03. The effect and uses of current electricity

At the end of this lesson, you will be competent to,

- design a household circuit for a given condition, and use it safely and productively without wasting electricity.
- use heating effect of current appropriately by controlling the factors which depend on the heating effect.
- electroplate necessary appliances by the process of electrolysis.
- construct a simple form apparatus which uses magnetic effect of current.
- construct various devices using principles and laws of electro-magnetic induction and investigate their action.

3.1 Domestic Electric Circuits

When considering the domestic electric circuit, it is important to have a basic knowledge of the components and the safety precautions in using electricity. In Sri Lanka, the basic electric power supplied to consumer from the national grid system is 230V. It is an **alternating current** (AC) supply of frequency 50Hz. The supply is given by a service cable which consist of two wires called **live wire** (L) and **neutral wire** (N).

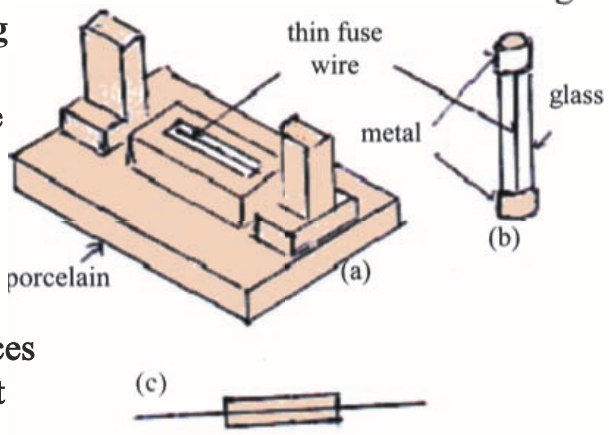


Fig 3.1 Circuit symbol of a fuse

Components of house wiring circuit

Fuse

Fuses are used to protect the appliances from the damages due to high current flowing in the circuit. It is a short length of thin wire made up of a lead and tin alloy. This wire is kept in a ceramic slab or in a glass tube as shown in Fig. 3.1 (a) and (b) for easy use. There are fuse wires which can conduct certain maximum currents such as 3A, 5A, 13A and 15A. The circuit symbol of a fuse is shown in Figure 3.1(c)

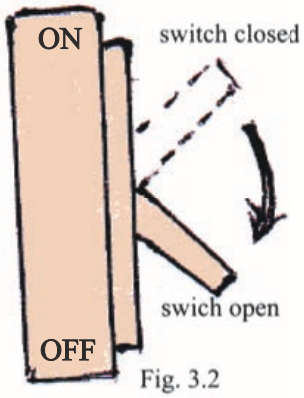
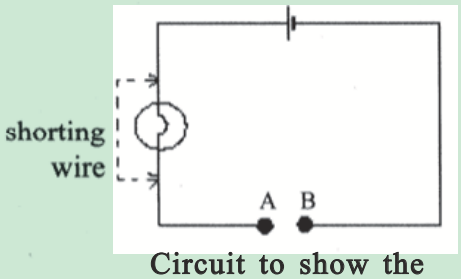


Fig. 3.2

If the current through the circuit exceeds the rated value of the fuse the thin wire melts or fuses and so stops the current flowing in the circuit, there- by protecting the appliance. Instead of fuses, miniature circuit breakers as shown in Fig. 3.2 are now in use in circuits. This component looks like a switch. They are of various ampere values. If the current exceed the rated value, the switch opens and stops the current. The circuit can be connected again by closing the switch.

Activity 3.1



Circuit to show the action of a fuse.

Connect the circuit shown in the Figure 3.3 with crocodile clips at A and B. Complete the circuit with a short length (about 3 cm) of gauge 36 tin wire placed between A and B. Check whether the lamp is on. Short the circuit across the lamp as shown in Figure 3.3 (as shown in dotted line). Observe what happens to the thin wire.

You will observe that the thin wire will melt in short circuiting the circuit, and the current is stopped due to the break in the circuit.

Electric meter

Electric meter is used to measure the units of electrical energy used in household circuits. KiloWatt-hour (kWh) is a unit of energy. If an electrical appliance of 1000 W is used for one hour, the energy consumed is one kiloWatt-hour. When we use electricity the circular disc fixed inside the meter will rotate which records the units of electrical energy used.

Fig:. 3.4 - Electric meter

$$1\ \text{kWh} = \frac{\text{amount of watt} \times \text{number of hours used}}{1000}$$

Main switch

Both live and neutral wires of the supply are connected to this switch. There is a fuse attached to the live wire. When the switch is opened the supply is stopped by disconnecting the two wires. This switch is used to disconnect the supply completely when necessary. (fig 3.5)

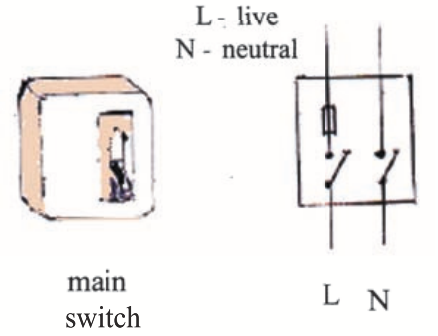


Fig. 3.5 Main switch

Trip Switch

Both live and neutral wires of the supply are connected to the trip switch. If there is a fault in any of the circuits in the house this switch opens automatically and disconnects the power supply. Therefore it protects the appliances from damage. (fig 3.6)

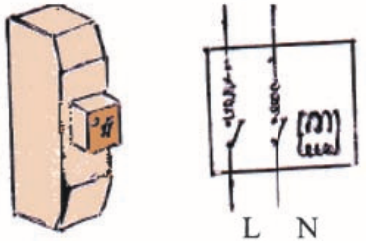


Fig. 3.6 Trip switch

Distribution box

Distribution box distributes the supply to branches of the house which consist of lamp circuits and plug base circuits. In each circuit the live wire is connected to a fuse or a miniature circuit breaker. Recently, distribution boxes are replaced by a miniature circuit breaker box. In some miniature circuit breaker boxes, the trip switch is also included. (fig 3.6)

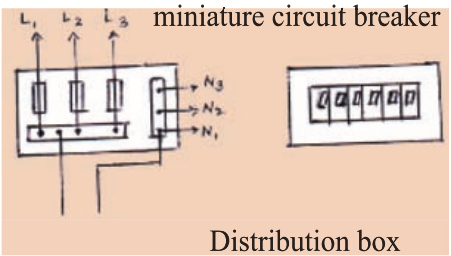
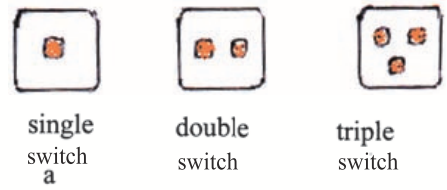


Fig. 3.7

Switches

Switches are used in lamp circuits and plug base circuits to connect or disconnect the circuit according to the needs.There are single,double and triple switches as shown in Figure 3.8 (a).Some switches can be used to operate a number of lamps from one place.



Plug bases

Plug bases as shown in Figure 3.8 (b) are used to get electric supply for appliances like electrical heaters,televisions or refrigerators.There are plug bases to get 5A,13A or 15A current.Two pin plugs and three-pin plugs, as shown in Figure 3.8(c) are used to get supply from the plug bases.To get these connections we use two core wires and three core wires as shown in Fig 3.9

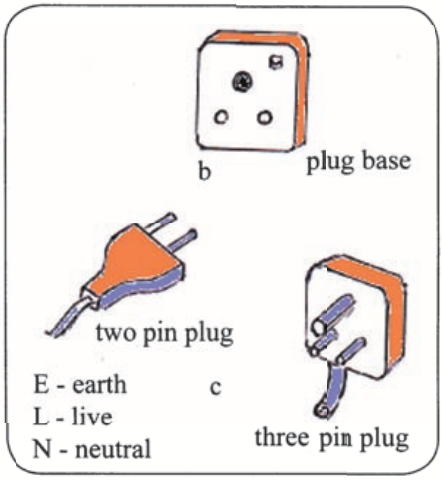


Fig. 3.8

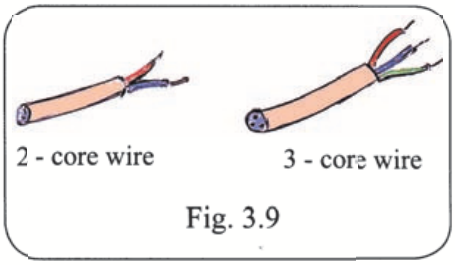


Fig. 3.9

Wires covered with Red/Brown colours are used for live connections,Wires covered with Blue/ Black colours are used for neutral connections and wires covered with Green/Green-yellow colours are used for earth connections.These are used as standards.To connect household circuits, we have to use various types of wires according to the needs.Information about some of these wire cords are given in Table 3.1

Wire code	Area of cross section of the wires(mm^2)	Rated maximum current* (A)	Colour	Instances of using
1/1.13	1.0	11	Red/black	for lamp circuits for 5A plug base circuits
7/0.50	1.5	15	Red/black	for 15 A plug base circuits
7/0.85	4	24	Red/black	for power supply from power post to distribution box
7/1.04	6	31	Red/black	
7/0.67	-	-	Green	

Table 3.1

Domestic electric circuit

Design of a household circuit using components mentioned above is shown in Figure 3.10 From the service supply these components are connected here in a certain order.Service wire is first connected to the household circuit through an electric meter.The live wire is connected to a fuse before connecting to the meter and this fuse is called service fuse. After the electric meter, these wires are connected to a main switch and then through the trip switch to a distribution box.Circuits to various branches of the house starts from the distribution box.All appliances are connected in parallel to the circuit as indicated in Fig 3.10

Connection of basic component of household circuit

lamp and plug base circuit

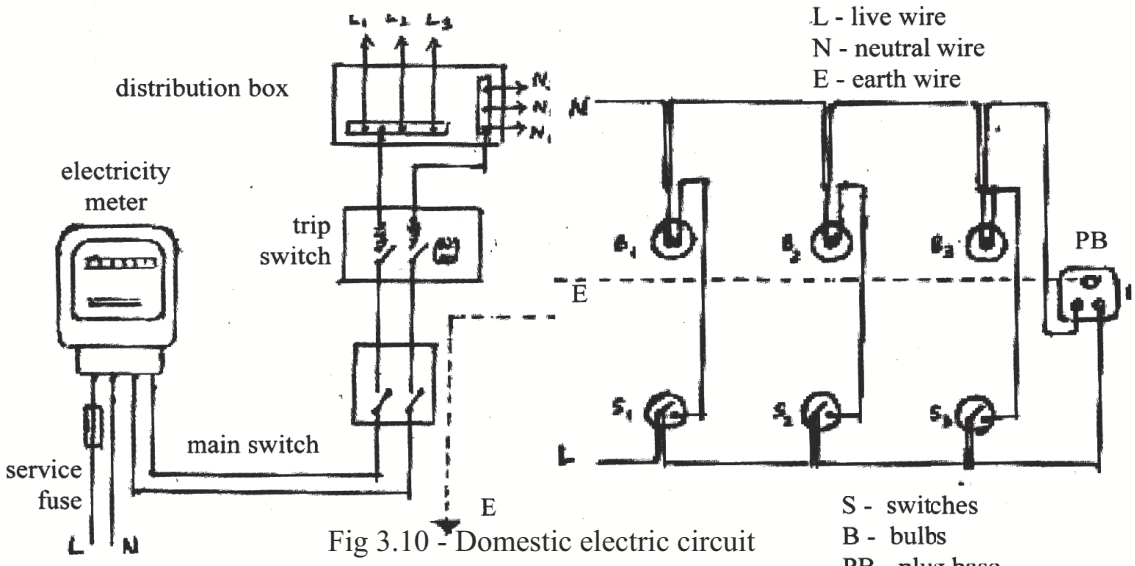


Fig 3.10 - Domestic electric circuit

Fig. 3.10 - Domestic electric circuit

Assignment 1

Design a household circuit containing two lamps and one plug base.

Two way switches

These swiches can be used to operate a lamp from two places.Using the two - way switches as shown in Figure 3.11, wire C can be connected to either A or B, so that the lamp can be operated from the required place.For example, from the top and bottom of the stairs.

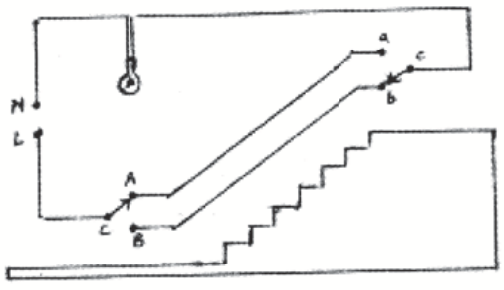


Fig 3.11- Two way Switch

Assignment 2- Save electricity for the next generation

Take the reading of the electricity meter in your home (or one of your group member's home).Note down the date and time.After two weeks, take the reading again.Calculate the number of units used.Repeat it for next two weeks.During this period switch off unnecessary lamps and fans.If you can replace filament bulbs with CFL bulbs it is better.Calculate the number of units used for the two weeks.Find the difference of the units used in the first two weeks and second two weeks.Calculate the energy that you can save.(in kiloWatt-hours)

Safety precautions in using electricity

- Use fuse wires of appropriate ampere value, not exceeding the maximum current in the curcuit.
- Do not connect number of electrical appliances consuming high amounts of electricity to the same plug base using a multiplug.
- Do not enter wires directly in to the plug base.
- Use the earth connection when connecting apparatus with metal cover to the supply.
- Test once in few days time whether the trip switch is properly working, by presing the test button.
- If the trip switch opens automatically, first open the main switch and then close the trip switch.After that, close the main switch.If the trip opens again get the help of an electrician.
- For a temporary connection use an extension board.Give the connection after connecting the appliances.
- When there is a power failure, do not connect appliances to the circuit or close the switches.
- In an emergency electric fire, use the main switch to disconnect the power supply.
- When electrical appliances are not in use, disconnect threir plugs from the plug base.
- When using appliances like electric iron it is safer to stand on a rubber carpet or wear rubber slippers.
- For necessary maintenance, get the service of a trained electrician.

3.2 Heating effect of current

Generation of heat due to electric current is called the heating effect of current

Activity 3.2

Take 2 cm length of thin nichrome wire coil and connect it to a torch cell and a key as shown in Fig 3.12. Press the key for about 30 seconds and touch the coil.What do you feel?Is it warm or cool?

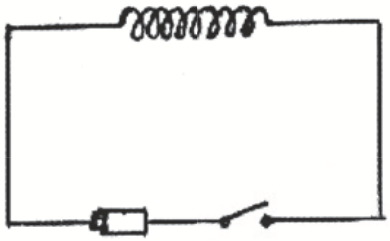


Fig. 3.12
Circuit to identify heating effect of current

You will feel here that the wire will get hot.It is clear that the hotness of the wire is due to the flow of electric current through the wire.This is called the heating effect of current.

Do you know?

When electrons pass through a wire, they can give some of their energy to the atoms in the wire and make them vibrate more, so that the wire gets hot.

How can we increase the heating effect of current? Let us consider what factors we have to change for it.

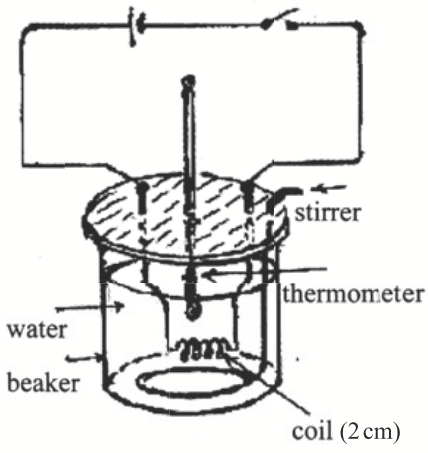


Fig. 3.13
Circuit to study heating effect of current

Activity 3.3

Take a small beaker half filled with water and cover it with a card board lid. Insert a 2 cm length of Nichrome wire coil into water and connect the end of the coil to a circuit as shown in the Figure 3.13.

Insert a thermometer into water. Close the key and stir the water, After 5 minutes time measure the temperature of water. Repeat the activity using two torch cells.

When using two cells in the above activity, the current increases.It is clear that as current increases, heating effect also increases. Variation of heating effect by changing resistance can be found by the following activity.

Activity 3.4

Remove the coil of the apparatus used for Activity 3.3 and replace it with 4 cm length of the same wire coil. Close the key and stir the water.After 5 minutes time measure the temperature of water.Compare this temperature with the temperature measured in stage one of the Activity 3.3

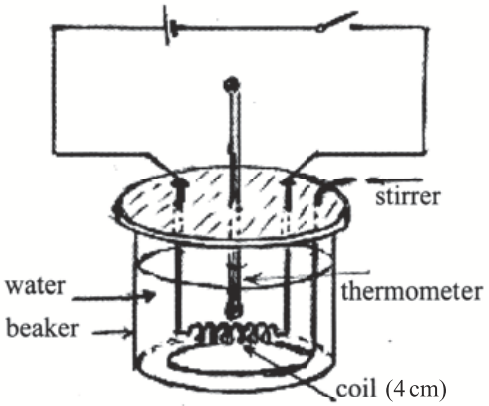


Fig. 3.14
Another circuit to study heating effect of current

Here we see that the temperature of water is greater than that in the first instance. Since the resistance of the coil increases as its length increases,it is clear that the heating effect also increases as the resistance increases.

Activity 3.5

Repeat the activity by using the same coil and same voltage supply and vary the time of passing current

You can observe here that the temperature of water increases as the time of passing current increases.Therefore it is clear that the heating effect increases as the time of passing current increases.

Do you know?

Supplied Voltage	=	V (volts)
Current through the coil	=	I (Ampere)
Resistance of the coil	=	R (Ohms)
Time of passing current	=	t (Seconds)
Electrical energy transmitted	=	$VIt = I^2Rt = \frac{V^2}{R}t$ (Joules)
E	=	VIt Joules

The variation of resistance of a conductor as its length increases can be found by the following activity.

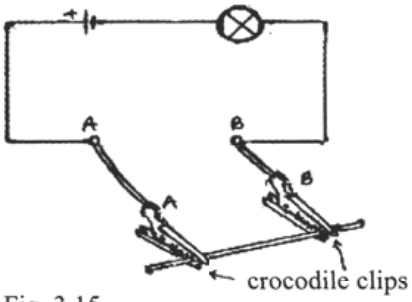


Fig. 3.15
Circuit to study the factors which effect the electrical resistance

Activity 3.6

Connect the circuit as shown with crocodile clips at A and B.To complete the circuit you need about 30 cm of gauge30 nichrome wire. Keep the clips closer on the wire and observe the brightness of the lamp.Now move the clips further apart and compare the brightness of the lamp with the above instance.

We see here that the brightness of the lamp increases when the clips are closer and the brightness decreases as the clips move apart.The brightness of the lamp decreases because the resistance of the wire increases as the length increases and the brightness of the lamp increases because the resistance of the wire decreases when the length decreases. Let us find the variation of resistance of the conductor as its area of cross section increases.

Activity 3.7

Using the same circuit (Figure 3.15) keep the clips on the wire 20 cm apart and note the brightness of the lamp. Now add another (identical)piece of nichrome wire between the clips so that the area of cross section is doubled.Compare the brightness of the lamp with the above instance.

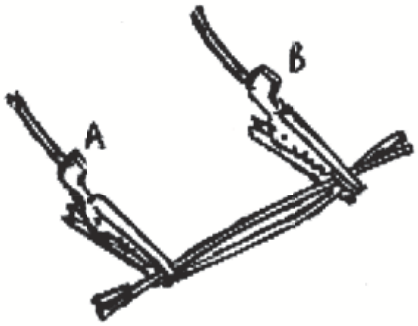


Fig. 3.16
Increasing the area of cross section of the wire

We see here that the brightness of the lamp increases when we use two wires instead of one wire. When using two wires, cross section area of the wire increases and the brightness of the lamp increases due to decrease of resistance.

Lets us find how the resistance of the conductor depends on its material.

Activity 3.8

Keep the clips 20 cm apart on the wire used in Activity 3.7 and note the brightness of the lamp.Now replace the nichrome wire by a copper wire of the same length and same cross sectional area (gauge 30) and observe the brightness of the lamp.

You will see that the brightness of the lamp is different from that in the first instant. Therefore it will be clear that the brightness of the lamp changes,because the resistance of the conductor changes according to the material of the conductor,even if the length and area of cross section are the same. Some home appliances which use the heating effect of the current is shown in the Figure 3.17 below.Make a list of electrical heaters in your home and check whether some of the appliances given below are in your list.

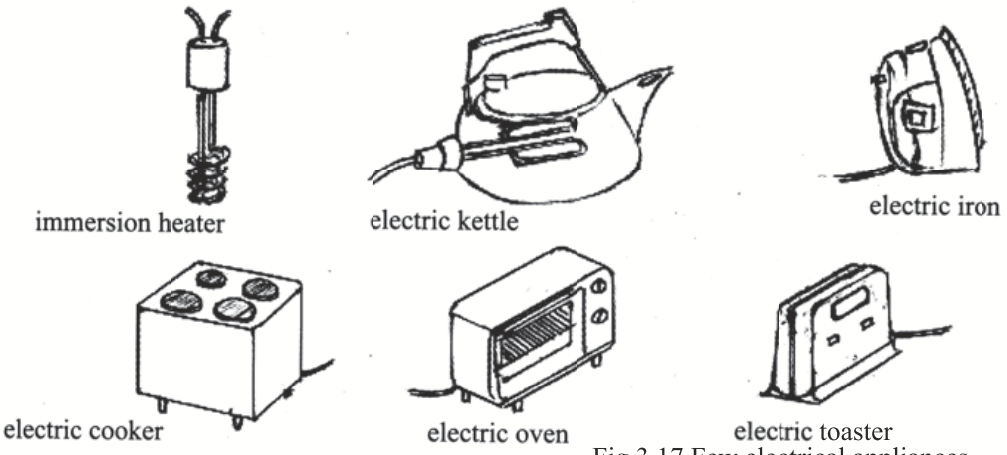


Fig 3.17 Few electrical appliances

3.3.Chemical effect of a current

Do all liquids conduct electricity? Let's find out from the following activity.

Activity 3.9

Connect the circuit as shown in Figure 3.18 to two electrodes in a beaker.Pour a liquid into the beaker. Complete the circuit by the switch and observe the glowing of the lamp.Try this with disitilled water, NaC1 solution,vineg ar,paraffin and dilute HCl (Remember to wash the apparatus each time when you change the liquid.)

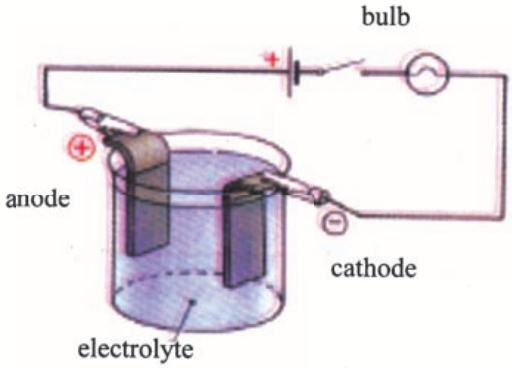


Fig 3.18 - An apparatus used to identify electrolytes

You will see that the bulb will glow when NaCl solution,vinegar and dilute HCl are used and that the bulb will not glow when using distilled water and paraffin. It is clear that the bulb will glow when liquids conduct electricity, and the bulb will not glow when they do not conduct electricity.

Substances when dissolved in water to give solutions which conduct electrictiy are called **electrolytes**.Conductors dipped in electrolytes are called **electrodes**.

The electrode at which current enters the elecrolyte is called the **anode**,and the electrode at which current leaves the electrolyte is called the **cathode**.

When electricity is passed through a liquid,chemical reactions, take place at the cathode and anode.There by chemical changes take place in the liquid.This is called **electrolysis**.The apparatus used for electrolysis is called **voltameter** (not a voltmeter).The voltameter is named according to the electrolyte and electrodes used.e.g. If the electrodes are copper and the electrolyte is a solution of copper salt the voltameter is named as a **copper voltameter.**

Let's find what will happen in the electrolysis of water.

Activity 3.10

Pass electricity through water using a water voltameter with two platinum electrodes connected to a battery as shown.Since water is a poor conductor of electricity,some sulphuric acid must be added to make it an electrolyte. Record your observations

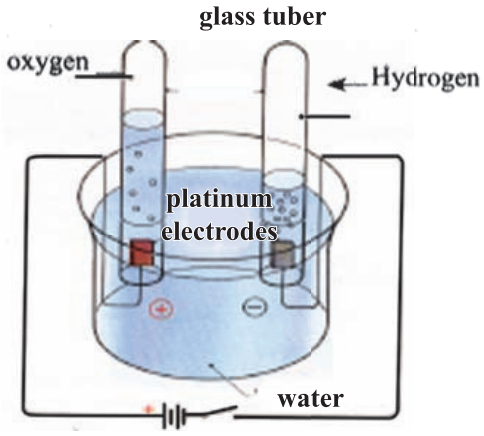


Fig 3.19 - An apparatus used for electrolysis of water

When the current is flowing, air bubbles appear at both (+) anode and (-) cathode. If you can collect and test these gases you will find that they are oxygen at the anode and hydrogen at the cathode. You will note here that the water has decomposed into oxygen and hydrogen, by the chemical effect produced by the electric current. The volume of gases produced are in the ratio 1:2

Let's find what will happen in the electrolysis of copper sulphate.

Activity 3.11

Arrange a copper voltameter as shown in the Figure 3.20 and connect it to the circuit. Before inserting the electrodes into the electrolyte, label them and find the mass of each (upto an accuracy of 0.1 gram). Pass a current of about 0.5 Amperes for about 30 minutes. Remove the electrodes,dry them carefully and find the new mass of each electrode.

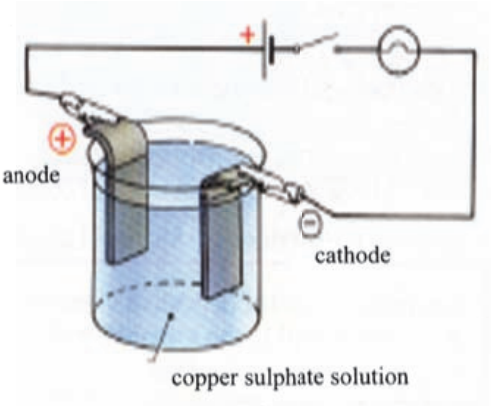


Fig 3.20 - An apparatus use for electrolysis of copper sulphate

You will note that cathode has gained in mass and anode has lost in mass, by an amount equal to the mass gained by the cathode.It is clear that a chemical reaction takes place at the electrodes due to the current flowing through the voltameter. (-)Cathode has gained in mass and is covered with a shiny copper coat.Therefore we say that the cathode is electroplated with copper.

Do you know?

The mass of metal deposited on the cathode in the process of electrolysis is proportional to the amount of current passed through the voltameter and the time of passing the current. This was first found by the scientist Michael Faraday.

Let's find how conduction of electricity takes place through an elecrtolyte. Chemical formula of copper sulphate is $CuSO_4$. When copper sulphate is dissolved in water it splits into two charged particles Cu^{2+} and SO_4^{2-} These are called ions.The ions so formed are the charge carriers for the passage of electricity through the electrolyte.

A Copper atom (Cu) loses two electrons to become a positive Cu^{2+} ion.As unlike charges attract, this Cu^{2+} ion drifts towards the negative cathode and gains two electrons to become an atom of copper. This gets deposited on the cathode. The SO_4^{2-} ion drifts towards the positive anode and completes the circuit.

Electro plating
Activity 3.12

Replace the copper cathode of Activity 3.11 by a clean metal object (e.g a key or badge)and pass a current of 0.5 amperes for a time of 30 minutes.Remove the object and observe it.

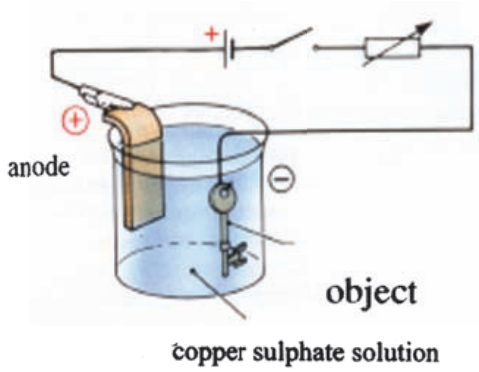


Fig 3.21 - An apparatus use for electroplating

You will see here that the metal object is plated with copper.Plating of one metal with another metal by electrolysis is called **electroplating.** In a similar way to copper plating in the Activity 3.12,spoons can be silver plated if they are used as cathode of a voltameter containing an electrolyte of silver.Chromium plating for cars and bicycles is achieved by a similar method but using electrolytc of a chromium salt.

Uses of electrolysis

- **Electroplating**

Most of the appliances used in the kitchen are Nickel plated.Vehicle parts are chromium plated to protect them from rusting.