppose due to some defect, the insulation of the live wire inside an electric iron is burnt then the live wire may touch the metallic body of the iron. If the earth wire is properly connected to the metallic body, current will pass into the earth through earth wire and it will protect us from electric shock. The earth, being a good conductor of electricity, acts as a convenient path for the flow of electric current that leaks out from the insulation.

Lightning Arresters:

Lightning arrestor is a device used to protect buildings from the effects of lightning. Lightning conductor consists of a metallic lightning rod (in the form of spikes) that remains in air at the top of the building. Major portion of the metal rod and copper cable are installed in the walls during its construction. The other end of the rod is placed deep into the soil. When lightning falls, it is attracted by the metallic rods at the top of the building. The rod provides easy route for the transfer of electric charge to the ground. In the absence of lightning arrestors, lightning will fall on the building and the building will be damaged.



Ohm's Law:

A German physicist, Georg Simon Ohm established the relation between the potential difference and current, which is known as Ohm's Law. This relationship can be understood from the following activity.

According to Ohm's law, at a constant temperature, the steady current 'I' flowing through a conductor is directly proportional to the potential difference 'V' between the two ends of the conductor.

I V. Hence, I / V = constant.

The value of this proportionality constant is found to be 1 / R

Therefore, I = (1 / R) V

V = IR

Here, R is a constant for a given material (say Nichrome) at a given temperature and is known as the resistance of the material. Since, the potential difference V is proportional to the current I, the graph between V and I is a straight line for a conductor.

Resistors in series:

Thus, if resistors are connected end to end, so that the same current passes through each of them, then they are said to be connected in series.

$$R_S = R_1 + R_2 + R_3$$

Resistances in Parallel:

Thus, when a number of resistors are connected in parallel, the sum of the reciprocals of the individual resistances is equal to the reciprocal of the effective or equivalent resistance. When 'n' resistors of equal resistances R are connected in parallel, the equivalent resistance is R / n.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Joule's Law of Heating:

Let 'I' be the current flowing through a resistor of resistance 'R', and 'V' be the potential difference across the resistor. The charge flowing through the circuit for a time interval's' is 'Q'.

The work done in moving the charge Q across the ends of the resistor with a potential difference of V is VQ. This energy spent by the source gets dissipated in the resistor as heat. Thus, the heat produced in the resistor is:

$$\mathbf{H = W = VQ}$$

You know that the relation between the charge and current is Q = I t. Using this, you get

$$\mathbf{H = V\,I\,t}$$

From Ohm's Law, V = I R. Hence, you have

$$\mathbf{H = I^2\,R\,t}$$

This is known as Joule's law of heating.

Joule's law of heating states that the heat produced in any resistor is:

Directly proportional to the square of the current passing through the resistor.

Directly proportional to the resistance of the resistor.

Directly proportional to the time for which the current is passing through the resistor.

Applications of Heating Effect:

Electric Heating Device:

The heating effect of electric current is used in many home appliances such as electric iron, electric toaster, electric oven, electric heater, geyser, etc. In these appliances Nichrome, which is an alloy of Nickel and Chromium is used as the heating element. Why? Because:

It has high resistivity, (ii) It has a high melting point, (iii) It is not easily oxidized.

Fuse Wire:

The fuse wire is connected in series, in an electric circuit. When a large current passes through the circuit, the fuse wire melts due to Joule's heating effect and hence the circuit gets disconnected. Therefore, the circuit and the electric appliances are saved from any damage. The fuse wire is made up of a material whose melting point is relatively low.

Filament in bulbs:

In electric bulbs, a small wire is used, known as filament. The filament is made up of a material whose melting point is very high. When current passes through this wire, heat is produced in the filament. When the filament is heated, it glows and gives out light. Tungsten is the commonly used material to make the filament in bulbs.

Domestic Electric Circuits:

The electricity produced in power stations is distributed to all the domestic and industrial consumers through overhead and underground cables. The diagram, which shows the general scheme of a domestic electric circuit.

In our homes, electricity is distributed through the domestic electric circuits wired by the electricians. The first stage of the domestic circuit is to bring the power supply to the main-box from a distribution panel, such as a transformer. The important components of the main-box are: (i) a fuse box and (ii) a meter. The meter is used to record the consumption of electrical energy. The fuse box contains either a fuse wire or a miniature circuit breaker (MCB). The function of the fuse wire or a MCB is to protect the house hold electrical appliances from overloading due to excess current.

An MCB is a switching device, which can be activated automatically as well as manually. It has a spring attached to the switch, which is attracted by an electromagnet when an excess current passes through the circuit. Hence, the circuit is broken and the protection of the appliance is ensured.

The electricity is brought to houses by two insulated wires. Out of these two wires, one wire has a red insulation and is called the 'live wire'. The other wire has a black insulation and is called the 'neutral wire'. The electricity supplied to your house is actually an alternating current having an electric potential of 220 V. Both, the live wire and the neutral wire enter into a box where the main fuse is connected with the live wire. After the electricity meter, these wires enter into the main switch, which is used to discontinue the electricity supply whenever required. After the main switch, these wires are connected to live wires of two separate circuits. Out of these two circuits, one circuit is of a 5 A rating, which is used to run the electric appliances with a lower power rating, such as tube lights, bulbs and fans. The other circuit is of a 15 A rating, which is used to run electric appliances with a high power rating, such as air-conditioners, refrigerators, electric iron and heaters. It should be noted that all the circuits in a house are connected in parallel, so that the disconnection of one circuit does not affect the other circuit. One more advantage of the parallel connection of circuits is that each electric appliance gets an equal voltage.

Overloading and Short Circuiting:

The fuse wire or MCB will disconnect the circuit in the event of an overloading and short circuiting. Over loading happens when a large number of appliances are connected in series to the same source of electric power. This leads to a flow of excess current in the electric circuit. When the amount of current passing through a wire exceeds the maximum permissible limit, the wires get heated to such an extent that a fire may be caused. This is known as overloading. When a live wire comes in contact with a neutral wire, it causes a 'short circuit'. This happens when the insulation of the wires get damaged due to temperature changes or some external force. Due to a short circuit, the effective resistance in the circuit becomes very small, which leads to the flow of a large current through the wires. This results in heating of wires to such an extent that a fire may be caused in the building.

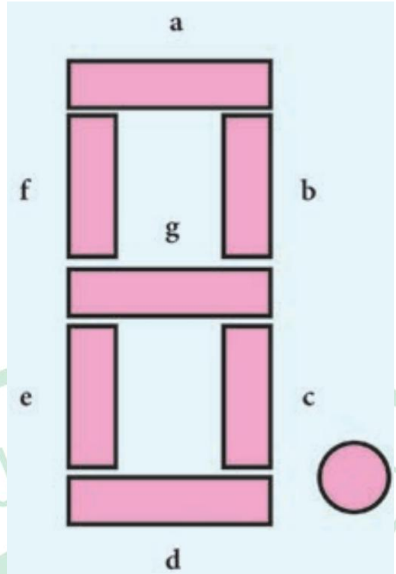
In domestic circuits, a third wire called the earth wire having a green insulation is usually connected to the body of the metallic electric appliance. The other end of the earth wire is connected to a metal tube or a metal electrode, which is buried into the Earth. This wire provides a low resistance path to the electric current. The earth wire sends the current from the body of the appliance to the Earth, whenever a live wire accidentally touches the body of the metallic electric appliance. Thus, the earth wire serves as a protective conductor, which saves us from electric shocks.

Led Bulb and Led Television:

An LED bulb is a semiconductor device that emits visible light when an electric current passes through it. The colour of the emitted light will depend on the type of materials used. With the help of the chemical compounds like Gallium Arsenide and Gallium Phosphide, the manufacturer can produce LED bulbs that radiates red, green, yellow and orange colours. Displays in digital watches and calculators, traffic signals, street lights, decorative lights, etc., are some examples for the use of LEDs.

Seven Segment Display:

A 'Seven Segment Display' is the display device used to give an output in the form of numbers or text. It is used in digital meters, digital clocks, micro wave ovens, etc. It consists of 7 segments of LEDs in the form of the digit 8. These seven LEDs are named as a, b, c, d, e, f and g. An extra 8th LED is used to display a dot.



Merits of a LED bulb:

As there is no filament, there is no loss of energy in the form of heat. It is cooler than the incandescent bulb.

In comparison with the fluorescent light, the LED bulbs have significantly low power requirement.

It is not harmful to the environment.

A wide range of colours is possible here.

It is cost-efficient and energy efficient.

Mercury and other toxic materials are not required.

One way of overcoming the energy crisis is to use more LED bulbs.

LED Television:

LED Television is one of the most important applications of Light Emitting Diodes. An LED TV is actually an LCD TV (Liquid Crystal Display) with LED display.

An LED display uses LEDs for backlight and an array of LEDs act as pixels. LEDs emitting white light are used in monochrome (black and white) TV; Red, Green and Blue (RGB) LEDs are used in colour television. The first LED television screen was developed by James P. Mitchell in 1977. It was a monochromatic display. But, after about three decades, in 2009, SONY introduced the first commercial LED Television.

Advantages of LED television:

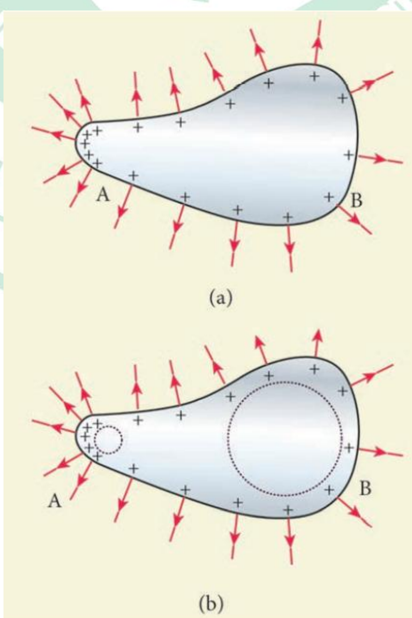
1. It has brighter picture quality.
2. It is thinner in size.
3. It uses less power and consumes very less energy.
4. Its life span is more.
5. It is more reliable.

Action of Points or Corona Discharge:

Consider a charged conductor of irregular shape.

We know that smaller the radius of curvature, the larger is the charge density. The end of the conductor which has larger curvature (smaller radius) has a large charge accumulation.

As a result, the electric field near this edge is very high and it ionizes the surrounding air. The positive ions are repelled at the sharp edge and negative ions are attracted towards the sharper edge. This reduces the total charge of the conductor near the sharp edge. This is called action of points or corona discharge.

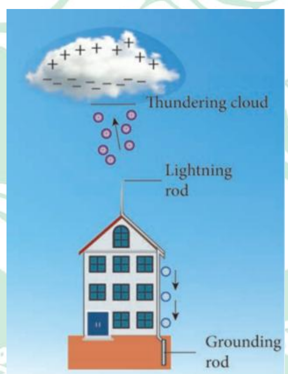


Lightning arrester or lightning conductor:

This is a device used to protect tall buildings from lightning strikes. It works on the principle of action at points or corona discharge.

This device consists of a long thick copper rod passing from top of the building to the ground. The upper end of the rod has a sharp spike or a sharp needle.

The lower end of the rod is connected to copper plate which is buried deep into the ground. When a negatively charged cloud is passing above the building, it induces a positive charge on the spike. Since the induced charge density on thin sharp spike is large, it results in a corona discharge. This positive charge ionizes the surrounding air which in turn neutralizes the negative charge in the cloud. The negative charge pushed to the spikes passes through the copper rod and is safely diverted to the Earth. The lightning arrester does not stop the lightning; rather it diverts the lightning to the ground safely.



Problems:

1. **Three resistors of resistances 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through the circuit.**

   Solution:

   $R1 = 5\ \Omega$, $R2 = 3\ \Omega$, $R3 = 2\ \Omega$, $V = 10\ V$

   $Rs = R1 + R2 + R3$, $Rs = 5 + 3 + 2 = 10$, hence

   $Rs = 10\ \Omega$

   The current,

$$I = \frac{V}{R_S} = \frac{10}{10} = 1\ A$$

2. **An electric heater of resistance 5 Ω is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minutes.**

   Solution:

   Given resistance R = 5 Ω, Current I = 6 A, Time t = 5 minutes = 5 × 60 s = 300 s

   Amount of heat produced, $H = I^2 Rt$, $H = 6^2 \times 5 \times 300$. Hence, H = 54000 J

3. **In the circuit diagram given below, three resistors R1, R2 and R3 of 5 Ω, 10 Ω and 20 Ω respectively are connected as shown. Calculate:**

   A) Current through each resistor

   B) Total current in the circuit

   C) Total resistance in the circuit

   Solution:

   Since the resistors are connected in parallel, the potential difference across each resistor is same (i.e. V=10V) Therefore, the current through R_1 is,

   $$I_1 = V / R_1 = 10 / 5 = 2A$$

   Current through $R_2 = I_2 = V / R_2 = 10 / 10 = 1A$

   Current through $R_3 = I_3 = V / R_3 = 10 / 20 = 0.5A$

   Total current in the circuit, $I = I_1 + I_2 + I_3 = 2 + 1 + 0.5 = 3.5\ A$

   Total resistance in the circuit $1/R_P = 1/R_1 + 1/R_2 + 1/R_3$

   $= 1/5 + 1/10 + 1/20$

   $= 4 + 2 + 1 / 20$

   $1 / R_P = 7 / 20$

   Hence, $R_P = 20 / 7 = 2.857\ \Omega$

4. **Three resistors of 1 Ω, 2 Ω and 4 Ω are connected in parallel in a circuit. If a 1 Ω resistor draws a current of 1 A, find the current through the other two resistors.**

Solution:

$R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 4\ \Omega$ Current $I_1 = 1$ A

The potential difference across the 1 Ω resistor = $\mathbf{I_1 R_1 = 1 \times 1 = 1\ V}$

Since, the resistors are connected in parallel in the circuit, the same potential difference will exist across the other resistors also.

So, the current in the 2 Ω resistor, $\mathbf{V / R_2 = 1 / 2 = 0.5A}$

Similarly, the current in the 4 Ω resistor, $\mathbf{V / R_3 = 1 / 4 = 0.25A}$