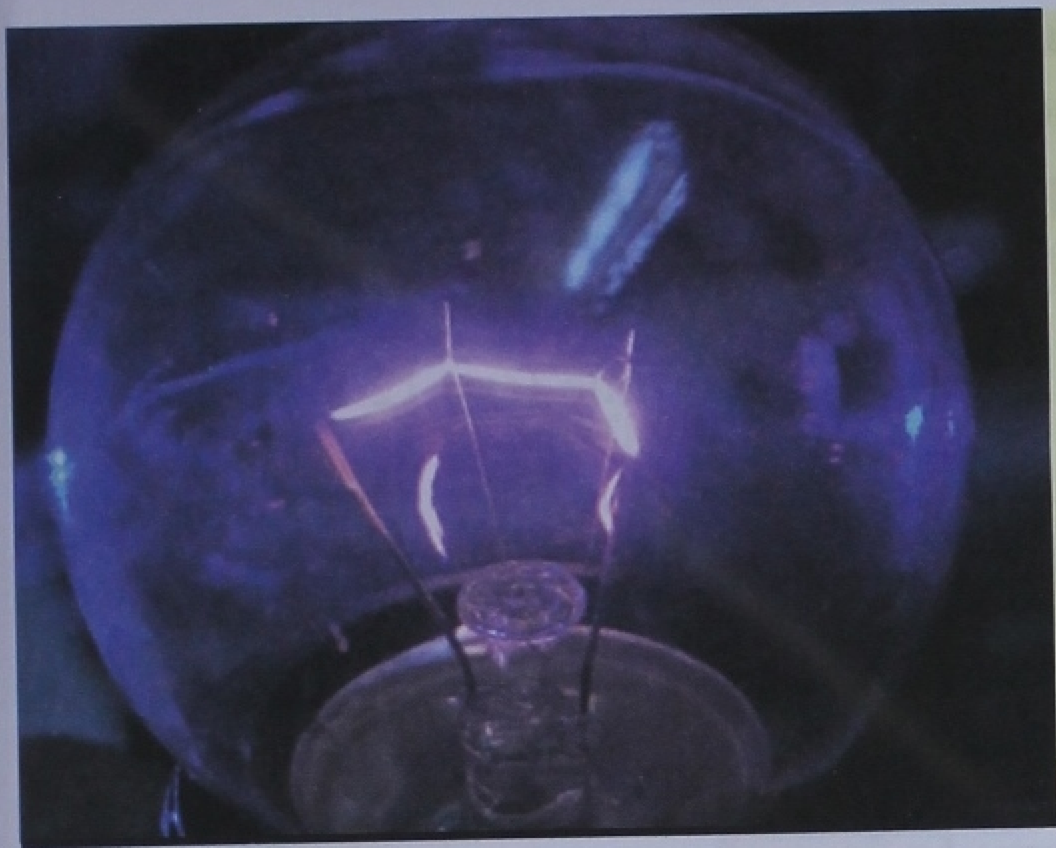


# 11 Current Electricity

**This chapter consists of the following topics**

- Electricity in motion (the electric current), strength of current, unit of charge and current.
- Electric potential, potential difference, unit of potential difference.
- Ammeter and voltmeter.
- Electric resistance, factors affecting the resistance.
- Heat analogy and water analogy.
- Ohm's law, definition of one ohm.
- Combination of resistances in series and in parallel.
- Heating effect of current with applications.
- Electric bulb and electric fuse.
- Power and rating of an electrical appliance.
- Commercial unit of electrical energy.

**Note :** The chapter on *Current Electricity* has been purposely inducted in this book although it is not a part of the syllabus. This will make the students to understand the basics of *Current Electricity* (*i.e.*, electricity in motion) which will be further useful in the learning of concepts of *Electromagnet* and *Electromagnetic Induction*.

## ELECTRIC CURRENT

When two charged conductors are joined together by a metallic wire, or are brought in contact, the free electrons flow from one conductor to the other. Electrons flow from the conductor with surplus of free electrons to the other conductor which is in deficit of free electrons. The motion of electrons stops when the concentration of electrons in both the conductors become equal.

*Such moving electrons flowing in a particular direction constitute an electric current.*



## STRENGTH OF AN ELECTRIC CURRENT

Strength of an electric current, through a conductor, is the amount of charge that flows through the conductor in one second. It is denoted by $I$.

Let $Q$ charge flows through a conductor in time $t$, then,

$$\text{Strength of current through conductor} = \frac{\text{charge that flows}}{\text{time taken}}$$

$$\therefore \quad I = \frac{Q}{t}$$

### Unit of charge and current (electric current)

The S.I. unit of charge is coulomb which is denoted by letter C and the unit of current is ampere which is denoted by letter A.

$$\therefore \quad I = \frac{Q}{t}$$

$$\Rightarrow \quad 1\text{ Ampere} = \frac{1\text{ Coulomb}}{1\text{ second}} \quad \text{or} \quad 1\text{ A} = \frac{1\text{ C}}{1\text{ s}}$$

Thus, strength of current through a conductor is said to be 1 ampere if 1 coulomb charge flows through it in 1 second.

Smaller units of current are :

Milli ampere (mA) $\Rightarrow 1\ mA = 10^{-3}\ A$

Micro ampere (μA) $\Rightarrow 1\ \mu A = 10^{-6}\ A$

Nano ampere (nA) $\Rightarrow 1\ nA = 10^{-9}\ A$

Peco ampere (μμA or pA) $\Rightarrow 1\ pA = 10^{-12}\ A$

Charge on one electron = $1{\cdot}6 \times 10^{-19}C$

The instrument used to measure the strength of current through a conductor is called **AMMETER**. Ammeter is connected in series with the given circuit.

**Do You Know ?**

- Currents of approximately 0·2A are potentially fatal, because they can make the heart to beat in an uncontrolled manner.
- The energy sources we use to make electricity can be renewable or non-renewable, but electricity itself is neither renewable nor non-renewable.



**Example 1 :**

If 6 coulomb of charge flows through a conductor in 3 seconds, find the strength of electric current.

**Solution :**

Given : Charge $(Q) = 6\ C$

and time $(t) = 3\ s$

$\therefore$ Current $(I) = \frac{Q}{t} = \frac{6\ C}{3\ s}$

$= 2$ **Ampere**

**Example 2 :**

An electric current of 5 ampere flows through a conductor for 12 seconds. Find the amount of charge.

**Solution :**

Given : Current $(I) = 5\ A$

and time $(t) = 12\ s$

Since, $I = \frac{Q}{t}$

$\Rightarrow Q = I \times t$

$= 5A \times 12\ s = 60\ C$

$\therefore$ **Amount of charge = 60 C**

**Example 3 :**

For how much time must a charge of 20 coulomb flow through a conductor to constitute a current of 4 ampere ?

**Solution :**

Given : Charge $(Q) = 20\ C$

and Current $(I) = 4\ A$

Since, $I = \frac{Q}{t}$

$\Rightarrow t = \frac{Q}{I} = \frac{20\ C}{4\ A} = 5\ s$

$\therefore$ **Required time = 5 s**

## ELECTRIC POTENTIAL

When two charged bodies are connected with the help of a conductor, excess electrons flow through the conductor from the body with higher concentration of electrons to the body with lower concentration of electrons as shown in Fig. 11.1.

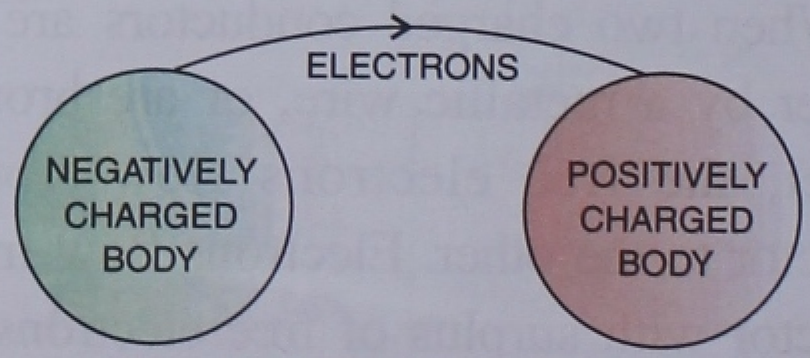



*Fig. 11.1 Flow of electrons*

The flow of excess electrons will take place from :

(i) a negatively charged conductor to a positively charged conductor as shown in Fig 11.1.

(ii) a negatively charged conductor to an uncharged conductor [see Fig. 11.2(a)].

(iii) an uncharged conductor to a positively charged conductor [see Fig. 11.2 (b)].

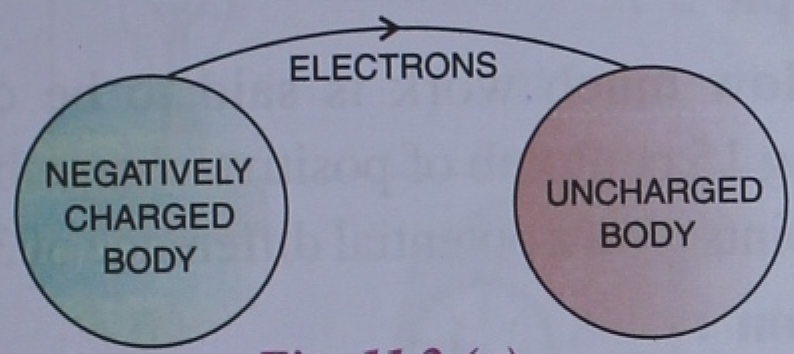



*Fig. 11.2 (a)*

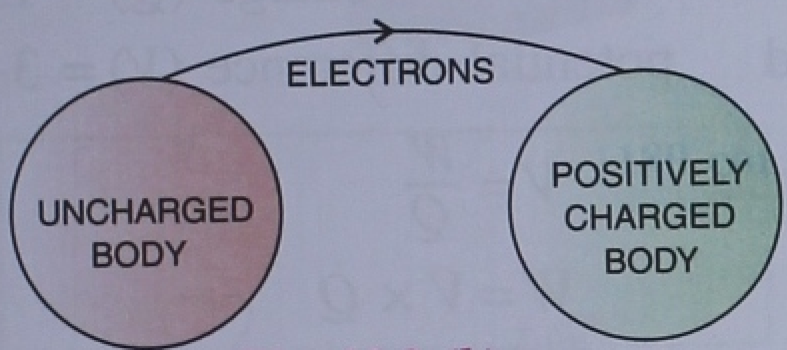



*Fig. 11.2 (b)*

Thus, *electric potential is the electric condition which determines the direction of flow of charge* (electrons) *from one body to another body.*

The conductor with higher concentration of electrons is said to be at a lower potential and the conductor with lower concentration of electrons is said to be at a higher potential. On connecting, electrons flow from the conductor at lower potential to the conductor at higher potential. Conventionally, we say that, electric current flows from the body at a higher potential to the body at a lower potential; for this reason, the electric current is called conventional current as shown in Fig. 11.3.

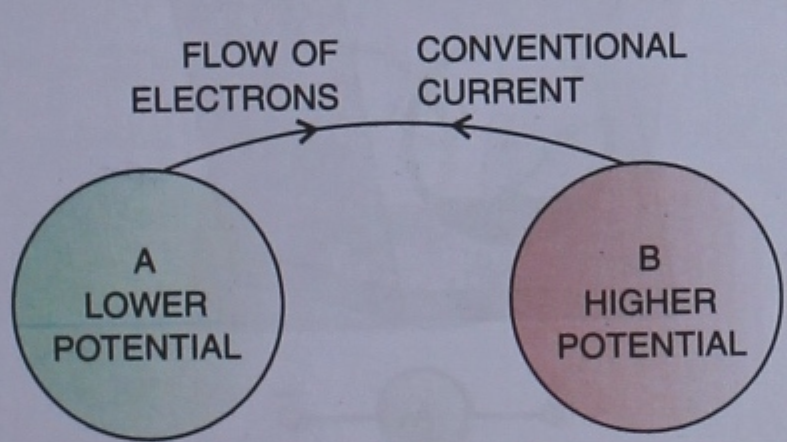



*Fig. 11.3 Electrons flow from A to B so the conventional current is from B to A*

For a battery, **electronic current** (flow of electrons) is from **negative terminal to positive terminal**, whereas the **conventional current** flows from **positive terminal to negative terminal** outside the battery.

In electrical circuits, the direction of conventional current is marked and not the direction of electronic current.

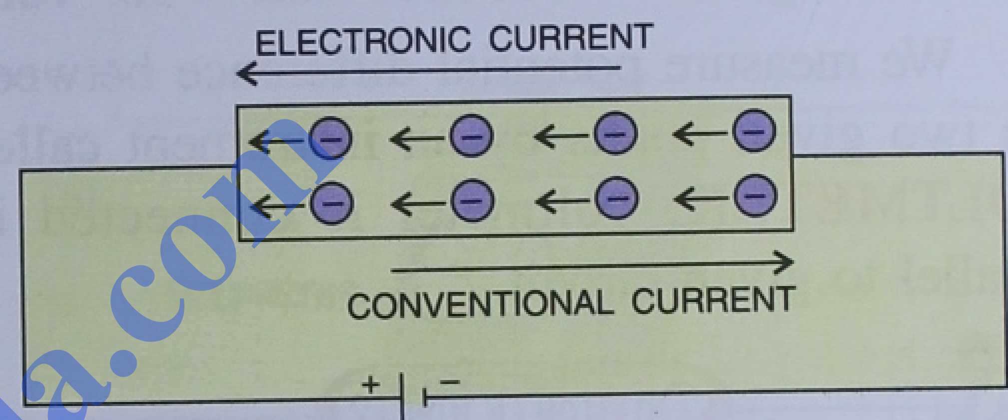



*Fig. 11.4 To show the direction of conventional and electronic currents*

We detect the direction of electric current with the help of GALVANOMETER.

## POTENTIAL DIFFERENCE

*Potential difference between any two points in an electric field is the amount of work done in moving a unit positive charge from one point to the other.*

Suppose $W$ joule of work is done in bringing $Q$ coulomb of positive charge from one point to the other. Then the potential difference ($V$) between the two points will be given by :

$$\text{Potential difference} = \frac{\text{Work done}}{\text{Charge moved}}$$

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

## Unit of Potential Difference

SI unit of potential difference is volt.

Since, the SI unit of work is joule and the SI unit of charge is coulomb

$$\therefore \quad 1 \text{ volt} = \frac{1 \text{ Joule}}{1 \text{ Coulomb}}$$

Thus, if 1 joule of work is done in moving 1 coulomb of positive charge between two points in an electric field, the potential difference between these two points is 1 volt.

The bigger units of potential difference are kilovolt and megavolt.

1 Kilovolt = 1000 volt.

1 Megavolt = 1000000 volt = $10^6$ volt

We measure potential difference between the two given points by an instrument called **VOLTMETER**. Voltmeter is connected in parallel to given circuit.

### Do You Know ?

- **Voltameter :** A glass or a plastic container containing two electrodes and an electrolytic solution is called voltameter. Voltameter is also called an electrolytic cell. It is different from voltmeter.
- **LED (Light Emitting Diode) :** LED can be used for lighting in place of an electric bulb or CFL, due to their high energy efficiency and low power consumption. LED glows even when a small electric current flows through it.

  LEDs are available in different colours.

*Note :* Electric circuit — The path along which an electric current can flow is called electric circuit.

**Example 4 :**

60 J of work is done in flowing 12 coulomb of positive charge between two points in an electric field. Find the potential difference between these two points.

**Solution :**

Given : Work ($W$) = 60 J

and charge moved ($Q$) = 12 C

$$\therefore \textbf{ Potential difference} = \frac{\text{Work done}}{\text{Charge moved}}$$

$$= \frac{60 \text{ J}}{12 \text{ C}} = \mathbf{5V}$$

**Example 5 :**

How much work is said to be done in moving 15 coulomb of positive charge between two points with a potential difference of 3·2 volt.

**Solution :**

Given : Charge ($Q$) = 15 C

and potential difference ($V$) = 3·2 V

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

$\Rightarrow \quad W = V \times Q$

$= 3{\cdot}2 \text{ V} \times 15 \text{ C} = 48 \text{ J}$

$\therefore$ **Required work done = 48 J**



## DESCRIPTION OF AMMETER AND VOLTMETER

**Ammeter :** The current flowing in a circuit is measured by an ammeter. It has a circular scale graduated in amperes as shown in Fig. 11.5. An ammeter is connected in series in

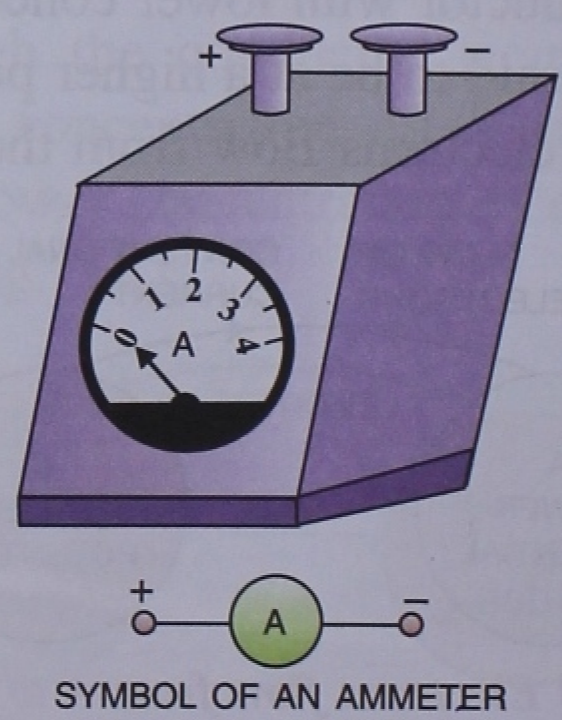



*Fig. 11.5 Ammeter*

a circuit. The terminal (+) is connected to the positive terminal of the cell and the terminal (–) is connected to the negative terminal of the cell through the other electrical components.

The Figs. 11.6(a) and 11.6(b) show the connection of ammeter in a circuit.

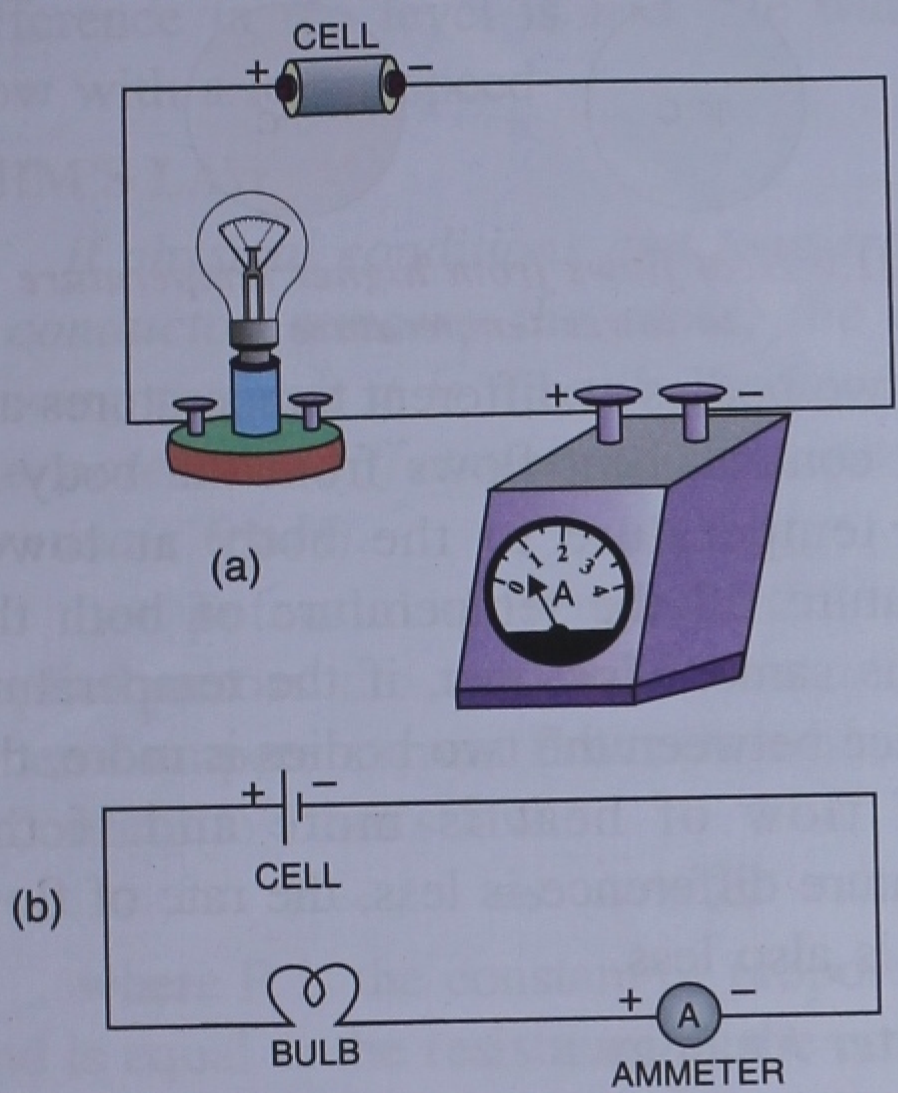



*Fig. 11.6 (a) Circuit with an ammeter*
*(b) Circuit diagram with an ammeter*

**Voltmeter :** The potential difference between the two points of a circuit is measured by a voltmeter. It has a graduated scale in volts as shown in Fig. 11.7. A voltmeter is connected

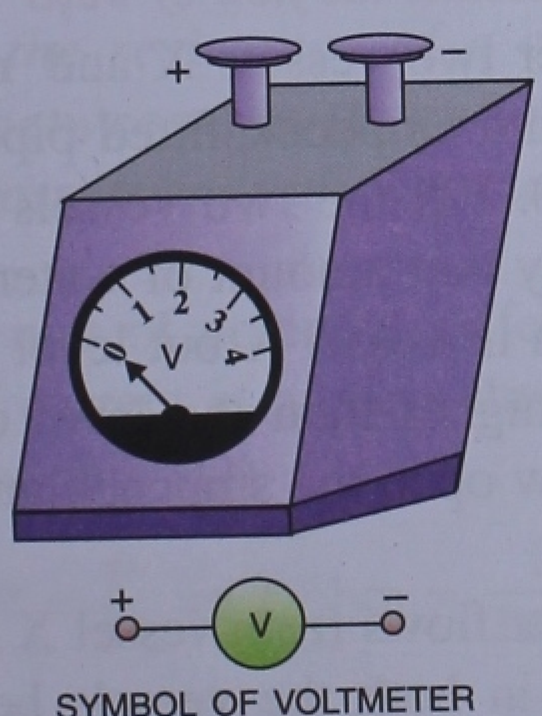



*Fig. 11.7 Voltmeter*

in parallel across the two points between which potential difference is to be measured. The terminal (+) is connected to the point which is connected to the positive terminal of the cell and the terminal (–) is connected towards the negative terminal of the cell. Figure 11.8 shows the connection of voltmeter in parallel in a circuit to find out the potential difference across a bulb.

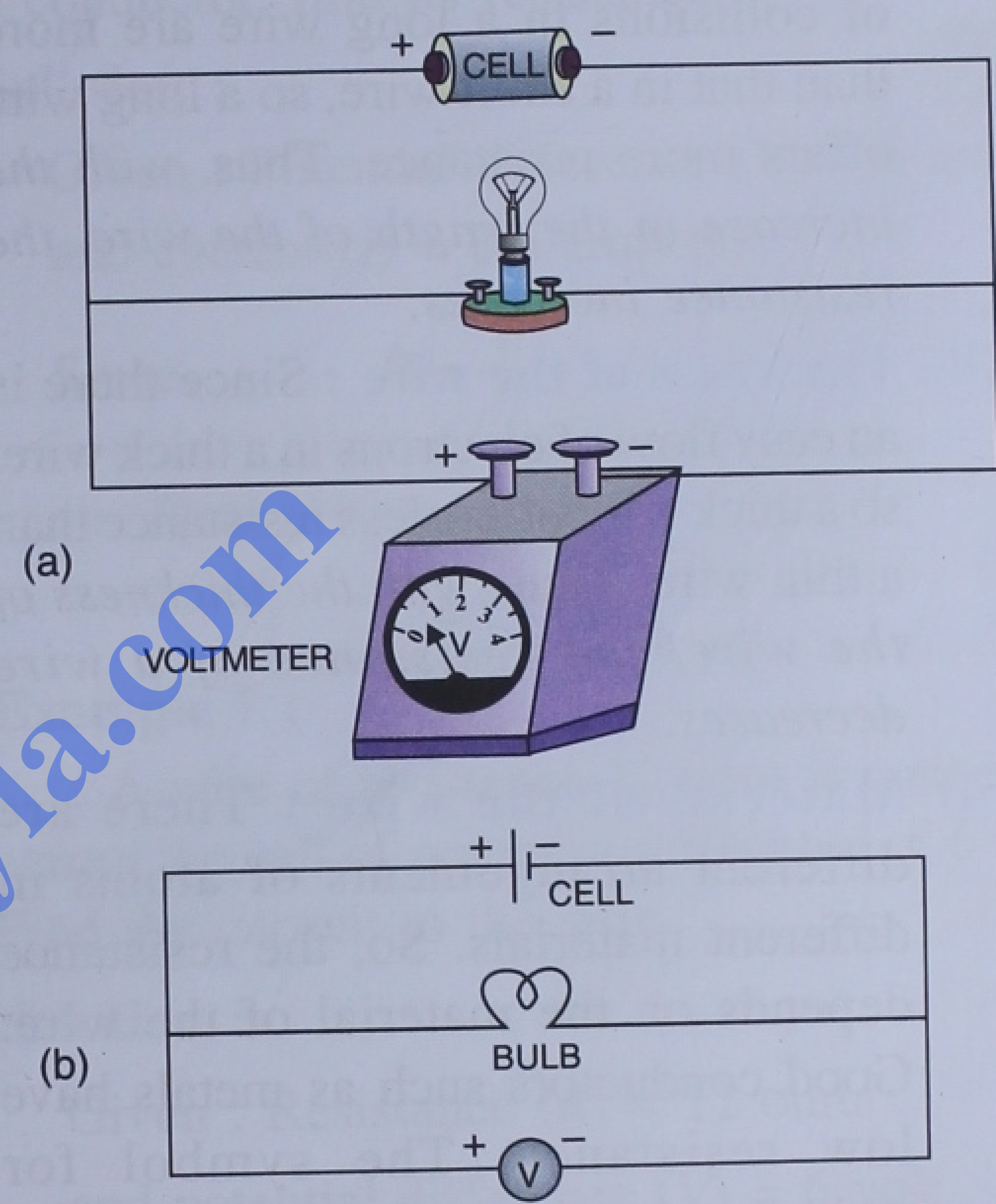



*Fig. 11.8 (a) A circuit in parallel with voltmeter*
*(b) Circuit diagram with a voltmeter*

**Classroom discussion :** Do you think that an electric car which uses rechargeable batteries does not waste energy or cause pollution ? Discuss.

## ELECTRICAL RESISTANCE

There is always some obstruction to the flow of current, when it flows through a conductor like a metal wire.

This obstruction in the flow of current is provided by the material of the conductor and is called its **electrical resistance**.

Since the current in a conductor flows due to the motion of free electrons in it, so the electrons collide with the atoms present in the conductor as they move through it. These collisions decrease the speed of electrons and thus resistance occurs in the flow.

The resistance of a wire depends on the following three factors :

(i) **Length of the wire :** Since the number of collisions in a long wire are more than that in a short wire, so a long wire offers more resistance. Thus, *with the increase in the length of the wire, the resistance increases.*

(ii) **Thickness of the wire :** Since there is an easy flow of electrons in a thick wire, so a thick wire offers less resistance than a thin wire. Thus, *with the thickness of the wire, the resistance of a wire decreases.*

(iii) **Material of the wire :** There are different arrangements of atoms in different materials. So, the resistance depends on the material of the wire. Good conductors such as metals have low resistance. The symbol for resistance is o—/\/\/\/—o .

The unit of resistance is ohm (denoted by Ω).

## AN IMPORTANT CONCEPT

When two points at different potentials are connected with the help of a conductor, electric current flows through the conductor from the point at a higher potential to the point at a lower potential till the potential of both the points is same.

If the potential difference between the two points is more, the current flowing through the conductor is more and if the potential difference between the two points is less, the current is less.

This concept can be made more clear from the following two analogies :

### (i) Heat Analogy :

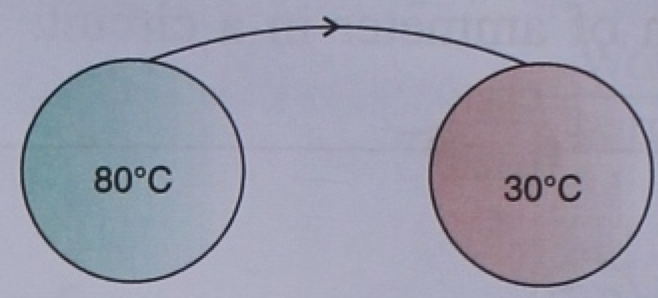



*Fig. 11.9 Heat flows from higher temperature to lower temperature*

If two bodies at different temperatures are kept in contact, heat flows from the body at higher temperature to the body at lower temperature till the temperature of both the bodies is same. Moreover, if the temperature difference between the two bodies is more, the rate of flow of heat is more and if the temperature difference is less, the rate of flow of heat is also less.

### (ii) Water Analogy :

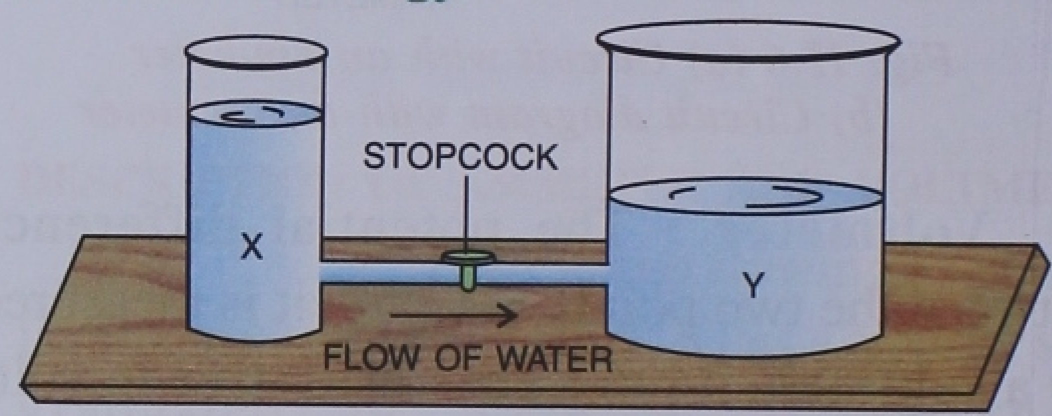



*Fig. 11.10 The difference in the (potential) level decides the flow of water*

Consider two vessels X and Y connected together with a stopcock fitted pipe as shown in Fig. 11.10. Fill the two vessels with water in such a way that amount of water is more in vessel Y than in vessel X but level of water in vessel X is higher than the level of water in vessel Y. Now open the stopcock and see what happens ?

The water flows from vessel X to vessel Y till the level in both the vessels becomes the same. Hence we conclude that it is the difference in the level of water which determines the flow and not the amount of water.

Moreover, if the difference in the level of water in two vessels is more, the water will flow from the vessel at higher level to the vessel at lower level, with higher speed. If the difference in the level is less, the water will flow with a lower speed.

## OHM'S LAW

*If physical conditions and temperature of a conductor remains the same, the current flowing through it is directly proportional to the potential difference applied across its terminals* (ends).

Let potential difference of V volt is applied across the terminals of a conductor, when I ampere current flows through it. Then according to Ohm's law :

$$V \propto I \quad \Rightarrow \quad V = RI$$

where R is the constant of proportionality and is equal to the resistance of the conductor.

### Defining 1 Ohm Resistance

According to Ohm's law :

$$V = RI$$

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

$$i.e., \quad \text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

Thus, *the resistance of a conductor is the ratio between the potential difference applied across its ends and the current flowing through it.*

When unit of potential difference is volt and that of current is ampere then the unit of resistance is ohm (Ω).

$$\therefore \quad R = \frac{V}{I} \Rightarrow 1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

*If by application of 1 volt potential difference across the terminals of a conductor 1 ampere current flows through the conductor then the resistance of the conductor is 1 ohm.*

***Note :*** Higher the resistance of a material (conductor) lower the current that can pass through it, for the same potential difference.

**Example 6 :**

If on application of 6 volt of potential difference, 0·5 ampere of current flows through a conductor, find its resistance.

**Solution :**

Given : Potential difference ($V$) = 6 volt and current ($I$) = 0·5 ampere.

$$\text{Since,} \quad R = \frac{V}{I}$$

$$\Rightarrow \textbf{Resistance} = \frac{6 \text{ V}}{0{\cdot}5 \text{ A}}$$

$$= \textbf{12 ohm}$$

**Example 7 :**

A wire of resistance 12 ohm is connected across the cell of potential difference of 6 volt. Find the current in the wire.

**Solution :**

Given : Resistance ($R$) = 12 ohm and potential difference ($V$) = 6 volt

$$\text{Since,} \quad V = RI \quad \Rightarrow \quad I = \frac{V}{R}$$

$$i.e., \quad \textbf{Current} = \frac{6 \text{ volt}}{12 \text{ ohm}}$$

$$= \textbf{0·5 Ampere}$$

**Example 8 :**

How much potential difference must be applied across the terminals of a wire with a resistance of 2·4 ohm so that a current of 1·5 ampere may flow through it ?

**Solution :**

Given : Resistance ($R$) = 2·4 ohm

and current ($I$) = 1·5 ampere

∴ $V = RI$

⇒ **Potential diff.** = 2·4 ohm × 1·5 ampere

= **3·6 volt**

**Example 9 :**

A lamp draws a current of 0·5A when it is connected to a 230 V supply. What is the resistance of the filament of the lamp ?

**Solution :**

$I = 0{\cdot}5\text{A},\ V = 230 \text{ volt},\ R = ?$

$$R = \frac{V}{I} = \frac{230}{0{\cdot}5} = \mathbf{460\ \Omega}$$

**Example 10 :**

Calculate the potential difference required across a conductor of resistance 10 Ω to pass a current of 2 A through it.

**Solution :**

$R = 10\ \Omega,\ I = 2\text{A},\ V = ?$

$V = IR = 2 \times 10 =$ **20 volt**

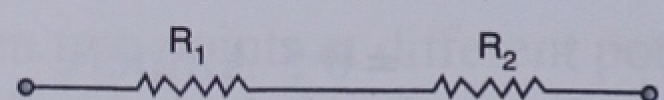
## COMBINATION OF RESISTANCES

Resistances can be combined together in two ways :

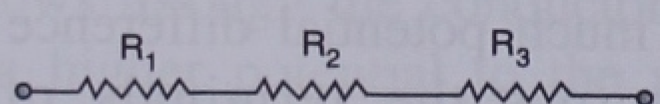
(1) in series, and (2) in parallel.

### (1) Combination of resistances in series

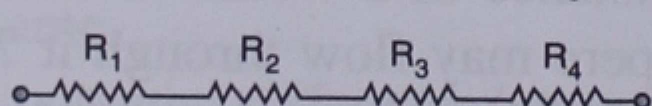
In this combination, the resistances are joined end to end as shown in Fig. 11.11.




(a) Two resistances $R_1$ and $R_2$ in series




(b) Three resistances $R_1$, $R_2$ and $R_3$ in series




(c) Four resistances $R_1$, $R_2$, $R_3$ and $R_4$ in series

*Fig. 11.11*

The *total resistance (R) of the combination in series is equal to the sum of resistances.*

Thus,

in Fig. 11.11(a), $R = R_1 + R_2$

in Fig. 11.11(b), $R = R_1 + R_2 + R_3$

in Fig. 11.11(c), $R = R_1 + R_2 + R_3 + R_4$

The complete circuit for the combination of resistances in series is shown below :

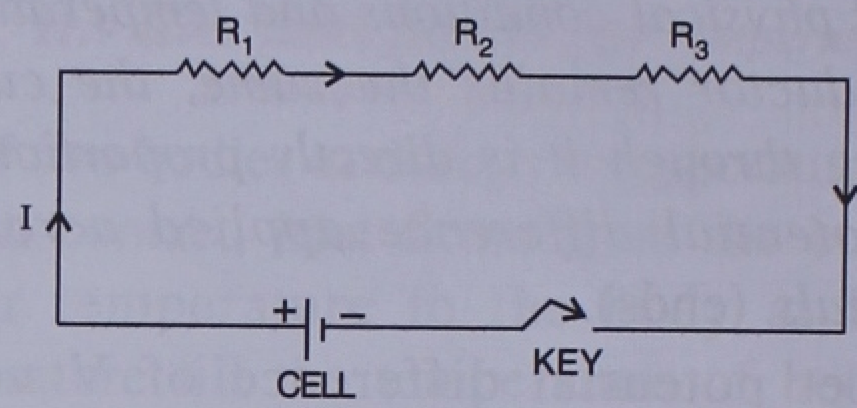
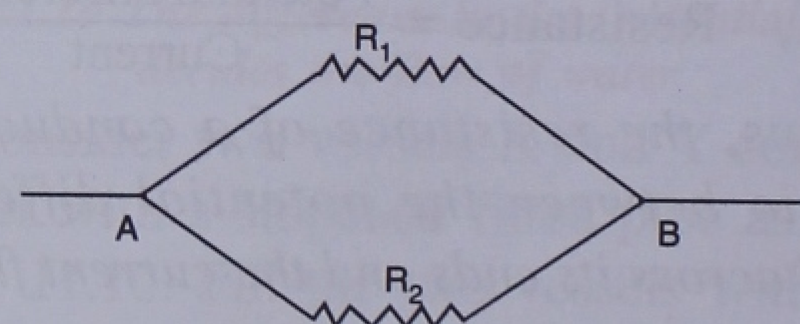



*Fig. 11.12 Resistances in series*

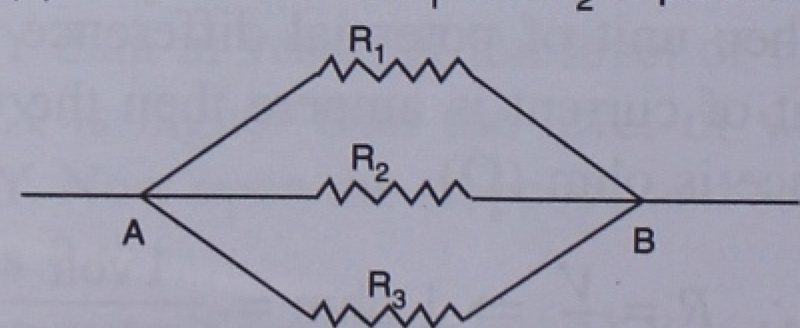
It must be noted here that *in series combination, the current flowing through each resistance and through the whole circuit is the same.*

### (2) Combination of resistances in parallel

In this combination, one end of each resistance is joined to one point and the other end of each resistance is joined to the other point as shown in Fig. 11.13.




(a) Two resistances $R_1$ and $R_2$ in parallel




(b) Three resistances $R_1$, $R_2$ and $R_3$ in parallel

*Fig. 11.13*

*The reciprocal of the total resistance (R) of the combination in parallel is equal to the sum of the reciprocals of the resistances.*

Thus,

in Fig. 11.13(a), $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

in Fig. 11.13(b), $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

and so on

The complete circuit for the combination of resistances in parallels is shown below :

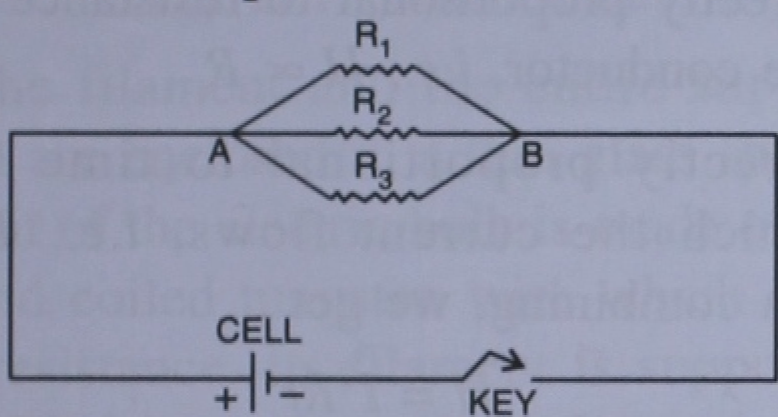



*Fig. 11.14 Resistances in parallel*

*It must be noted here that in parallel combination, the potential difference across each resistance and across the whole combination is the same.*

**Example 11 :**

Find the total resistance when two resistances of 5 ohm and 10 ohm are combined in : (i) series (ii) parallel.

**Solution :**

Given : $R_1 = 5$ ohm and $R_2 = 10$ ohm

**(i) In series :**

**Total resistance,** $R = R_1 + R_2$

$= 5$ ohm + 10 ohm

= **15 ohm**

**(ii) In parallel :** Let total (equivalent) resistance be $R$ ohm

$\therefore \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

$\Rightarrow \quad \frac{1}{R} = \frac{1}{5} + \frac{1}{10} = \frac{2+1}{10} = \frac{3}{10}$

*i.e.* $R = \frac{10}{3} = 3\frac{1}{3}$

$\therefore$ **Total resistance = $3\frac{1}{3}$ ohm**

**Example 12 :**

Find the equivalent resistance when three resistances of 8 ohm, 12 ohm and 24 ohm are combined in : (i) series (ii) parallel.

**Solution :**

Given : $R_1 = 8$ ohm, $R_2 = 12$ ohm and $R_3 = 24$ ohm.

(i) **In series :** Let equivalent resistance be $R$ ohm.

$\therefore \quad R = R_1 + R_2 + R_3$

= 8 ohm + 12 ohm + 24 ohm

= **44 ohm**

(ii) **In parallel :** Let equivalent resistance be $R$ ohm.

Then, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\Rightarrow \quad = \frac{1}{8} + \frac{1}{12} + \frac{1}{24}$

$= \frac{3+2+1}{24} = \frac{6}{24} = \frac{1}{4}$

$\Rightarrow \quad R = 4$

*i.e.* **equivalent resistance = 4 ohm**

## HEATING EFFECT OF CURRENT

Whenever an electric current is passed through a conductor, it gets heated up. This means that electrical energy given to the conductor gets converted into heat energy, so this effect is known as **heating effect** of electric current.

**Experiment :** An insulated copper wire about 1 m long is wound completely on a wooden stick. The ends of the wire are connected to a battery and a switch as shown in Fig. 11.15. The switch is now closed and after few minutes when the wire is touched, it appears hot. This shows that on passing current through a metal wire, it gets heated.

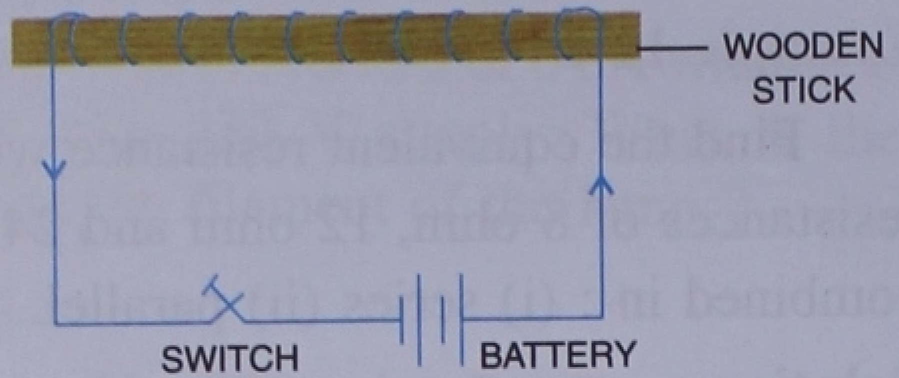



*Fig. 11.15*

To show the heating effect of current on a bulb.

- Connect a bulb to a cell with the help of a conducting copper wire, as shown in Fig 11.16.

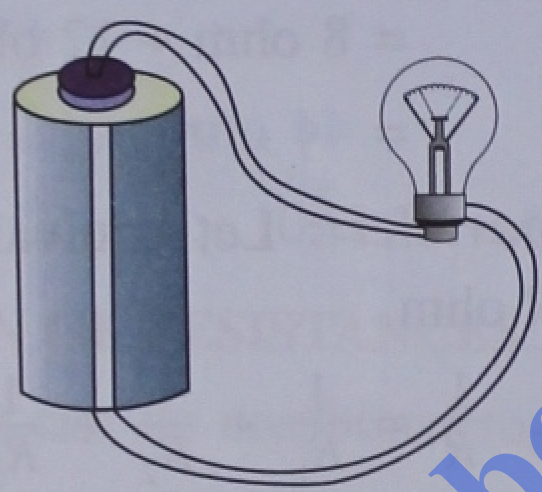


*Fig. 11.16*

- What do you observe after a few minutes ? Do you observe any heating effect ?

You will observe that temperature at the ends of the copper wire remains unchanged but the glass of the bulb gets heated (or becomes hot).

Heating of the bulb in this activity shows the heating effect of current on the bulb.

Joule, the famous scientist studied the heating effect of current in detail and found that the heat produced in a conductor due to current passing through it depends on three factors. The relation between the amount of heat produced and these three factors are known as Joule's laws of heating effect of current.

## JOULE'S LAWS OF HEATING EFFECT OF CURRENT

According to Joule's laws, the amount of heat (H) produced in a conductor is :

1. directly proportional to the square of the current '$I$', *i.e.*, $H \propto I^2$
2. directly proportional to resistance '$R$' of the conductor, *i.e.*, $H \propto R$
3. directly proportional to time '$t$' for which the current flows, *i.e.*, $H \propto t$. On combining, we get :

$$H = I^2Rt$$

## APPLICATIONS OF HEATING EFFECT OF CURRENT

There are many applications of heating effect of current in our daily life. Some of the heating effects of current on household appliances are : an electric iron when hot is used for ironing, an electric room heater is used for warming up of room, geyser is used for warming of water, *etc*.

## ELECTRIC BULB

An electric bulb consists of a tungsten filament with a coating of thorium. It has the following characteristic properties.

1. It has a very high melting point of about 3300°C.
2. It has high resistance.
3. The coating of thorium provides extra brightness to the tungsten when it glows.

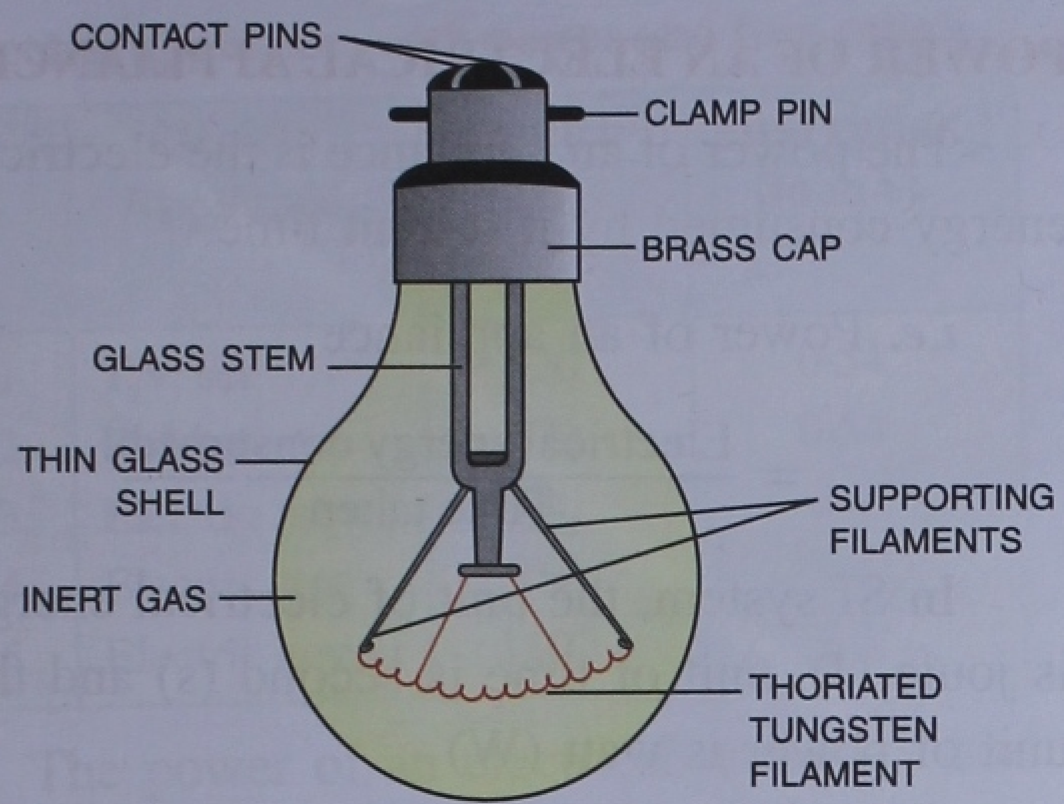



*Fig. 11.17 Electric bulb*

The filament and the entire supporting system are enclosed in a thin glass shell. The filament of the electric bulb is made of a very thin and coiled tungsten wire which offers a large resistance. Its filament is supported on thick nickel-iron wires attached to a glass stem. The ends of the filament are connected to contact pins through thick lead wires. When current flows through the filament, its temperature immediately (in no time) rises to about 2500°C and it starts giving light and a little amount of heat. To prevent the tungsten from getting oxidised in the presence of air at high temperature, the bulb is filled with inert gases like nitrogen or argon at a very low pressure.

An electric bulb converts electrical energy into heat energy and light energy.

Sometimes, the filament gets damaged or it breaks. In this case the bulb does not glow. We call it a fused bulb.

### Lighting a bulb by electric cell

The bulb should be placed or screwed in the "bulb holder" and the cell in the "cell holder".

The bulb lights up only when the bulb and the connecting wire form a complete circuit, which starts from one terminal of the electric cell and ends at the other terminal. There should be no gap in its path, otherwise the bulb won't glow. The bulb will also not glow, if the path starts and returns to the same terminal. An electric bulb is used for lighting but it also gives heating effect which actually is a waste of electrical energy. This wastage can be reduced by using fluorescent lights in place of bulbs. The compact fluorescent lamps (CFL) available in the market reduces wastage of electrical energy by reducing the heat produced due to lighting. They can also be fixed on the ordinary bulb holders.

**Do You Know ?**

Thomas Alva Edison (AD 1847-1931) invented the electric bulb.

## ELECTRIC FUSE

A fuse is a safety device in an electric circuit which melts and break the circuit when excess current passes through it.

Fuse wire is used at the beginning of our house-hold circuit. This prevents the entire household wiring from getting damaged if a particular appliance draws an excess amount of current. When a large current flows through the circuit, the fuse wire gets heated up and melts away. In this way, the circuit breaks and hence prevents any damage to the circuit or an appliance.

### Characteristics of a fuse

(1) It has a short length wire with a low melting point. Fuse wire is made of an alloy containing equal amounts of lead and tin. It melts at about 200°C.

(2) Fuse wire has high resistance as compared to the resistance of the connecting wire. In

case of an overload, the temperature of fuse wire rises much faster than the connecting (copper) wire, it melts.

Most of the electrical appliances such as electric irons, geysers, room heaters, hot plates, ovens, toasters, *etc*. essentially have heating coils which are made up of high resistance wires such as nichrome wires. As the name suggests, it is an alloy of nickel and chromium. Nichrome has high resistance and hence can produce large amount of heat. It also has a very high melting point. It does not get oxidised easily even at high temperatures.

### To show heating effect of current on nichrome.

Take a 5 cm long nichrome wire, make a loop of it and connect it to a battery of two cells with the help of copper wires.

You will observe that the wire becomes red hot. Which means electrical energy changes to heat energy.

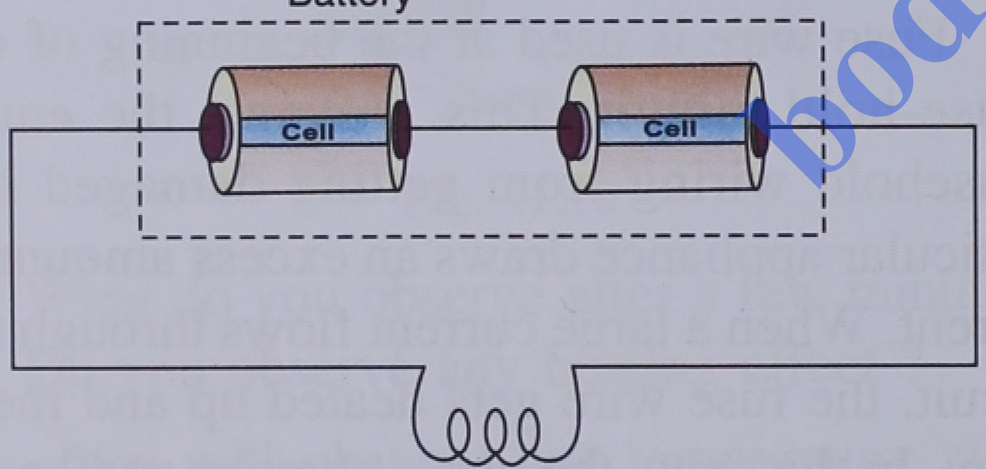



*Fig. 11.18*

**Do You Know ?**

These days, the use of Miniature Circuit Breakers (MCBs) is quite popular in place of traditional fuses. They are actually switches which turn off on their own in case the current in the circuit exceeds the safety limits. Simply turning them on, revives the circuit.

## POWER OF AN ELECTRICAL APPLIANCE

The power of an appliance is the electrical energy consumed by it in unit time.

*i.e.* Power of an appliance

$$= \frac{\text{Electrical energy consumed}}{\text{Time taken}}$$

In SI system, the unit of electrical energy is joule (J), unit of time is second (s) and the unit of power is watt (W)

$$\therefore P \text{ (in watt)} = \frac{\text{Electrical energy (in Joule)}}{\text{Time (in second)}}$$

$$\Rightarrow \quad 1 \text{ watt} = \frac{1 \text{ Joule}}{1 \text{ second}}$$

$$\text{or} \quad 1\,W = \frac{1\,\text{J}}{1\,\text{s}}$$

Thus, *if an electrical appliance consumes 1 joule of electrical energy in 1 second, the power of the appliance is 1 watt.*

## RATING OF AN ELECTRICAL APPLIANCE

Every electrical appliance is marked with its power and the potential difference at which it works. This marking is called rating of an electrical appliance.

When an electric bulb is marked 40W-220V, it means that, if the bulb is connected to a potential difference (voltage) of 220 V, the power consumed by the bulb is 40 W, *i.e.*, the bulb will consume 40 J of electrical energy in every one second. In other words, we can say that the bulb will convert 40 J of electrical energy into heat and light energy in each second.

**Electric appliances with power and fuse rating**

| S.No. | Electric Appliance | Power it draws (in watt) | Fuse rating (in mA) |
|---|---|---|---|
| 1. | T.V. set | 120 | 0·54 |
| 2. | Refrigerator | 120 | 0·54 |
| 3. | Electric mixer | 750 | 3·4 |
| 4. | Electric iron | 750 | 3·4 |
| 5. | Electric geyser | 1500 | 7·0 |

The power of an electrical appliance can also be obtained by finding the product of the potential difference applied and the current flowing through it. Thus,

Power = Potential difference × Current

$\Rightarrow \quad P = VI$

$\Rightarrow$ 1 Watt = 1 volt × 1 ampere

*i.e.* $\quad 1\ W = 1\ V \times 1\ A$

## COMMERCIAL UNIT OF ELECTRICAL ENERGY

Electrical energy is generally measured in a unit called B.O.T. (Board of Trade) unit or kWh, *i.e.,* kilowatt-hour.

*1 kilowatt hour is defined as the amount of energy consumed when an electrical appliance of power 1 kilowatt is used for 1 hour. The energy consumed in our houses, shops, factories, etc. is measured in kWh.*

Since, $\quad \text{Power} = \dfrac{\text{Energy}}{\text{Time}}$

$\Rightarrow \quad$ Energy = Power × Time

*i.e.* $\quad$ Energy (in kWh) = Power (in kW) × time (in hr)

Hence, $\quad$ **1 kWh** = 1 kW × 1 hr

= (1000 W) × (60 × 60 s)

= 36,00,000 *J*.

= $\mathbf{3{\cdot}6 \times 10^6\ J}$

## Direct current (D.C.) and alternating current (A.C.)

In general, our main supply has A.C. nature while many of our appliances require D.C. to operte. Following are some of the differences between the two.

1. A.C. changes its magnitude and direction periodically while D.C. neither changes its direction nor the magnitude.
2. It is cheap as well as easy to convert A.C. into D.C. with the help of a rectifier but it is not economical to convert D.C. into A.C.
3. Production of A.C. is much more economical and convenient as compared to the production of D.C.
4. In A.C., voltage can be increased or decreased with the help of a transformer; but in D.C., this cannot be done.

**Example 13 :**

An electric current of 2 ampere flows through a conductor of resistance 5 ohm for 30 seconds. Find the heat energy produced.

**Solution :**

Since, energy = Power × Time $\Rightarrow E = P \times t$

Also, $P = VI \quad \Rightarrow \quad E = VIt$

Now, $V = RI \quad \Rightarrow \quad E = (RI)\ It = I^2Rt$

Given : $I = 2$ A, $R = 5$ ohm and $t = 30$ s

$\therefore$ **Heat energy produced (*H*)**

$= I^2Rt$

$= (2)^2 \times 5 \times 30$ J

= **600 J**

**Example 14 :**

An electric current of 6 ampere flows through a resistance of 12 ohm for 2 minutes.

Calculate :

(i) the heat energy produced

(ii) the electrical energy consumed

(iii) the power developed

**Solution :**

Given : $I = 6$ A, $R = 12$ ohm and $t = 2$ min. = 120 s

**(i) Heat energy produced**

$= I^2Rt$

$= (6)^2 \times 12 \times 120$ J

$=$ **51840 J**

**(ii) Electrical energy consumed**

= Heat energy produced

$=$ **51840 J**

**(iii) Power developed**

$$= \frac{\text{Electrical energy consumed}}{\text{Time taken}}$$

$$= \frac{51840}{120} \text{ Watt} = \mathbf{432\ W}$$

**Example 15 :**

An electrical appliance is rated as 400W-200V.

(i) What do you understand by this statement ?

(ii) How much current will flow through the appliance when in use ?

(iii) Calculate the resistance of the appliance.

**Solution :**

(i) An electrical appliance rated as 400W-200V means that when the appliance is connected to a 200 volt supply, it will consume a power of 400 watt, *i.e.*, it will consume 400 J of electrical energy in each second.

(ii) Since, power ($P$) = 400 W and potential difference ($V$) = 200 V.

$\therefore \quad P = VI$

$\Rightarrow \quad \mathbf{I} = \frac{P}{V} = \frac{400\text{ W}}{200\text{ V}} = \mathbf{2\ A}$

(iii) Since, $V = 200$ V and $I = 2$ A

$\therefore \quad V = RI$

$\Rightarrow \quad \mathbf{R} = \frac{V}{I} = \frac{200\text{ V}}{2\text{ A}}$

$=$ **100 ohm**

**Example 16 :**

An electrical appliance of power 1·5 kW is used for 4 hours each day. Find :

(i) the electrical energy consumed in kWh, each day.

(ii) the electrical energy consumed in 60 days.

(iii) the cost of electrical energy consumed in 60 days at the rate of ₹ 8.60 per kWh.

**Solution :**

Given : Power = 1·5 kW and time = 4 hr

**(i) Electrical energy consumed each day**

= Power × Time

= 1·5 kW × 4 hr

= **6 kWh**

**(ii) Electrical energy consumed in 60 days**

= 6 × 60 kWh

= **360 kWh**

**(iii) Cost of electrical energy consumed in 60 days**

= 360 × ₹ 8.60

= **₹ 3,096**

## RECAPITULATION

- On joining two charged conductors through a metallic wire, the excess electrons flow from the conductor with surplus of free electrons (negatively charged) to the conductor with deficit of free electrons (positively charged) till the concentration of electrons in both the conductors is same.
- The direction of current in a conductor is opposite to the direction of flow of electrons through it.
- The strength of current through a conductor is the rate of flow of charge through it.

  $\text{Current} = \frac{\text{Charge}}{\text{Time}}$ *i.e.* $I = \frac{Q}{t}$
- Electric potential is the condition which determines the direction of flow of electric charge from one body to another.
- Potential difference between two points is the work done in moving a unit positive charge from one point to another.
- Electric current is defined as the rate of flow of charge. It is measured in ampere.
- According to Ohm's law, physical conditions and temperature remaining the same, the potential difference across a conductor is directly proportional to the current flowing through it.
- The flow of current through a conductor is opposed by a characteristic property of the conductor known as its resistance.
- According to Ohm's law, potential difference = Current × resistance *i.e.* $V = IR$.
- According to Joule's law of heating effect of current, $H = I^2Rt$ where I is the current flowing through the conductor, R is its resistance and $t$ is the time during which the current flows through the conductor.
- Work done in an electric current = Electrical energy consumed = Power × time.
- Commercial unit of energy is kWh which is also called Board of Trade (B.O.T.) unit.

  And, 1 kWh = $3{\cdot}6 \times 10^6$ J.
- The electrical energy consumed in our houses, shops, factories, *etc.*, is measured in kWh.
- A positively charged body is said to be at positive potential and a negatively charged body is said to be at negative potential.
- (a) If one coulomb of charge flows through a conductor in one second, the current through the conductor is one ampere.

  (b) If one joule of work is done in flowing one coulomb positive charge through a conductor, then the potential difference across the terminals of the conductor is one volt.
- (a) An ammeter measures the current in a circuit and is connected in series.

  (b) A voltmeter measures the potential difference between any two points of a circuit and is connected in parallel.



## TEST YOURSELF

### A. Short Answer Questions

1. State whether the following statements are *true* or *false*. Rewrite the false statement correctly.
   (a) Flow of protons constitutes an electric current.
   (b) Resistance is the obstruction to the flow of current.
   (c) SI unit and commercial unit of electrical energy has no connection between them.
   (d) A fuse wire has a high melting point.
   (e) Overloading of electric current circuits can lead to short circuiting.
2. Fill in the blanks :
   (a) When a short-circuit takes place, the fuse wire ........................ and breaks the ....................
   (b) The electric meter in our house measure electrical energy in ................ or ................

(c) One kilowatt hour is equal to ................ Joules

(d) A fuse wire should have low ........................

3. Match the following :

| | |
|---|---|
| (a) Electric power | (i) volt |
| (b) Resistance | (ii) joule |
| (c) Current | (iii) coulomb |
| (d) Electrical energy | (iv) watt |
| (e) Electric charge | (v) ampere |
| (f) Potential difference | (vi) ohm. |

4. Tick the most appropriate answer :

(a) Electric current is the flow of

(i) protons (ii) electrons

(iii) neutrons (iv) none of these

(b) Current is measured in

(i) joules (ii) watts

(iii) volts (iv) amperes

(c) Potential difference is measured in

(i) joules (ii) volts

(iii) watts (iv) amperes

(d) The unit for resistance is

(i) amperes (ii) joules

(iii) volts (iv) ohms

(e) All wires used in electric circuits should be covered with

(i) a colouring material

(ii) a conducting material

(iii) an insulating material

(iv) none of these

(f) Electrical work done per unit time is

(i) electrical energy (ii) electric current

(iii) electrical circuit (iv) electrical power

(g) One kilowatt is equal to

(i) 100 watts (ii) 1000 watts

(iii) 10 watts (iv) none of these

(h) Fuse wire is an alloy of

(i) tin-lead (ii) copper-lead

(iii) tin-copper (iv) lead-silver

(i) A fuse wire should have

(i) A low melting point

(ii) High melting point

(iii) Very high melting point

(iv) None of these.

(j) A bulb of 100 watt means, it will consume electrical energy at the rate of

(i) 100 joules per second

(ii) 100 kJ per second

(iii) 1000 joules per second

(iv) 100 joules per minute.

5. Define the following :

(a) electric current (b) electric power

(c) electric rating (d) resistance

(e) potential difference (f) electrical circuits

(g) electrical energy

6. Answer the following :

(a) Name three sources of electricity.

(b) State the Ohm's law.

(c) State Joule's law of heating effect.

(d) Derive the relationship between joule and kWh.

(e) What happens to heat produced in a conductor if the time for which current flows is made half.

(f) Name four appliances based on heating effect of current.

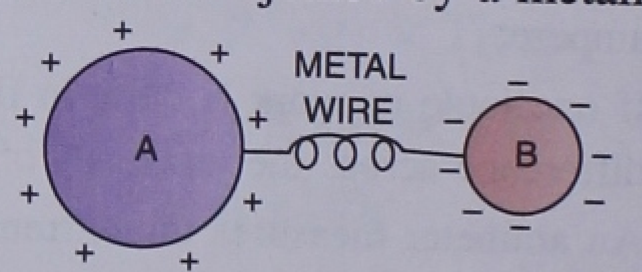
(g) How does a fuse work ?

(h) An electric bulb is marked as 220V-60W. What does it mean ?

(i) "The power of an electrical appliance is 500W". What do you understand by this statement ?

## B. Long Answer Questions

1. The following diagram shows two charged conductors A and B joined by a metallic wire.




If A is positively charged and B is negatively charged, state :

(a) the direction of flow of electrons.

(b) the direction of flow of electric current.

2. How can electric current be maintained through a conductor ?

3. What will be the direction of current when two charged conductors at different potentials are joined together by a metal wire ?

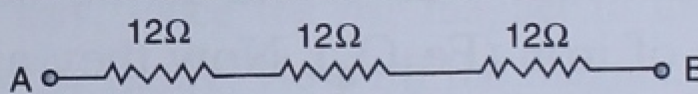
4. Define :

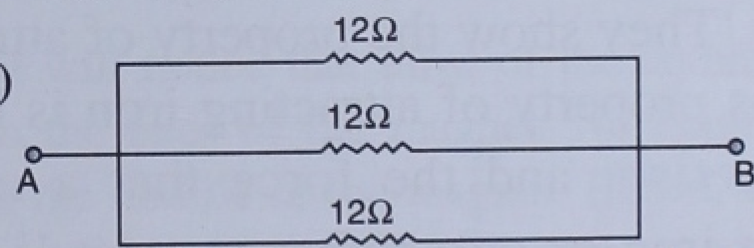
(a) Electric potential of a charged body.

(b) Potential difference between two points.

5. State and define the unit of :
   (a) current (b) potential difference
   (c) resistance (d) electric power
6. What do you understand by the resistance of a conductor ? State its cause. Also, name three factors on which the resistance of a conductor depends.
7. Two wires are made of same material. Which of the following will have greater resistance :
   (a) thick wire or thin wire.
   (b) long wire or short wire.
8. What do you understand by the heating effect of current ? Name three factors on which the heat produced in a conductor depends.

## C. Numerical Problems

1. If 8 coulomb charge flows through a conductor in 2 seconds, find the strength of electric current. **[4A]**
2. An electric current of 12 ampere flows through a conductor for 15 seconds. Find the amount of charge that flows. **[180 coulomb]**
3. During how much time must a charge of 30 coulomb flow through a conductor to constitute a current of 1·5 ampere ? **[20 s]**
4. 90 J of work is done in flowing 6 coulomb of positive charge between two points in an electric field. What is the potential difference between these two points ? **[15 V]**
5. How much work must be done in flowing 24 coulomb of positive charge between two points with potential difference of 6 volt ? **[144 J]**
6. If by the application of 100 volt of potential difference, 2·5 ampere of current flows through a conductor, find its resistance. **[40 ohm]**
7. A potential difference of 15 volt is applied across the terminals of a resistance of 6 ohm. Find the current through the resistance. **[2·5 A]**
8. Find the potential difference to be applied across a conductor of resistance 6·5 ohm so that a current of 3·2 ampere may flow through it. **[20·8 V]**
9. Find the total resistance when two resistances of 2 ohm and 3 ohm are connected in :
   (a) series (b) parallel
   **[(a) 5 ohm (b) 1·2 ohm]**
10. Find the equivalent resistance when three resistances of 4 ohm, 6 ohm and 12 ohm are connected in : (a) parallel (b) series
    **[(a) 2 ohm (b) 22 ohm]**
11. An electric current of 3 ampere flows through a conductor of 10 ohm resistance for 2 minutes. Calculate the heat energy produced. **[10800 J]**
12. An electric current of 1·5 ampere flows through a conductor of 16 ohm for 5 minutes. Calculate :
    (a) the heat energy produced
    (b) the electrical energy consumed
    (c) the power developed
    **[(a) 10800 J (b) 10800 J (c) 36 W]**
13. An electrical appliance is rated as 60W-150V.
    (a) What do you understand by this statement ?
    (b) How much current will flow through the appliance when in use ?
    (c) Calculate the resistance of the appliance.
    **[(b) 0·4 A (c) 375 ohm]**
14. In each of the following cases, find the total resistance between A and B.
    (a)


    (b)


    **[(a) 36 Ω (b) 4 Ω]**
15. An electric iron of power 1·5 kW is used for 30 minutes. Calculate the electrical energy consumed in :
    (a) kilowatt-hour
    (b) joule
    **[(a) 0·75 kWh (b) $2{\cdot}7 \times 10^6$ J]**



### PROJECT ACTIVITY

1. Visit an electrical repair shop and collect information on the different types of fuses and their uses.
2. Test the conduction of electricity through various fruits and vegetables. Display your result in tabular form.