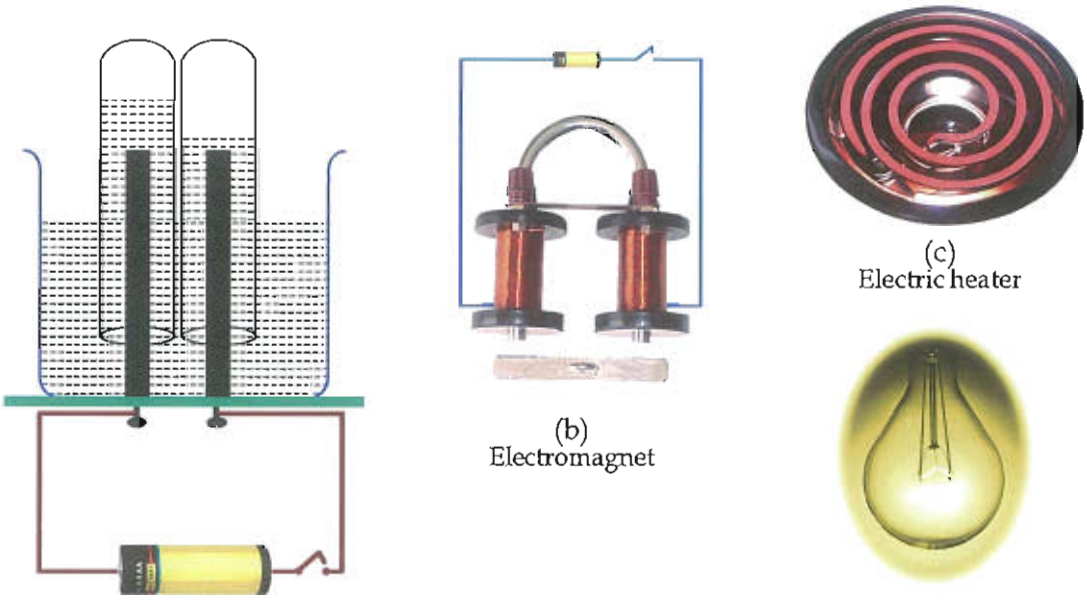
5 EFFECTS OF ELECTRIC CURRENT

Susi and Radhika are having a discussion on the plating of gold on ornaments. Susi is of the opinion that molten gold is coated over the ornament using a very thin brush. But Radhika wonders how it is possible that such a precious metal like gold is coated using a brush. Susi suggests that they consult Molly teacher. Thus they approach Molly teacher.



(a) Electrolysis of water

(b) Electromagnet

(c) Electric heater

(d) A glowing bulb

Fig. 5.1

Haven't you studied about the electrolysis of water? Which form of energy is used for splitting water into its components, hydrogen and oxygen?

★ Let's try an experiment to see whether other compounds can also be split into their components as water is split using electrical energy.

The chemical effect of electric current

Fill three fourth of two beakers with dilute copper sulphate solution. Keep one solution for a comparative study. Dip two carbon electrodes in the other. Connect the two electrodes to the terminals of a battery. Prepare a note on the observations

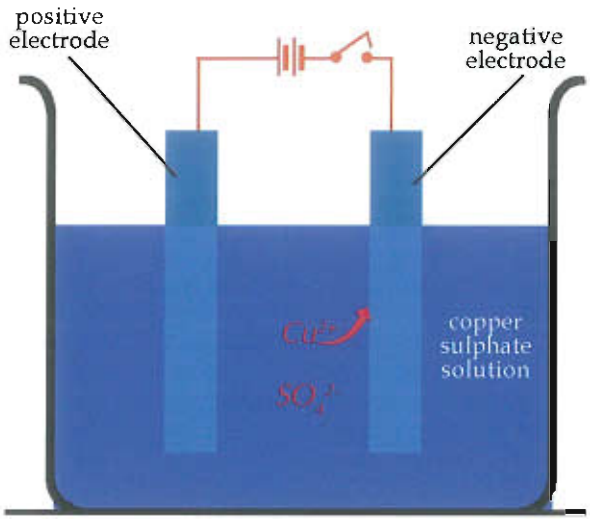


Fig. 5.2

and record your conclusions. The following questions will help you in preparing the note.

- In which form do the components exist in the copper sulphate solution?
- Which among these ions is positive and which is negative?
- In which electrode did you notice a colour change?
- What could be the reason for this colour change?
- How did the copper ions change into copper atoms?
- What might have happened to the copper sulphate solution?
- What was the need of electrical energy here?

Let's repeat the experiment with a slight change. Replace the carbon rod used as positive electrode by a thin copper plate. After passing electric current for 10 minutes take out the copper plate used as positive electrode and examine it. Record your observations and conclusion.

- What happened to the copper plate?

- In which direction did the negative ions in the solution move?

Let's examine what happens when ions reach the positive electrode.

Sulphate ions (SO_4^{2-}) reach the positive electrode. The copper atoms in the positive copper electrode release two electrons and enter the solution as copper ions (Cu^{2+}). The number of copper ions entering the solution from the positive electrode per second is equal to the number of copper ions which receive two electrons from the negative electrode. Then they get deposited as copper atoms on the negative electrode. Therefore the number of copper ions in the solution does not change.

Hope it is now clear to you what happens to the concentration of the solution on using copper as the positive electrode.

Ionic conduction

In ordinary conductors the electric current is caused by the motion of free electrons. But in electrolytes it is due to the motion of free ions.

In an electrolyte positive ions move towards the negative electrode, receive electrons from there, get neutralised and become neutral atoms. Similarly, negative ions move towards the positive electrode and get neutralised by giving out electrons. The electrons released by the negative ions help to complete the flow of current in the external circuit. The circuit is thus completed. The conduction of electricity through the electrolyte is ionic conduction.

Electroplating

Electroplating is the process of coating a metal on the surface of a conductor by electrolysis. A solution containing the metallic salt is used for this. This solution is the electrolyte. The electrolyte to be taken must contain the salt of the metal to be coated. The electrolyte will contain the ions of the metal. Metal ions are positive. Therefore the metal ions have a tendency to move towards the negative electrode. The driving force for this can be provided using a battery.

Suppose an iron nail is to be electroplated with chromium.

★ What will be the positive electrode?

★ And the negative electrode?

★ What will be the appropriate electrolyte? (See Table 5.1)

Draw the circuit diagram for this.

Complete Table 5.1 on the basis of your findings on electroplating.

It is seen that the mass of the metal deposited on the negative electrode increases with time and current.

- Haven't you understood that, the mass of the metal deposited on the negative electrode increases with increase in the quantity of charge?
- The relation between the mass of the metal deposited and the charge flowing in the circuit was discovered and stated as a law by Michael Faraday.

The mass of the substance liberated from an electrode or deposited on the electrode is directly proportional to the charge that is passed through the electrolyte.

If the charge that flows is Q coulomb and the mass of the substance liberated/ deposited is m kilogram, then $m \alpha Q$

$$\text{or } m = \text{constant} \times Q$$

The mass of the substance also varies with the material used.

★ Can you write down some uses of electroplating?

- Improves the appearance.
-

Now can't you clear the doubts of Susi and Radhika regarding the plating of gold on ornaments?

Heating effect of electric current

While Suraj was ironing, his younger sister asked him, "How does the electric iron get heated?"

Object to be electroplated	Positive electrode	Negative electrode	Electrolyte
An iron cup with silver			Silver nitrate solution or the mixed solution of sodium cyanide and silver cyanide.
An aluminium spoon with gold			A mixed solution of sodium cyanide and gold cyanide
The handle of a bicycle with chromium			Chromic acid

Table 5.1

Suraj : *Because the heating coil of the electric iron gets heated when current flows through it.*

Sister : *Then why is it that the metal wire which carries current into the coil does not get heated?*

Let's find out.

Pass current through a short nichrome wire from a 6 V battery. What do you observe? What effect of electricity is this?

In Fig. 5.3 an aluminium wire and a nichrome wire of the same length and thickness are shown connected to a 6 V battery.

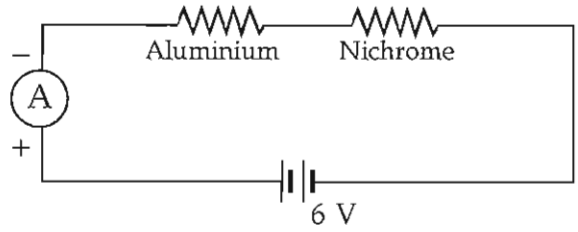


Fig. 5.3

★ In which mode are the conducting wires connected - series or parallel?

- -

★ If the current flowing through the aluminium wire is 0.5 A, what is the current flowing through the nichrome wire?

- -

★ Which of the two wires in the circuit, aluminium or nichrome, has greater resistance?

- -

★ Which one gets heated more?

- -

★ What is the reason for this wire getting heated more ?

- -

★ From this experiment, which factor do you think influenced the heat produced when electricity is passed through it?

- -

Replace the nichrome wire in the circuit by an aluminium wire. Pass current for the same interval of time as in the previous case.

★ What change did you observe in the aluminium wires?

- -

★ How did the resistance in the circuit change when the nichrome wire was replaced?

- -

★ What happened to the current in the circuit?

- -

★ If so, can you mention another factor that influences the heat produced when current is passed?

- -

Take some water in a glass tumbler and dip a thermometer in it. Connect the ends of a nichrome wire to the terminals of a battery eliminator using connecting wires and complete the circuit. Immerse the nichrome wire fully in water. Switch on the eliminator and observe the thermometer reading after about three minutes. Note the thermometer reading again, approximately at the sixth minute.

★ What change occurs in the temperature of the water as the time of passing current is increased?

- -

★ Write another factor that influences the heat produced due to the current.

- -

On the basis of the observations and conclusions made so far, list the factors that influence the heat produced due to the flow of electric current.

- current
-

Joule's Law

An authentic and comprehensive study of the factors influencing the heat produced by electric current was conducted by the scientist James Prescott Joule. The law proposed by him is Joule's law.

The heat produced by an electric current flowing through a conductor is equal to the product of the square of the current passed, the resistance of the conductor and the time for which the current is passed. This is Joule's law.

★ If I is the current passed in ampere (A), R is the resistance in ohm (Ω) and t is the time in second (s) and the heat produced H in joule (J), write down the equation relating them.

H = ...

This is the work (W) done by the current in the circuit.

Therefore, Joule's law can be written as, $W = I^2 Rt$

Using Ohm's law, try other ways of writing this equation.

- H = VIt
-

Calculate the heat produced when a current of 2A is passed through a 200 Ω resistor for 5 minutes.

I = 2 A

R = 200 Ω

t = 5 minutes = 5 × 60 = 300 s

H = I^2Rt

= 2 × 2 × 200× 300 J

= 240000 J

- Calculate the heat developed when a potential difference of 230 V is maintained across a conductor of resistance 92 Ω for 14 minutes. What is the current in the circuit?
- What is the heat produced in 10 minutes in an electric heater connected to a 240 V supply if 4 A current flows through it?
- What is the time taken to produce 320000 J heat in a resistor of 200 Ω if the current passed is 2 A?

We know that there are heating coils in electrical devices like electric heater, electric iron etc. which become red hot on passing current. They are made of nichrome. What are the characteristics of nichrome which make it suitable for use as heater coils in heating devices?

- High melting point.
-

Do all these heating devices produce heat at the same rate? Let's find out.

Electric power

★ Have you noticed the markings 650 W or 750 W on electric irons. What do these indicate?

Power is the rate at which work is done.

Electric power = $\frac{\text{work done by electric current}}{\text{time}}$

$P = W/t$

$P = H/t = I^2 Rt/t = ...$

★ What is the unit of electric power?

On the basis of Ohm's Law, rewrite the equation for calculating electric power $P = I^2 R$ using I and V, and then V and R. Write the answers in the science diary.

- $P = I^2R$
-

The resistance of an electric heater is 250 Ω. If a current of 3 A flows through it, what is the power of the instrument?

$R = 250\ \Omega$

$I = 3\ A$

$P = I^2R = 3 \times 3 \times 250 = 2250\ W$

- If the current through an electric kettle working at 230 V is 2 A, what is the power of the kettle?
- If the resistance of an electrical appliance working at 240 V is 120 Ω, what is its power?

In the case of electrical appliances it is not power alone that is mentioned. The statement of power alone may not give the complete information. The statement that the power of a bulb is 40 W alone is not sufficient. The voltage at which the power is 40 W should also be mentioned. This is why the marking 60 W, 230 V is given on bulbs and other electrical devices. In India the electric supply is at 230 V. The electric supply voltage may be different in different countries.

Discuss the problems given below.

- What is the resistance of a bulb which is marked 40 W, 220 V? If the bulb works in 100 V what will be the current flowing through it? Then what will be its power?
- Calculate the heat produced when a 500 W heater works for 10 minutes.

Find out the power of different electrical devices in your house and note them down in the science diary.

Electrical device	Power
Electric iron	
CFL	
Incandescent lamps	

Do you know any device that ensures safety by making use of the heating effect of current?

Safety fuse

Have you noticed wiring (circuit) getting damaged at times due to excess flow of current while using electrical devices?

Have you come across overloading which is the consumption of current excessively, much more than the circuit can take, by connecting electric appliances using adapters (multiple sockets) or by any other means? What do you mean by overloading? Find out.

You may have noticed sparks produced in distribution lines when they come in contact with each other. What may be the reason?

★ What change occurs to the current in a circuit due to short circuit or overloading? What is its after-effect? Discuss and record.

Safety fuse is a device used to protect the circuit in such situations. Examine a safety fuse and list its parts.

Fig. 5.4

- A porcelain block which is fixed permanently in the circuit.
-
-

Let's examine the peculiarities of a fuse wire.

- It is an alloy of tin and lead.
- If excessive current flows through the wire it will melt and break. If so its melting point should be less than that of ordinary metals.

Is there any limit for the current carrying capacity of a fuse wire? Examine different fuse wire cartridges and note the values marked in each of them.

★ By now you might have understood that if there is a short circuit or overloading in a circuit, current will increase. Relate the high current in the circuit and the low melting point of the fuse wire and discuss how the fuse wire ensures safety of the circuit and record it in the science diary.

Electric sources of light

Having observed an electric lamp and an electric heater, Thomas had a doubt: Are the heater coils of the two made of the same material?

Make different types of lamps of the same power work and observe the light emitted by each. Do all lamps emit light alike? Find out different types of lamps and make a list.

- Incandescent lamp
-

What is the main energy change that takes place in these?

Incandescent lamp

Examine an incandescent lamp and list its parts

- A thin tungsten filament.
-

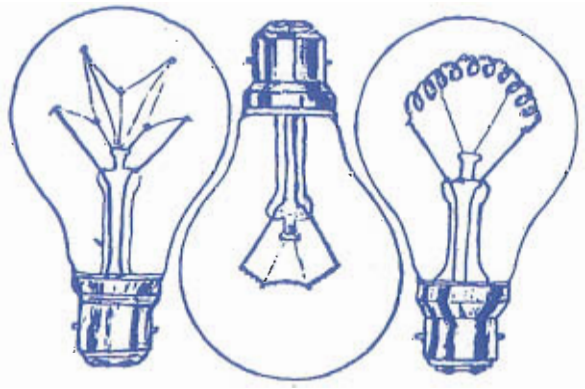


Fig. 5.5

You have learnt the factors on which the resistance of a conductor depends. You know that the resistance of a conductor increases with its length (ℓ) and decreases with the increase in area of cross section (A).

Then,

$R \propto \ell$

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

So $R \propto \frac{\ell}{A}$

Therefore we can write $R = \rho \frac{\ell}{A}$ where ρ (ro) is a constant

$\rho = \frac{AR}{\ell}$ This constant is resistivity.

This is different for different materials. Its unit is ohmmetre (Ωm).

Tungsten is the pure metal with maximum resistivity.

★ This metal is used for making the filament of a bulb. What happens to its resistance when its area of cross section is reduced by drawing it into a very thin wire?

★ What happens when current is passed through it?

★ When a current is sent through the filament of a bulb, it glows and turns white. What are the forms of energy that we get from it?

Incandescent means glowing on being heated. Hence the filament lamp is called incandescent lamp.

Find out the characteristics of tungsten that make it suitable for use as the filament of an incandescent lamp.

- High melting point.
- High ductility (can be drawn into a thin wire)
- Ability to remain white hot for a very long time.
-
-

Take a piece of tungsten filament out of a broken bulb. Pass electric current through it from a 6 V battery. What do you observe? On the basis of your observations discuss the need for evacuating a bulb.

In early days, vacuum bulbs were used. Later they were used by filling them with inert gases at low pressure. By this the evaporation of the filament could be reduced and its longevity and efficiency could be increased. Isn't it a problem that a major part of energy is lost as heat in such bulbs? How can this loss of energy be reduced?

Discharge lamps

You might have seen sodium vapour lamps being used as street lights in many towns. Such lamps that work without filaments are called discharge lamps. Let's try to know their parts.

- A glass tube filled with a suitable gas at low pressure.
- Electrodes at both ends of this tube.

A high voltage is applied on the electrodes of the tube. The gas gets ionised.

As a result of the collision of ions and electrons with unionised particles, light is produced.

The colour of the light thus produced depends on the nature of the gas that is used in the discharge lamp.

Sl. No.	Gas in the discharge tube	Colour of light
1.	Neon	Orange red
2.	Nitrogen	Red
3.	Sodium vapour	Yellow
4.	Mercury vapour	White
5.	Chlorine	Green
6.	Hydrogen	Blue

The fluorescent lamps used in houses is another form of the discharge lamp.

Fluorescent lamps

Analyse Fig. 5.6 and list the parts of a fluorescent lamp.

•

•

When electricity is passed through the heating coil of a fluorescent lamp it gets heated and electrons are emitted. The emitting power of these coils is increased by coating thorium oxide on it. The tube in the lamp has mercury in it. As the lamp starts functioning mercury gets evaporated. The electrons emitted from the heating coil collide with mercury atoms. As a result of this, ultraviolet rays are produced from mercury atoms. These rays are absorbed by the fluorescent materials and changed into visible light.

Now let's compare a fluorescent lamp with a filament lamp.

Switch on a 40 W fluorescent lamp and a 40 W filament lamp in your house.

★ From which lamp do you get more light?

- -

★ Hold your hand very close to the two lamps. Which lamp gave more heat to your hand?

- -

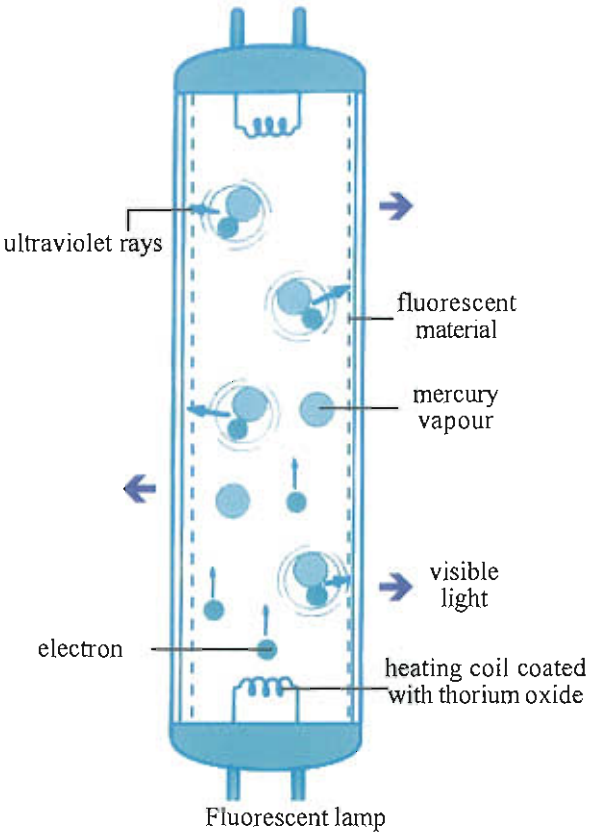


Fig. 5.6

★ Which lamp wastes more energy as heat?

- -

★ Hold your hand between a filament lamp and a wall. Then hold the hand between a long fluorescent lamp and the wall. Which lamp casts a bigger shadow?

- -

On the basis of these activities, find out the advantages of fluorescent lamps over filament lamps and record them in the science diary.

- The longevity of a fluorescent lamp is nearly five times that of a filament lamp.

•

CF lamps (Compact Fluorescent Lamps) are widely used in order to reduce the

Fig. 5.7

consumption of electricity. Don't you want to know how we get light from these lamps which are comparatively shorter than fluorescent lamps?

Normally, a CFL has a unit of electronic circuit and a fluorescent tube containing mercury vapour. How is the size of a CFL different from that of an ordinary fluorescent lamp?

With the help of an electronic circuit, high frequency electricity (at 40 kHz or more) is supplied between the electrodes of the tube.

As a result electrons are emitted from the electrodes.

The Electronic circuit of CFL

Fig. 5.8

* How are ultraviolet rays produced inside the CFL tube?

---

* How are these rays converted into visible light?

Let's find out the merits of CFL, shall we?

- A very low power is enough.
-

CF lamps are available from 3 W onwards. Find from the labelling on them the actual power of the so called zero watt filament lamps available in market.

LED lamps

LED (Light Emitting Diode) is an electronic device which converts electrical energy into light energy using very little power. LED lamps emitting light of different colours are available. Depending on the mode of construction, certain LED lamps emit light in more than one colour. LED lamps giving white light (white LED) are extensively used as street lights, automobile headlights and in households.

Fig. 5.9

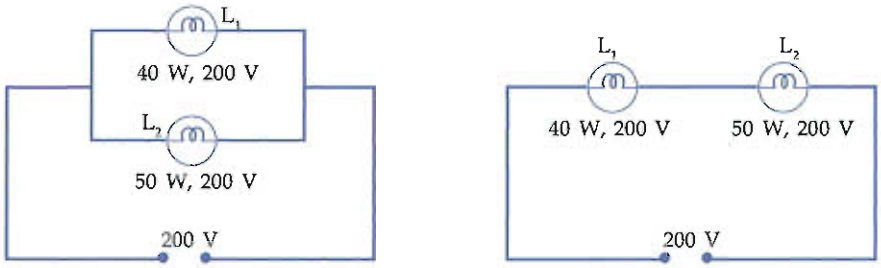
Let's hope that within the next two years some of the big cities will be completely lit by LED.

Are there advantages only while using fluorescent lamps and CF lamps? Don't they have disadvantage too? Discuss and find out the problems.

- High initial cost
- The threat posed to the environment by the mercury and the fluorescent material inside discarded tubes, as pollutants.
-

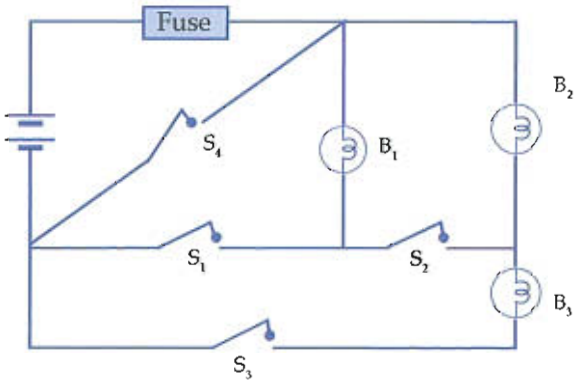
You have understood that any type of lamp when examined has advantages and disadvantages. Therefore let's use them judiciously when required.

Follow up Activities

1. The area of cross section of a conductor is 2 mm^2 and its resistance is 20 Ω. What will its resistance be when its length is doubled?
2. 

   Compare the intensities of light emitted by lamps L_1 and L_2 in circuits A & B.
3. When an electric lamp is switched on, no visible light is produced inside it. Yet it gives out light.
   (a) What type of lamp is this?
   (b) Explain how light is obtained from it.
   (c) What are the advantages of this lamp?
4. Explain how the inner side of a metallic cup is electroplated with silver.
5. Electrolysis of dilute aqueous solution of copper sulphate is done using carbon rods.
   (a) What happens to the mass of the positive electrode? And what about the mass of the negative electrode?
   (b) What change occurs to the concentration of the electrolyte?
   (c) If copper plates are used instead of carbon rods for electrolysis, what happens to the concentration of the electrolyte and the mass of the electrodes?
   (d) Justify your answers.

6. A heater is labelled 800 W, 400 V.
   (a) What does this labelling mean?
   (b) What is the power of the instrument when it is given a potential difference of 200 V? What is the current flowing through it?
   (c) If a potential difference of 100 V is given to the heater, what will the power of the instrument be?
7. Observe the circuit



   (a) When only switch S_1 is on, what do you observe?
   (b) When only switch S_2 is on, what do you observe?
   (c) When only switch S_3 is on, what do you observe?
   (d) Suggest two methods to make all lamps in the circuit glow.
   (e) What happens when all the switches are on? What is the reason? And when S_4 alone is switched on?