UNIT 2

Electric charge and electric current

Learning Objectives

After completing this lesson, students will be able to:

- Understand the electric charge, electric field and Coulomb's law
- Explain concepts of electric current, voltage, resistance and Ohm's law
- Draw electrical circuit diagrams, series and parallel circuits
- Explain effects of electric current like
  heating or thermal effect , chemical effect , magnetic effect
- Understand direct and alternating currents
- Know safety aspects related to electricity

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Introduction

Like mass and length, electric charge also is a fundamental property of all matter. We know that matter is made up of atoms and molecules. Atoms have particles like electrons, protons and neutrons. By nature, electrons and protons have negative and positive charges respectively and neutrons do not have charge. An electric current consists of moving electric charges. Electric current is the flow of charges just like water currents are due to the flow of water molecules. Water molecules tend to flow from areas of higher gravitational potential to lower gravitational potential. Similarly, electric current flows from higher electric potential to lower electric potential. Electricity is an important source of energy in the modern times.

2.1 Electric charges

We know that all matter is made up of tiny particles called, atoms. Inside each atom there is a nucleus with positively charged protons and chargeless neutrons and negatively charged electrons orbiting the nucleus. Usually there are as many electrons as there are protons and the atoms themselves are neutral.

As electrons are revolving in the orbits of an atom, they can be easily removed from an atom and also added to it. If an electron is removed from the atom, the atom becomes positively charged. Then it becomes a positive ion. If an electron is added in excess to an atom then the atom is negatively charged. This atom is called negative ion. More than one electron can also be removed from or added to atoms to make them accordingly more positive and more negative (Fig. 2.1).

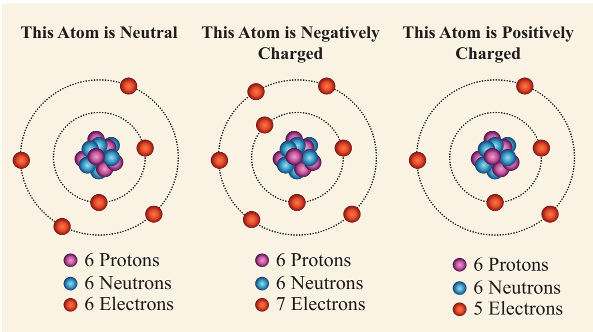


Figure 2.1 Atoms and charges

When you rub a plastic comb on your dry hair, the comb obtains power to attract small pieces of paper, is it not? When you rub the comb vigorously, electrons from your hair leave and accumulate on the edge of the comb. Your hair is now positively charged as it has lost electrons. The comb is negatively charged as it has gained electrons (Fig. 2.2).

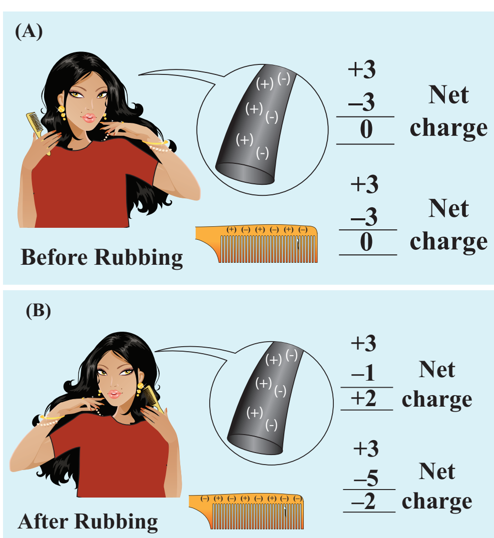
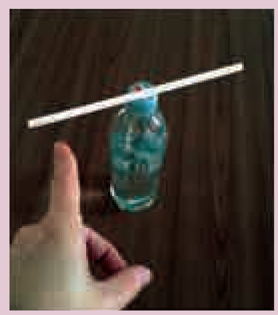
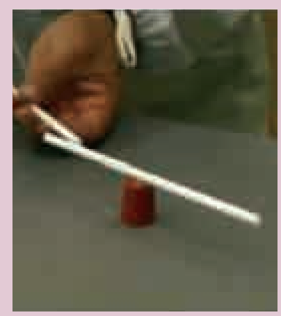


Figure 2.2 Frictional electricity

Activity 1

Take a straw which is used for drinking cool drinks. Cut a piece of it and place it on a plastic cap of a bottle as shown in the figure. Switch off the fan so that the piece does not fly away. Rub your fingers against a muslin or terri-cotton cloth and then bring it near the tip of the piece of straw. Observe what happens to it? It rotates because of deflection, doesn't it? Why does it deflect? Now instead of your finger bring another straw which is rubbed as said. The deflection is in the opposite direction. Can you give the reasons?





2.1.1 Measuring electric charge

Electric charge is measured in coulomb and the symbol for the same is C. The charge of an electron is numerically a very tiny value. The charge of an electron (represented as e) is the fundamental unit with a charge equal to 1.6×10^{-19} C. This indicates that any charge (q) has to be an integral multiple (n) of this fundamental unit of electron charge (e).

$$q = ne$$

here, n is a whole number.

DO YOU KNOW?

There is a wrong understanding that we need protons to get a positive charge. Actually, protons are well seated inside the nucleus of an atom. They cannot be easily removed from or added to the nucleus of an atom. We deal only with electrons for getting a negative as well as positive ions. The excess electrons make an object negative and deficit of electrons make it positive.

Can you guess how many electrons accumulate to make 1 C of electric charge?

Exercise 2.1

How many electrons will be there in one coulomb of charge?

Solution:

Charge on 1 electron, e = 1.6 x 10^{-19} C

q=ne or n=q/e

∴ number of electrons in 1 coulomb

$$= \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons}$$

Practically, we also have μC (micro coulomb) nC (nano coulomb)and pC (pico coulomb) as units of electric charge.

1 μC = 10^{-6} C, 1nC=10^{-9} and 1pC = 10^{-12}C

Electric charge is additive in nature. The total electric charge of a system is the algebraic sum of all the charges located in the system. For example, let us say a system has two charges +5C and −2C. Then the total or net charge on the system is, (+5C) + (−2C) = +3C.

2.1.2 Electric force

Among electric charges there are two types of electric force (F). One is attractive and another is repulsive. The like charges repel and unlike charges attract. **The force existing between the charges is called as 'electric force'.** These forces are non-contact forces, and hence can be experienced even when the charges are not in contact.

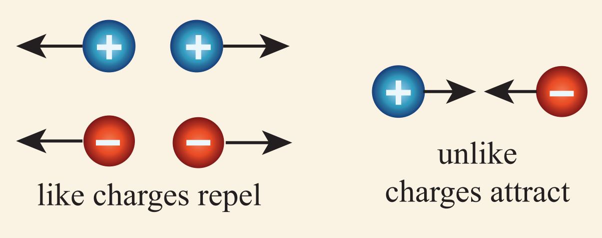


Figure 2.3 Electrostatic forces

The numerical value (magnitude) of electric force between two charges depend on the,

i. value of charges on them,
ii. distance between them and
iii. nature of medium between them.

DO YOU KNOW?

Electrostatic forces between two point charges obey Newton's third law. The force on one charge is the action and on the other is reaction and vice versa.

2.1.3 Electric field

The region in which a charge experiences electric force forms the 'electric field' around the charge. Often electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed (Fig. 2.4). The direction of the electric field is the direction of the force that would act on a small positive charge. Therefore the lines representing the electric field are called 'electric lines of force'. **The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field.** Electric lines of force are imaginary lines. The strength of an electric field is represented by how close the field lines are to one another.

For an isolated positive charge the electric lines of force are radially outwards and for an isolated negative charge they are radially inwards.

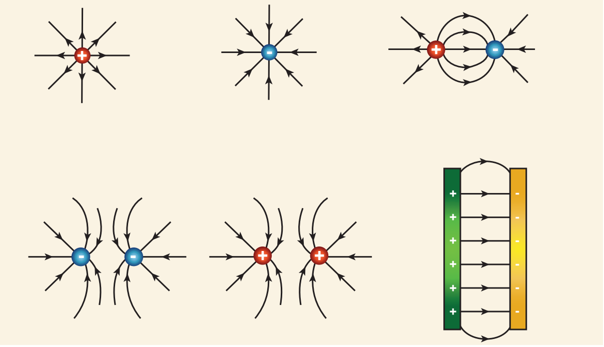


Figure 2.4 Electric lines of force

Electric field at a point is a measure of force acting on a unit positive charge placed at that point. A positive charge will experience force in the direction of electric field and a negative charge will experience in the opposite direction of electric field.

2.1.4. Electric potential

Though there is an electric force (either attractive or repulsive) existing among the charges, they are still kept together, is it not?. We now know that in the region of electric charge there is an electric field. Other charges experience force in this field and vice versa. There is a work done on the charges to keep them together. This results in a quantity called 'electric potential'.

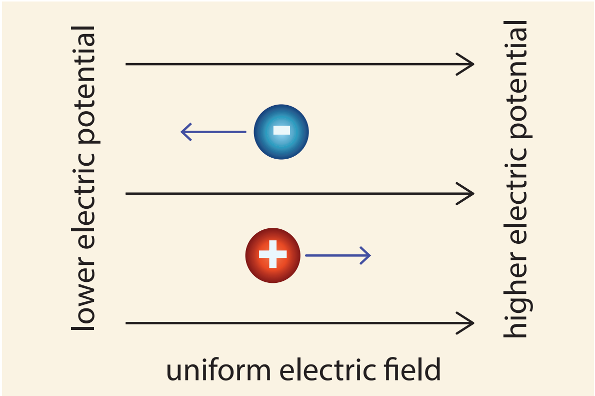


Figure 2.5 Electric potential and Electric field

Electric potential is a measure of the work done on unit positive charge to bring it to that point against all electrical forces. The electric potential (V) near positive charges is positive and near a negative charges is negative. Other positive charges have a tendency to move from higher potential to lower potential and negative charges the other way.

2.2 Electric current

When the charged object is provided with a conducting path, electrons start to flow through the path from higher potential to lower potential region. Normally, the potential difference is produced by a cell or battery. When the electrons move, we say that an electric current is produced. That is, an electric current is formed by moving electrons.

2.2.1 Direction of current

Before the discovery of the electrons, scientists believed that an electric current consisted of moving positive charges. Although we know this is wrong, the idea is still widely held, as the discovery of the flow of electrons did not affect the basic understanding of the electric current. The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'. This is depicted in Figure 2.6.

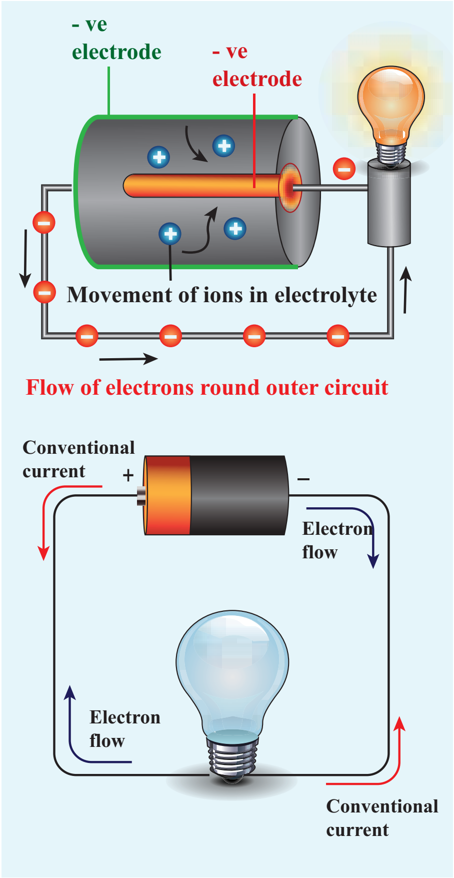


Figure 2.6 Electric current

In a battery, the potential of the positive terminal is maintained positive and the negative terminal is negative. Electrons are removed from the positive terminal and enriched at the negative terminal internally by means of chemical reaction or other processes. When a connection is given externally by a conducting wire, electrons flow from the negative terminal to the positive of the cell. Conventional current or simply the current, behaves as if positive charges cause the current flow. Although in reality it is the electron that moves in one direction, in equivalence, we consider as if it is the positive charges are moving in the opposite direction. This is taken as the direction of 'current'.

In electrical circuits the positive terminal is represented by a long line and negative terminal as a short line. Battery is the combination of more than one cell as shown in the Fig. 2.7.

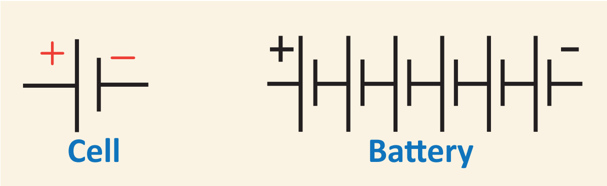


Figure 2.7 Cell and battery

2.2.2 Measurement of electric current

We can measure the value of current and express it numerically. **Current is the rate at which charges flow past a point on a circuit.** That is, if q is the quantity of charge passing through a cross section of a wire in a time t, quantity of current (I) is represented as,

$$I = q/t$$

The standard SI unit for current is ampere with the symbol A. Current of 1 ampere means that there is one coulomb (1C) of charge passing through a cross section of a wire every one second (1 s).

1 ampere = 1 coulomb / 1 second (or)

$1\ A = 1\ C / 1\ s = 1CS^{-1}$

Ammeter is an instrument used to measure the strength of the electric current in an electric circuit.

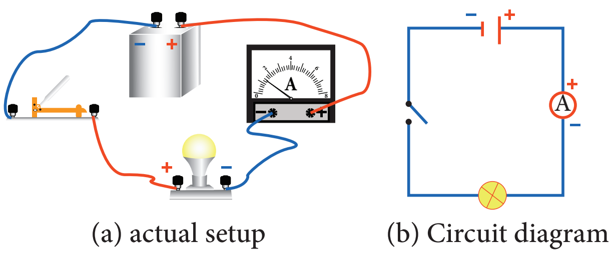


Figure 2.8 Ammeter in a circuit

The ammeter is connected in series in a circuit where the current is to be found. . The current flows through the positive '+' red terminal of ammeter and leaves from the negative '–' black terminal.

Exercise 2.2

Suppose, 25 C of charge is determined to pass through a wire of any cross section in 50 s, what is the measure of current?

Solution:

I = q / t = (25 C) / (50 s) = 0.5 C/s = 0.5 A

Exercise 2.3

The current flowing through a lamp is 0.2A. If the lamp is switched on for one hour, What is the total electric charge that passes through the lamp?

Solution:

I = q / t; q = I x t

Time has to be in second.

$\therefore 1hr = 1\times60\times60\ s = 3600\ s$

$q = I \times t = 0.2A\times3600s = 720C$

2.2.3 Electromotive force (e.m.f)

Imagine that two ends of a water pipe filled with water are connected. Although filled with water, the water will not move or circle around the tube on its own. Suppose, you insert a pump in between and the pump pushes the water, then the water will start moving in the tube. Now the moving water can be used to produce some work. We can insert a water wheel in between the flow and make it to rotate and further use that rotation to operate machinery.

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Likewise if you take a circular copper wire, it is full of free electrons. However, they are not moving in a particular direction. You need some force to push the electrons to move in a direction. The water pump and a battery are compared in Figure 2.9.

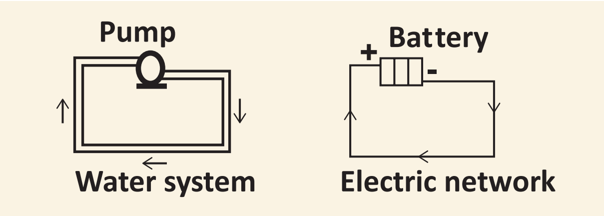


Figure 2.9 Battery is analogues to water pump

Devices like electric cells and other electrical energy sources act like pump, 'pushing' the charges to flow through a wire or conductor. The 'pumping' action of the electrical energy source is made possible by the 'electromotive force' (e.m.f). The electromotive force is represented as (e). The e.m.f of an electrical energy source is the work done (W) by the source in driving a unit charge (q) around the complete circuit.

$$\varepsilon = W/q$$

where, W is the work done or the non-electrical energy converted into electrical energy measured in joules and q is the amount of charge. The SI unit of e.m.f is joules per coulomb (JC^{-1}) or volt (V). In other words **the e.m.f of an electrical energy source is one volt if one joule of work is done by the source to drive one coulomb of charge completely around the circuit.**

Exercise 2.4

The e.m.f of a cell is 1.5V. What is the energy provided by the cell to drive 0.5 C of charge around the circuit?

Solution: $\varepsilon = 1.5V$ and $q = 0.5C$

$\varepsilon = W/q$; $W = \varepsilon \times q$; Therefore $W = 1.5 \times 0.5 = 0.75J$

DO YOU KNOW?

Though the word force is present in electro motive force, it is not a force. Scientists who worked with electricity in earlier days thought that there is force acting on the electrons in moving them through the wire. But, instead of considering the force, considering the potential difference which produces the movement became easy for handling the concepts. But, the name still remains as such but e.m.f is still measured in volt.

2.2.4 Potential difference (p.d)

One does not just let the circuit connect one terminal of a cell to another. Often we connect, say a bulb or a small fan or any other electrical device in an electric circuit and use the electric current to drive them. This is how a certain amount of electrical energy provided by the cell or any other source of electrical energy is converted into other form of energy like light, heat, mechanical and so on. For each coulomb of charge passing through the light bulb (or any appliances) the amount of electrical energy converted to other forms of energy depends on the potential difference across the electrical device or any electrical component in the circuit. The potential difference is represented by the symbol V.

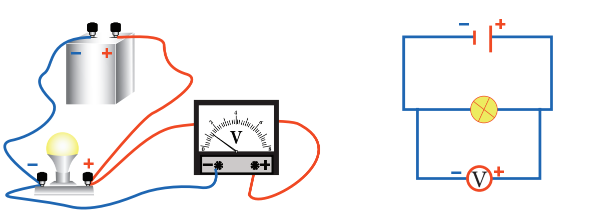
$$V = W/q$$

where, W is the work done, that is the amount of electrical energy converted into other forms of energy measured in joule and q is amount of charge measured in coulomb. The SI unit for both e.m.f and potential difference is the same in volt (V).

Note: Difference between e.m.f and potential difference:

As both e.m.f and potential difference are measured in volt, they may appear the same. But they are not. The e.m.f refers to the voltage developed across the terminals of an electrical source when it does not produce current in the circuit. Potential difference refers to the voltage developed between any two points (even across electrical devices) in an electric circuit when there is current in the circuit.

Voltmeter is an instrument used to measure the potential difference. To measure the potential difference across a component in a circuit, the voltmeter must be connected in parallel to it. Say, you want to measure the potential difference across a light bulb you need to connect the voltmeter as given in Figure 2.10.



(a) actual setup (b) Circuit diagram

Figure 2.10 Connection of voltmeter in a circuit

Note the positive ('+') red terminal of the voltmeter is connected to the positive side of circuit and the negative ('–') black terminal is connected to the negative side of the circuit across a component (light bulb in the above illustration).

Exercise 2.5

A charge of 2x10^4 C flows through an electric heater. The amount of electrical energy converted into thermal energy is 5 MJ. Compute the potential difference across the ends of the heater.

$V = W/q$ that is 5×10^6 J / 2×10^4 C = 250 V

2.2.5 Resistance

The Resistance (R) is the measure of opposition offered by the component to the flow of electric current through it. The opposition to the flow of current is caused in terms of opposition to the flow of electrons by other electrons and the thermal vibrations. Different electrical components offer different electrical resistance.

Even the conducting wires offer resistance to the flow of electric current through it. But, it is very much negligible. Metals like copper, aluminium etc., have very much negligible resistance. That is why they are called good conductors. On the other hand, materials like nicrome, tin oxide etc., offer high resistance to the electric current. We also have a category of materials called insulators; they do not conduct electric current at all (Glass, Polymer, rubber and paper). All these materials are needed in electrical circuits to have usefulness and safety in electrical circuits.

The resistance offered by a material at a particular temperature depends on the,

i. geometry of the material and

ii. nature of the material.

The SI unit of resistance is ohm with the symbol (Ω). **One ohm is the resistance of a component when the potential difference of one volt applied across the component drives a current of one ampere through it.**

We can also control the amount of flow of current in a circuit with the help of resistance. Such components used for providing resistance are called as 'resistors'. The resistors can be fixed or variable.

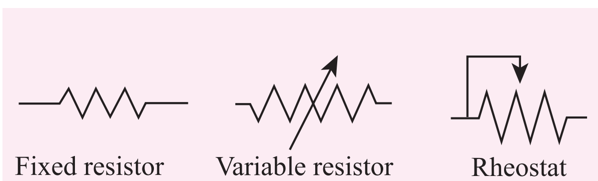


Figure 2.11 Circuit symbol for resistor

Fixed resistors have fixed value of resistance, while the variable resistors like rheostats can be used to obtain desired value of resistance as shown in Figure 2.11.

2.2.6 Ohm's law

Ohm's law states that electric potential difference across two points in an electrical circuit is directly proportional to the current passing through it. That is,

$$V \propto I$$

The proportionality constant is the resistance (R) offered between the two points.

Hence, Ohm's law is written as,

$$V = R\,I \quad \text{(or)} \quad V = I\,R$$

Where V is the potential difference across the component in volt(V), I is the current flowing through the component in ampere(A) and R is the resistance of the component in ohm (Ω).

Any appliance connected to the circuit offers resistance. We can measure it by measuring the current (I) flowing through them and the potential difference (V) across them. Once we measure these two quantities, we can compute R from the formula R=V/I. When we plot a graph by taking current (I) in the x-axis and voltage (V) in the y-axis, we get a straight line as shown in Fig 2.13. The slope of the line gives the value of resistance (R)

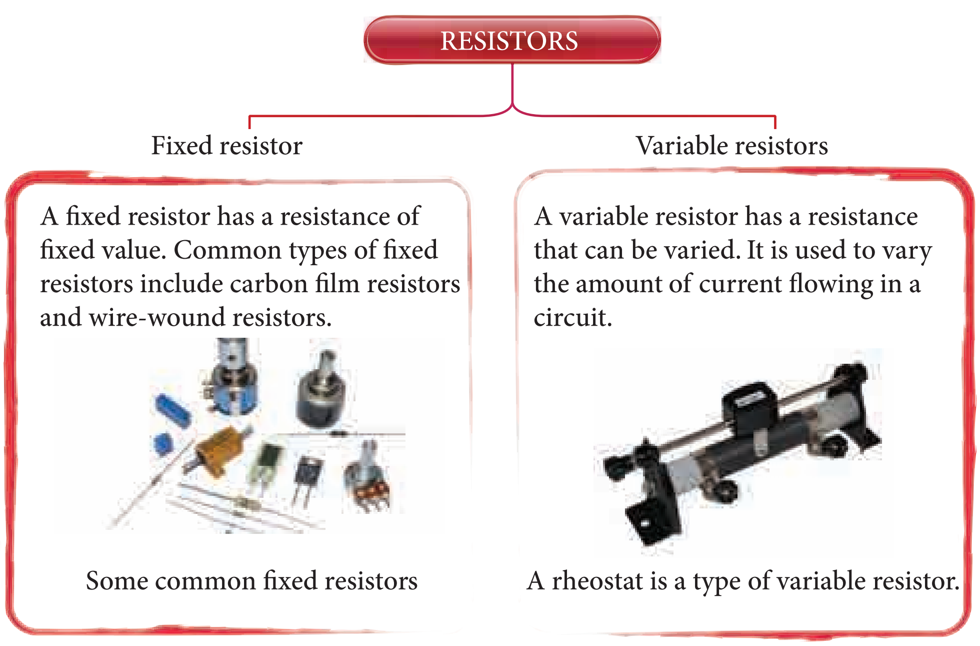


Figure 2.12 Types of resistors

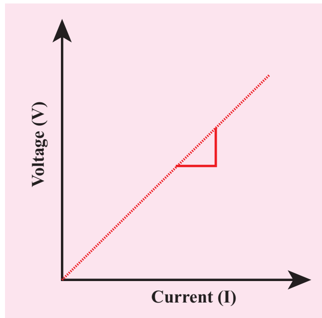


Figure 2.13 Relation between Current and Voltage

Example 2.6

A potential difference of 230 V applied across the heating coil drives a current of 10 A through it. Calculate the resistance of the coil.

V = 230 V; I = 10A

R = V/ I that is 230/10 = 23Ω

Know your Scientist

Georg Simon Ohm, is a well-known German physicist who discovered the relation between potential difference, current and resistance. This relation is named after him, as Ohm's law. The ohm, the physical unit measuring electrical resistance, also was named after him.

He was born in March 16, 1789, at Erlangen, Bavaria in Germany. Ohm became professor of mathematics at the Jesuits' College at Cologne in 1817. His work greatly influenced the theory and applications of current electricity. Georg Ohm resigned his post at Cologne. He accepted a position at the Polytechnic School of Nürnberg in 1833. In 1841 he was awarded the Copley Medal of the Royal Society of London and was made a foreign member a year later. He died on July 6, 1854, in Munich.

2.3 Electric circuit diagram

To represent an electrical wiring or solve problem involving electric circuits, the circuit diagrams are made.

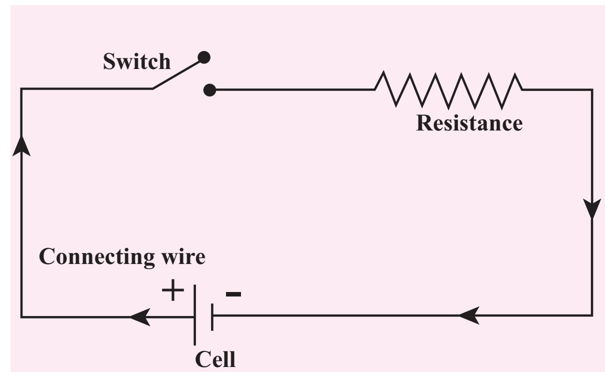


Figure 2.14 Typical electric circuit

The four main components of any circuits namely the, (i) cell, (ii) connecting wire, (iii) switch and (iv) resistor or load are given above. In addition to the above many other electrical components are also used in an actual circuit. A uniform system of symbols has been evolved to describe them. It is like learning a sign language, but useful in understanding circuit diagrams.

Activity 2

Take a condensed electronic circuit board in a TV remote or old mobile phone. Look at the electrical symbols used in the circuit. Find out the meaning of the symbols known to you.

2.3.1 Some common symbols in the electrical circuit

Some of the symbols are shown in Table 1.

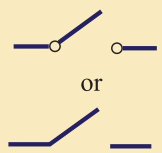
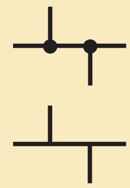
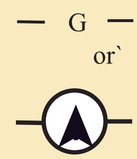
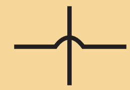
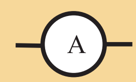
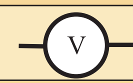
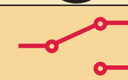
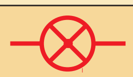
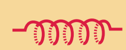
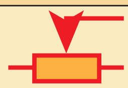
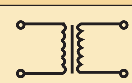
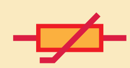
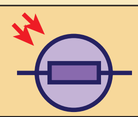
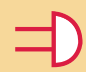
Symbol	Device	Symbol	Device	Symbol	Device
	Switch		Wires joined		galvanometer
	Cell		Wires crossed		ammeter
	Battery		Fixed resistor		Voltmeter
	D .c . power supply		variable resistor (rheostat)		Two-way switch
	A.c. power supply		fuse		Earth connector
	Light bulb		Coil of wire		capacitor
	Potentiometer		transformer		thermistor
	light-depemdent resistor (LDR)		Semiconductor diode		bell

Table 2.1 Common symbols in electrical circuits

2.3.2 Different electrical circuits

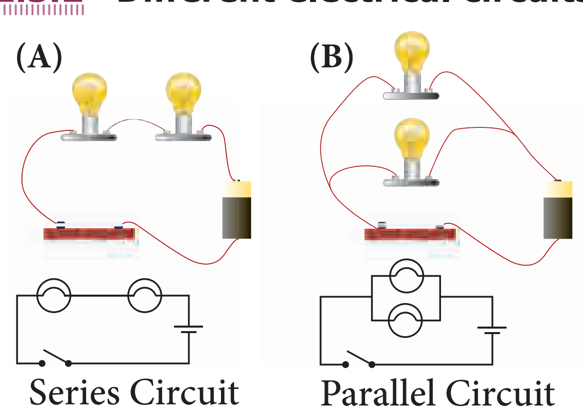


Figure 2.15 Series and parallel connections

Look at the two circuits, shown in Figure 2.15. In Figure A two bulbs are connected in series and in Figure B they are connected in parallel. Let us look at each of these separately.

Series circuits

Let us first look at the current in a series circuit. In a series circuit the components are connected one after another in a single loop. In a series circuit there is only one pathway through which the electric charge flow. From the above we can know that the current I all along the series circuit remain same. That is in a series circuit the current in each point of the circuit is same.

Now, for example, let us consider three resistors of resistances R_1, R_2 and R_3 that are connected in series. When resistors are connected in series, same current is flowing through each resistor as they are in a single loop. If the potential difference applied between the ends of the combination of resistors is V, then the potential differences across each resistor R_1, R_2 and R_3 are V_1, V_2 and V_3 respectively as shown in Figure 2.16.

The net potential difference, $V = V_1 + V_2 + V_3$

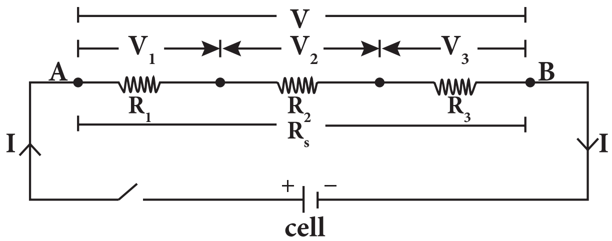


Figure 2.16 Resistors in series

By Ohm's law, V_1 = IxR$_1$; V_2 = IxR$_2$; V_3 = IxR$_3$; and V = IxR$_S$

where R_3 is the equivalent or effective resistance of the series combination.

Hence, (IxR$_s$) =(IxR$_1$)+ (IxR$_2$) + (IxR$_3$) = Ix($R_1 + R_2 + R_3$)

$$R_S = R_1 + R_2 + R_3$$

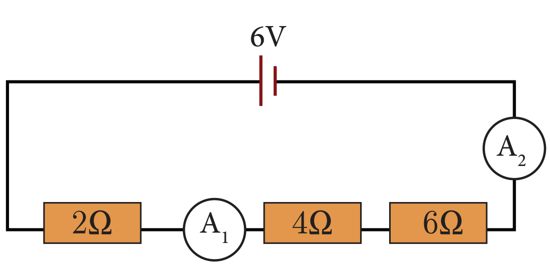
Thus, the equivalent resistance of a number of resistors in series connection is equal to the sum of the resistance of individual resistors.

Suppose, n resistors are connected in series, then the equivalent resistor is,

$$R_S = R_1 + R_2 + R_3 + \ldots\ldots + R_n$$

Exercise 2.7

Look at the series circuit below.



a. What is the effective resistance of the three resistors?

b. What is the current measured by ammeter A_1 and ammeter A_2?

c. What is the potential difference across each resister?

Solution:

a) Effective resistance $R = R_1 + R_2 + R_3$

$= 2 + 4 + 6 = 12\Omega$

b) Since, V= 6 V and effective resistance is 12Ω

I= V/R = 6V/12Ω = 0.5A

As the same current flows through both the resistors, both the ammeters A_1 and A_2 will show the same current of 0.5A.

c) Let V1, V2 and V3 be the potential difference across the 2Ω, 4Ω, 6Ω resisters respectively, then

$V_1 = I \times R_1 = 0.5A \times 2\Omega = 1V$

$V_2 = I \times R_2 = 0.5A \times 4\Omega = 2\ V$

$V_3 = I \times R_3 = 0.5A \times 6\Omega = 3\ V$

Now, we can see that V = V1+V2+V3 = 6 V

Parallel circuits

In parallel circuits, the components are connected to the e.m.f source in two or more loops. In a parallel circuit there is more than one path for the electric charge to flow. In a parallel circuit the sum of the individual current in each of the parallel branches is equal to the main current flowing into or out of the parallel branches. Also, in a parallel circuit the potential difference across separate parallel branches are same.

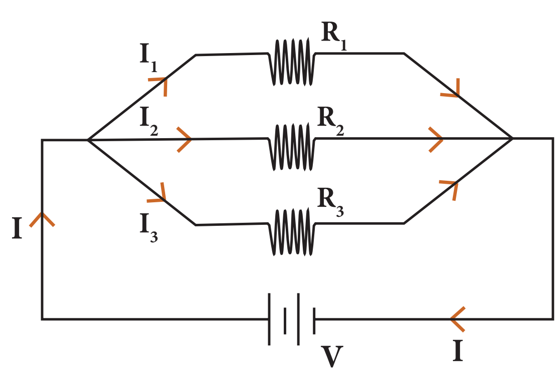


Figure 2.17 Resistors in parallel

Consider three resistors of resistances R_1, R_2 and R_3 connected in parallel. A source of e.m.f with voltage V is connected to the parallel combination of resistors. A current I entering the combination gets divided into I_1, I_2 and I_3 through R_1, R_2 and R_3 respectively as shown in Fig. 2.17.

The total current I is, $I = I_1 + I_2 + I_3$

By Ohm's law, $I_1 = V/R_1$; $I_2 = V/R_2$; $I_3 = V/R_3$; and $I = V/R_P$

where R_P is the equivalent or effective resistance of the parallel combination.

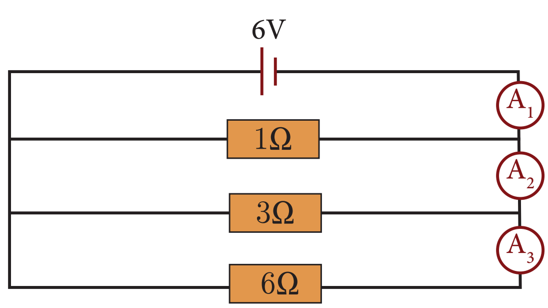
$(V/R_P) = (V/R_1) + (V/R_2) + (V/R_3) = V x(1/R_1 + 1/R_2 + 1/R_2)$

$1/R_P = 1/R_1 + 1/R_2 + 1/R_2$

Thus, the reciprocal of the effective resistance of resisters in parallel ($1/R_P$) is equal to the sum of the reciprocal of all the individual resistance.

Exercise 2.8

Figure shows three resistors of values 1 Ω, 3 Ω, and 6 Ω connected in parallel to a 6 V dry cell.



(a) What is the effective resistance of the three resistors?

(b) What is the p.d. across each resistor?

(c) What is the current measured by ammeters A_1, A_2 and A_3?

Solution:

(a) $1/R_p = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_p = 1/1 + 1/3 + 1/6$

$1/R_p = 9/6$

$\therefore R_p = 0.667\ \Omega$

(b) As the resistors are in parallel, the p.d. across each resistor is equal, $\therefore$ p.d. = 6V

(c) (i) $I = V/R = 6\ V/6\ \Omega = 1\ A$

Current measured by ammeter A_1 is 1 A

(ii) Current through 3 Ω resistor

$= 6\ V/3\ \Omega = 2\ A$

Current measured by ammeter A_2

$= 1\ A + 2\ A = 3\ A$

(iii) Current through the 1 Ω resistor

$= 6\ V/1\ \Omega = 6\ A$

Current measured by ammeter A_3

$= 6\ A + 3\ A = 9\ A$

Alternatively, since V = 6 V and effective resistence R = 0.667 Ω, current measured by ammeter

$A_3 = 6\ V / 0.667\ \Omega = 9\ A$

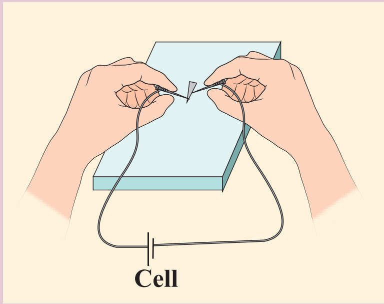
2.4 Effects of electric current

When current flows in a circuit it exhibits various effects. The main effects are heating, chemical and magnetic effects.

2.4.1 Heating effect

Activity 3

Cut an arrow shaped strip from aluminium foil. Ensure that the head is a fine point. Remove any paper backing it may have. Keep the arrow shaped foil on a wooden board. Connect a thin pin to two lengths of wire. Connect the wires to the terminals of electric cell, may be of 9V. Press one pin onto the pointed tip and other pin at a point about one or two mm away. Can you see that the tip of aluminium foil starts melting?



When the flow of current is 'resisted' generally heat is produced. This is because the electrons while moving in the wire or resistor suffer resistance. Work has to be done to overcome the resistance which is converted in to heat energy. **This conversion of electrical energy in to heating energy is called 'Joule heating'** as this effect was extensively studied by the scientist Joule. This forms the principle of all electric heating appliances like iron box, water heater, toaster etc. Even connecting wires offer a small resistance to the flow of current. That is why almost all electrical appliances including the connecting wires feel warm when used in an electric circuit.

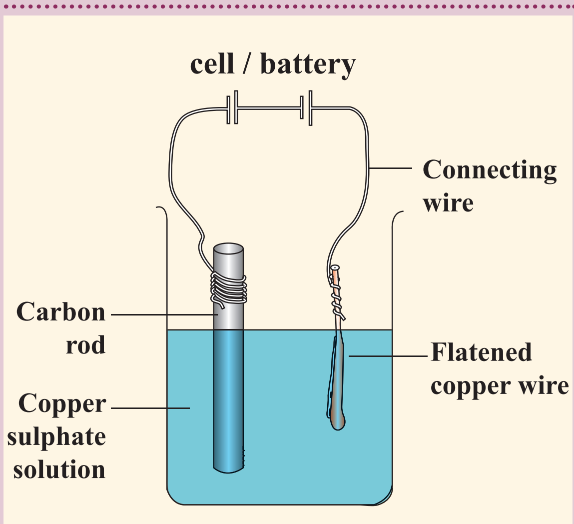
Caution:

The heating effect and the chemical effect experiments have to be performed only with a dc cell of around 9V. The 9V dc cell will not give any electrical shock.

Students at any cost **should not use** the main domestic electric supply which is a 220V ac voltage. If it is used it will give a heavy electric shock leading to a severe damage to our body.

2.4.2 Chemical effect

Activity 4



Take a beaker half filled with copper sulphate solution. Take a carbon rod from a used dry cell. Wind a wire on its upper end. Take a thick copper wire, clean it well and flatten it with a hammer. Immerse both the copper wire and carbon rod in the copper sulphate solution. Connect the carbon rod to the negative terminal of an electric cell and copper wire to the positive terminal of the cell. Also ensure that the copper and the carbon rod do not touch each other, but are close enough. Wait and watch. After some time you would find fine copper deposited over the carbon rod. This is called as electroplating. This is due to the chemical effect of current.

So far we have come across the cases in which only the electrons can conduct electricity. But, here when current passes through electrolyte like copper sulphate solution, both the electron and the positive copper ion conduct electricity. **The process of conduction of electric current through solutions is called 'electrolysis'. The solution through which the electricity passes is called 'electrolyte'.** The positive terminal inserted in to the solution is called 'anode' and the negative terminal 'cathode'. In the above experiment, copper wire is anode and carbon rod is cathode.

DO YOU KNOW?

Extremely weak electric current is produced in the human body by the movement of charged particles. These are called synaptic signals. These signals are produced by electro-chemical process. They travel between brain and the organs through nervous system.

2.4.3 Magnetic effect of electricity

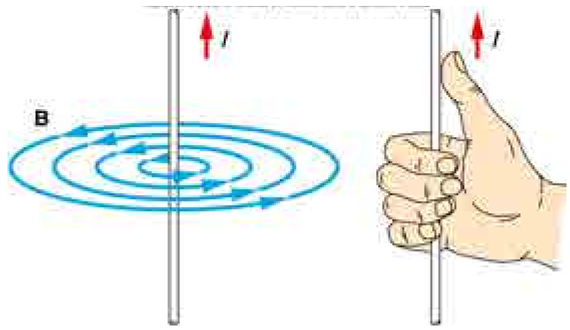


Figure 2.18 Direction of current and magnetic field

A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current. This is called magnetic effect of current. The discovery of the scientist Oersted and the 'right hand thumb rule' are detailed in the chapter on Magnetism and Electromagnetism in this book.

Direction of current is shown by the right hand thumb and the direction of magnetic field is shown by other fingers of the same right hand (Fig. 2.18).

2.5 Types of current

There are two distinct types of electric currents that we encounter in our everyday life: direct current (dc) and alternating current (ac).

2.5.1 Direct current

We know current in electrical circuits is due to the motion of positive charge from higher potential to lower potential or electron from lower to higher electrical potential. Electrons move from negative terminal of the battery to positive of the battery. Battery is used to maintain a potential difference between the two ends of the wire. Battery is one of the sources for dc current. The dc is due to the unidirectional flow of electric charges. Some other sources of dc are solar cells, thermocouples etc. The graph depicting the direct current is shown in Fig. 2.19.

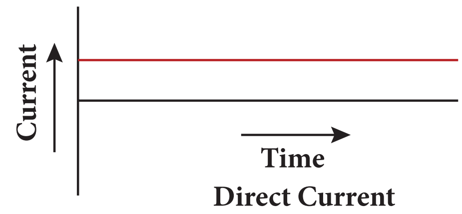


Figure 2.19 Wave form of dc

Many electronic circuits use dc. Some examples of devices which work on dc are cell phones, radio, electric keyboard, electric vehicles etc.

2.5.2 Alternating current

If the direction of the current in a resistor or in any other element changes its direction alternately, the current is called an alternating current. The alternating current varies sinusoidally with time. This variation is characterised by a term called as frequency. **Frequency is the number of complete cycle of variation, gone through by the ac in one second.** In ac, the electrons do not flow in one direction because the potential of the terminals vary between high and low alternately. Thus, the electrons move to and fro in the wire carrying alternating current. It is diagrammatically represented in Fig. 2.20.

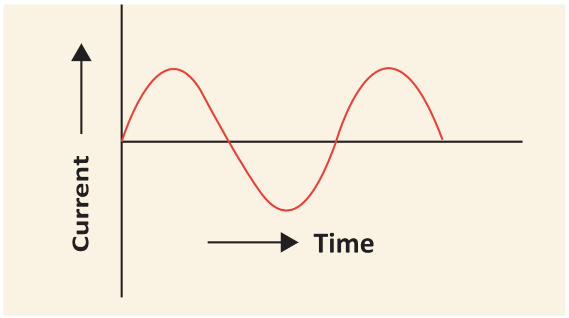


Figure 2.20 Wave form of ac

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Domestic supply is in the form of ac. When we want to use an electrical device in dc, then we have to use a device to convert ac to dc. **The device used to convert ac to dc is called rectifier.** Colloquially it is called with several names like battery eliminator, dc adaptor and so on. The device used to convert dc in to ac is called inverter. The symbols used in ac and dc circuits are shown in Fig. 2.21.

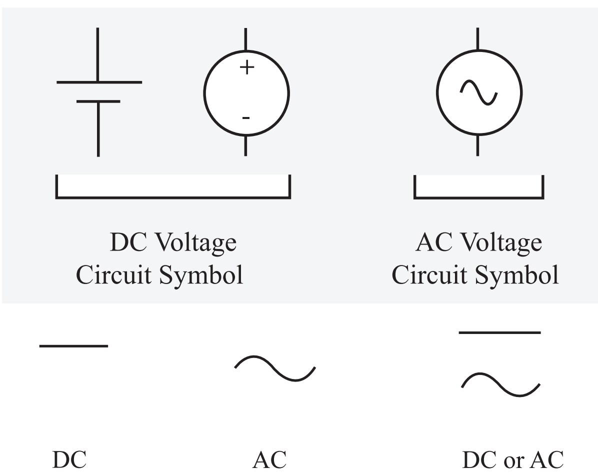


Figure 2.21 The symbol used in ac and dc circuit diagrams

> **DO YOU KNOW?** Joule's heating effect of current is common to both direct and alternating current.

2.5.3 Advantages of ac over dc

The voltage of ac can be varied easily using a device called transformer. The ac can be carried over long distances using step up transformers. The loss of energy while distributing current in the form of ac is negligible. Direct current cannot be transmitted as such. The ac can be easily converted into dc. Generating ac is easier than dc. The ac can produce electromagnetic induction which is useful in several ways.

2.5.4 Advantage of dc over ac

Electroplating, Electro refining, electrotyping can be done only using dc. Electricity can be stored only in the form of dc.

> **DO YOU KNOW?** In India, the voltage and frequency of ac used for domestic purpose is 220V and 50Hz respectively where as in United States of America it is 110V and 60 Hz respectively.

2.6 Safe handling of electrical energy

Electricity is to be handled with much precaution because the passage of electricity causes heavy damage to human body. As electric current produces heat, several safety aspects are to be strictly adhered while handling electric current.

2.6.1 Dangers of electricity and precautions to be taken

The following are the possible dangers as for as electric current is concerned.

i. Damaged insulation – Do not touch the bare wire, use safety glows and stand on insulating stool or rubber slippers while handling electricity.

ii. Overheating of cables – use quality ISI certified cable wires for domestic wiring

iii. Overload of power sockets – Do not connect too many electrical devices to a single electrical socket.

iv. Inappropriate use of electrical appliances – Always use the electrical appliances according to the power rating of the device like ac point, TV point, microwave oven point etc.

v. Environment with moisture and dampness – keep the place where there is electricity out of moisture and wetness as it will lead to leakage of electric current.

vi. Beyond the reach of children – The electrical sockets are to be kept away from the reach of little children who do not know the dangers of electricity.

2.6.2 Safety features

There are many safety features to be followed while handling electricity. Some of them are given below.

Ground connection

The metal bodies of all the electrical appliances are to be connected to the ground by means of a third wire apart from the two wires used for electrical connection. Normally the ground connection wire will be green in colour while the main wire is in red and the return wire is in black. This ground connection provides an easy path for the current avoiding it from flowing through our body. All the ground wires from various electrical sockets are connected together finally to a thick copper wire that is buried deep in to the ground so that the excess current could directly pass in to the ground without passing in to our body.

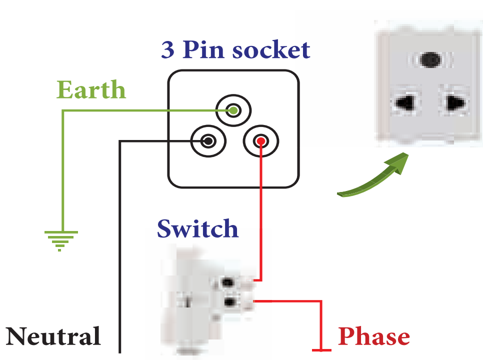


Figure 2.22 Earth and other connections given to a three pin socket

DO YOU KNOW?

Resistance of a dry human body is about 1,00,000 ohm. Because of the presence of water in our body the resistance is reduced to few hundred ohm. Thus, a normal human body is a good conductor of electricity. Hence, precautions are required while handling with electricity.

Trip switch

It is an electromechanical device which does not allow a current beyond a particular value by automatically switching off the connection. We have trip switches of various current ratings used for specific purposes. It works on relay principle. A set of the trip switches used in electrical connections is shown in Figure 2.23.

Figure 2.23 Set of trip switches

Fuse

A fuse is another safety mechanism which works on joule heating principle. Fuse is a wire made up of a Nickel and Chromium alloy which has a definite melting point. If current passes through the fuse beyond a particular desired value, the excess heat produced melts the fuse wire, thus the electrical connection is cut-off. Fuse has to be kept in tight a ceramic enclosure to avoid the melting heat from producing fire accidents.

Figure 2.24 Fuse with ceramic carrier

Points to remember

- Electric charge is a fundamental property of all matter.
- The unit of electric charge is coulomb with a symbol C.
- The charge of an electron is negative of 1.6×10-19 C (represented as e). This is the fundamental unit of charge.
- Like charges repel and unlike charges attract.
- Electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed.
- Electric current flows from higher electric potential to lower electric potential.
- The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'.
- The standard SI unit for current is the ampere with the symbol A.
- The SI unit for both e.m.f and potential difference is the same in volt (V).
- The opposition to the flow of current is called resistance.
- Metals like copper, aluminium etc., have very much negligible resistance. Thus they are good conductors.
- The SI unit of resistance is ohm with the symbol Ω.
- The four main components of any circuit are: cell, connecting wire, switch and resistor.
- In a parallel circuit there is more than one path for the electric charge to flow.
- The main effects when current flows in a circuit are heating, chemical and magnetic effects.
- There are two distinct types of electric currents that we encounter in our everyday life: direct current (dc) and alternating current (ac).
- Dangers of electricity are: damaged insulation, overheating of cables, overload of power sockets, inappropriate use of electrical appliances and environment with moisture and dampness.
- Safety features to be followed are: Ground connection, Trip switch, Fuse

A-Z GLOSSARY

Electric charge	It is the fundamental property of matter.
Electric field	The region around a charge in which another charge experiences electric force.
Electric lines of force	The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field.
Electric potential	It is a measure of the work done on unit positive charge to bring it to that point against all electrical forces.
Electric current	Current is the rate at which charges flow across a conductor in a circuit.
Ammeter	An instrument used for measuring the amount of electric current.

e.m.f	It is the work done by the electrical energy source in driving a unit charge around the complete circuit.
Voltmeter	It is an instrument used to measure the potential difference.
Resistance	The measure of opposition offered by the component to the flow of electric current through it.
Resistors	Components used for providing resistance are called as resistors.
Electrolyte	The solution through which electric current flows.
Anode	The positive terminal in the electrolyte.
Cathode	The negative terminal in the electrolyte.
Alternating current	If the direction of the current in a resistor or in any other element changes its direction alternately, the current is called an alternating current.

TEXT BOOK EXERCISES

I. Choose the correct answer

1. In current electricity, a positive charge refers to,
   a) presence of electron
   b) presence of proton
   c) absence of electron
   d) absence of proton

2. Rubbing of comb with hair
   a) creates electric charge
   b) transfers electric charge
   c) either (a) or (b)
   d) neither (a) nor (b)

3. Electric field lines ________ from positive charge and ________ in negative charge.
   a) start; start   b) start; end
   c) start: end   d) end; end

4. Potential near a charge is the measure of its ________ to bring a positive charge at that point.
   a) force   b) abiility
   c) tendency   d) work

5. In an electrolyte the current is due to the flow of,
   a) electrons
   b) positive ions
   c) both (a) and (b)
   d) neither (a) nor (b)

6. Heating effect of current is called,
   a) Joule heating
   b) Coulomb heating

c) voltage heating

d) Ampere heating

7. The following is not a safety device.

a) fuse b) trip switch

c) ground connection d) wire

8. Electroplating is an example for

a) heating effect b) chemical effect

c) flowing effect d) magnetic effect

9. Resistance of a wire depends on,

a) temperature b) geometry

c) nature of material d) all the above

10. In India the frequency of alternating current is,

a) 220 Hz b) 50 Hz

c) 5 Hz d) 100 Hz

II. Match the following

1. Electric Charge	(a) ohm
2. Potential difference	(b) ampere
3. Electric field	(c) coulomb
4. Resistance	(d) newton per coulomb
5. Electric current	(e) volt

III. True or False

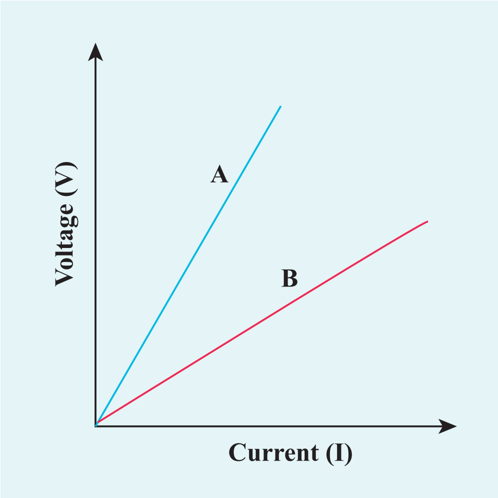
1. Electrically neutral means it is either zero or equal positive and negative charges.
2. Ammeter is connected in parallel in any electric circuit.
3. The anode in electrolyte is negative.
4. Current can produce magnetic field.
5. Electric fuse works on Joule heating principle.

IV. Fill in the blanks

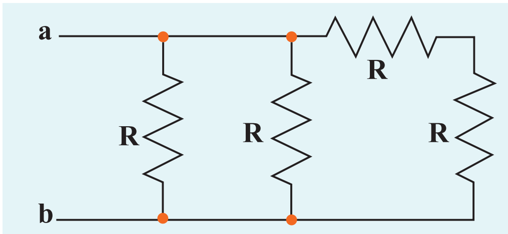
1. Electrons move from ________ potential to ________ potential.
2. The direction opposite to the movement of electron is called ________ current.
3. The e.m.f of a cell is analogues to ________ of a pipe line.
4. The domestic electricity in India is an ac with a frequency of ________ Hz.
5. Trip switch is a ________ safety device.

V. Conceptual questions

1. A bird sitting on a high power electric line is still safe. How?
2. Two resistors 12Ω and 6Ω are first connected in series and then in parallel. The current-voltage graph for the two connections will be represented by which lines in the graph?



3. Does a solar cell always maintain the potential across its terminals constant? Discuss.
4. What is the effective resistance across the terminals a and b of the arrangement of resistors?



5. Can electroplating be possible with alternating current?

VI. Answer the following

1. On what factors does the electrostatic force between two charges depend?
2. What are electric lines of force?
3. Define electric field.
4. Define electric current and give its unit.
5. State Ohm's law.
6. On what factor does the resistance of a wire depend at a particular temperature?
7. Name any two appliances which work under the principle of heating effect of current.
8. Draw a circuit with a 2Ω and 5Ω resistors in series. Connect another 3Ω resistor parallel to the above connection.
9. How are the home appliances connected in general, in series or parallel. Give reasons.
10. List the safety features while handling with electricity.

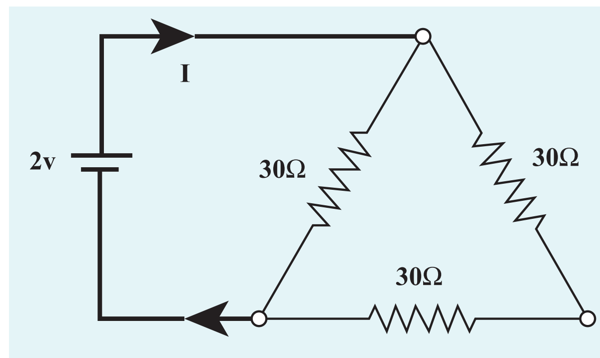
VII. Exercises

1. Rubbing a comb on hair makes the comb get – 0.4C. (a) Find which material has lost electron and which one gained it. (b) Find how many electrons are transferred in this process.
2. Calculate the amount of charge that would flow in 2 hours through an element of an electric bulb drawing a current of 2.5A.
3. The values of current I flowing through a resistor for various potential differences V across the resistor are given below. What is the value of resistor?

I (ampere)	0.5	1.0	2.0	3.0	4.0
V (volt)	1.6	3.4	6.7	10.2	13.2

   [Hint: plot V-I a graph and take slope]

4. Find the value of current in the circuit.



5. A wire of resistance 10 Ω is bent in the form of a circle .Find the effective resistance between the points A and B which lies on the diameter.

REFERENCE BOOKS

Fundamentals of Physics by K.L Gomber and K. L.Gogia

Concepts of Physics by H.C Verma

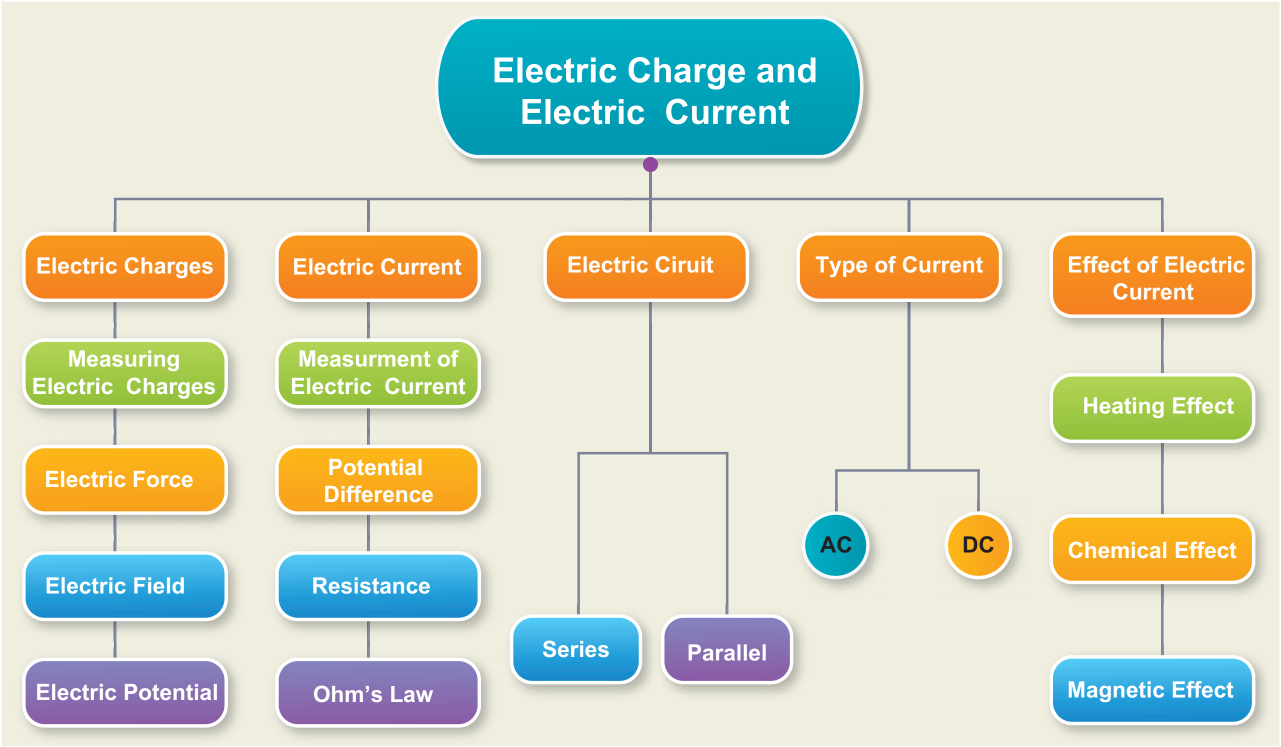
General Physics by W.L. Whiteley

INTERNET RESOURCES

http://www.qrg.northwestern.edu/projects/vss/docs/propulsion/1-what-is-an-ion.html

https://www.explainthatstuff.com/batteries.html

https://www.woodies.ie/tips-n-advice/how-the-fusebox-works-in-the-home-new



ICT CORNER

Ohm's Law Verification

This activity enables to learn the relationship between current and potential difference.

Step 1

- Type the URL link given below in the browser OR scan the QR code.
- You can vary the value of **V** and **R** to know the change the **current flowing across the conductor**
- On the right you can do the changes in V and R to learn the variations.

Step1

Step2

Step3

Step4

Browse in the link:

URL: https://phet.colorado.edu/en/simulation/ohms-law

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*Pictures are indicative only