



## Unit 14

# CURRENT ELECTRICITY

**After studying this unit, students will be able to:**

- define electric current.
- describe the concept of conventional current.
- understand the potential difference across a circuit component and name its unit .
- describe Ohm's law and its limitations.
- define resistance and its unit( $\Omega$ ).
- calculate the equivalent resistance of a number of resistances connected in series and also in parallel.
- describe the factors affecting the resistance of a metallic conductor.
- distinguish between conductors and insulators.
- sketch and interpret the  $V-I$  characteristics graph for a metallic conductor, a filament lamp and a thermistor.
- describe how energy is dissipated in a resistance and explain Joule's law.
- apply the equation  $E=I.Vt = I^2 Rt = V^2 t / R$  to solve numerical problem.
- calculate the cost of energy when given the cost per kWh.
- distinguish between D.C and A.C.
- identify circuit components such as switches, resistors, batteries etc.
- describe the use of electrical measuring devices like galvanometer, ammeter and voltmeter (construction and working principles not required).
- construct simple series (single path) and parallel circuits (multiple paths).
- predict the behaviour of light bulbs in series and parallel circuit such as for celebration lights.
- state the functions of the live, neutral and earthwires in the domestic main supply.
- state reason why domestic supplies are connected in parallel.
- describe hazards of electricity (damage insulation, overheating of cables, damp conditions).
- explain the use of safety measures in household electricity, (fuse, circuit breaker, earthwire).

### Science, Technology and Society Connections

**The students will be able to:**

- calculate the total cost of electrical energy used in one month (30 day) at home. suggest ways how it can be reduced without compromising the comforts and benefits of electricity.
- describe the damages of an electric shock from appliances on the human body.
- identify the use of fuses, circuit breakers, earthing, double insulation and other safety measures in relation to household electricity.

## CURRENT ELECTRICITY

Charges in motion constitute electric current. This chapter will introduce you to current electricity and related phenomena such as conventional current, Ohm's law, electric power, Joule's heating effect, hazards of electricity and safety measures. We will also learn how current or voltage is measured in a circuit by electrical devices.

### 14.1 ELECTRIC CURRENT

Most of the electric charge around us is bound in neutral atoms. It is not easy to overcome the electrostatic force of attraction between the nuclei and electrons in an atom. However, in metals some electrons are not tightly bound to nuclei and are free to move around randomly. They have weak force between them and the nucleus. Similarly, in solutions some positive and negative charges can freely move around randomly. When such free charges are exposed to an external electric field, they move in a specific direction, and thus constitute current.

Electric current is produced due to the flow of either positive charge or negative charge or both of charges at the same time. In metals, the current is produced only due to the flow of free electrons i.e., negative charges. In case of electrolyte its molecules in aqueous solution dissociate among positive and negative ions. So the current in electrolyte is produced due to the flow of both positive and negative charges.

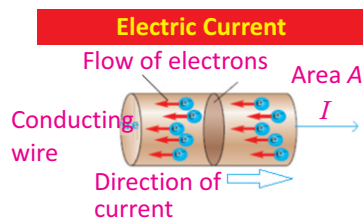
**The rate of flow of electric charge through any cross-sectional area is called current.**

*If the charge  $Q$  is passing through any area in time  $t$ , then current  $I$  flowing through it will be given by*

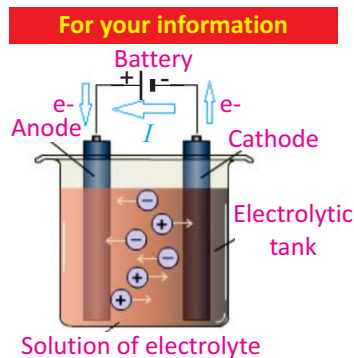
$$\text{Current} = \frac{\text{Charge}}{\text{Time}}$$

$$\text{or} \quad I = \frac{Q}{t} \quad \dots\dots\dots (14.1)$$

SI unit of current is ampere (A).



The current is the rate of flow of charge.



In electrolysis, current is produced due to flow of both positive and negative charges. In the electrolyte, positive ions are attracted to the cathode and negative ions are attracted to the anode. This movement of ions within the electrolyte constitutes an electric current within the internal circuit.

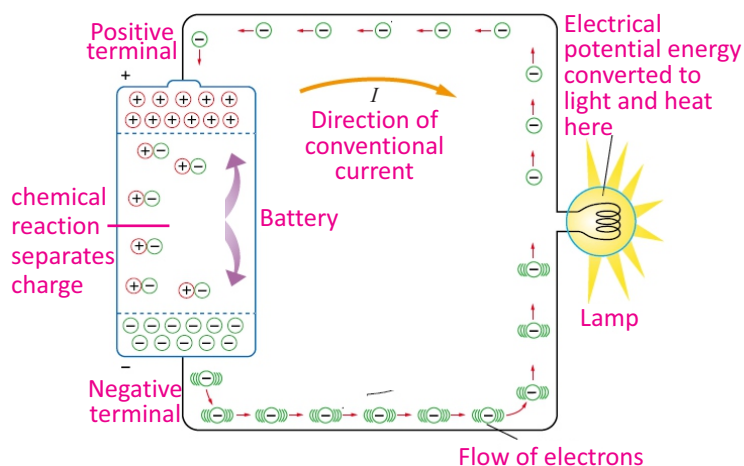
## CURRENT ELECTRICITY

If a charge of one coulomb passes through a cross-sectional area in one second, then current is one ampere. Smaller Units of current are milli ampere (mA), micro ampere ( $\mu\text{A}$ ), which are defined below as:

$$1 \text{ mA} = 10^{-3} \text{ A}$$

$$1 \mu\text{A} = 10^{-6} \text{ A}$$

Battery is one of the sources of current. The electrochemical reaction inside a battery separates positive and negative electric charges (Fig.14.1). This separation of charges sets up potential difference between the terminals of the battery. When we connect a conducting wire across the terminals of the battery, the charges can move from one terminal to the other due to the potential difference. The chemical energy of the battery changes to electrical potential energy. The electrical potential energy decreases as the charges move around the circuit. This electrical potential energy can be converted to other useful forms of energy (heat, light, sound etc.). It is only the energy which changes form but the number of charge carriers and the charge on each carrier always remains the same (i.e., charge carriers are not used up). Instead of electrical potential energy we use the term electric potential which is potential energy per unit charge.



**Fig.14.1:** Schematic diagram of battery as a current source

**Example 14.1:** If 0.5 C charge passes through a wire in 10 s, then what will be the value of current flowing through the wire?

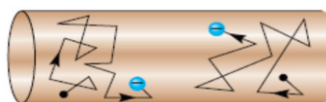
**Solution:** Given that,  $Q = 0.5 \text{ C}$ ,  $t = 10 \text{ s}$ , therefore by using

$$I = Q/t = 0.5 \text{ C}/10 \text{ s} = 0.05 \text{ A} = 50 \text{ mA}$$

### Quick Quiz

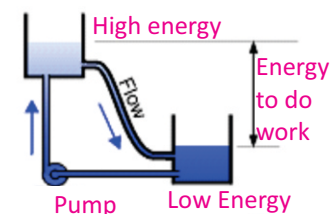
How long does it take a current of 10 mA to deliver 30 C of charge?

### Connection



In the absence of any external source no current passes through the conductor due to random motion of electrons.

### For your information



A battery raises electric charge back up to higher voltage (energy) just like a pump which pushes water back up to high energy so it can flow and do work again.

## CURRENT ELECTRICITY

### Conventional Current

Before the idea of free electrons which constitute current in metals, it was thought that current in conductors flows due to the motion of positive charges. Therefore, this convention is still in use. We can understand the concept of conventional current from the following analogies.

We know that when the ends of heated copper wire are at different temperatures, heat energy flows from the end at higher temperature to the end at lower temperature. The flow stops when both ends reach the same temperature. Water in a pipe also flows from higher level to the lower level. Similarly, when a conductor is connected to a battery, it pushes charges to flow current from higher potential to the lower potential (Fig. 14.2). The flow of current continues as long as there is a potential difference.

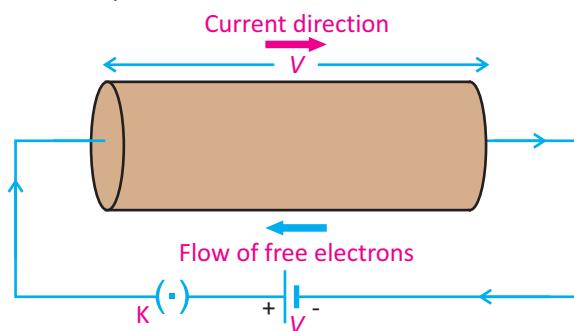


Fig. 14.2: Current flows in a conductor when it is connected to a battery

Conventional current is defined as:

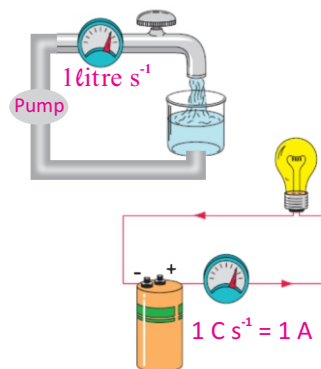
*Current flowing from positive to negative terminal of a battery due to the flow of positive charges is called conventional current*

Conventional current produces the same effect as the current flowing from negative terminal to the positive terminal due to the flow of negative charges.

### The Measurement of Current

How can we come to know that current has been established in the conductor? For this purpose, we use different electrical instruments which detect the current in the circuit. Galvanometer and ammeter are some common examples of current measuring instruments.

### Physics insight



The flow of charge in a circuit is like the flow of water in a pipe except that a return wire is needed in order to have a complete conducting path.

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Galvanometer is very sensitive instrument and can detect small current in a circuit (Fig.14.3). A current of few milliamperes is sufficient to cause full scale deflection in it. While making the connections polarity of the terminals of the galvanometer should be taken into consideration. Generally, the terminal of the galvanometer with red colour shows the positive polarity while that of with black colour shows the negative polarity. An ideal galvanometer should have very small resistance to pass the maximum current in the circuit.

After suitable modification galvanometer can be converted into an ammeter (Fig. 14.4). A large current of the range such as 1 A or 10 A can be measured by means of ammeter. Like galvanometer, ammeter is also connected in series, so the current flowing in the circuit also passes through the ammeter (Fig.14.5).

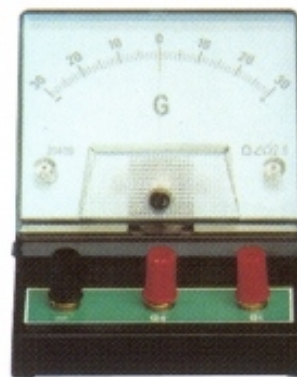


Fig.14.3: A galvanometer



Fig.14.4: An ammeter

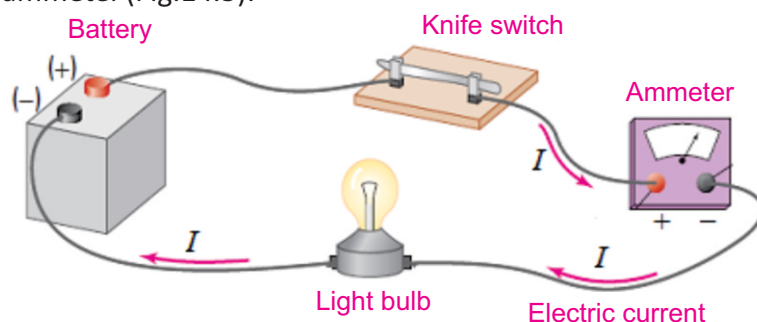


Fig.14.5: Schematic diagram showing the measurement of current

### 14.2 POTENTIAL DIFFERENCE

When one end A of a conductor is connected to the positive terminal and its other end B is connected to the negative terminal of the battery, then the potential at A becomes higher than the potential at B (Fig.14.6).

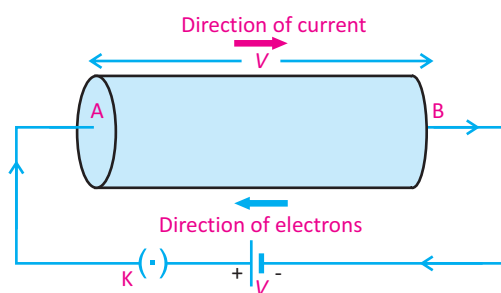


Fig.14.6

#### Do you know?

The galvanometer has been named after Luigi Galvano (1737-1798). He, while dissecting a frog's leg, discovered that dissimilar metals touching the leg caused it to twitch. This chance discovery, the invention of the chemical cell and the battery.

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This causes a potential difference between the two ends of the conductor. The flow of current continues as long as there is a potential difference. The agency which provides the potential difference for the steady flow of current in the copper wire is the battery. As the current flows from higher potential to the lower potential through the conductor, the electrical energy (due to current) is converted into other forms (heat and light etc.).

When current flows through the conductor, it experiences a resistance in the conductor by collisions with atoms of the conductor. The energy supplied by the battery is utilized in overcoming this resistance and is dissipated as heat and other forms of energy. The dissipation of this energy is accounted for by the potential difference across the two ends of the light bulb. Thus

***Potential difference across the two ends of a conductor causes the dissipation of electrical energy into other forms of energy as charges flow through the circuit.***

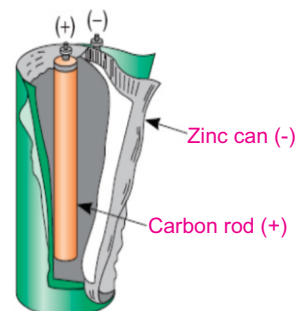
SI unit of potential difference is volt. A potential difference of 1 V across a bulb means that each coulomb of charge or 1 ampere of current that passes through the bulb consumes 1 joule of energy. When a bulb is lit, the energy is taken from the current and is transformed into light and heat energy.

### 14.3 ELECTROMOTIVE FORCE (e.m.f)

A source of electromotive force (e.m.f.) converts non-electrical energy (chemical, thermal, mechanical etc.) into electrical energy. Examples of sources of e.m.f. are batteries, thermocouples and generators. When a conductor is connected to a battery, current flows through it due to potential difference.

For the continuous flow of current through a wire, battery supplies energy to the charges. The positive charge leaves the positive terminal of the battery, passes through the conductor and reaches the negative terminal of the battery. As a positive charge enters the battery at its lower potential point (negative terminal), the battery must supply energy, say  $W$  to the positive charge to drive it to a point of higher

#### For your information



In a dry cell chemical energy changes into electric energy.

#### Do you know?

The volt is named after the Italian physicist Alessandro Volta (1745-1827), who developed the first practical electric battery, known as a voltaic pile. Because potential difference is measured in units of volts, it is sometimes referred to as voltage.



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potential i.e., positive terminal. Now we define e.m.f. of the source as:

*It is the energy supplied by a battery to a unit positive charge when it flows through the closed circuit. Or The energy converted from non-electrical forms to electrical form when one coulomb of positive charge passes through the battery.*

$$\text{Thus } e.m.f = \frac{\text{Energy}}{\text{Charge}}$$

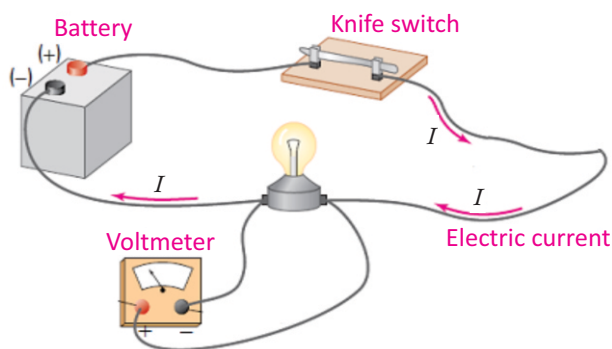
$$\text{or } E = \frac{W}{Q} \quad \dots\dots\dots (14.2)$$

where  $E$  is the e.m.f.,  $W$  is energy converted from non-electrical forms to electrical form and  $Q$  is positive charge.

The unit for e.m.f. is  $\text{JC}^{-1}$  which is equal to volt (V) in SI system. Hence, if the e.m.f. of the battery is 2 V, the total energy supplied by the battery is 2 joules when one coulomb of charge flows through the closed circuit.

### The Measurement of Potential Difference

The potential difference across a circuit component (e.g. light bulb) can be measured by a voltmeter (Fig. 14.7) connected directly across the terminals of the component. The positive terminal of the battery is connected to the positive terminal of the voltmeter and the negative terminal of the battery is connected to the negative terminal of the voltmeter.



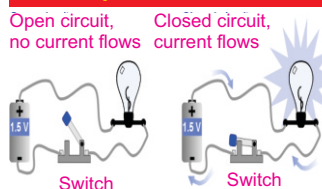
**Fig. 14.8:** Schematic diagram for measuring potential difference in a circuit

An ideal voltmeter should have very large value of resistance so that no current passes through it. Voltmeter is always connected in parallel with the device across which the potential difference is to be measured (Fig. 14.8).



**Fig.14.7:** A voltmeter

#### For your information



#### For your information



A digital multimeter can be used to measure current, resistance and potential difference. Here, the multimeter is in voltmeter mode to measure the potential difference across a battery.

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### The Measurement of e.m.f

In general, e.m.f refers to the potential difference across the terminals of the battery when it is not driving current in the external circuit. So in order to measure e.m.f of the battery we connect voltmeter directly with the terminals of the battery as shown in Fig. 14.9.

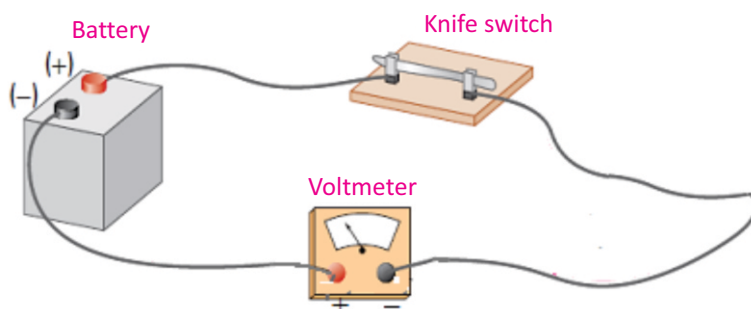


Fig. 14.9: Schematic diagram for measuring e.m.f. of the battery

## 14.4 OHM'S LAW

**Activity 14.1:** Take a nichrome wire of about 50 cm length and apply a potential difference of 1.5 V from a battery (Fig.14.10a). Measure the current flowing through the wire using an ammeter connected to it in series. Also measure the potential difference across the wire using a voltmeter connected across it. Obtain a set of readings for  $I$  and  $V$ , by increasing the number of cells. Plot a graph between  $I$  and  $V$ . This will be a straight line (Fig.14.10-b).

If  $V$  is the potential difference across the two ends of any conductor, then current  $I$  will flow through it. The value of the current changes with the changes in potential difference and is explained by Ohm's law, stated as:

*The amount of current passing through a conductor is directly proportional to the potential difference applied across its ends, provided the temperature and the physical state of the conductor does not change.*

$$\text{i.e., } I \propto V \text{ or } V \propto I \\ \text{or } V = IR$$

where  $R$  is the constant of proportionality, and is the resistance of the conductors. Its SI unit is ohm, denoted by a

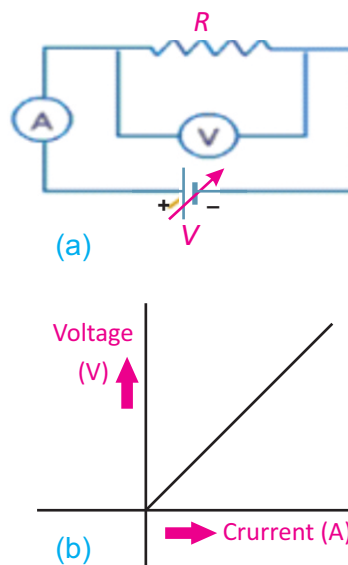


Fig. 14.10



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symbol  $\Omega$ . If a graph is plotted between the current  $I$  and the potential difference  $V$ , a straight line will be obtained.

**Resistance:** The property of a substance which offers opposition to the flow of current through it is called its resistance.

This opposition comes from the collisions of moving electrons with atoms of the substance.

### Unit of Resistance: ohm

The SI unit of resistance  $R$  is ohm. If we put  $V = 1 \text{ V}$ , and  $I = 1 \text{ A}$ , the value of  $R$  will be  $1 \Omega$ . Thus

*When a potential difference of one volt is applied across the ends of a conductor and one ampere of current passes through it, then its resistance will be one ohm.*

**Example 14.2:** Reading on voltmeter connected across a heating element is  $60 \text{ V}$ . The amount of current passing through the heating element measured by an ammeter is  $2 \text{ A}$ . What is the resistance of the heating coil of the element?

**Solution:** Given that,  $V = 60 \text{ V}$ ,  $I = 2 \text{ A}$

Using Ohm's law

$$V = IR$$

$$\text{or} \quad R = \frac{V}{I} = \frac{60 \text{ V}}{2 \text{ A}} = 30 \text{ V A}^{-1} = 30 \Omega$$

### 14.5 V-I Characteristics of Ohmic and Non Ohmic Conductors

Ohm's law is valid only for certain materials.

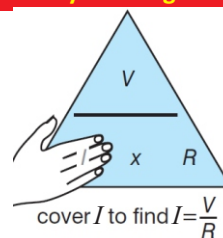
*Materials that obey Ohm's law, and hence have a constant resistance over a wide range of voltages, are said to be ohmic. Materials having resistance that changes with voltage or current are non-ohmic.*

Ohmic conductors have a linear voltage-current relationship over a large range of applied voltages (Fig. 14.11-a). The straight line shows a constant ratio between voltage and current. Ohm's law is obeyed. For example, most metals show ohmic behaviour.

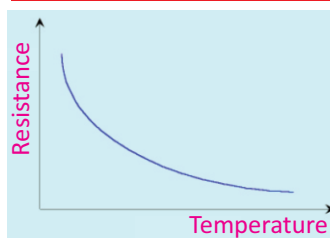
#### For your understanding

1. In order to measure current through a resistance, ammeter is always connected in series with the resistance.
2. In order to measure potential difference across a resistance, voltmeter is always connected in parallel with the resistance.

#### Physics Insights



#### For your information



A thermistor is a temperature dependent resistor and its resistance decreases as temperature rises. Thermistor is used in a circuit that senses temperature change.

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Non ohmic materials have a non linear voltage-current relationship. For example, filament lamp, and thermister. The resistance of filament rises (current decreases) as it gets hotter, which is shown by the gradient getting steeper (Fig.14.11-b). A thermister (a heat sensitive resistor) behaves in the opposite way. Its resistance decreases (current increases) as it gets hotter (Fig. 14.11-c). This is because on heating, more free electrons become available for conduction of current.

### 14.6 FACTORS AFFECTING RESISTANCE

A short pipe offers less resistance to water flow than a long pipe. Also the pipe with larger cross sectional area offers less resistance than the pipe having smaller cross sectional area. Same is the case for the resistance of wires that carry current. The resistance of a wire depends both on the cross sectional area and length of the wire and on the nature of the material of the wire. Thick wires have less resistance than thin wires. Longer wires have more resistance than short wires. Copper wire has less resistance than steel wire of the same size. Electrical resistance also depends on temperature.

At a certain temperature and for a particular substance

1. The resistance  $R$  of the wire is directly proportional to the length of the wire i.e.,

$$R \propto L \quad \text{..... (14.3)}$$

It means, if we double the length of the wire, its resistance will also be doubled, and if its length is halved, its resistance would become one half.

2. The resistance  $R$  of the wire is inversely proportional to the area of cross section  $A$  of the wire i.e.,

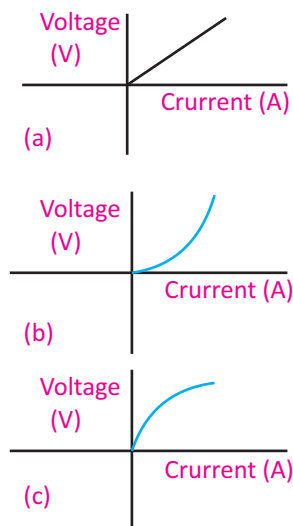
$$R \propto \frac{1}{A} \quad \text{..... (14.4)}$$

It means that a thick wire would have smaller resistance than a thin wire.

After combining the two equations, we get

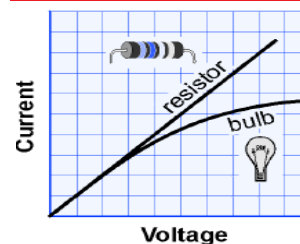
$$R \propto \frac{L}{A}$$

$$R = \rho \frac{L}{A} \quad \text{..... (14.5)}$$



**Fig.14.11:** Voltage vs current graph for  
(a) Fixed resistance  
(b) Filament lamp  
(c) Thermister

### Point to ponder!



The current versus voltage graph of a resistor is a straight line with a constant slope. The graph for light bulb is curved with a decreasing slope. What can you infer from this?

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where ' $\rho$ ' is the constant of proportionality, known as specific resistance. Its value depends upon the nature of conductor i.e., copper, iron, tin, and silver would each have a different values of ' $\rho$ '.

If we put  $L = 1$  m, and  $A = 1$  m<sup>2</sup> in Eq. (14.5), then  $R = \rho$ , i.e., the resistance of one metre cube of a substance is equal to its specific resistance. The unit of ' $\rho$ ' is ohm-metre ( $\Omega$  m).

**Example 14.3:** If the length of copper wire is 1 m and its diameter is 2 mm, then find the resistance of this copper wire.

**Solution:** Given that, length of the wire  $L = 1$  m, diameter of the wire  $d = 2$  mm  $= 2 \times 10^{-3}$  m

Cross sectional area of the wire

$$A = \pi d^2/4 = \frac{3.14 \times (2 \times 10^{-3})^2}{4} \text{ m}^2$$

$$A = 3.14 \times 10^{-6} \text{ m}^2$$

Specific resistance of copper  $\rho = 1.69 \times 10^{-8} \Omega \text{ m}$

Now we have  $R = \rho \times L/A = 1.69 \times 10^{-8} \Omega \text{ m} \times 1 \text{ m} / 3.14 \times 10^{-6} \text{ m}^2$

$$R = 0.54 \times 10^{-2} \Omega$$

### Interesting Information

Diamond does not conduct electricity, because it has no free electrons. However, it is very good at conducting heat because its particles are very firmly bonded together. Jewellers can tell if a diamond is a real diamond or a fake one made from glass, by holding it to their lips. A real diamond feels very cold due to good ability of transferring heat four or five times better than copper.

## 14.7 CONDUCTORS

Why do we always use metal wires for conduction of electricity? Because, they are good conductors of electricity and offer less resistance to the flow of current. But how can they conduct electricity with much ease? Metals like silver and copper have excess of free electrons which are not held strongly with any particular atom of metals. These free electrons move randomly in all directions inside metals. When we apply an external electric field these electrons can easily move in a specific direction. This movement of free electrons in a particular direction under the influence of an external field causes the flow of current in metal wires. The resistance of conductors increases with increase in temperature. This is due to increase in the number of collisions of electrons with themselves and with the atoms of the metals.

## 14.8 INSULATORS

All materials contain electrons. The electrons in insulators, like rubber, however, are not free to move. They are tightly

### For your information

Metal	Specific resistance ( $10^{-8} \Omega \text{ m}$ )
Silver	1.7
Copper	1.69
Aluminium	2.75
Tungsten	5.25
Platinum	10.6
Iron	9.8
Nichrome	100
Graphite	3500

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bound inside atoms. Hence, current cannot flow through an insulator because there are no free electrons for the flow of current. Insulators have very large value of resistance. Insulators can be easily charged by friction and the induced charge remains static on their surface. Other examples of insulators are glass, wood, plastic, fur, silk, etc.

### 14.9 COMBINATION OF RESISTORS

(i) Series combination (ii) Parallel combination

Resistors can be connected in two ways.

#### (i) Series Combination

In series combination, resistors are connected end to end (Fig. 14.12) and electric current has a single path through the circuit. This means that the current passing through each resistor is the same.

#### Equivalent Resistance of Series Circuit

The total voltage in a series circuit divides among the individual resistors so the sum of the voltage across the resistance of each individual resistor is equal to the total voltage supplied by the source. Thus, we can write as

$$V = V_1 + V_2 + V_3 \quad \dots\dots\dots (14.6)$$

where  $V$  is the voltage across the battery, and  $V_1, V_2, V_3$  are the voltages across resistors  $R_1, R_2$  and  $R_3$  respectively. If  $I$  is the current passing through each resistor, then from Ohm's law

$$\begin{aligned} V &= IR_1 + IR_2 + IR_3 \\ V &= I(R_1 + R_2 + R_3) \quad \dots\dots\dots (14.7) \end{aligned}$$

We can replace the combination of resistors with a single resistor called the equivalent resistance  $R_e$  such that the same current passes through the circuit. From Ohm's law

$$V = IR_e$$

Thus, Eq. (14.7) becomes

$$\begin{aligned} IR_e &= I(R_1 + R_2 + R_3) \\ R_e &= R_1 + R_2 + R_3 \quad \dots\dots\dots (14.8) \end{aligned}$$

Thus, the equivalent resistance of a series combination is equal to the sum of the individual resistances of the

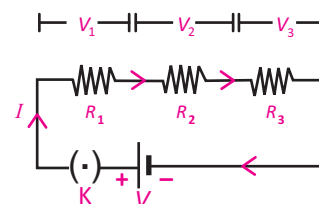


Fig.14.12: Three resistors in series combination

#### Do you know?

We use heating effect of an electric current for different purposes. For example, when a current flows through the filament of a bulb, it glows white hot and gives out light. Electric heaters have very thin wires that glow red hot when a current flows.

#### Quick Quiz

Which metal is used as the filament of an electric bulb? Explain with reason.

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combination.

If resistances  $R_1, R_2, R_3, \dots, R_n$  are connected in series, then the equivalent resistance of the combination will be given by

$$R_e = R_1 + R_2 + R_3 + \dots + R_n$$

**Example 14.4:** If two resistors of  $6 \text{ k}\Omega$  and  $4 \text{ k}\Omega$  are connected in series across a  $10 \text{ V}$  battery, then find the following quantities:

- Equivalent resistance of the series combination.
- The current flowing through each of the resistance.
- Potential difference across each of the resistances.

**Solution:** Given that,  $R_1 = 6 \text{ k}\Omega$  and  $R_2 = 4 \text{ k}\Omega$

(a) The equivalent resistance of the series combination is  $R_e = R_1 + R_2$

$$\text{or } R_e = 6 \text{ k}\Omega + 4 \text{ k}\Omega = 10 \text{ k}\Omega$$

(b) If a battery of  $10 \text{ V}$  is connected across the equivalent resistance  $R_e$ , the current passing through it is given by

$$I = \frac{V}{R_e} = \frac{10 \text{ V}}{10 \text{ k}\Omega} = 1.0 \times 10^{-3} \text{ A} = 1 \text{ mA}$$

In the case of series combination same current would pass through each resistance. Hence, current through  $R_1$  and  $R_2$  would be equal to  $1 \text{ mA}$ .

(c) Potential difference across  $R_1 = V_1 = IR = 1.0 \times 10^{-3} \text{ A} \times 6 \text{ k}\Omega = 6 \text{ V}$

Potential difference across  $R_2 = V_2 = IR_2 = 1.0 \times 10^{-3} \text{ A} \times 4 \text{ k}\Omega = 4 \text{ V}$

### (ii) Parallel Combination

In parallel combination one end of each resistor is connected with positive terminal of the battery while the other end of each resistor is connected with the negative terminal of the battery (Fig.14.13). Therefore, the voltage is same across each resistor which is equal to the voltage of the battery i.e.,

$$V = V_1 = V_2 = V_3$$

### Equivalent Resistance of Parallel Circuit

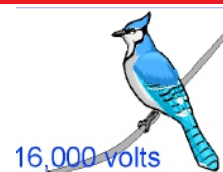
In parallel circuit, the total current is equal the sum of the currents in various resistances i.e.,

$$I = I_1 + I_2 + I_3 \quad \dots \dots \dots (14.9)$$

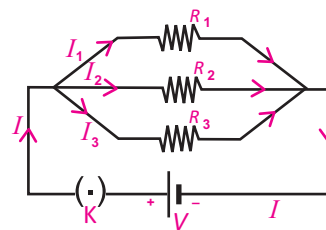
Since the voltage across each resistance is  $V$ , so by Ohm's law

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2} \text{ and } I_3 = \frac{V}{R_3}$$

### Point to ponder!



A bird can sit harmlessly on high tension wire. But it must not reach and grab neighboring wire. Do you know why?



**Fig 14.13:** Three resistors in parallel combination

## CURRENT ELECTRICITY

Thus, Eq.14.9 becomes

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$I = V \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) \quad \text{..... (14.10)}$$

We can replace the combination of resistors with a single resistor called the equivalent resistance  $R_e$  such that the same current passes through the circuit. From Ohm's law  $I = V/R_e$ . Thus, Eq. 14.10 becomes

$$\frac{V}{R_e} = V \left[ \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right]$$

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \text{..... (14.11)}$$

Thus, the reciprocal of equivalent resistance of a parallel combination is sum of the reciprocals of the individual resistances, which is less than the smallest resistance of the combination. If resistances  $R_1, R_2, R_3, \dots, R_n$  are connected in parallel, then the equivalent resistance of the combination will be given by

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

Parallel circuits have two big advantages over series circuits.

1. Each device in the circuit receives the full battery voltage.
2. Each device in the circuit may be turned off independently without stopping the current flowing to the other devices in the circuit. This principle is used in household wiring.

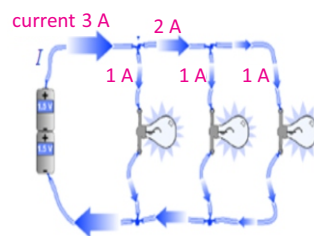
**Example 14.5:** If in the circuit (Fig. 14.13),  $R_1 = 2 \, \Omega$ ,  $R_2 = 3 \, \Omega$ ,  $R_3 = 6 \, \Omega$ , and  $V = 6 \, \text{V}$ , then find the following quantities:

- (a) equivalent resistance of the circuit.
- (b) current passing through each resistance.
- (c) The total current of the circuit.

**Solution:** (a) As the resistors are connected in parallel, equivalent resistance  $R_e$  of the combination is given by

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

### For your information



In parallel circuit current divides into branches.

### For your information

A circuit diagram is a symbolic method of describing a real circuit. The electric symbols used in circuit diagrams are standard, so anyone familiar with electricity can interpret a circuit diagram.



## CURRENT ELECTRICITY

$$\frac{1}{R_e} = \frac{1}{2\Omega} + \frac{1}{3\Omega} + \frac{1}{6\Omega} = \left[ \frac{1}{2} + \frac{1}{3} + \frac{1}{6} \right] \times \frac{1}{\Omega}$$

$$\frac{1}{R_e} = \frac{6}{6\Omega}$$

or  $R_e = 1\Omega$

This value is smaller than the lowest value of the resistance in the combination which is always the case in parallel circuits.

**(b)** In parallel combination, the potential difference across each of the resistance is same and is equal to the potential of the battery, which is 6 V. Therefore,

Current through  $R_1$  is  $I_1 = \frac{V}{R_1} = \frac{6\text{ V}}{2\Omega} = 3\text{ A}$

Current through  $R_2$  is  $I_2 = \frac{V}{R_2} = \frac{6\text{ V}}{3\Omega} = 2\text{ A}$

Current through  $R_3$  is  $I_3 = \frac{V}{R_3} = \frac{6\text{ V}}{6\Omega} = 1\text{ A}$

**(c)** Sum of the currents passing through the resistances in parallel combination is equal to the total current  $I$  of the circuit. Therefore, total current is 6 A.

**Activity 14.2:** Connect a battery to a small 2.5 V light bulb and observe the brightness of the bulb. Connect a second light bulb in parallel with the first and observe the brightness of the bulbs. Now add a third bulb in parallel with the others and note the brightness of the bulbs. Does the brightness of the bulbs differs from the bulbs connected in the series with the battery? Explain.

### 14.10 ELECTRICAL ENERGY AND JOULE'S LAW

Turbine runs generator to produce electrical energy when water falls on it from higher gravitational potential to lower gravitational potential. Similarly, when charge moves from a higher electric potential to a lower potential, it delivers electric current. Thus, the process during which charges continuously move from a higher potential to a lower

#### For your information

If the values of all the resistors in a parallel circuit are the same, the overall resistance can be determined by

$$\frac{1}{R_e} = \frac{N}{R}$$

i.e.,  $R_e = \frac{R}{N}$

where  $N$  is the total number of resistors and  $R$  is the resistance of each individual resistor.

#### For your information

##### Typical power ratings

Appliance	Power (watts)
Electric stove	5,000
Electric heater	1,500
Hair dryer	1,000
Iron	800
Washing machine	750
Light bulb	100
Small fan	50
Clock radio	10

## CURRENT ELECTRICITY

potential, becomes a continuous source of electrical energy.

Consider two points with a potential difference of  $V$  volts. If one coulomb of charge passes between these points; the amount of energy delivered by the charge would be  $V$  joule. Hence, when  $Q$  coulomb of charge flows between these two points, then we will get  $QV$  joules of energy. If we represent this energy by  $W$ , then

Electrical energy supplied by  $Q$  charge  $W = QV$  joules

Now current, when charges  $Q$  flow in time  $t$ , is defined as:

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

$$\text{or } Q = It$$

So the energy supplied by  $Q$  charge in  $t$  seconds  $= W = V \times I \times t$

This electrical energy can be converted into heat and other forms in the circuit.

From Ohm's law, we have  $V = IR$

So the energy supplied by  $Q$  charge is  $W = I^2 R t = \frac{V^2 t}{R}$

This equation is called Joule's law, stated as:

*The amount of heat generated in a resistance due to flow of charges is equal to the product of square of current  $I$ , resistance  $R$  and the time duration  $t$ .*

This energy can be utilized for different useful purposes. For example, bulb converts this energy into light and heat, heater and iron into heat, and fans into mechanical energy. Usually, this energy appears as heat in the resistance. This is the reason that we get heat when current passes through a heater.

**Example 14.6:** If a current of  $0.5$  A passes through a bulb connected across a battery of  $6$  V for  $20$  seconds, then find the rate of energy transferred to the bulb. Also find the resistance of the bulb.

**Solution:** Given that,  $I = 0.5$  A,  $V = 6$  V,  $t = 20$  s

Now using the formula,

Energy  $W = VIt$

we get, Energy  $= 6$  V  $\times$   $0.5$  A  $\times$   $20$  s  $= 60$  J

So the rate of energy transferred must be  $60$  J in  $20$  s or  $3$  J s<sup>-1</sup> or  $3$  watt.

### For your information

Energy-saver light bulbs transform much more of the electrical energy into light and much less into wasted heat energy. An energy-saver light bulb that uses  $11$  J of electrical energy each second gives the same amount of light as an "ordinary" incandescent bulb that uses  $60$  J of electrical energy each second.

### For Your Understanding

All electrical appliances have power rating, given in watts or kilowatts. An appliance with a power rating of  $1$  W transfers  $1$  joule of electrical energy each second. So a  $60$  W light bulb converts  $60$  J of electrical energy each second into light energy and heat energy. To find out the total energy an appliance transfers from the mains, we need to know the number of joules transferred each second and the number of seconds for which the appliance is ON.

## CURRENT ELECTRICITY

Now using, Energy =  $W = I^2 R t$

We get resistance as

$$3 = (0.5)^2 \times R \times 20$$

$$R = 3 \times 1/20 \times 1/0.25 = 3/5 = 0.6 \Omega$$

### 14.11 ELECTRIC POWER

*The amount of energy supplied by current in unit time is known as electric power.*

Hence power  $P$  can be determined by the formula

$$\text{Electric power } P = \text{electrical energy/time} = W/t$$

where  $W$  is the electrical energy given by

$$W = QV$$

Therefore, above equation becomes

$$\text{Electric power } P = \frac{QV}{t} = IV = I^2 R$$

When current  $I$  is passing through a resistor  $R$ , the electric power that generates heat in the resistance is given by  $I^2 R$ . The unit of electric power is watt which is equal to one joule per second ( $1 \text{ Js}^{-1}$ ). It is represented by the symbol  $W$ . Electric bulbs commonly used in houses consume 25 W, 40 W, 60 W, 75 W and 100 W of electric power.

**Example 14.7:** The resistance of an electric bulb is  $500 \Omega$ . Find the power consumed by the bulb when a potential difference of 250 V is applied across its ends.

**Solution:** Given that,  $R = 500 \Omega$ ,  $V = 250 \text{ V}$

Using the formula,  $I = V/R$

$$I = 250 \text{ V} / 500 \Omega = 0.5 \text{ A}$$

$$\text{and Power } P = I^2 R = (0.5 \text{ A})^2 \times 500 \Omega = 125 \text{ W}$$

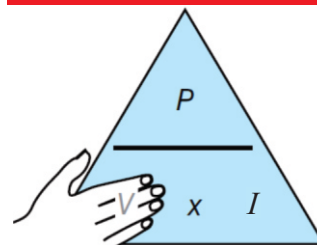
### Kilowatt-Hour

Electric energy is commonly consumed in very large quantity for the measurement of which joule is a very small unit. Hence, a very large unit of electric energy is needed which is called kilowatt-hour. It is defined as

#### Electrical grounding

The Earth is a fairly good electrical conductor. Hence, if a charged object is connected with the Earth by a piece of metal, the charge is conducted away from the object to the Earth. This convenient method of removing the charge from an object is called **grounding** the object. As a safety measure, the metal shells of electrical appliances are grounded through special wires that give electric charges in the shells paths to the Earth. The round post in the familiar three-prong electric plug is the ground connection.

#### Remembering power formula



$$\text{cover } V \text{ to find } V = \frac{P}{I}$$

#### Do you know?

Although the light intensity from a 60 W incandescent light bulb appears to be constant, the current in the bulb fluctuates 50 times each second between  $-0.71 \text{ A}$  and  $0.71 \text{ A}$ . The light appears to be steady because the fluctuations are too rapid for our eyes to perceive.

## CURRENT ELECTRICITY

*The amount of energy delivered by a power of one kilowatt in one hour is called kilowatt-hour.*

$$\begin{aligned}\text{One kilowatt-hour } 1 \text{ kWh} &= 1000 \text{ W} \times 1 \text{ hour} \\ &= 1000 \text{ W} \times (3600 \text{ s}) \\ &= 36 \times 10^5 \text{ J} = 3.6 \text{ MJ}\end{aligned}$$

The energy in kilowatt-hour can be obtained by the following formula:

The amount of energy in kilowatt-hour

$$= \frac{\text{watt} \times \text{time of use in hours}}{1000}$$

The electric meter installed in our houses measures the consumption of electric energy in the units of kilowatt-hour according to which we pay our electricity bills. If the cost of one kilowatt-hour i.e., one unit is known, we can calculate the amount of electricity bill by the following formula:

Cost of electricity = number of units consumed  $\times$  cost of one unit

$$= \frac{\text{watt} \times \text{time of use in hours}}{1000} \times \text{cost of one unit}$$

**Example 14.8:** Calculate the one month cost of using 50 W energy saver for 8 hours daily in your study room. Assume that the price of a unit is Rs. 12.

**Solution:** Given that, Power = 50 W = 0.05 kW, time = 8 hours

Number of units consumed =  $8 \times 30 \times 0.05 = 12$  units

Therefore, total cost =  $12 \times 12 = \text{Rs. } 144$

### 14.12 DIRECT CURRENT AND ALTERNATING CURRENT

The current derived from a cell or a battery is direct current (d.c.) - since it is unidirectional. The positive and negative terminals of d.c sources have fixed polarity, therefore, level of d.c remains constant with time (Fig.14.14). On the contrary, there is also a current which changes its polarity again and again.

Such a current that changes direction after equal intervals of time is called alternating current or a.c (Fig.14.15). This type of current is produced by AC generators.

#### Self Assessment

A light bulb is switched on for 40 s. If the electrical energy consumed by the bulb during this time is 2400 J, find the power of the bulb.

#### Remember

- To work out the energy transferred, the time must be in seconds and the power in watts.
- To work out the cost, the power must be in kilowatts and the time must be in hours.

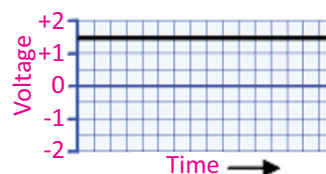


Fig.14.14: variation of voltage with time.

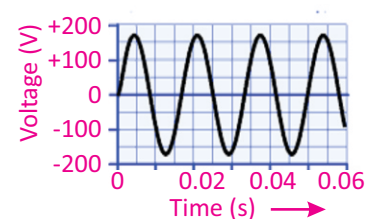


Fig. 14.15: Variation of voltage with time.

## CURRENT ELECTRICITY

*The time interval after which the a.c voltage or current repeats its value is known as its time period.*

The change in the values of voltage and current corresponds to the frequency of the source. In Pakistan, alternating current oscillates 50 times every second. Thus, its frequency is 50 Hz. Alternating current has advantages that make it more practical for use in transferring electrical energy. For this reason, the current supplied to our homes by power companies is alternating current rather than direct current.

### Supply to a House

The electric power enters our house through three wires. One is called **earthwire or ground wire (E)**. This carries no electricity. The earthwire is connected to a large metal plate buried deep in the ground near the house. The other wire is maintained at zero potential by connecting it to the Earth at the power station itself and is called **neutral wire (N)**. This wire provides the return path for the current. The third wire is at a high potential and is called **livewire (L)**. The potential difference between the livewire and the neutral wire is 220V.

Our body is a good conductor of electricity through which current can easily pass. Therefore, if a person holds livewire, current will start flowing to the ground while passing through his body which may prove fatal for the person. All electrical appliances are connected across the neutral and the livewires. The same potential difference is therefore applied to all of them and hence these are connected in parallel to the power source.

### House Wiring

Figure 14.16 shows the system of house wiring. The wires coming from the mains are connected to electricity meter installed in the house. The output power from the electric meter is taken to the main distribution board and then to the domestic electric circuit.

The main box contains fuses of rating about 30 A. A

#### Colour coding

Livewire (L): Red or brown  
Neutral wire (N): Black or blue  
Earthwire (E): Green/yellow

Effect of electric currents on the body	
Current	Effect
0.001 A	Can be felt
0.005 A	Is painful
0.010 A	Causes involuntary muscle contractions (spasms)
0.015 A	Causes loss of muscle control
0.070 A	Goes through the heart; causes serious disruption; probably fatal if current lasts for more than 1 s.

## CURRENT ELECTRICITY

separate connection is taken from the livewire of each appliance. The terminal of the appliance is connected to the livewire through a separate fuse and a switch. If the fuse of one appliance burns out, it does not affect the other appliances.

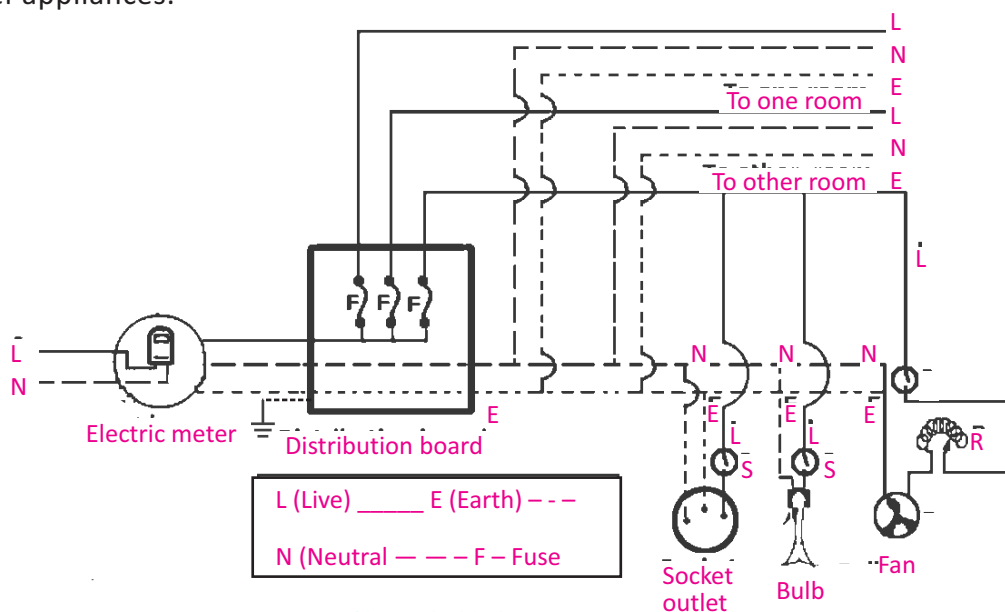


Fig.14.16: Wiring system of household electricity

In house wiring, all appliances are connected in parallel with each other. This means they all get the full mains voltage and one can turn ON any appliance without having to turn ON another.

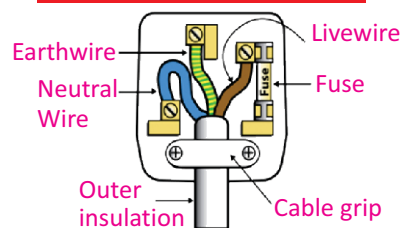
### 14.13 HAZARDS OF ELECTRICITY

While electricity has become part and parcel of our lives, care should be taken to save ourselves from its hazardous effects. Voltage of 50 V and current of 50 mA can be fatal. Major dangers of electricity are electric shock and fire. Here we discuss some faults in electrical circuits that may cause electricity hazards.

#### Insulation Damage

All electrical wires are well insulated with some plastic cover for the purpose of safety. But when electrical current exceeds the rated current carrying capacity of the conductor, it can produce excess current that can damage insulation due to overheating of cables. This results into a short circuit which

#### For your information



This is the correct way of wiring of a three pin main plug. Put everything in proper place. Fuse is placed for safety purpose. In case of excess current, it will burn out and will break the circuit.



## CURRENT ELECTRICITY

can severely damage electrical devices or persons.

A short circuit occurs when a circuit with a very low resistance is formed. The low resistance causes the current to be very large. When appliances are connected in parallel, each additional appliance placed in circuit reduces the equivalent resistance in the circuit and increases the current through the wires. This additional current might produce enough thermal energy to melt the wiring's insulation which causes a short circuit, or even starts a fire.

Short circuit can also occur when the livewire and the neutral wires come in direct contact (Fig.14.17).

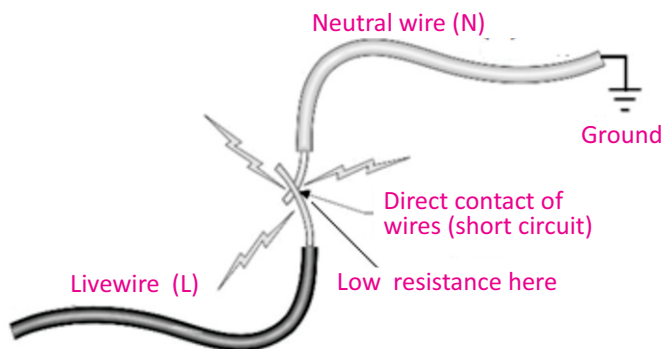


Fig. 14.17: Short circuit

In order to avoid such situations, the wires carrying electricity should never be naked. Rather they should be covered with good insulator. Such an insulation covered wire is called cable. Constant friction may also remove the insulation from the wire whereas too much moisture also damages the insulation. In such a situation, it is advisable to use a cable with two layers of insulation.

### Damp Conditions

Dry human skin has a resistance of 100, 000 ohms or more! But under damp conditions (wet environment) resistance of human skin is reduced drastically to few hundred ohms. Therefore, never operate any electrical appliance with wet hands. Also keep switches, plugs, sockets and wires dry.

### Precautionary Symbols



Do not expose to water



Do not use electrical equipment near inflammable materials

### For your information



Do not fly kites near electricity lines. It may cause some fatal accident.

### 14.14 SAFE USE OF ELECTRICITY IN HOMES

In order to protect persons, devices and property from the hazards of electricity there is a need of extensive safety measures in household electricity. Take much care to use fuses and circuit breakers in an electric circuit as safety devices. They prevent circuit overloads that can occur when too many appliances are turned ON at the same time or when a short circuit occurs in one appliance.

#### Fuse

A fuse is a safety device that is connected in series with the livewire in the circuit to protect the equipments when excess current flows. It is short and thin piece of metal wire that melts when large current passes through it. If a large, unsafe current passes through the circuit, the fuse melts and breaks the circuit before the wires become very hot and cause fire.

Fuses are normally rated as 5 A, 10 A, 13 A, 30 A, etc. Different types of fuses are shown in Fig.14.18.

Following safety measures should be taken while using fuses in household electrical circuits:

- (i) Fuses to be used should have slightly more rating than the current which the electrical appliance will draw under normal conditions. For example, for a lightning circuit choose a 5 A fuse as the current drawn by each lamp is very small (about 0.4 A for a 100 W lamp). In such circuit, 10 lamps of 100 W can be safely used as the total current drawn is only 4 A which can be calculated using the formula  $P = VI$ .

Identifying Circuit Components	
Wires crossed not joined	
Wires crossed at a junction	
Variable resistor	
Fixed resistor	
Diode	
Earth or ground	
Battery or DC supply	
Capacitor	
Time-varying or AC supply	
Ammeter	
Voltmeter	
Ohmmeter	
Thermistor or temperature-dependent resistor	
Switch	
Lamp/bulb	



Fig. 14 .18: Different types of fuses

## CURRENT ELECTRICITY

- (ii) Fuses should be connected in the livewire so that the appliance will not operate after the fuse has blown.
- (iii) Switch OFF the main before changing any fuse.

### Circuit Breaker

The circuit breaker (Fig. 14.19) acts as a safety device in the same way as a fuse. It disconnects the supply automatically if current exceeds the normal value. When the normal current passes through the livewire the electromagnet is not strong enough to separate the contacts. If something goes wrong with the appliance and large current flows through the livewire, the electromagnet will attract the iron strip to separate the contacts and break the circuit (Fig. 14.20). The spring then keeps the contacts apart. After the fault is repaired, the contacts can then be pushed back together by pressing a button on the outside of the circuit breaker box.



Fig. 14.19: Circuit Breaker

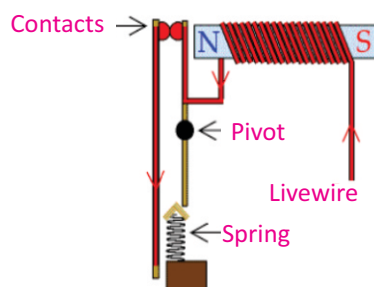


Fig. 14.20: Working principle of circuit breaker

### Earthwire

Sometimes, even the fuse cannot capture the high currents coming from the livewire into the household appliance. Earthing further protects the user from electric shock by connecting the metal casing of the appliance to Earth (a wired connection to the bare ground). Many electrical appliances have metal cases, including cookers, washing machines and refrigerators. The Earthwire provides a safe route for the current to flow through, if the livewire touches the casing (Fig.14.21). We will get an electric shock if the livewire inside an appliance comes loose and touches the metal casing.

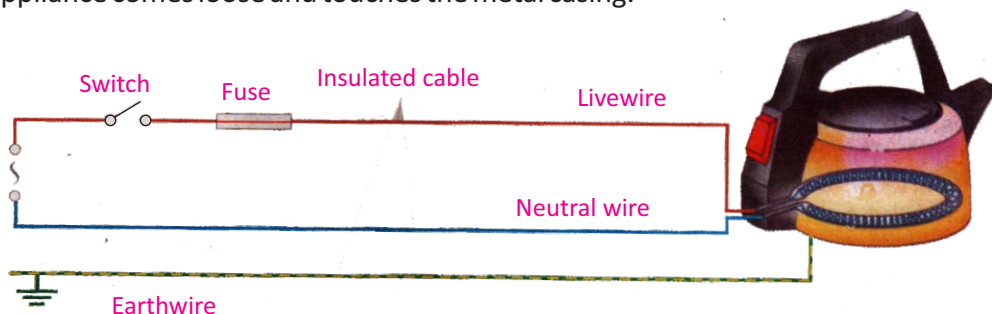


Fig. 14.21

## CURRENT ELECTRICITY

However, the earth terminal is connected to the metal casing, so the current goes through the Earthwire instead of passing through our body and causing an electric shock. A strong current passes through the Earthwire because it has a very low resistance. This breaks the fuse and disconnects the appliance.

### SUMMARY

- The time rate of flow of electric charge through any cross section is called electric current.
- The current due to flow of positive charge which is equivalent to current due to flow of negative charge in opposite direction is known as conventional current.
- Ampere is the SI unit of current.
- e.m.f. is the total amount of energy supplied by the battery or the cell in moving a one coulomb of positive charge from the -ve to the +ve terminal of the battery.
- Ohm's law states that the current  $I$  passing through a conductor is directly proportional to the potential difference  $V$  applied across its ends provided the temperature and physical state of the conductor do not change.
- Resistance  $R$  is a measure of opposition to the flow of current through a conductor. Its SI unit is ohm. It is denoted by the symbol  $\Omega$ . When a potential difference of one volt is applied across the ends of a conductor and one ampere of current passes through it, then its resistance will be one ohm.
- Materials in which electrons can freely move so as to pass electricity are called conductors while in insulators no free electrons are available for the conduction of electricity.
- The equivalent resistance  $R_e$  of a series combination of ' $n$ ' resistances is given by

$$R_e = R_1 + R_2 + R_3 + \dots + R_n$$

- The equivalent resistance  $R_e$  of a parallel combination of ' $n$ ' resistances is given by

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

- Galvanometer is a sensitive instrument which detects current in a circuit. It is always connected in series with the circuit.
- Ammeter is an electrical instrument which measures larger current. It is always connected in series in a circuit.
- Voltmeter is an electrical instrument used to measure potential difference between two points in a circuit. It is always connected parallel to a circuit component.

## CURRENT ELECTRICITY

- The amount of heat energy generated in a resistance due to flow of electric current is equal to the product of the square of current, resistance and the time interval ( $W = I^2 R t$ ). This is called Joule's law.
- kilowatt-hour is the amount of energy obtained from a source of one kilowatt in one hour. It is equal to 3.6 mega joule.
- The current which does not change its direction of flow is known as direct current or d.c.
- The current which changes its direction of flow after regular intervals of time is known as alternating current or a.c.

### MULTIPLE CHOICE QUESTIONS

Choose the correct answer from the following choices:

- An electric current in conductors is due to the flow of
  - positive ions
  - negative ions
  - positive charges
  - free electrons
- What is the voltage across a  $6\ \Omega$  resistor when 3 A of current passes through it?
  - 2 V
  - 9 V
  - 18 V
  - 36 V
- What happens to the intensity or the brightness of the lamps connected in series as more and more lamps are added?
  - increases
  - decreases
  - remains the same
  - cannot be predicted
- Why should household appliances be connected in parallel with the voltage source?
  - to increase the resistance of the circuit
  - to decrease the resistance of the circuit
  - to provide each appliance the same voltage as the power source
  - to provide each appliance the same current as the power source
- Electric potential and e.m.f
  - are the same terms
  - are the different terms
  - have different units
  - both (b) and (c)
- When we double the voltage in a simple electric circuit, we double the
  - current
  - power
  - resistance
  - both (a) and (b)
- If we double both the current and the voltage in a circuit while keeping its resistance constant, the power
  - remains unchanged
  - halves
  - doubles
  - quadruples

## CURRENT ELECTRICITY

- viii. What is the power rating of a lamp connected to a 12 V source when it carries 2.5 A?
- |           |            |
|-----------|------------|
| (a) 4.8 W | (b) 14.5 W |
| (c) 30 W  | (d) 60 W   |
- ix. The combined resistance of two identical resistors, connected in series is  $8\ \Omega$ . Their combined resistance in a parallel arrangement will be
- |                 |                  |
|-----------------|------------------|
| (a) $2\ \Omega$ | (b) $4\ \Omega$  |
| (c) $8\ \Omega$ | (d) $12\ \Omega$ |

### REVIEW QUESTIONS

- 14.1. Define and explain the term electric current.
- 14.2. What is the difference between electronic current and conventional current?
- 14.3. What do we mean by the term e.m.f.? Is it really a force? Explain.
- 14.4. How can we differentiate between e.m.f. and potential difference?
- 14.5. Explain Ohm's law. What are its limitations?
- 14.6. Define resistance and its units.
- 14.7. What is the difference between conductors and insulators?
- 14.8. Explain the energy dissipation in a resistance. What is Joule's law?
- 14.9. What is difference between D.C and A.C?
- 14.10. Discuss the main features of parallel combination of resistors.
- 14.11. Determine the equivalent resistance of series combination of resistors.
- 14.12. Describe briefly the hazards of household electricity.
- 14.13. Describe four safety measures that should be taken in connection with the household circuit.
- 14.14. Design a circuit diagram for a study room that needs the following equipments in parallel:
- |     |  |
|-----|--|
| (a) | One 100 W lamp operated by one switch.   |
| (b) | One reading lamp fitted with a 40 W bulb which can be switched ON and OFF from two points. |
| (c) | What is the advantage of connecting the equipments in parallel instead of series?          |

### CONCEPTUAL QUESTIONS

- 14.1. Why in conductors charge is transferred by free electrons rather than by positive charges?
- 14.2. What is the difference between a cell and a battery?
- 14.3. Can current flow in a circuit without potential difference?
- 14.4. Two points on an object are at different electric potentials. Does charge necessarily flow between them?
- 14.5. In order to measure current in a circuit why ammeter is always connected in series?
- 14.6. In order to measure voltage in a circuit voltmeter is always connected in parallel. Discuss.



## CURRENT ELECTRICITY

- 14.7. How many watt-hours are there in 1000 joules?
- 14.8. From your experience in watching cars on the roads at night, are automobile headlamps connected in series or in parallel.
- 14.9. A certain flash-light can use a 10 ohm bulb or a 5 ohm bulb. Which bulb should be used to get the brighter light? Which bulb will discharge the battery first?
- 14.10. It is impracticable to connect an electric bulb and an electric heater in series. Why?
- 14.11. Does a fuse in a circuit control the potential difference or the current?

### NUMERICAL PROBLEMS

- 14.1. A current of 3 mA is flowing through a wire for 1 minute. What is the charge flowing through the wire? **Ans. (180  $\times 10^{-3}$  C)**
- 14.2. At 100,000  $\Omega$ , how much current flows through your body if you touch the terminals of a 12 V battery? If your skin is wet, so that your resistance is only 1000  $\Omega$ , how much current would you receive from the same battery? **Ans. (1.2  $\times 10^{-4}$  A, 1.2  $\times 10^{-2}$  A)**
- 14.3. The resistance of a conductor wire is 10 M $\Omega$ . If a potential difference of 100 volts is applied across its ends, then find the value of current passing through it in mA. **Ans. ( 0.01 mA)**
- 14.4. By applying a potential difference of 10 V across a conductor, a current of 1.5 A passes through it. How much energy would be obtained from the current in 2 minutes? **Ans. (1800 J)**
- 14.5. Two resistances of 2 k $\Omega$  and 8 k $\Omega$  are joined in series, if a 10 V battery is connected across the ends of this combination, find the following quantities:
- (a) The equivalent resistance of the series combination.
  - (b) Current passing through each of the resistances.
  - (c) The potential difference across each resistance.
- Ans. [(a) 10 k $\Omega$  (b) 1 mA (c) 2 V, 8 V]**
- 14.6. Two resistances of 6 k $\Omega$  and 12 k $\Omega$  are connected in parallel. A 6 V battery is connected across its ends, find the values of the following quantities:
- (a) Equivalent resistance of the parallel combination.
  - (b) Current passing through each of the resistances.
  - (c) Potential difference across each of the resistance.
- Ans. [(a) 4 k $\Omega$ , (b) 1 mA, 0.5 mA (c) 6 V]**
- 14.7. An electric bulb is marked with 220 V, 100 W. Find the resistance of the filament of the bulb. If the bulb is used 5 hours daily, find the energy in kilowatt-hour consumed by the bulb in one month (30 days). **Ans. (484  $\Omega$ , 15 kWh)**
- 14.8. An incandescent light bulb with an operating resistance of 95  $\Omega$  is labelled "150 W."

## CURRENT ELECTRICITY

Is this bulb designed for use in a 120 V circuit or a 220 V circuit?

**Ans. (It has been designed for 120 V)**

14.9. A house is installed with

- (a) 10 bulbs of 60 W each of which are used 5 hours daily.
- (b) 4 fans of 75 W each of which run 10 hours daily.
- (c) One T.V. of 100 W which is used for 5 hours daily.
- (d) One electric iron of 1000 W which is used for 2 hours daily.

If the cost of one unit of electricity is Rs.4. Find the monthly expenditure of electricity (one month = 30 days).

**Ans. (Rs.**

**1020/-)**

14.10. A 100 W lamp bulb and a 4 kW water heater are connected to a 250 V supply. Calculate (a) the current which flows in each appliance (b) the resistance of each appliance when in use.

**Ans. [(a) 0.4 A, 16 A (b) 625  $\Omega$ , 15.62  $\Omega$ ]**

14.11. A resistor of resistance 5.6  $\Omega$  is connected across a battery of 3.0 V by means of a wire of negligible resistance. A current of 0.5 A passes through the resistor.

Calculate

- (a) Power dissipated in the resistor.
- (b) Total power produced by the battery.
- (c) Give the reason of difference between these two quantities.

**Ans. [(a) 1.4 W**

**(b) 1.5 W**

**(c) some power is lost by the internal resistance of the battery]**