Wireman Control Panel

(Job Role)

Qualification Pack: Ref. Id. ELE/Q7302

Sector: Electronics

Textbook for Class XI

विद्यया ऽमृतमश्नुते

एन सी ई आर टी
NCERT

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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Foreword

The National Curriculum Framework–2005 (NCF–2005) recommends bringing work and education into the domain of the curricular, infusing it in all areas of learning while giving it an identity of its own at relevant stages. It explains that work transforms knowledge into experience and generates important personal and social values such as self-reliance, creativity and cooperation. Through work one learns to find one's place in the society. It is an educational activity with an inherent potential for inclusion. Therefore, an experience of involvement in productive work in an educational setting will make one appreciate the worth of social life and what is valued and appreciated in society. Work involves interaction with material or other people (mostly both), thus creating a deeper comprehension and increased practical knowledge of natural substances and social relationships.

Through work and education, school knowledge can be easily linked to learners' life outside the school. This also makes a departure from the legacy of bookish learning and bridges the gap between the school, home, community and the workplace. The NCF–2005 also emphasises on Vocational Education and Training (VET) for all those children who wish to acquire additional skills and/or seek livelihood through vocational education after either discontinuing or completing their school education. VET is expected to provide a 'preferred and dignified' choice rather than a terminal or 'last-resort' option.

As a follow-up of this, NCERT has attempted to infuse work across the subject areas and also contributed in the development of the National Skill Qualification Framework (NSQF) for the country, which was notified on 27 December 2013. It is a quality assurance framework that organises all qualifications according to levels of knowledge, skills and attitude. These levels, graded from one to ten, are defined in terms of learning outcomes, which the learner must possess regardless of whether they are obtained through formal, non-formal or informal learning. The NSQF sets common principles and guidelines for a nationally recognised qualification system covering Schools, Vocational Education and Training Institutions, Technical Education Institutions, Colleges and Universities.

It is under this backdrop that Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal, a constituent of NCERT has developed learning outcomes based modular curricula for the vocational subjects from Classes IX to XII. This has been developed under the

Centrally Sponsored Scheme of Vocationalisation of Secondary and Higher Secondary Education of the Ministry of Human Resource Development.

This textbook takes care of generic skills embedded in various job roles in a comprehensive manner and also provides more opportunities and scope for students to engage with these common and necessary skills, such as communication, critical thinking and decision making in different situations pertaining to different job roles.

I acknowledge the contribution of the development team, reviewers and all the institutions and organisations, which have supported in the development of this textbook.

NCERT would welcome suggestions from students, teachers and parents, which would help us to further improve the quality of the material in subsequent editions.

Hrushikesh Senapaty
Director
National Council of Educational
Research and Training

New Delhi
June 2018

About the Textbook

India is one of the largest growing consumer electronics markets in the Asia-Pacific Region. The electronics sector produces electronic equipment for industries and consumer electronics products, such as mobile devices, television sets and circuit boards. Industries within electronics include telecommunications, equipment, electronic components, industrial and consumer electronics.

The growth of the electronics sector has accelerated due to increased consumer spent around the world. As developing economies grow, consumer's demand for electronic products also increases. Countries that produce electronics now have a strong consumer base that can afford new electronic products. Increased competition is driving down the costs associated with electronics production and expanding the availability of affordable electronic products.

A Wireman — Control Panel reads the wiring diagram and routes, and wires various components within the panel in accordance with the diagram. The person is responsible for wiring all components present within the panel as per specifications provided by the design engineering team. The person must have the ability to work in high decibel noise environment and in standing position for long hours.

The textbook for the job role of 'Wireman — Control Panel' has been developed to impart knowledge and skills through hands-on learning experience, which forms a part of experiential learning. Experiential learning focusses on the learning process of an individual. Therefore, the learning activities are student-centered rather than teacher-centered. The textbook has been developed with the contribution of expertise from subject and industry experts and academicians, making it a useful and inspiring teaching–learning resource material for students. Care has been taken to align the content of the textbook with the National Occupational Standards (NOSs) for the job role so that the students acquire necessary knowledge and skills as per the performance criteria mentioned in the respective NOSs of the Qualification Pack (QP).

The textbook has been reviewed by experts so as to make sure that the content is not only aligned with the NOSs but is also of high quality.

The NOSs for the job role of Wireman — Control Panel covered through this textbook are as follows.

1. ELE/N7302: Wiring control panel
2. ELE/N9962: Interacting with co-workers
3. ELE/N9963: Maintaining safe work surroundings

Unit 1 explains the basic building blocks of electrical and electronics. It explains how electricity is formed and energy is transformed from one form to another. The concept of conductors and insulators has been explained in this Unit. Besides, static and dynamic electricity have been explained. The basic electrical circuit and circuit components have also been dealt with in this Unit. The concept of open and closed circuit, series and parallel connection has also been illustrated. The Ohm's law has been explained and verified through practical experiment. The Kirchoff's current and voltage law has also been verified through practical experiment. Unit 2 discusses several important basic electrical components that are commonly found in circuits. These components are the fundamental building blocks of electrical and electronic circuits, and can be found in large numbers in a control panel, printed circuit board, etc. This Unit provides a basis for recognising and understanding the fundamentals of circuit schematics.

Unit 3 helps identify the values of resistors and capacitor, which are the fundamental components of electrical and electronics industry. Unit 4 explains the concept and importance of electrical earthing system, various types of earthing and methods to do earthing. Unit 5 deals with cabling, process of preparing cables and setting up a connection. Unit 6 discusses workplace health and safety regulations, safety training, and the knowledge and skill to effectively identify and potentially eliminate safety hazards at workplace.

Unit 7 gives an overview of various hand and electrical tools used for the installation of equipment in the control panel, such as screwdriver, phase tester, stripper, plier, etc. Unit 8 explains the assembly of electromechanical devices and the components required for electromechanical assembly. Unit 9 aims to provide knowledge and skill of preparing wire by using appropritate tools. Unit 10 explains the hazards associated with panel assembly and wiring.

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Contents

Do You Know?

According to the 86^{th} Constitutional Amendment Act, 2002, free and compulsory education for all children in 6-14 year age group is now a Fundamental Right under Article 21-A of the Constitution.

EDUCATION IS NEITHER A PRIVILEGE NOR FAVOUR BUT A BASIC HUMAN RIGHT TO WHICH ALL GIRLS AND WOMEN ARE ENTITLED

Give Girls Their Chance !

Unit 1

Basics of Electricity and Electronics

Introduction

Electricity holds an important place in modern society. Almost all appliances used these days work on electricity. Even the automobile industry has launched cars, which run on electricity instead of fuel. If the power supply of a city breaks down, hospitals, hostels, offices, schools, food storage plants, banks and shops will also stop working.

Fig. 1.1(a) A wireman monitoring a control panel


Fig. 1.1(b) A lineman repairing electric fault

Electricity is defined as the flow of electric charge. Where do the charges come from? How do they move? Where do they move? To explain what is electricity, we need to go beyond the matter and molecules to atoms that make everything we interact with. It is important to understand the concept of electricity for installation and troubleshooting of electrical appliances.

Electric elements include controlled and uncontrolled sources of energy, resistors, capacitors and inductors. An electric circuit should be designed in such a manner that it is able to perform the desired functions. Analysis of electric circuits refer to computations required to determine unknown quantities, such as voltage, current and power associated with one or more elements in the circuit. As shown in Figs 1.1(a) and 1.1(b), to work in the area

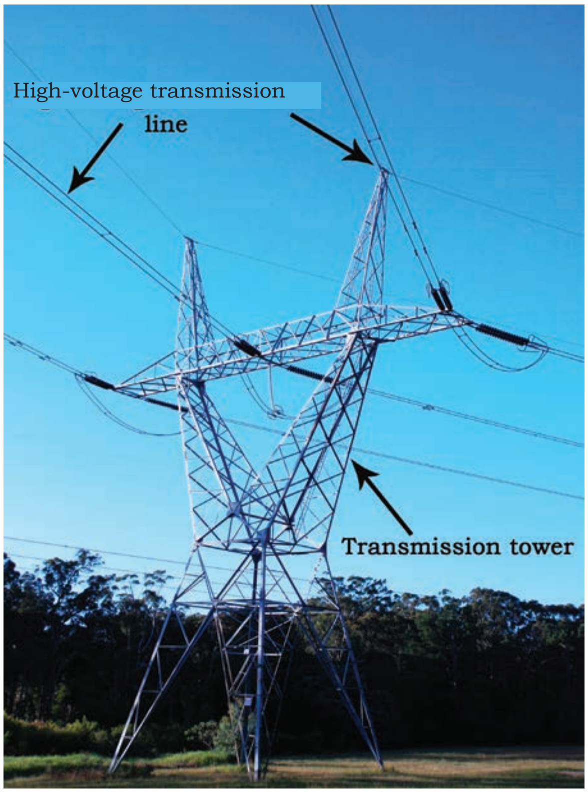


Fig.1.2 Transmission tower


Fig.1.3 Natural discharge of charge

of electrical engineering, a person should have the basic knowledge of electric circuit analysis and laws. Other systems like mechanical, hydraulic, thermal, magnetic and power are easy to analyse and model by a circuit. To learn how to analyse the models of these systems, first one needs to learn the techniques of circuit analysis. This Unit briefly discusses some of the basic circuit elements and laws that will help students get a background of the subject. The students can, hence, apply their knowledge to design, build and demonstrate their own circuits.

Electricity

Electricity is a set of physical phenomena associated with the presence and flow of electric charge. Electricity gives a wide variety of well-known effects, such as lightning, static electricity, electromagnetic induction and electrical current. In addition, electricity permits the creation and reception of electromagnetic radiation, such as radio waves. Electrical energy can be easily transferred from one location to another with minimum loss through a transmission tower (Fig. 1.2).

Source of electricity

Energy is the driving force for the universe. It is a quantitative property of a system. Natural electricity is generated by thunderstorm and lightning as shown in Fig. 1.3.

Energy transformation

There are different forms of energy, such as thermal energy, hydel energy, solar energy, wind energy, nuclear energy, etc. According to the law of conservation of energy, energy can neither be created nor destroyed. It can only change its form. One form of energy can be converted to another. Electrical energy can be generated by transforming several type of energies.

Nuclear → Electrical
Chemical → Electrical
Hydel → Electrical
Thermal → Electrical
Solar → Electrical
Wind → Electrical

Fig 1.4 shows various power stations, such as solar, thermal, hydel and wind. Figs. 1.5(a) and (b) show how electrical energy can be generated and distributed from a hydel and thermal power plant.

Fig.1.4 Different type of power stations

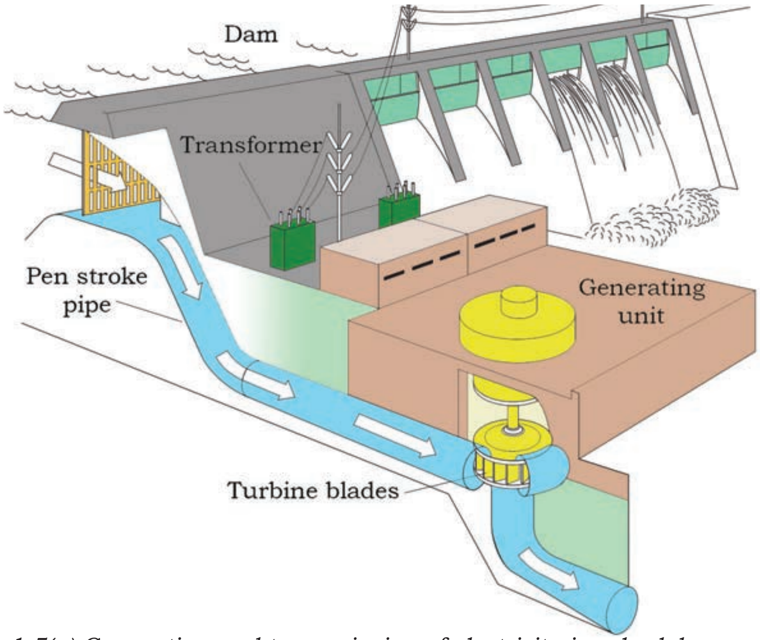


Fig.1.5(a) Generation and transmission of electricity in a hydel power plant

Notes

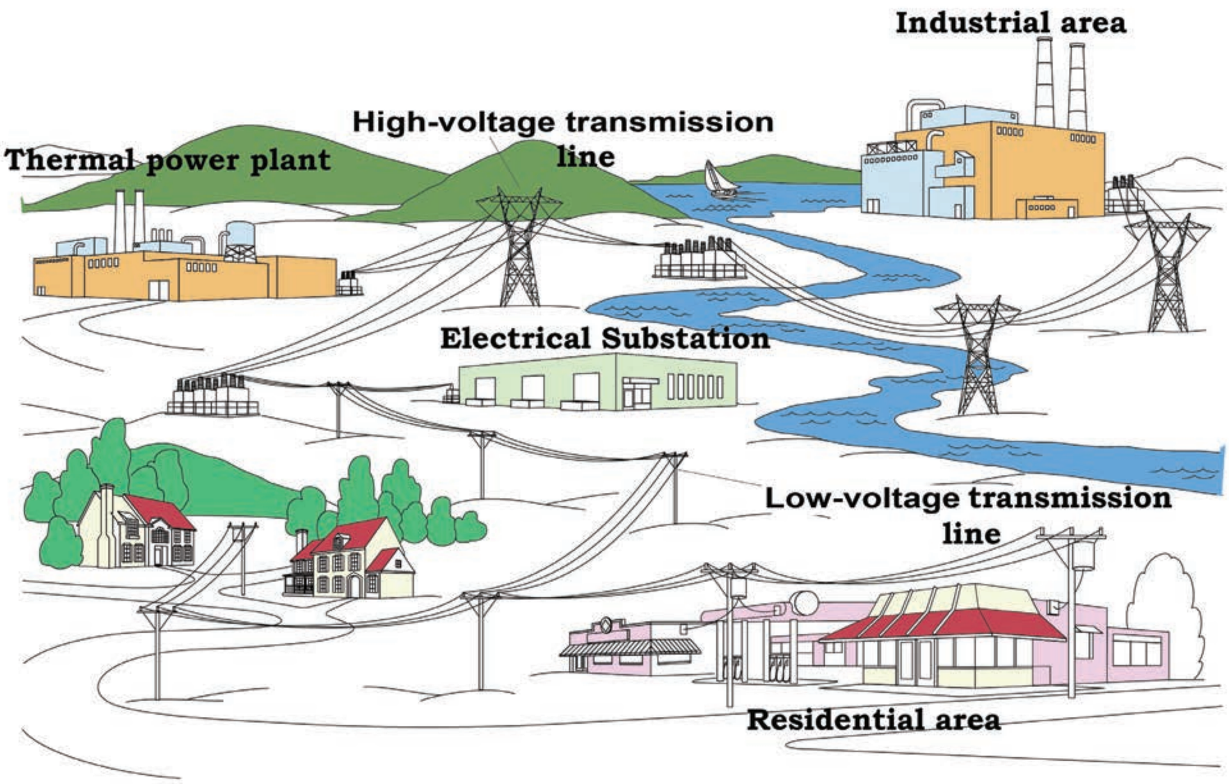


Fig. 1.5(b) Generation, transmission and distribution of electricity in a thermal power plant

Energy foundation

To understand electricity, we need to know about atoms. Everything in the universe solid, liquid or gas is made of atoms. An atom is the smallest constituent unit of matter. Atoms are so small that millions of them can fit on the head of a pin.

Atom

The centre of an atom is called the 'nucleus'. Atoms consist of subatomic particles — protons, neutrons and electrons. The protons and neutrons are very small, and electrons are even smaller. Electrons spin around the nucleus in shells at a great distance from the nucleus. Protons carry positive (+) charge, electrons carry negative (–) charge, and neutrons are neutral. The positive charge of the protons is equal to the negative charge of the electrons. Electrons move in their orbit around the nucleus. The positively charged protons attract negatively charged electrons, and hence, hold the atomic structure as shown in Fig. 1.6.

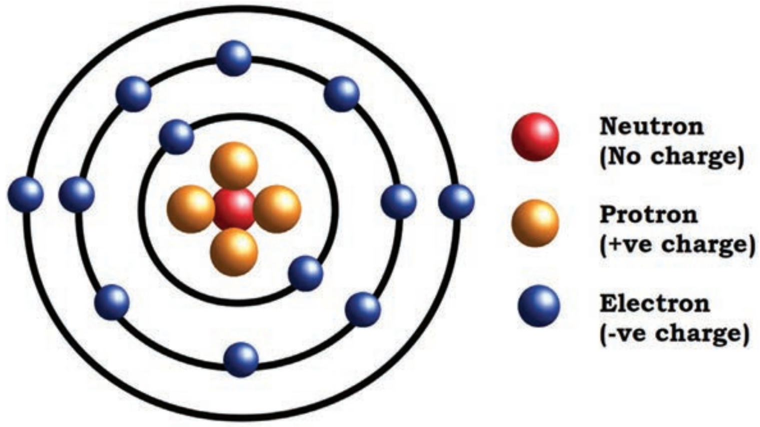


Fig.1.6 Atomic structure

Charge

Electric charge is the basic property of electrons, protons and other subatomic particles. Opposite charges attract each other and similar charges repel each other. This makes electrons and protons stick together to form atoms. One foundational unit of electrical measurement is 'coulomb', which measures electric charge proportional to the number of electrons in an imbalanced state. It was discovered by Charles-Augustine de Coulomb.

One coulomb of charge is equal to 6×10^{18} (6,250,000,000,000,000,000) electrons. The symbol for electric charge quantity is capital letter 'Q' and the unit of coulomb is abbreviated by the capital letter 'C'.

Flow of charge inside a wire: Free electrons randomly move from one point to another inside a conductor. Due to this random flow, the net electric charge of a conductor is zero. When an external power source is attached, the net flow of electrons is in one direction. This movement of electrons results in current. If there is a current of 1 ampere passing through a wire, it theoretically means that 6×10^{18} electrons are moving from one point to another in 1 second as shown in Fig. 1.7.

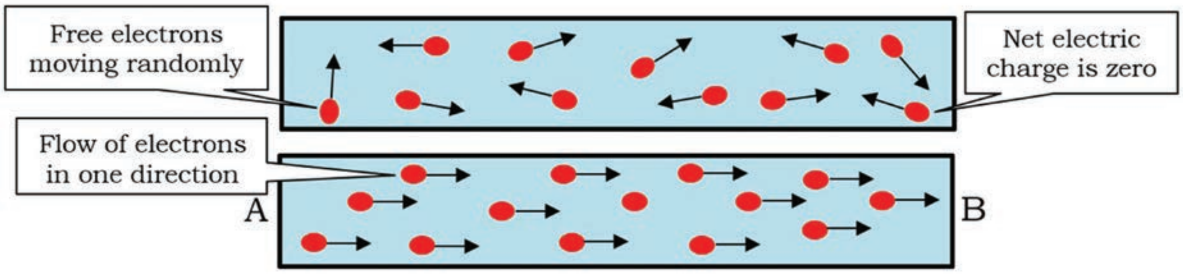


Fig.1.7 Flow of electrons

Conductors and insulators

When electrons move, current is generated. As in case of a piece of wire, the electrons are passed from atom to atom, creating electrical current from one end to another.

Conductors

The material, in which electrons are loosely held, can move easily. These are called conductors. Metals like copper, aluminium and steel are good conductors of electricity.

Insulators

The material, which holds electrons tightly and do not allow movement of electrons through them, are called insulators. Rubber, plastic, cloth, glass and dry air are good insulators and have high resistance.

Types of electricity

Electricity can be classified as:

1. Static electricity
2. Dynamic or current electricity

Static electricity

Static electricity is the result of imbalance between negative and positive charges in an object. When electrons do not move from one point to another, it is called static electricity. Static electricity exists in the form of direct current (DC). Energy stored in an electric cell or battery is an example of static electricity.

Dynamic or current electricity

Current electricity flows through wires or other conductors and transmits energy to devices. The flow of electricity is possible only because of the flow of charged particles, i.e., electrons. When electrons are in motion, the electricity, thus, generated is called dynamic or current. Dynamic electricity exists in the form of alternate current (AC). Dynamic electricity cannot be stored. It has to be converted to static electricity for storing it. Current flowing through electrical wire and electrical AC generator are examples of dynamic electricity.

Assignment 1

- Discuss the different sources of electricity, and also renewable and non-renewable sources of electricity.
- Prepare a data sheet, in which electricity generating capacity of five hydel power generating stations, are mentioned.
- List the name of top five thermal power plants in India as per their electricity generating capacity.

Notes

Electrical quantities

Current, voltage and resistance are the three basic building blocks of electricity and electronics and are known as 'electrical quantities'. One cannot see energy flowing through a wire or voltage of a battery with the naked eye.

An electric circuit is formed when a conductive path is created to allow free electrons to move continuously. This continuous movement of free electrons through the conductors of a circuit is called 'current', and is often referred to in terms of 'flow', just like the flow of some liquid through a hollow pipe.

The force motivating electrons to 'flow' in a circuit is called 'voltage'. Voltage is the specific measure of potential energy that is always relative between two points.

Free electrons tend to move through conductors with some degree of friction or opposition to motion. This opposition to motion is called 'resistance'. The amount of current in a circuit depends on the amount of voltage available to motivate the electrons, and also the amount of resistance in the circuit to oppose electron flow.

Table 1.1 Standard units of measurement for current, voltage and resistance

Quantity	Symbol	Unit of measurement	Unit abbreviation
Current	I	Ampere	A
Voltage	V	Volt	V
Resistance	R	Ohm	Ω

The symbol given for each quantity is the standard alphabetical letter used to represent that quantity in an algebraic equation. Each unit of measurement is named

Alessandro Volta
(1745–1827)

Andre M. Ampere
(1775–1836)

Georg Simon Ohm
(1789–1854)

Fig. 1.8 Famous scientists

after a famous scientist. Amp after Frenchman **Andre M. Ampere**, volt after Italian **Alessandro Volta** and Ohm after German **Georg Simon Ohm** (Fig. 1.8).

When these quantities are in DC form, they are represented by capital letters, i.e., 'R' for resistance and 'V' for voltage, which are both self-explanatory, whereas, 'I' stands for current.

Voltage

Voltage is the potential difference between two points. Voltage is also the amount of work required to move one coulomb charge from one point to another. Mathematically, it can be written as:

$V=W/Q$

where,

'V' is the voltage

'W' is the work in joule

'Q' is the charge in coulomb

In an electric circuit, battery is used as an electric potential. Battery is one of the sources of voltage in an electric circuit. Inside a battery, chemical reactions provide the energy needed to flow electrons from negative to positive terminal.

When voltage is applied in an electric circuit, negatively charged particles are pulled towards higher voltages, whereas, positively charged particles are pulled towards lower voltages. Therefore, current in a wire or resistor always flows from higher to lower voltage.

A voltmeter is used to measure voltage (or potential difference) between two points in a system. The value of voltage is measured in volt or joules per coulomb. The symbolic representation of voltage is **'V'** or **'v'**. **'V'** is for DC voltage and **'v'** for AC voltage.

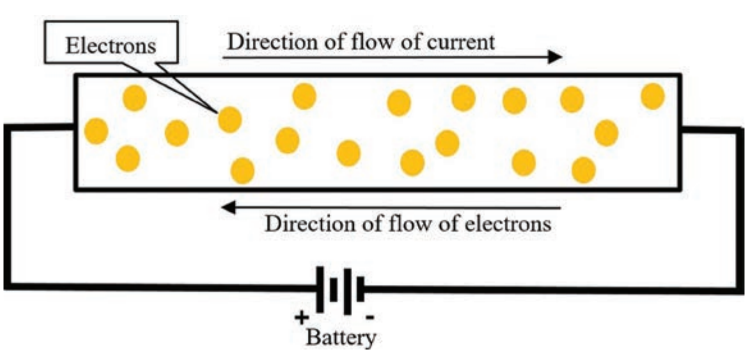


Fig. 1.9 Flow of electrons on application of DC supply

Example 1: When 1 joule of work is done to move 1 coulomb charge from one point to another, the potential difference between the two points is said to be one volt.

Current

Electric charge, often called current, is the flow of electrons. These electrons carry charge. The electrons flow from one place to another. Moving electrons generate more charge. The amount of charge with electrons flowing from one place to another is called electric current (Fig. 1.12). The unit of measuring current is ampere (A). The symbolic representation of current is 'I' or 'i'. 'I' is for DC current and 'i' for AC current. Mathematically, it can be written as

$$I = Q/t$$

where,

'I' is the current
'Q' is the amount of charge in coulombs
't' is the time in seconds

Note: Coulomb is the unit of charge.

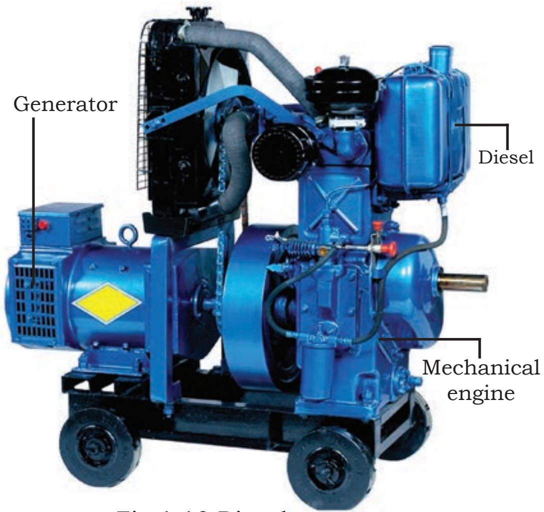


Fig.1.10 Diesel generator

Fig.1.11 Battery as a source of DC voltage

Example 2: If 1 coulomb charge passes through a point in 1 second, it will represent 1 ampere current. Conventionally, the direction of current is taken as opposite to the flow of electrons.

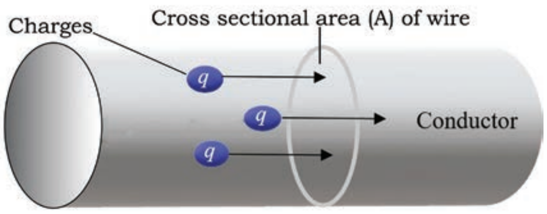


Fig. 1.12 Flow of charge through a cross section 'A'

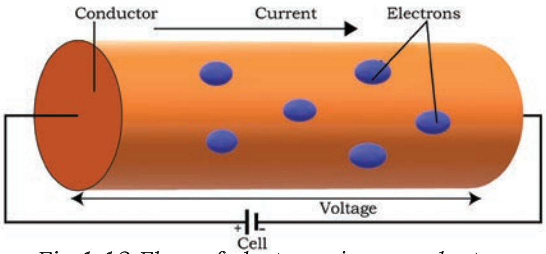


Fig.1.13 Flow of electrons in a conductor

Classification of current

Depending on the movement of electrons in an electric circuit, current can be classified as

1. Direct current (DC)
2. Alternating current (AC)

Direct current

It is unidirectional in nature, i.e., movement of electrons takes place only in one direction. This means that the current flows only in one direction. DC voltage source (like batteries and cells) produces direct current. Direct current is used in a wall clock, remote control, vehicles, automobile, cell phone, etc.

Alternating current

It is bidirectional in nature. The movement of electrons takes place in two directions, i.e, current flows in two directions. AC voltage sources (like AC generator) produce alternating current. Hydel power plants, thermal power plants, etc., are examples of alternating voltage sources. Alternating current is used in ceiling fan, cooler, washing machine, etc. In India, standard AC generating frequency (f) of alternating current is 50 hertz.

Frequency can be defined as 'the number of cycles in one second'. Point A to point B represents one cycle. Hertz (Hz) is the unit of frequency.

Example 3: 50 Hz represents 50 cycles in 1 second.

The main difference between AC and DC current is the direction of the flow of electrons. In alternating current (AC), the movement of electric charge periodically reverses direction. In direct current (DC), the flow of electric charge is only in one direction.

The usual wave form of an AC power circuit is a sine wave (Fig. 1.14). In certain applications, different wave forms are used, such as triangular or square waves. Audio and radio signals carried on electrical wires are also examples of alternating current.

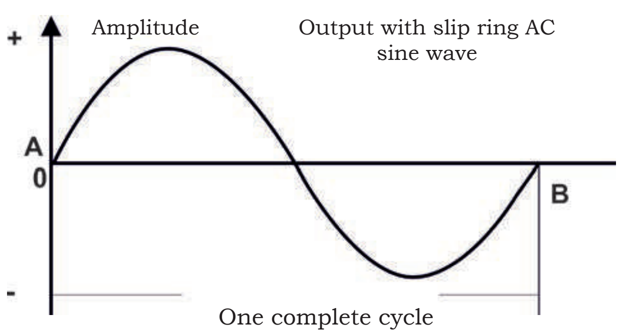


Fig. 1.14 Cycle of AC signal

Resistance

In conductors, electrons are loosely held and can move easily. In insulators, electrons are tightly bound to their atoms and do not move easily. A high voltage electromotive force (EMF) is required to move the electrons in an insulating material. Thus, the insulator holds the electricity safely. On the other hand, a small voltage or EMF is required to move the electrons in any conductor. In conductors, the resistance is low, while in insulators, it is high.

As the name suggests, a resistor resists the flow of electrons, and hence, electric current in the circuit. Conceptually, resistance controls the flow of electric current. Electrical conductance, which easily passes current, is opposite the quantity to electrical resistance. Resistance is represented by the symbol 'R'. The SI unit of electrical resistance is Ohm (Ω), while electrical conductance is measured in siemens (S).

Electric power

Electric power is the rate at which electric energy is transferred by a circuit. Electric power, is the rate of doing work, i.e., amount of work done in one second. Power is represented by the symbol 'P'. The SI unit of power is watt (W), which is equal to one joule per second. It is named after Scottish inventor James Watt (1736–1819).

Fig. 1.15 James Watt (1736–1819)

Electric horsepower (hp) is another unit of measuring power. It is equal to 746 watt. It is slightly higher than mechanical horsepower, which is 745.7 joules per second.

The electric power in watt produced by an electric current I consisting of a charge of Q coulombs every t seconds passing through an electric potential (voltage) difference of V is:

P = Work done per unit time = $QV/t = V \times I$

Where,

Q is electric charge in coulombs

't' is time in seconds

'I' is electric current in ampere

'V' is electric potential or voltage in volts

$P=W/t$ or $P=I^2R$

Where,

'W' is the work done in joules

't' is the time in seconds

Power can also be defined in terms of current and voltage, i.e., product of voltage and current results in power. Watt is the measure of energy flow. Since watt is a very small unit of power, we need a much larger unit like kilowatt, which is equal to 1000 watts, in actual practice.

Fig. 1.16 Domestic Efficiency Lighting Programme (DELP) 9 Watt LED

Since, the product of power and time gives electrical energy, therefore, the unit of electrical energy is watt hour or kilowatt hour. One watt hour of energy is consumed when 1 watt of power is used for 1 hour. The commercial unit of electric energy is kilowatt hour (kWh).

$$1\text{kWh} = 1000 \text{ watt} \times 3600 \text{ second}$$
$$= 3.6 \times 10^6 \text{ watt second or } 3.6 \times 10^6 \text{ joule}$$

For example, the power of this LED is 9 watt (Fig. 1.16). This 9 watt defines it will do 9 joules of work in 1 second. LED is the replacement of compact fluorescent lamp (CFL). LEDs are more efficient than CFLs.

Assignment 2

A 100 watt electric bulb is lighted for two hours daily and four 40 watt bulbs are lighted for four hours daily. Calculate the energy consumed (in kWh) in 30 days.

Power factor

In an AC circuit, various components are connected together, such as resistor, inductor and capacitor. These components consume power. When voltage is applied to an inductor, it opposes the change in current. Current builds up more slowly than voltage, lagging in time and phase. In this way, it can be stated that current lags voltage. In case of a capacitor, voltage is directly proportional to the charge on it. Current must lead the voltage in time and phase to conduct charge on the plates and raise the voltage. When inductor or capacitor is involved in an AC circuit, current and voltage do not peak at the same time. The fraction of period difference between the peaks, expressed in degrees, is called 'phase difference'. The phase difference is <= 90 degrees. Because of this phase difference in voltage and current, power in capacitor and inductor will be minimum. In other words, it can be said that this power will be radiated by the circuit. This power is known as 'reactive power'.

Know more...

The Government of India launched the National Programme for LED-based Home and Street Lighting in New Delhi for energy conservation by reducing its consumption. Along with this programme, the government also launched a scheme for Light Emitting Diode (LED) bulb distribution under the Domestic Efficient Lighting Programme (DELP) to enable consumers in Delhi to register requests for LED bulbs under DELP.

In case of resistor, both current and voltage are in the phase. Therefore, power applied to the resistor gets utilised. This power is called 'real' or 'true' power. Combination of true and reactive power is called apparent power.

Power factor is the ratio of real power to apparent power. Value of power factor varies from 0 to 1. It is denoted by cos Ø.

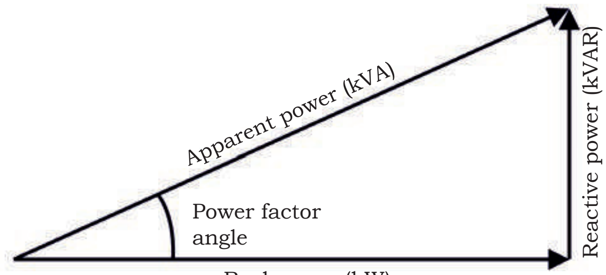


Fig. 1.17 Power factor triangle

Power factor = Real power/Apparent power

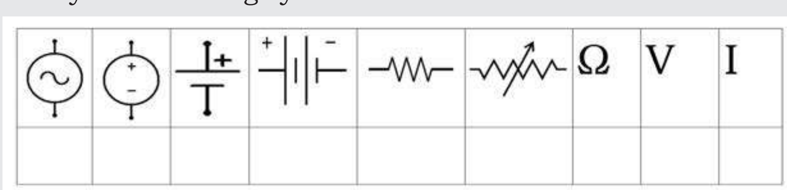
Referring to Fig. 1.17, it can be observed that as reactive power starts reducing, real and apparent power become equal. When real power and apparent power become equal, it means that the AC circuit is resistive in nature, i.e., it will only have a resistive component in the circuit. Hence, it can be summarised that reactive power due to capacitor and inductor will not get utilised by the circuit.

Apparent power is the total power given to the circuit, whereas, reactive power is the unutilised power, and real power is the power utilised by the circuit.

Assignment 3

Practical Exercise 1

Identify the following symbols and write down their names.



Practical Exercise 2

Draw the circuit as shown in Fig. 1 and indicate voltage, current, resistance and power.

Material required

Battery of 9V, fixed resistor of 3 Ohm, bulb or LED of 5 watt

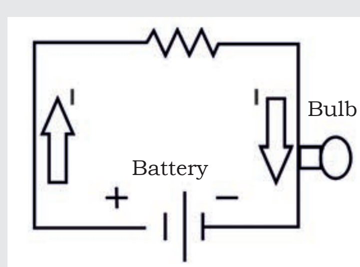


Fig. 1

Practical Exercise 3

Identify live, neutral and earth on power socket as shown in Fig. 2.

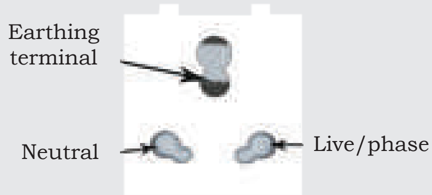


Fig. 2 A 3-pin socket

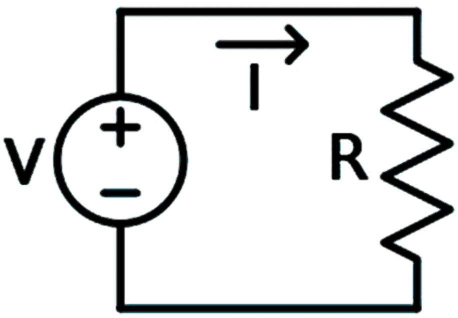


Fig.1.18 Basic electric circuit

Basic electric circuit

An electrical circuit supplies electricity to an electrical device. This device is called 'load'. Before the load operates, electricity must have a complete path from the source to the load and back to the source.

This path for electricity is called 'circuit'. An electric circuit is an interconnection of electric components so that electric charge is made to flow along a closed path (circuit), usually, to perform some useful task. In Fig. 1.18, the voltage source V on the left drives a current I around the circuit, delivering electrical energy into the resistor R. From the resistor, the current returns to the source, completing the circuit.

The components in an electric circuit include resistor, capacitor, inductor, semiconductor, integrated circuit, etc. Electronic circuits contain active components, usually, semiconductors. The simplest electric components are passive in nature. They may temporarily store energy. They do not contain any source of energy. The components of a circuit can be active or passive.

Active and passive components

There are two classes of electronic components—active and passive.

Active components

Fig.1.19 Active components

They produce energy in the form of voltage or current. These components require an external source for operation. Some of the common examples of active components are diode and transistors. If we connect a diode to a circuit, and then, connect this circuit to the supply voltage, the diode will not conduct the current until the supply voltage reaches 0.3 (in case of Germanium) or 0.7V (in case of Silicon).

Passive components

They do not produce energy in the form of voltage or current. These components do not require an external source for operation. Some of the common examples of passive components are resistor, capacitor, inductor, etc. Like a diode, a resistor does not require 0.3 or 0.7 V, i.e., when we connect it to the supply voltage, it starts work automatically without using a specific voltage.

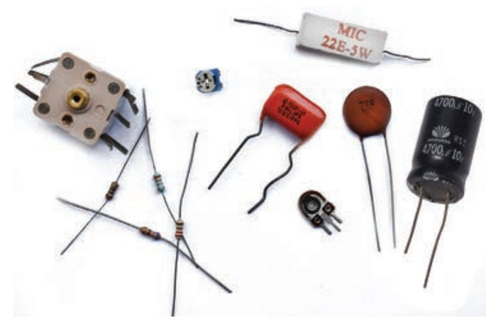


Fig.1.20 Passive components

In simple words, active components are energy donors and passive components are energy acceptors.

Open and closed circuit

A circuit is a closed path or loop around which electric current flows. If the circuit is complete, it is called 'closed' and the device receives power to work. If this path is broken, the circuit is said to be 'open' and the device does not work [Figs. 1.21 (a) and (b)].

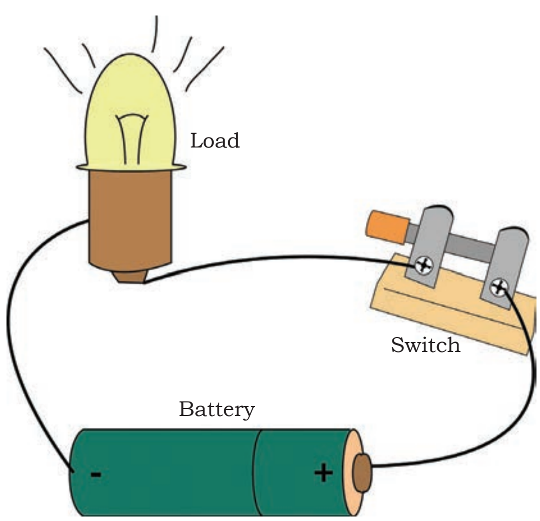


Fig.1.21(a) Closed circuit

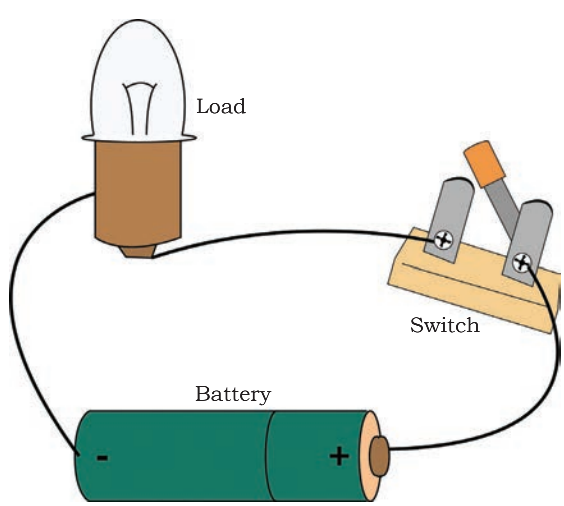


Fig.1.21(b) Open circuit

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Practical Exercise 4

Analysis of open and closed circuit—Prepare the circuit to glow the lamp as shown in Figs. 1 and 2.

Material required

9-volt battery, connecting wire, resistor, lamp, wire stripper, wire cutter and switch

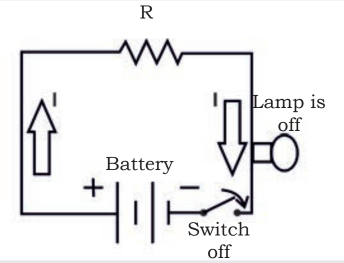

Fig.1 Open circuit

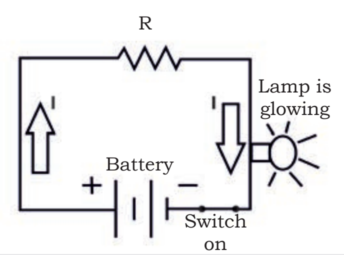

Fig. 2 Closed circuit

Procedure

Follow the steps given below to form a circuit.

1. Take a battery and identify its positive and negative terminals.
2. Take a wire. Cut it using a wire cutter and strip the insulation using a wire stripper.
3. Connect the wire to the positive and negative terminals of the battery.
4. Connect a resistor to the wire, which is connected to the positive terminal of the battery.
5. Connect the other terminal of the resistor to one of the terminals of the lamp.
6. Connect the other terminal of the lamp to one of the terminals of the switch.
7. Connect the other terminal of the switch to the wire, which is connected to the negative terminal of the battery.

Observation

When the switch is turned 'on', the lamp starts glowing.

Practical Exercise 5

Construct a test lamp.

Material required

1 bulb, 1 bulb holder, wire, wire cutter, wire stripper and plug

Circuit diagram

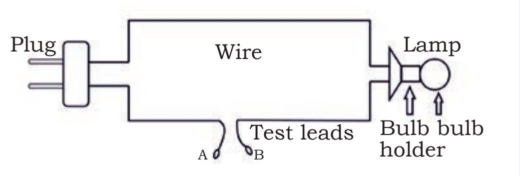

Fig.1 Circuit diagram for test lamp

Procedure

1. Cut the wire into two pieces, each one metre long, using a wire cutter.
2. Now, you have two pieces of wire. Strip the insulation of the wire terminals.
3. Fix the bulb holder using one end of the two pieces of wires and install a light bulb onto the holder.
4. The other two ends of the wires are free. Fix a two-pin plug on those free pairs of wires. It means you can light up the bulb if you put a two-pin plug in a live two-pin socket.
5. Check the continuity of the test lamp, i.e., see if the bulb turns on when the plug is inserted in a live two-pin socket.
6. Now, pull out the plug from the socket.
7. Finally, you need to slice one of the wires in the middle and remove insulation from each of the cut ends for half-an-inch so that the bare copper is clearly visible.
8. Your test lamp is ready for experiment. Always use a cap to cover the bare copper wire to avoid accidents.

Series and parallel circuit

Electronic circuits are arranged in many ways. Circuits are named on the basis of how the components are connected. The two simplest form of circuits are series and parallel.

Series circuit

In a series circuit, electric loads are connected along a single path. Therefore, the current flowing across the path will remain the same. Since, there is only one path for the electrical current to flow, all electric load in the circuit will stop working if a wire is cut or a switch is turned on. If a battery connected to the circuit has insufficient charge or energy, there will be insufficient current supply in the circuit. In this case, the battery needs to be replaced. Adding two batteries in the series may also solve the problem. In the series circuit, the arrows show the flow of current.

A series circuit or 'series-connected circuit' is a circuit having just one current path. Fig. 1.22 (a) is an example of a 'series circuit', in which a

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battery of constant potential difference V (volt), and three resistances (R_1, R_2 and R_3) are all connected in series.

Since a series circuit has just one current path, all components in it carry the same current I.

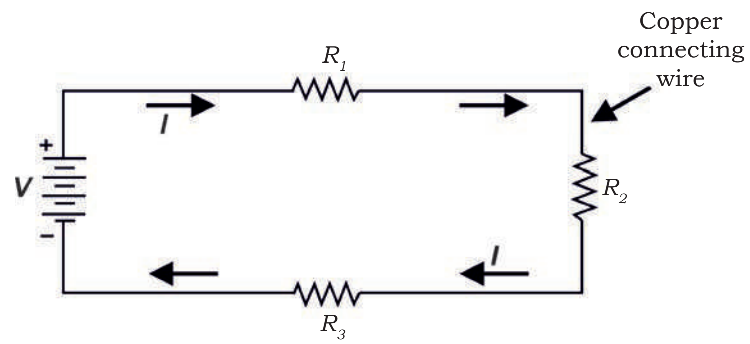


Fig. 1.22(a) Series circuit

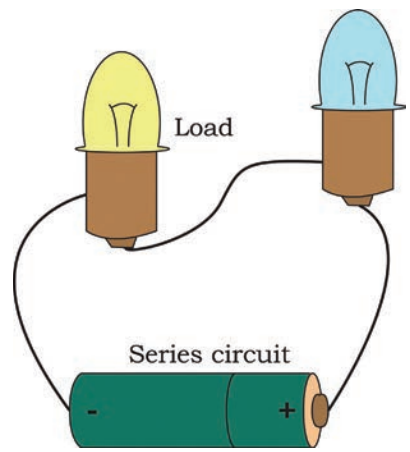


Fig. 1.22(b) Bulb connected in series circuit

The current I is assumed to be the flow of positive charge, and thus, flows out of the positive terminal of the battery, and through the external circuit, re-enters the battery at the negative terminal. This is indicated by arrows in Fig. 1.22(a).

In a series circuit, the total resistance, R_T is equal to the sum of the individual resistances. Thus, particularly, in case of Fig. 1.22(a), the battery sees total resistance, $R_T = R_1 + R_2 + R_3$, while in the general case of 'n' resistances connected in series, the total resistance is as follows:

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

Parallel circuit

In a parallel circuit, electric load in the circuit forms multiple paths. Since, there are a number of paths, even if one electric load stops working, the other electric loads in the circuit will still work. The current from the source divides, so some of the current flows through one path and the rest through other paths. This means that the power source must supply more current to power a parallel circuit than a series circuit, which may run down the battery faster. In a parallel circuit shown in Fig.1.23(a), the arrows represent the direction of current flow.

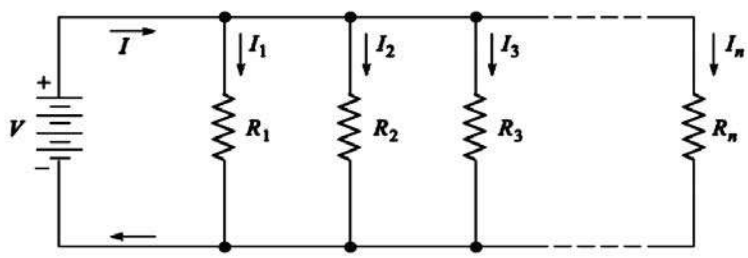
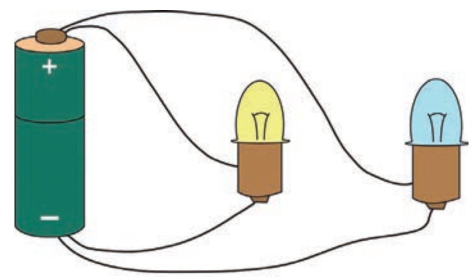


Fig.1.23(a) Parallel circuit



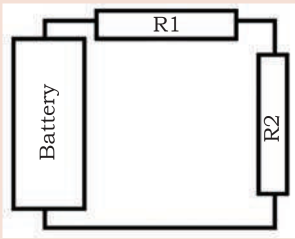
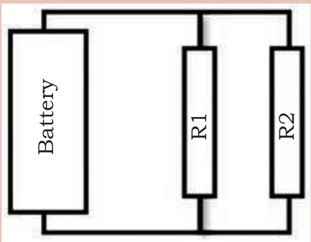
Parallel circuit

Fig.1.23(b) Bulbs connected in a parallel circuit

A parallel circuit is one, in which the battery current divides into a number of parallel paths. This is shown in Fig. 1.23(a), in which a battery of constant V volts delivers a current of I ampere to a load consisting of any number of n resistances connected in parallel.

Total resistance of the parallel circuit is as follows:

$R_T = (R_1 \times R_2 \times R_3 \times \ldots\ R_n)/(R_1 + R_2 + R_3 + \ldots\ldots + R_n)$

Key concept	Diagram
For a **series circuit**, R_1 is said to be in series with R_2. For these circuits, the current flowing through each device in series is the same. Adding the voltages across each element in series is equal to the total (battery) voltage.	 *Fig.1(a)*
For a **parallel circuit**, R_1 is said to be parallel to R_2. For these circuits, the voltage across each device in parallel is the same. Adding the current through each element in parallel is equal to the total (battery) current.	 *Fig.1(b)*

Activity

Draw and show more than one way to light a bulb. Can you do it with one wire? Can you do it with two wires? How many different ways can you think of?

Assignment 4

- Build series and parallel connections of resistors and calculate the resistance.
- Set up a circuit, in which three resistors of different values are connected in series and parallel. Then, manually calculate the value of total resistance in both series and parallel connections. Verify the values using an ohmmeter.

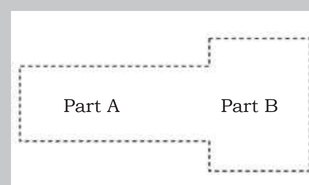
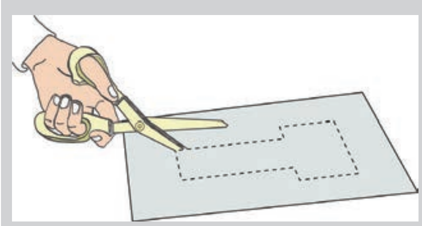
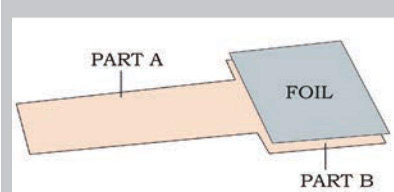
Practical Exercise 6

Making a bulb holder

Material required

Cardboard (thin) measuring 15×6 cm, aluminium foil measuring 6×4 cm, a pair of scissors, glue stick, push pin, pen, light bulb and tape

Procedure

Cut out the shape as shown in Fig. 1.	 *Fig. 1*
Lay the shape on top of the cardboard. Use a pen to trace around it, and then, cut the piece of cardboard as shown in Fig. 2.	 *Fig. 2*
Glue the piece of aluminium foil onto Part B of the bulb holder as shown in Fig. 4.	 *Fig. 3*

Use a push pin to poke a hole near the middle part as shown in Fig. 4. Part A uses a pen to widen the hole.

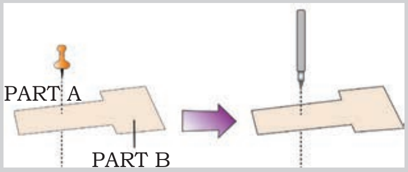


Fig. 4

Make sure the hole is large enough for the bulb to fit in. Then, loop Part A around the backside of Part B. Tape it into place as shown in Fig. 5.

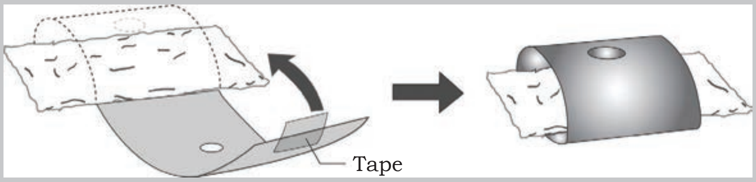


Fig. 5

Practical Exercise 7

Making an electric circuit using bulb holders

Material required

Bulb holder, light bulb, cardboard measuring 20 × 15 cm (8 × 6 inch), battery (C or D cell), two brads, push pin, pen, two connecting wires (stripped on each end), measuring 15 cm (6 inch) in length, electrical tape.

Procedure

1. Attach the battery to the cardboard circuit board by moving it down towards a narrow side of the cardboard.
2. Prepare to attach the bulb holder to the cardboard circuit board by using a push pin to poke holes in the bulb holder and the cardboard circuit board.
3. Use the tip of a pen to widen the holes, and then, use brads to lock the bulb holder in place on the circuit board as shown in Fig. 1.

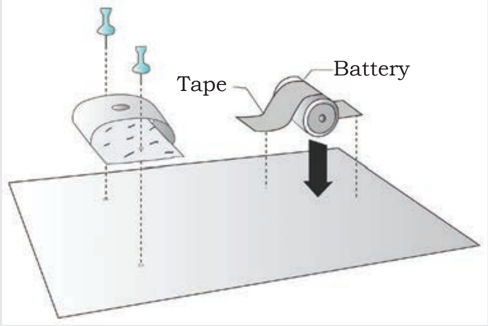


Fig. 1 Cardboard circuit

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4. Tape one end of a connecting wire to the terminal of the battery. Wrap the other end around the bulb holder brad.
5. Tape one end of the other connecting wire to the battery's other terminal. Lay the other end into the bulb holder hole as shown in Fig. 2.

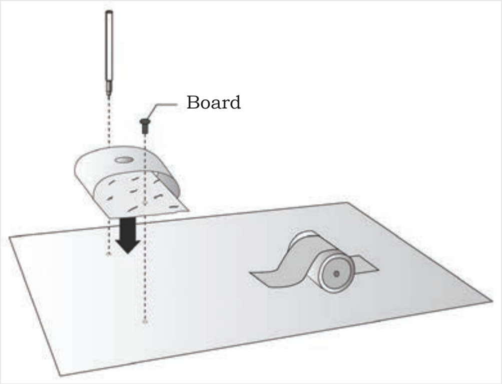

Fig. 2

6. Place the bulb into the bulb holder. Make sure the bottom of the bulb touches the aluminium foil as shown in Fig. 3.

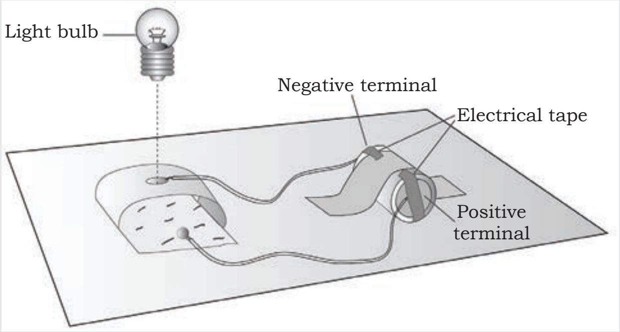

Fig. 3

Ohm's law

Georg Simon Ohm (16 March 1789–6 July 1854) was a German physicist and mathematician. As a school teacher, Ohm began his research with the new electrochemical cell. He investigated the relationship between current and voltage in a resistor and published his experimental results in 1827. Ohm's law can be used to understand the behaviour of electricity in individual components, as well as, in complete circuits.

Ohm's experiment

A DC variable supply voltage is connected with positive terminal at point 'a' and negative terminal at 'b' as shown in Fig. 1.24. As voltage is increased, current recorded by the ammeter also increases. For every voltage value the current is recorded and the corresponding point is plotted on the rectangular graph. With this, a straight line graph passing through the origin is obtained in the first quadrant.

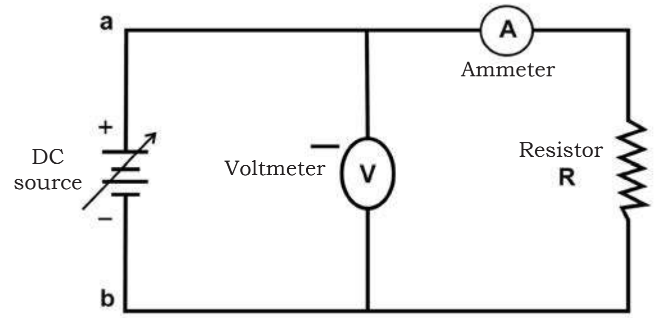

Fig. 1.24 Diagrammatic representation of Ohm's experiment

Next, terminals of the variable DC supply are interchanged, i.e., 'a' is connected to –ve polarity of dc supply and 'b' is connected to +ve polarity of dc supply. Since both the voltmeter and ammeter are moving coil meters, their individual connection should also be interchanged so that the meters can read up the scale.

This is done to reverse the direction of flow of current through the resistor R. Again, the voltage is varied and corresponding to each voltage, current is recorded and the pairs of V and I are plotted in the third quadrant.

Experiment results

The experiment results indicate that there is a linear relationship between current and voltage, both in the first and third quadrant. The slope of straight line is also same in both the quadrants, which shows that the potential difference across the terminals of the conductor is proportional to the current passing through it, i.e., V α I as shown in Fig. 1.25.

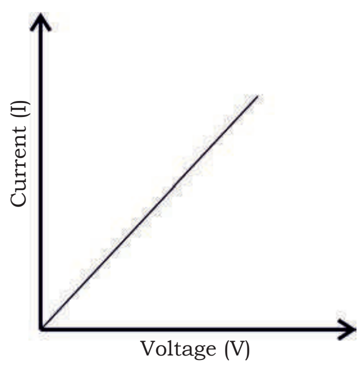

Fig.1.25 Linear relationship between voltage and current

Also, it is found that for a constant current in the conductor, resistance should be proportional to the potential difference, i.e., V α R.

Combining the two proportionalities, we have

V α IR

Or V= k (I × R)

where, k is a constant of proportionality. However, the units of voltage, current and resistance are defined, so that the value of k = 1. When the current is 1 amp and voltage is 1 volt, the resistance is 1Ω.

1 = k . 1 . 1

Thus, the equation becomes

V= IR

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Thus, the Ohm's Law states that "current is directly proportional to the applied voltage" or "the current in a conductor is directly proportional to the potential difference between the terminals of the conductor and inversely proportional to the resistance of the conductor".

It means that if voltage increases, current will increase, and if voltage decreases, current will also decrease. Also, if the voltage remains constant, as the resistance increases, the current goes on decreasing and vice versa. Therefore, when the voltage is constant, the resistance is inversely proportional to current. When resistance increases, current decreases, and if resistance decreases, current increases.

The above constitute is called Ohm's Law, if we let

'V' = voltage or EMF applied to the conductor

'I' = current flowing into the conductor

'R' = resistance of the conductor

With volts (V), current (I) in amperes and resistance (R) in Ohm, the Ohm's law is

$V = IR$

Practical Exercise 8

Verify Ohm's law in the given electrical circuit.

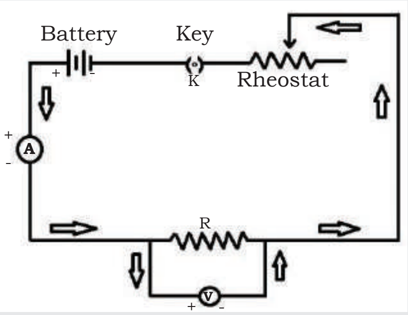

Fig. 1. Circuit diagram of Ohm's law

Material required

Rheostat, resistor, ammeter, voltmeter, voltage supply of 5V DC

Procedure

1. Using the DC circuit trainer, connect the circuit as shown in Fig.1.
2. Connect the variable voltage supply to both the ends of the rheostat as shown in the circuit diagram.
3. Connect the ammeter in series of the rheostat as shown in the circuit diagram.

4. Connect the voltmeter in parallel of the rheostat as shown in the circuit diagram.
5. Now, start measuring the voltage and current by varying the position of the rheostat knob from minimum to maximum position.
6. When the rheostat knob is at minimum position, maximum current will flow through the circuit and vice versa.
7. Increase the voltage from 0–10 v and measure the current at each step, and then, record it in the table given below.

V (Volt)	0	1	2	3	4	5	6	7	8	9	10
1 (mA)											

8. Observe the number of readings and fill them in the table.
9. Now, with this data, plot a graph between voltage and current.

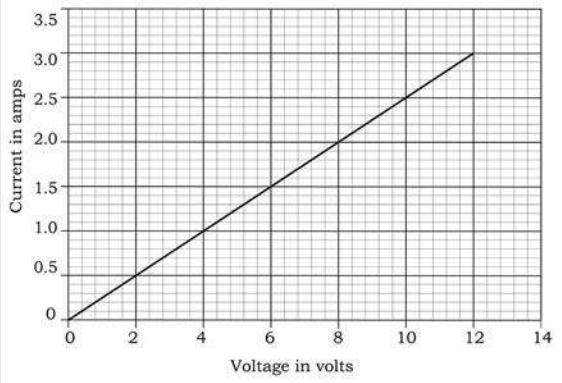

Fig. 2

10. The graph between voltage and current will be linear (Fig. 2), i.e., there will be proportionality in voltage and current. If the voltage increases due to any factor, then the current will also increase with the same value.

The relationship between current, voltage and resistance is important for all electrical networks.

	Current	Voltage	Resistance
Symbol	I	V	R
Unit	Ampere (A)	Volt (V)	Ohm (Ω)

Problems in Ohm's law

Some of the solved examples to understand the Ohm's Law better are as follows.

Example 1: A 10 V battery is connected to an electric bulb of 20 Ohm resistance. Find the current flowing through the electric bulb.

NOTES

Solution: Here,

$V = 10\ V$

$R = 20\ \Omega$

The current flowing through the electric bulb is given by

$V = I\ R$

$I = V/R$

$I = 10/20$

$I = 0.5$ ampere, so the current flowing through the bulb is 0.5 ampere.

Example 2: An electric iron of resistance 40 Ω is connected to a supply voltage. The current flowing through the electric iron is 6 ampere. Find the voltage applied to the electric iron.

Solution: Here, $I = 6\ A$, $R = 40\ \Omega$

Voltage equation is given by

$V = I\ R$

So, voltage is expressed as $V = 6 \times 40$

$V = 240$ volts

Example 3: A 110 V voltage source supplies power to a halogen light. The current flowing through the halogen light is 5 A. Find the resistance of the halogen light.

Solution: Here, $V=110V$, $I=5A$

The resistance is given by

$R = V\ /\ I$

$R = 110/5$

$R = 22\ \Omega$

So, the resistance of Halogen light is 22 Ohm.

Assignment 5

A. Solve the problems based on Ohm's law.

1. A voltage of 9 Volt is applied across a 3 Ohm resistor. Calculate if current is flowing.
2. A 6 Ohm resistor passes a current of 2 amps. What is the voltage across it?
3. What is the voltage of a circuit with a resistance of 255 Ohm and a current of 3 amp?
4. A small electrical pump is labeled with a rating of 5 amp and a resistance of 30 Ohm. At what voltage is it designed to operate?

5. A 9 Volt battery is hooked up to a light bulb with a rating of 2 Ohm. How much current passes through the light bulb?
6. A lamp is plugged into a power socket, which provides 110 volt. An ammeter attached to the lamp shows 2 amp flowing through the circuit. How much resistance is the lamp providing?
7. If your skin has a resistance of 9000 Ohm and you touch a 9 Volt battery, how much current will flow through your body?
8. How much current will flow through your body with a skin resistance of 12,000 Ohm, if you touch a 120 Volt house potential?
9. Suppose you are soaked in seawater and your resistance is lowered to 1000 Ohm. Now, how much current will flow through your body if you touch a 9 Volt battery?
10. When you are soaked in seawater, how much current will flow through your body if you touch a 120 Volt house potential?

B. Write the electrical symbols and units for the following.

	Current	Voltage	Resistance
Symbol			
Unit			

C. In the following table, from the given quantities, calculate the unknown quantities. The unit 'k' stands for kilowatt, which means 1000 watts.

Voltage	Current	Resistance	Power
100 V	5A		
12 V		1 Ohm	
	5A	8 Ohm	
230 V	13A		
	3A	150 Ohm	
50 V		20 Ohm	
		40 Ohm	1 kW
	0.5 A		2.5 W
250 V			62.5 W

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D. Find the electrical quantities in the circuit as shown in Fig. 1.
   1. Calculate the equivalent resistance of this circuit.
   2. Calculate the total current drawn.

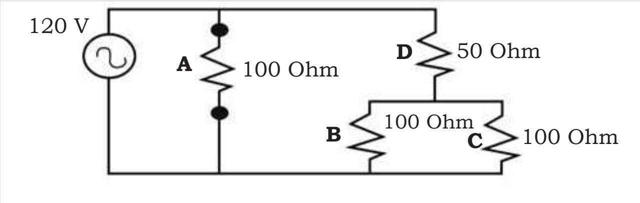

Fig. 1

   3. Calculate the voltage across following:
      Resistor 'A' ....
      Resistor 'B' ....
      Resistor 'C' ....
      Resistor 'D' ....
   4. Calculate the amount of power consumed by the circuit.

E. Find the following quantities for the circuit in Fig. 2.
   1. Calculate the voltage across each load when the switch is open.
   2. Calculate the current drawn from the battery.
   3. Calculate the voltage drop across each resistor.
   4. Calculate the equivalent resistance in the circuit.

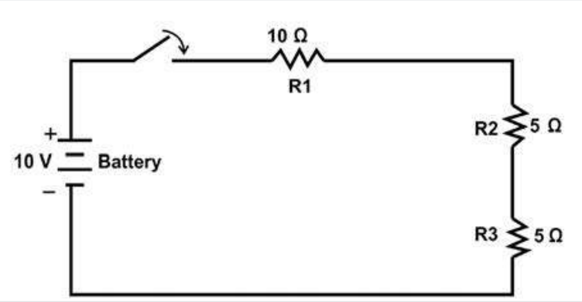

Fig. 2

Kirchhoff's laws

These laws are named after Gustav Kirchhoff, a German physicist. Kirchhoff defined the basic relationship between voltage (V) and current (I). These laws of Kirchhoff are used for circuit analysis. Kirchhoff's laws relate to the conservation of energy, which states that energy cannot be created or destroyed but only changed to different forms. This can be expanded to laws of conservation of voltage and current. In any circuit, the voltage across each series component (carrying the same current) can be added to find the total voltage. Similarly, the total current entering a junction in a circuit must be equal to the sum of the current leaving the junction. Kirchhoff's law is classified as:

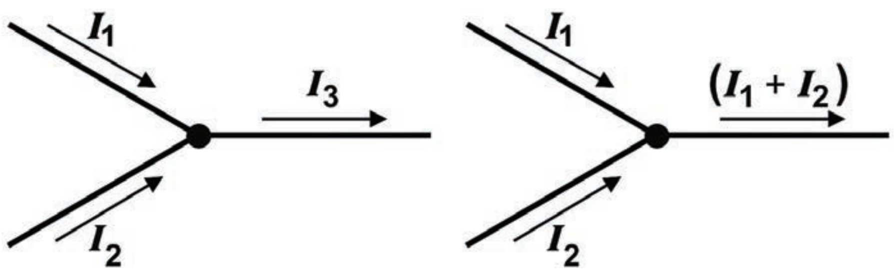

Fig. 1.26 Kirchhoff's current law

1. Kirchhoff's current law
2. Kirchhoff's voltage law

Kirchhoff's current law

Kirchhoff's current law states that total incoming currents at a point is equal to the total outgoing current. It can be understood by an example. Consider that I_1 and I_2 are coming towards a point. Current I_1 and I_2 are incoming current as they are coming towards a point as shown in Fig. 1.26. Current I_3 is outgoing current with respect to the point. The sum of incoming current I_1 and I_2 is equal to the sum of outgoing current I_3.

Mathematically, at a point

$$I_1 + I_2 = I_3$$

In a series circuit, the total current flowing remains the same at any point (Figs. 1.27 and 1.28).

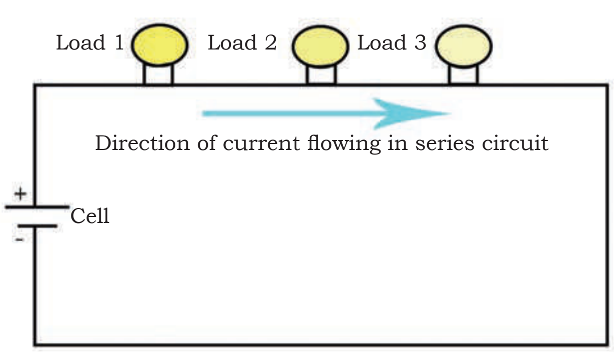

Fig. 1.27 Loads connected in a series circuit

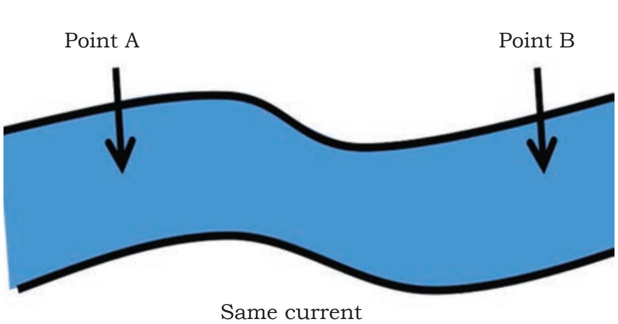

Fig. 1.28 Analogy of current in series circuit

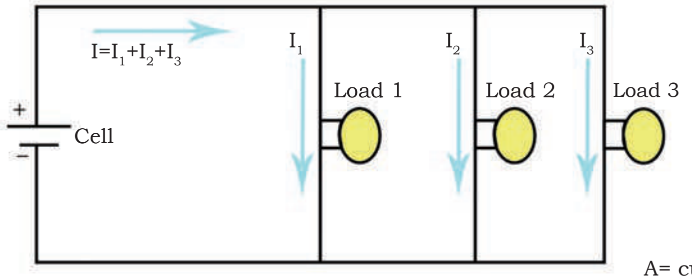

Fig.1.29 Loads connected in a parallel circuit

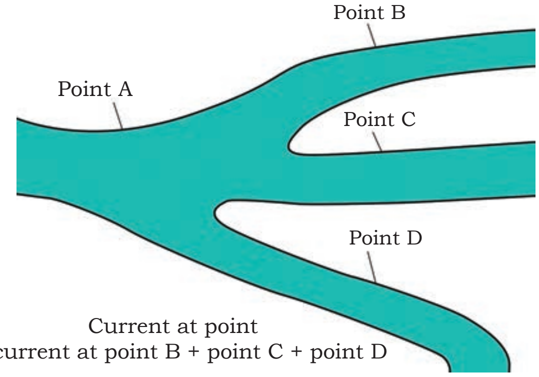

Fig. 1.30 Analogy of current in parallel circuit

In a parallel circuit, the total current flowing in the circuit is divided in parallel branches (Figs. 1.29 and 1.30).

Kirchhoff's voltage law

Kirchhoff's voltage law states that total voltage drop across the loads in a circuit is equal to the total voltage applied to the circuit. In other words, it states that the algebraic sum of the product of currents and resistance in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the EMF in that path is zero.

In other words, $\sum IR + \sum EMF = 0$

Let us now write the equation for Fig. 1.31 in accordance with Kirchhoff's voltage law. To do this, we start at any point and move completely around the circuit, listing the 'voltage drops' and the 'voltage rises' as we proceed (in doing this, remember that we have defined that going from 'minus to plus' constitutes a RISE in voltage and going from 'plus to minus' constitutes a DROP in voltage). Thus, if we agree to list all 'voltage drops' on the left-hand side of our equations and all 'voltage rises' on the right-hand side, the Kirchhoff's voltage equation for Fig.1.29 will be: $R_1I + V_2 + R_2I = V_1$

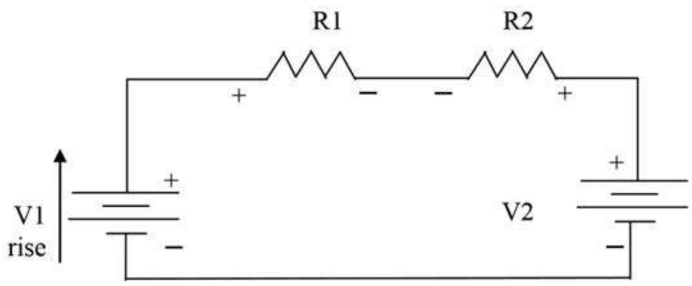

Fig. 1.31 Circuit diagram for Kirchhoff's voltage law analysis

Note, that V_2 appears as a voltage drop as we go through the battery from plus to minus (+ to –). Alternatively, putting all battery voltages on the right-hand side, the above equation becomes

$R_1I + R_2I = V_1 – V_2$.

Hence, $I = (V_1 - V_2)/(R_1+R_2)$

It can be understood with an example. Consider a circuit, in which three loads are used, i.e., R_1, R_2, R_3. Total applied voltage to the circuit is V. Voltage drop across the loads are V_1, V_2, V_3. Therefore, according to Kirchhoff's voltage law, the total applied voltage (V) is equal to the sum of individual voltage drop (V_1, V_2, V_3) across the loads.

Mathematically,

$V=V_1+V_2+V_3$

As shown in Fig. 1.32, the voltage drop across the loads are 5V, 2V, 3V. The total applied voltage is 10V.

10V = 5V + 2V + 3V

In a parallel circuit, the total voltage provided by the source is equal to the voltage across each parallel branch.

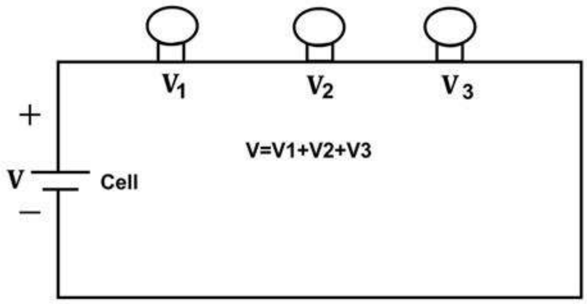

Fig. 1.32 Electric circuit with series connected loads

Analogy

Fig. 1.33 Analogy of voltage in series circuit

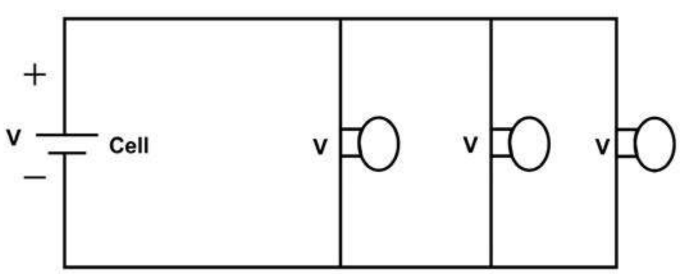

Fig. 1.34 Parallel circuit

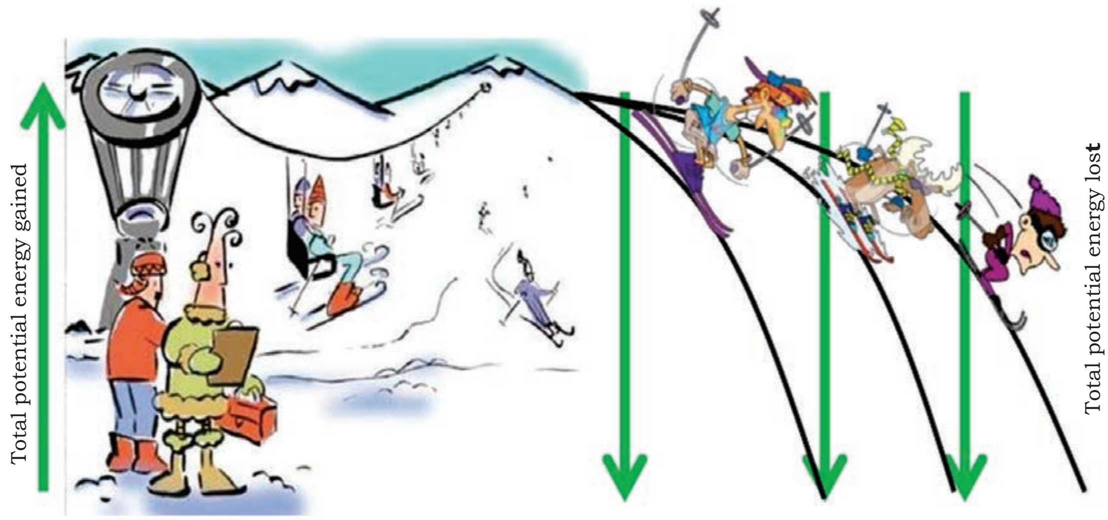

Fig. 1.35 Analogy of voltage in parallel circuit

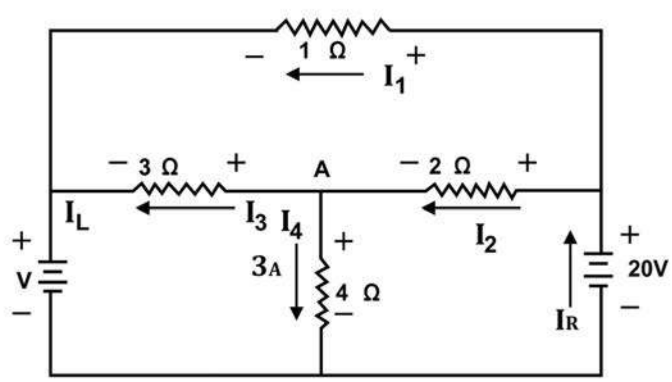

Fig. 1.36 Diagrammatic representation of Kirchhoff's law

Analysis of Kirchhoff's law

Analyse the circuit given in Fig.1.36 with 3A of current running through the 4Ω resistor and

- determine the current passing through the other resistors.
- determine the voltage of the battery on the left.
- determine the power delivered to the circuit by the battery on the right.

Procedure

Identify the current through the resistors by the value of the resistor (I_1, I_2, I_3, I_4) and the current flowing through the batteries (I_{Left} and I_{Right}).

Start with the 2Ω resistors. Apply the loop rule to the circuit on the lower right.

$$20\text{ V} = I_2(2\Omega) + (3\text{A})(4\Omega)$$

$$I_2 = 4\text{A}$$

Start circuit analysis from 3Ω resistors. Apply the junction rule at point A in the centre of the circuit.

$$I_2 = I_3 + I_4$$

$$4\text{A} = I_3 + 3\text{ A}$$

$$I_3 = 1\text{ A}$$

Notes

- The current through 1Ω resistor certainly runs from right to left. If we apply the loop rule to top circuit, we will have to run against that current. This changes what is normally considered as a potential drop into a potential increase.

  $I_1(1\Omega) = (4A)(2\Omega) + (1A)(3\Omega)$

  $I_1 = 11A$

- Apply the loop rule to the outer circuit to get the voltage of the battery on the left (continuing with the assumption that the current is running counter clockwise). We find ourselves running through the left battery backwards. This changes what is normally considered as a higher potential to a lower potential.

  $20V = (11A)(1\Omega) + V_L$

  $V_L = 9V$

- Let us verify this result by repeating the procedure for the bottom circuit.

  $20\ V = (4A)(2\Omega) + (1A)(3\Omega) + V_L$

  $V_L = 9\ V$

- The power delivered to the circuit by the battery on the right is the product of its voltage and the number of times current drives around the circuit. We already have the voltage (it is given in the problem). All that remains is to determine the current. Apply the junction rule to the junction on the left.

  $I_L = I_1 + I_3$

  $I_L = 11A + 1A$

  $I_L = 12A$

  and again to the junction at the bottom

  $I_R = I_L + I_4$

  $I_R = 12A + 3A$

  $I_R = 15A$

- To find the power of the battery on the right

  $P = VI$

  $P = (20V)(15A)$

  $P = 300W$

NOTES

Assignment 6

1. Determine the current through each resistor in the circuit shown in Fig. 1

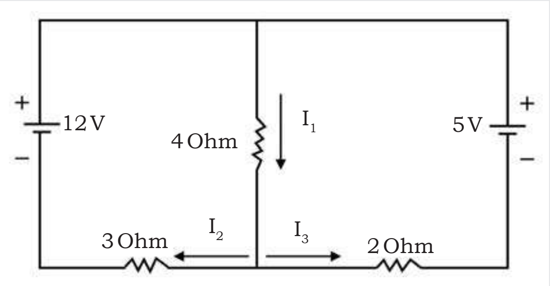

Fig. 1

2. Verify Kirchhoff's law by observing the reading in ammeter and voltmeter as shown in Fig. 1.

Practical Exercise 9

Material required

DC trainer kit of KVL and KCL, connecting cords and power supply

Procedure

1. Using the DC circuit trainer, connect the circuit shown below.

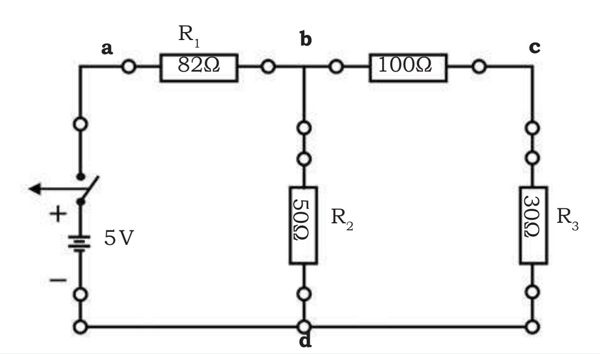

Fig. 2

2. Measure the values of voltage and current of each resistor in the circuit and record it in the table given below.

	R_1(Ohm)	R_2(Ohm)	R_3(Ohm)	R_4(Ohm)
I (mA)				
V (Volt)				

3. Measure the voltage and current values across the resistors R_1, R_2, R_3 and R_4. Note the reading in the table. Observe the total voltage applied in the circuit and the voltage drop across individual resistors.

4. If total applied voltage in the circuit and voltage drop across the individual resistor are equal, then we can say that Kirchhoff's voltage law is verified.

Notes

Energy consumption in home appliances

Calculation of energy

To calculate the energy consumption of home appliances, the following technique is used. We know that

Power = Energy/Time

or

Energy = Power × Duration of Usage (Time)

By modifying this formula slightly, we can determine the energy consumption per day.

Energy consumption/day = Power consumption × hours used/day

Where,

(a) Energy consumption will be measured in kilowatt hours (kWh) like on your utility bills.
(b) Power consumption will be measured in Watt.
(c) Hours will be the actual time for which you use the appliance every day.

Since we want to measure energy consumption in kilowatt hours, we must change the way power consumption is measured from watt to kilowatt (kWh). We know that 1 kilowatt hour (kWh) = 1,000 watt hours. So, we can adjust the formula given above to

Energy consumption/day (kWh) = Power consumption (watts/1000) × hours used/day

Example 1: Calculating energy use of a ceiling fan

Solution: If you use a ceiling fan (200 watts) for four hours per day for 120 days a year, what would be the annual energy consumption?

Use this formula.

Energy consumption/day (kWh) = Power consumption (watts/1000) × hours used/day

Energy consumption per day (kWh) = (200/1000) × 4 (hours used/day).

NOTES

Energy consumption per day (kWh) = (1/5) × 4 energy consumption per day (kWh) = 4/5 or .8. So, the energy consumption per day is .8 kWh. To find out energy for 120 days, do simple multiplication.

.8 × 120 = 96 kWh

Check Your Progress

A. Multiple choice questions

1. Which of the following components is used to close or break the circuit?
   (a) Bulb
   (b) Switch
   (c) Wire
   (d) Electric cell
2. Which of the following components is used to provide resistance?
   (a) Heat
   (b) Energy
   (c) Product
   (d) Resistor
3. The frequency (f) of alternating current is _________ Hertz in India.
   (a) 45
   (b) 60
   (c) 50
   (d) 55
4. In a series circuit, current remains ____________ and voltage ____________.
   (a) divided, same
   (b) same, same
   (c) divided, divided
   (d) same, divided
5. In a parallel circuit, current is ____________ and voltage remains the ____________.
   (a) divided, same
   (b) same, same
   (c) divided, divided
   (d) same, divided
6. The amount of work done in one second is called _________.
   (a) power
   (b) current
   (c) voltage
   (d) charge
7. Ohm's law states that _______________.
   (a) voltage is directly proportional to the applied voltage
   (b) voltage is directly proportional to the applied current
   (c) current is directly proportional to the applied voltage
   (d) current is directly proportional to the applied current

8. The amount of charge flowing through a point in one second is called _______________.
   (a) voltage
   (b) current
   (c) power
   (d) charge
9. The amount of work required to move a unit coulomb charge from point A to point B called ____________.
   (a) current
   (b) charge
   (c) voltage
   (d) power
10. What are the basic building blocks that all matter is composed of?
    (a) electrons, neutrons and protons
    (b) electrons, protons and ions
    (c) neutrons, protons and ions
    (d) electrons, neutrons and charged ions
11. Electric charge can be produced by _______________.
    (a) sticking
    (b) rubbing
    (c) oiling
    (d) passing AC current
12. An electron has ______________ charge.
    (a) positive
    (b) negative
    (c) zero
    (d) sometimes positive, sometimes negative
13. A proton has _____________ charge.
    (a) positive
    (b) negative
    (c) zero
    (d) sometimes positive, sometimes negative
14. A neutron has _____________ charge.
    (a) positive
    (b) negative
    (c) zero
    (d) sometimes positive, sometimes negative
15. The unit of electric current is _____________.
    (a) ampere
    (b) volt
    (c) watt
    (d) joule
16. The unit of electrical power is __________________.
    (a) volt
    (b) watt
    (c) joule
    (d) ampere

Notes

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17. The term used to designate electrical pressure is ____________________.
    - (a) voltage
    - (b) watt
    - (c) joule
    - (d) ampere
18. The statement, which correctly represents Ohm's law, is ________________.
    - (a) V = IR
    - (b) V = R/I
    - (c) R = VI
    - (d) I = R/V
19. If V = 50 V and I = 5 A, then R = ______?
    - (a) 50 Ω
    - (b) 5 Ω
    - (c) 10 Ω
    - (d) 2 Ω
20. If P = 50 W and R = 2 Ω, then I = ______?
    - (a) 50 A
    - (b) 5 A
    - (c) 10 A
    - (d) 2 A

B. Fill in the blanks

1. In ____________ circuit, current remains the same and voltage divided.
2. In ____________ circuit, current is divided and voltage remains the same.
3. The amount of ____________ done in one second is called power.
4. A component used to close or break a circuit is ____________.
5. Proton has ____________ charge.
6. The unit of electrical ____________ is watt.
7. "Current is directly proportional to the applied voltage." This law is given by ____________.
8. 1kWh = ____________ watt × ____________ second.
9. Switch is used for ____________ and _______________ of circuit.
10. Electrons have ____________ charge.
11. The relationship between voltage, current and resistance by Ohm's Law.

    Voltage = Current × Resistance

    This will mean that

    $I = \frac{V}{R}$ Current = ____________ ÷ ____________

    and $R = \underline{V}$ ____________ = ____________ ÷ ___________

C. State whether the following statements are True or False

1. The frequency (f) of alternating current is 60 hertz in India.
2. Electrons are electrically neutral.
3. Due to rubbing of two bodies, electric charge is produced.
4. The relationship between voltage, current and resistance is given by Kirchhoff's law.
5. The unit of current is ampere.
6. Resistor easily passes current.
7. The unit of voltage is watt.
8. The unit of power is joule/second.
9. Current in a circuit is due to applied voltage.
10. 1kWh = 1000 watt × 3600 seconds.

D. Short answer questions

1. What is volt?
2. What is the supply frequency of supply voltage?
3. What is electric current?
4. What does 10A mean?
5. Explain diagrammatically how the components are connected in a series circuit.
6. Explain diagrammatically how the components are connected in a parallel circuit.
7. What will happen to a series circuit if a bulb gets fused? Will the circuit be close in this case?
8. List an appliance where resistors are used.
9. What are different variable resistors?
10. How are AC and DC currents different from each other?
11. List appliances that use DC power.
12. (a) Calculate the resistance 'R' in the circuit (Fig. 1).

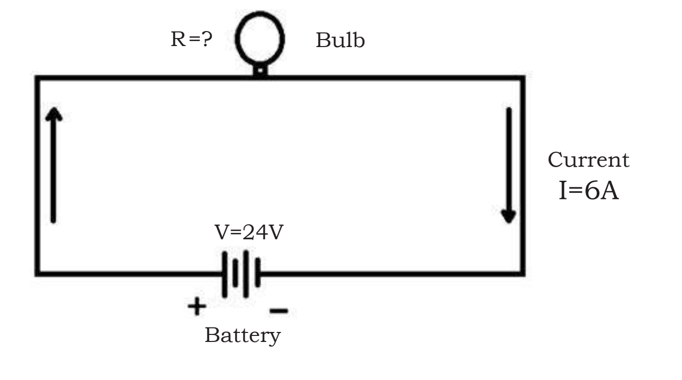

Fig. 1

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(b) Calculate the voltage 'V' in the circuit (Fig. 2).

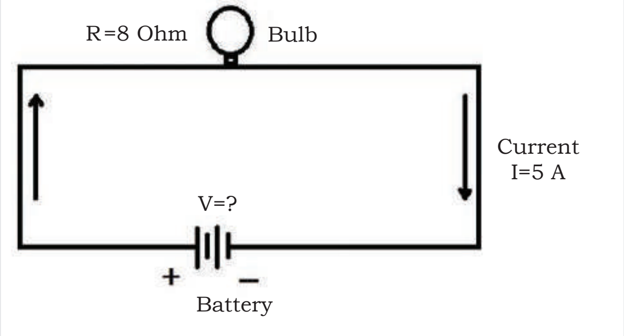

Fig. 2

(c) Calculate the voltage 'V' in the circuit (Fig. 3).

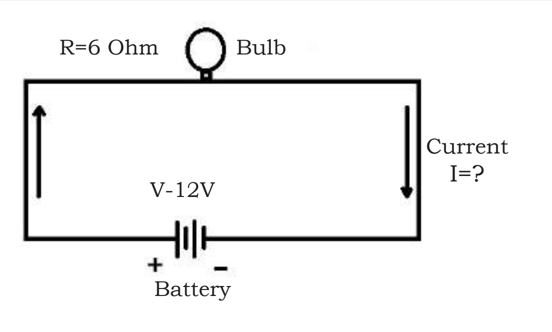

Fig. 3

(d) Verify the KCL and KVL and find I_1, I_2, I_3 for Fig. 4.

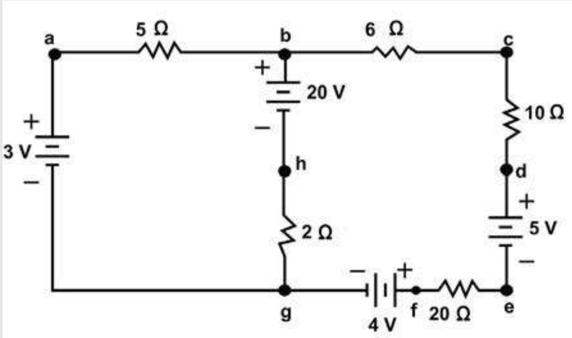

Fig. 4

Unit 2

Electrical and Electronic Components

Introduction

There are several important electrical components that are commonly found in circuits. These components are the fundamental building blocks of electrical and electronic circuits, and can be found in large numbers in a control panel, printed circuit board, etc. They can be used and combined with each other in different ways to form a new circuit. This Unit will help students to understand the fundamentals of circuit schematics.

An electrical control system includes a number of components, which are assembled together to form a circuit as shown in Fig. 2.1. It is important to understand about the components assembled in the control panel. Each component has its data sheet on which its details are mentioned.

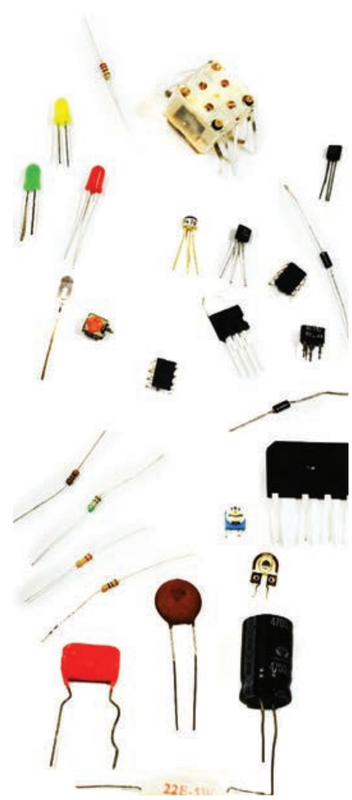

Fig. 2.1 Basic circuit components

Before assembling an electric circuit, a wireman must have detailed knowledge of the components. The person must be able to distinguish the components physically. There are some common components, which are used in almost every control system, such as resistor, capacitor, integrated circuit, LED, etc. The person must know the characteristics of each component, dependence of each component on different parameters and the basic construction of each component.

Resistor

Resistor is one of the fundamental components in an electrical and electronic device as shown in Fig. 2.2. A resistor opposes the movement of electrons. This opposition is called 'resistance'. The resistor controls the current flow, and also drops the voltage across it, thus, lowering the voltage levels within circuits. It has two ends. High-power resistors are used to dissipate electrical power. Resistors can have fixed resistance value. This fixed resistance value can change slightly when there is a change in temperature, time or operating voltage. Resistors whose value can be changed are called 'variable resistors'. These variable resistors can be used to control different parameters. For example, in a radio circuit, the variable resistor is used as a volume control component. Resistor family can be classified into two types.

1. Linear resistor
2. Non-linear resistor

Fig. 2.2 Resistor

Linear resistor

In this type of resistor, the value of resistance is directly proportional to the applied voltage. There are two types of linear resistor.

1. Fixed resistor
2. Variable resistor

Fixed resistor

Such a resistor has a fixed resistance value. Fixed resistor family includes carbon composition resistor, film resistor, wire wound resistor and cracked carbon resistor.

Carbon composition resistor

This comprises general purpose resistors, consisting of carbon and silica. Carbon and silica provide the specified resistance between two leads. Carbon composition resistors give a uniform performance and are available in ¼, ½ and 1 watt. The value of resistance is printed in the form of colour code.

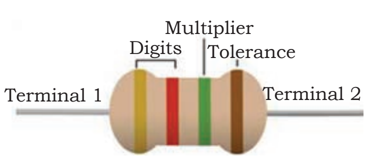

Fig. 2.3(a) Colour-coded resistor

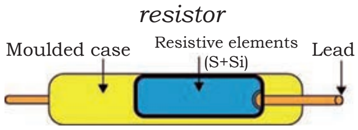

Fig. 2.3(b) Internal structure of carbon composition resistor

Film resistor

Carbon film resistor, metal film resistor and thick film resistor are the three forms of film resistor.

In carbon film resistor, pure carbon is deposited on a ceramic rod by high temperature thermal decomposition. By controlling the thickness of pure carbon, a wide range of resistance value can be produced in a resistor. Such a resistor has better stability than carbon composition resistor.

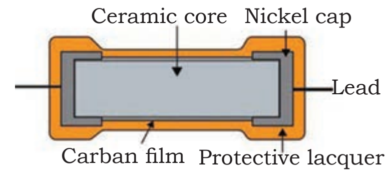

Fig. 2.4 Internal structure of carbon film resistor

In metal film resistor, the glass of ceramic substrate is coated with a thin film of metal or alloy or metal oxide. Such a resistor gives the best reliability and stability. It can handle overload for a short time and is used in electronic equipment.

A thick film resistor is formed by applying a resistive film, mixture of glass and conductive material to a substrate of silicon. Thick film technology is used to produce high resistance value resistors. These values are printed on a cylindrical or flat substrate. The range of resistance value is 1 ohm to 100 kilo-ohm and wattage up to 200 watt.

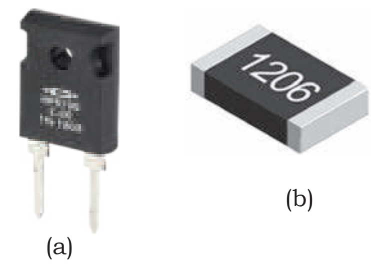

Fig. 2.5(a) Thick film resistor (b) Surface mount thick film resistor

Wire wound resistor

Such a resistor consists of a high resistance wire. This wire is, usually, made of nickel-chromium alloy, which wound on a ceramic core in the resistor. Such resistors can operate in high temperatures. They have high wattage rating. The range of resistance value of these resistors varies from 1 ohm to 100 kilo-ohm and wattage rating up to 200 watt.

Fig. 2.6(a) Wire wound resistor

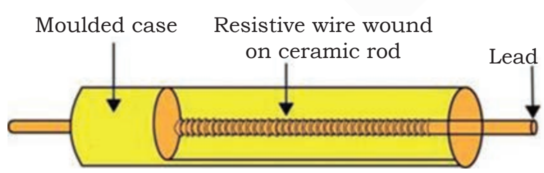

Fig. 2.6(b) Internal structure of a wire wound resistor

Cracked carbon resistor

This type of resistor uses decomposed hydrocarbon vapour on ceramic rod at 900^0 to 1000^0 C. These hydrocarbons provide the required resistance value.

Variable resistor

The resistance value in such a resistor can be changed using a rotating knob. Variable resistor family includes potentiometer and trimmer.

Potentiometer

It is a three-terminal variable resistor. Out of the three terminals, two end terminals are used for input and output, and the centre terminal is used as a variable

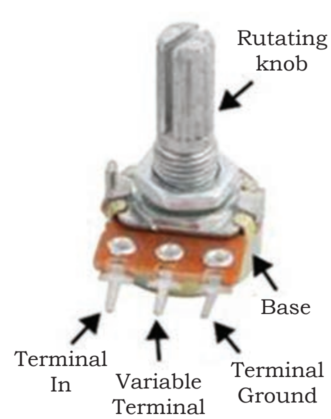

Fig. 2.7(a) Potentiometer

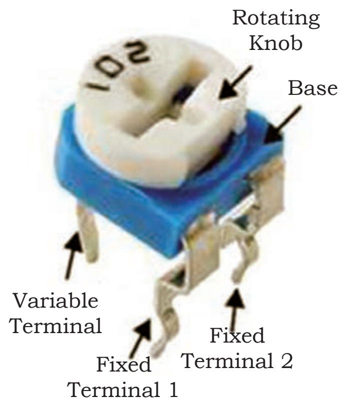

Fig. 2.7 (b) Trimmer

terminal. The resistance value can be changed using a rotating knob. Such a resistor has carbon composition. It is used to control voltage and current in an electric circuit.

Trimmer

It is miniature adjustable resistor composed of a resistive element like carbon or silica. It can be directly mounted on a printed circuit board. Its resistance value can be adjusted using a small screwdriver. Usually, it is mounted on audio-video circuits.

Non-linear resistor

In non-linear resistor, the current is not directly proportional to the applied voltage. Such a resistor has the property to change its resistance value in accordance with the applied voltage, temperature or light intensity. Non-linear resistor family includes thermistor (temperature dependent resistor), varistor (voltage dependent resistor), photoresistor (light dependent resistor). Fig. 2.8 shows the symbolic representation of linear and non-linear resistors.

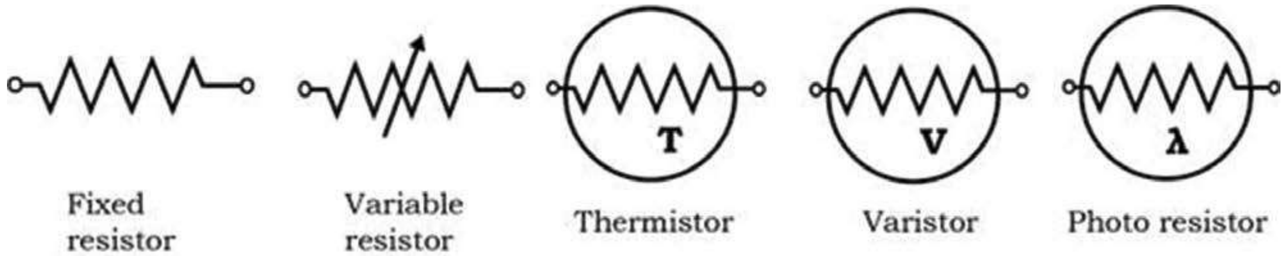

Fig. 2.8 Symbolic representation of linear and non-linear resistors

Thermistor

It is a thermally sensitive resistor, i.e., the resistance changes in accordance with the change in the temperature. There are two types of thermistor.

- Negative temperature coefficient (NTC)
- Positive temperature coefficient (PTC)

In NTC, the resistance decreases exponentially with increase in temperature, whereas, in PTC, the resistance increases with increase in temperature. Typical NTC and PTC are shown in Figs. 2.9(a) and 2.9(b).

Fig. 2.9 (a) Negative temperature coefficient (NTC) thermistor

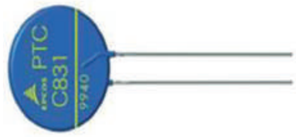

Fig. 2.9 (b) Positive temperature coefficient (PTC) thermistor

Varistor

It is a voltage dependent resistor (VDR). Its resistance value changes in accordance with the applied voltage. It is used to protect a circuit and circuit components. There are two types of voltage dependent resistors, i.e., silicon carbide VDR and metal oxide VDR.

Fig. 2.10 Varistor

Photoresistor

It is a light dependent resistor (LDR). Its resistance value changes in accordance with light illumination. In darkness, the resistance is high and when an LDR gets illuminated, the resistance decreases. The LDR consists of light sensitive semiconductor. The photoconductive material is deposited on the ceramic substrate. LDR is used in automatic light control switches, for automatic brightness control in television sets, streetlights, alarm clocks, burglar alarm circuit, etc.

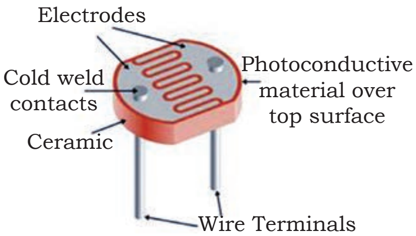

Fig. 2.11 Light dependent resistor (LDR)

Assignment 1

Identify and name the different types of resistor and write their resistance value.

Resistor	Name and resistance value
	Name __________________ Name and resistance value _____________
	Name __________________ Name and resistance value _____________
	Name __________________ Name and resistance value _____________
	Name __________________ Name and resistance value _____________

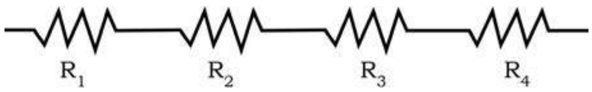

Fig. 2.12: Series connection of resistors

Series connection of resistors

$R_{\text{equivalent}} = R_1 + R_2 + R_3 + \ldots$

Series key idea: Current is the same in each resistor by Kirchhoff's current law (Fig. 2.12).

Features of resistors in series

1. Series resistances add: $R_s = R_1 + R_2 + R_3 + \ldots$
2. The same current flows through each resistor in series.
3. Individual resistors in series do not get the total source voltage but divide it.

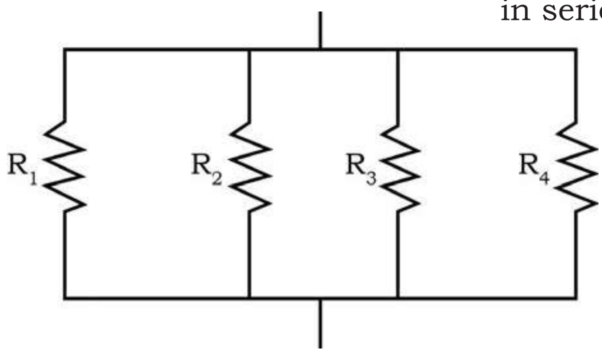

Fig. 2.13: Parallel connection of resistors

Parallel connection of resistors

$1/R_{\text{equivalent}} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$

Parallel key idea: Voltage is the same in each resistor by Kirchhoff's voltage law (Fig. 2.1).

Practical Exercise 1

Demonstrate the way to calculate resistance, current, voltage drop and power dissipation of a series circuit.

Material required

Pen and paper

Procedure

Suppose the voltage output of the battery in Fig. 1 is 12V, and the resistances are R1 = 1Ω, R2 = 6Ω and R3 = 13Ω.

(a) What is the total resistance?

(b) Find out the current.

(c) Calculate the voltage drop in each resistor, if these add up to equal the voltage output of the source.

(d) Calculate the power dissipated by each resistor.

(e) Find out the power output of the source and show that it equals the total power dissipated by the resistors.

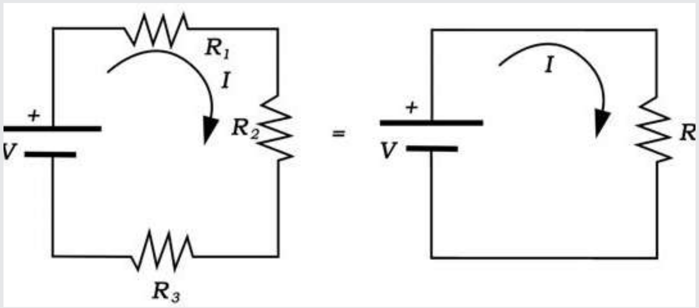

Fig. 1

Solution for (a)

The total resistance is simply the sum of individual resistances as given in this equation:

$R_s=R_1+R_2+R_3=1\Omega+6\Omega+13\Omega=20\Omega$

Solution for (b)

The current is found using Ohm's law, V = IR. Entering the value of the applied voltage, the total resistance yields the current for the circuit.

$I=V \times R_s=12\ V \times 20\Omega=0.6A$

Solution for (c)

The voltage or IR drop in a resistor is given by Ohm's law. Entering the current and the value of the first resistance yields the following.

$V_1 = IR_1 = (0.600A)\ (1\ \Omega) = 0.600\ V$

Similarly,

$V_2 = IR_2 = (0.600A)\ (6\ \Omega) = 3.60\ V$

and

$V_3 = IR_3 = (0.600A)\ (13.0\ \Omega) = 7.80\ V$

Discussion for (c)

The three IR drops add to 12 V, as predicted:

$V_1 + V_2 + V_3 = (0.600 + 3.60 + 7.80)\ V = 12\ V$

Strategy and solution for (d)

The easiest way to calculate power in watt (W) dissipated by a resistor in a DC circuit is to use Joule's law, P= IV, where P is electric power. In this case, each resistor has the same full current flowing through it. By substituting Ohm's law V = IR into Joule's law, we get the power dissipated by the first resistor as

$P_1 = I^2R_1 = (0.600\ A)2(1.00\ \Omega) = 0.360\ W$

Similarly,

$P_2 = I^2R_2 = (0.600\ A)2(6.00\ \Omega) = 2.16\ W$

and

$P_3 = I^2R_3 = (0.600\ A)2(13.0\ \Omega) = 4.68\ W.$

Discussion for (d)

Power can also be calculated using either P= IV or $P=V_2R$, where V is the voltage drop across the resistor (not the full voltage of the source). The same values will be obtained.

Solution for (e)

The easiest way to calculate power output of the source is to use P = IV, where V is the source voltage. This gives

$P = (0.600\ A)(12.0\ V) = 7.20\ W$

Discussion for (e)

Note, coincidentally, the total power dissipated by the resistors is also 7.20W, the same as the power generated by the source.

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That is,

$P_1 + P_2 + P_3 = (0.360 + 2.16 + 4.68)$ W = 7.20 W

Power is energy per unit time (watts), and so conservation of energy requires the power output of the source to be equal to that of the total power dissipated by the resistors.

Practical Exercise 2

Calculating resistance, current, power dissipation and output of a parallel circuit.

Material required

Pen and paper

Procedure

Let the voltage output of the battery and resistances in the parallel connection as in Fig. 1 be the same as previously considered in the series connection: V = 12.0 V, R_1 = 1.00 Ω, R_2 = 6.00 Ω, and R_3 = 13.0 Ω,

(a) What is the total resistance?

(b) Find out the total current.

(c) Calculate the currents in each resistor and show these add up to equal the total current output of the source.

(d) Calculate the power dissipated by each resistor.

(e) Find out the power output of the source and show that it equals the total power dissipated by the resistors.

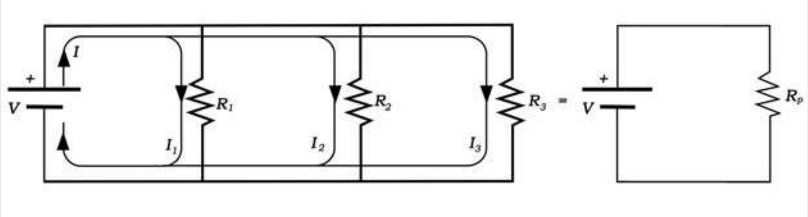

Fig. 1 Parallel circuit

Solution for (a)

The total resistance for a parallel combination of resistors is found using the equation given below. Entering known values gives

$$1/R_p=1/R_1+1/R_2+1/R_3=1/1.00\ \Omega+1/6.00\ \Omega+1/13.0\ \Omega$$

Thus,

$$1/R_p=1.00\ \Omega+0.1667\ \Omega+0.07692\ \Omega=1.2436\ \Omega$$

(Note that in these calculations, each intermediate answer is shown with an extra digit.) We must invert this to find the total resistance R_p. This will yield

$$R_p=1/1.2436\ \Omega=0.8041\ \Omega$$

The total resistance with the correct number of significant digits is R_p = 0.804 Ω

Discussion for (a)

R_p is, as predicted, less than the smallest individual resistance.

Solution for (b)

The total current can be found from Ohm's law, substituting R_p for the total resistance. This gives

$I=V/R_p=12.0\ V/0.8041\ \Omega=14.92\ A$

Discussion for (b)

Current I for each device is much higher than for the same devices connected in series (see the previous example). A circuit with parallel connections has a lower total resistance than the resistors connected in series.

Strategy and solution for (c)

The individual currents are easily calculated from Ohm's law, since each resistor gets the full voltage. Thus,

$I_1=V/R_1=12.0V/1.00\ \Omega=12.0\ A$

Similarly,

$I_2=V/R_2=12.0\ V/6.00\ \Omega=2.00\ A$

and

$I_3=V/R_3=12.0\ V/13.0\ \Omega=0.92\ A$

Discussion for (c)

The total current is the sum of the individual currents.

$I_1 + I_2 + I_3 = 14.92\ A$

This is consistent with conservation of charge.

Strategy and solution for (d)

The power dissipated by each resistor can be found by using any of the equations relating power to current, voltage and resistance, since all three are known. Let us use $P=V^2/R$, since each resistor gets full voltage. Thus,

$P_1=V^2/R_1= (12.0\ V)^2/1.00\ \Omega=144\ W$

Similarly,

$P_2=V^2/R_2= (12.0\ V)^2/6.00\ \Omega=24.0\ W$

and

$P_3=V^2/R_3= (12.0\ V)^2/13.0\ \Omega=11.1\ W$

Discussion for (d)

The power dissipated by each resistor is considerably higher in parallel circuit than when connected in series to the same voltage source.

Strategy and solution for (e)

The total power can be calculated in several ways. Choosing P = IV, and entering the total current, yields

$P = IV = (14.92\ A)\ (12.0\ V) = 179\ W$

Discussion for (e)

Total power dissipated by the resistors is also 179 W.

$P_1 + P_2 + P_3 = 144\ W + 24.0\ W + 11.1\ W = 179\ W$

This is consistent with the law of conservation of energy.

Overall discussion

Note that both the current and power in parallel connections are greater than for the same devices in series.

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There are a number of factors, such as material, thickness, length and temperature, which affect the resistance value of a wire.

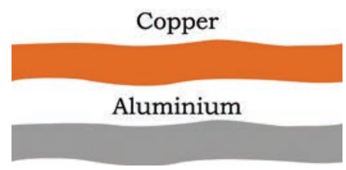


Fig. 2.14 Material used for wire


Fig. 2.15 Thickness of wire

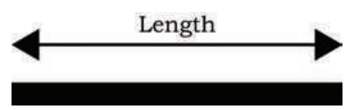


Fig. 2.16 Length of wire


Fig. 2.17 Temperature of wire

Assignment 2

Calculate the value of equivalent resistance in parallel and series circuits, where value of resistors are R_1= 10 and R_2 = 20 Ohm.

Capacitor

The word 'capacitor' specifies capacity. It represents the capacity to store energy. In a capacitor, energy is stored in the form of electric field. Capacitance is measured in Farad (F). A capacitor has two parallel sections. It is between these sections that energy is stored. It consists of two metallic conducting sections (plates) separated by an insulator (dielectric material) as shown in Fig. 2.18. A metallic conductor can be made of aluminium, copper, etc. A dielectric can be ceramic, mica, electrolyte, air, paper, etc. It stores charges on its metallic plates, which generate the electric field between the plates. Hence, it stores energy in the form of electric field.

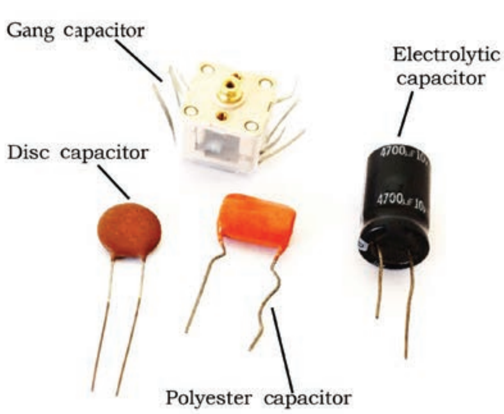


Fig. 2.18 Capacitor

Capacitor is one of the fundamental components of electrical and electronic devices. The parameters of a capacitor are the maximum voltage that it can withstand without damage, charge store capacity, polarity of terminals, i.e., positive and negative terminals as shown in Fig. 2.19.

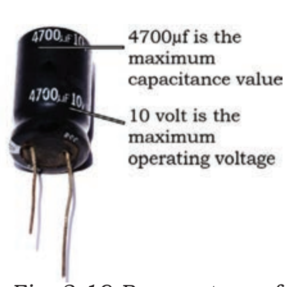


Fig. 2.19 Parameters of a capacitor

Mathematically,

$Q = C \times V$

where, Q= Charge in coulomb

C= Capacitance in farad

V= Voltage in volt

For example: When 250V is applied across the capacitor of capacitance value 10μF, the amount of charge stored by it is given by

$$Q = C \times V$$

$$Q = 10 \times 10^{-6} \times 250$$

$$Q = 2.5 \text{ mC}$$

Assignment 3

Calculate the following for a capacitor.

1. Determine the voltage across a 1000 pF capacitor to charge it with 2C.
2. The charge on the plates of a capacitor is 6 mC when the potential between them is 2.4 kV. Determine the capacitance of the capacitor.
3. For how long must a charging current of 2A be fed to a 5F capacitor to raise the potential difference between its plates by 500 V (Hint: I=Q/t).
4. A direct current of 10A flows into a previously uncharged 5μF capacitor for 1 mS. Determine the potential difference between the plates (Hint: I=Q/t).

Assignment 4

Given below are different types of capacitor. Read about their specifications on the Internet.

List the following parameters of capacitors.

- Operating temperature
- Maximum operating voltage
- Maximum capacitance storage
- Supply type

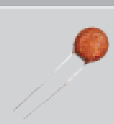
Capacitor image and name			
Ceramic capacitor		Axial electrolytic capacitor	
Radial electrolytic capacitor		Paper capacitor	
Surface mount resistor		Polyester capacitor	

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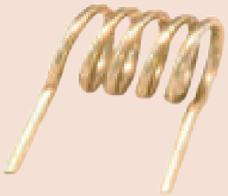
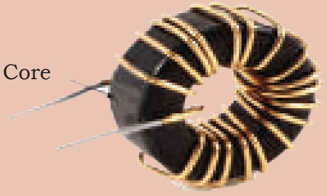
Fig. 2.20 Inductor

Inductor

The word 'inductor' defines induction. Induction is the process or action of bringing about rise. In Inductor, this rise takes place in the form of energy. Inductor is constructed when a conductor material is wound on a magnetic material. Inductor is like a coil as shown in Fig. 2.20. When current flows through the coil, a magnetic field appears around the wire. This way, we can say that an inductor stores energy in the form of magnetic field along the coil. If the current flowing through an inductor changes, a changing magnetic field appears across the wire. This changing magnetic field induces a voltage across the two ends of the wire(s). Inductor opposes the change in the electric current passing through it. This property of opposition is known as 'inductance'.

Table 2.1: Different type of inductors

Type	Name
	Air gap inductor
	Ferrite core inductor
	SMT inductor

Semiconductor

Semiconductors are material that have electrical conductivity between that of an insulator and a conductor. Silicon and germanium are the semiconductors that are widely used in the electronic industry. Semiconductor material are of two types, i.e., intrinsic and extrinsic.

Intrinsic (pure)

It is the pure form of a semiconductor. The word pure here specifies that this semiconductor does not contain any impurity atom. For example, pure form of silicon contains only the atoms of silicon and no other impurity atom is present. The absence of impurity atom results in less conductivity of the semiconducting material. To improve the conductivity of intrinsic semiconductor, an impurity atom has to be added, which is discussed in extrinsic semiconductor.

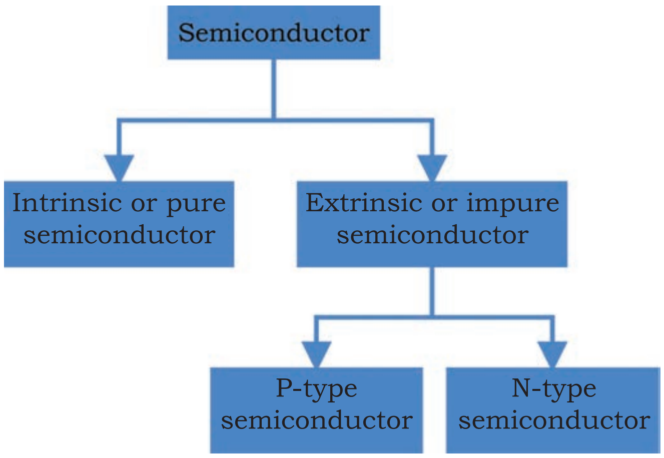


Fig. 2.21 Types of semiconductor

Extrinsic (impure)

When impurity atoms are added to the pure (intrinsic) form of a semiconductor, it is called extrinsic semiconductor. Extrinsic semiconductor is also known as 'impure semiconductor'. Extrinsic semiconductors are classified into N-type and P-type. For example, if there is a presence of impurity atoms [like Arsenic (As)] in the pure form of silicon, it is called 'doping'. Doping increases the conductivity of a semiconductor.

Since the atomic number of silicon is 14, its electronic configuration is 2, 4 and 8. Thus, silicon has four electrons in the outermost shell. In order to increase the conductivity, more free carriers need to be added. As silicon has four electrons in its outermost shell, it is better to add an impurity atom having valence (number of atoms in the outermost shell) either five (penta) or three (tri). The atoms that have five electrons in their outermost shell are known as pentavalent. The atoms that have three electrons in their outermost shell are known as trivalent.

- When pentavalent impurity atom is added, an extrinsic semiconductor is formed, which is known as N-type semiconductor.
- When trivalent impurity atom is added, an extrinsic semiconductor is formed which is known as P-type semiconductor.

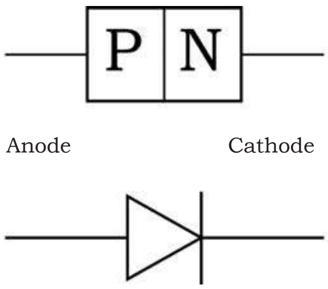


Fig. 2.22 Diode symbol

Diode

Two semiconductors, i.e., P-type and N-type are combined to form a new component, which is known as diode. 'Di' defines two. Thus, a diode has two terminals — anode and cathode as shown in Figs. 2.22 and 2.23.

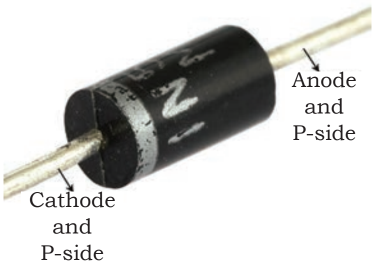


Fig. 2.23 Diode

A diode can be used for switching applications on and off. A diode passes current only in one direction. The P-side is called anode and N-side cathode. When the anode and cathode of a PN-junction diode are connected to external voltage sources such that the positive end of a battery is connected to the anode and negative to the cathode, the diode is said to be in a forward bias condition or we can say that it will act as a closed switch (it will turn 'ON'). In a forward bias condition, the diode will pass the current through it.

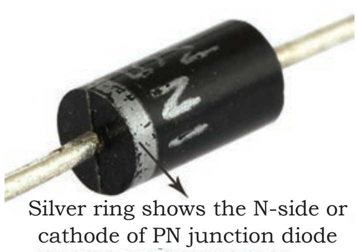


Fig. 2.24 Silver ring in diode

When the P-side of the diode is connected to the negative terminal of the battery and N-side to the positive terminal, the diode is said to be in reverse bias condition or we can say that it will act as an open switch (it will turn 'OFF'). In reverse bias condition, the diode will not pass the current through it.

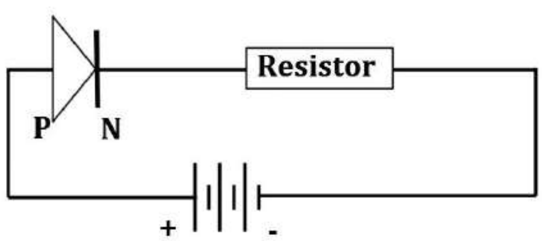


Fig. 2.25 Current will flow in this circuit as diode is in forward bias condition

When the anode of diode is connected to the positive terminal and cathode to the negative of the battery, then the diode is said to be in forward bias condition. In this state, current flows through the diode.

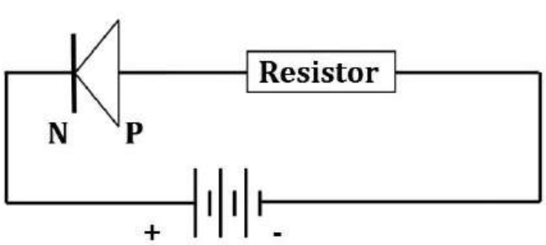


Fig. 2.26 Current will not flow in this circuit as diode is in reverse bias condition

When the anode diode is connected to the negative terminal and cathode to the positive of the battery, then the diode is said to be in reverse bias condition. In this state, current does not flow through the diode.

Transistor

Transistor is a three-layer semiconductor device. Transistors can be of two types — bipolar junction transistor (BJT) and field effect transistor (FET). BJT has three layers, i.e., emitter, base and collector. The point where the two layers touch each other is called 'junction'. The junction where the emitter and base layers touch each other is called 'emitter base junction'. The junction where collector and base layers touch each other is called 'collector base junction'.

The transistor acts as a switch or can be used for amplification.

To understand the functioning of a transistor, we can relate it with the water supply system in our houses. The storage tank, which is kept on the roof of a building, is similar to the emitter in the transistor, which acts as a source of charge carrier (i.e., electrons and holes in semiconductor). The tap on the ground is similar to the base of the transistor. This tap controls the flow of water. Likewise, the base controls the flow of charge carrier. The bucket on the ground collects the water coming from the storage tank. Likewise, the collector of the transistor collects the charge carriers coming from the emitter (Fig. 2.27). Therefore, there are two junctions in the transistor, i.e., emitter and collector based junctions.

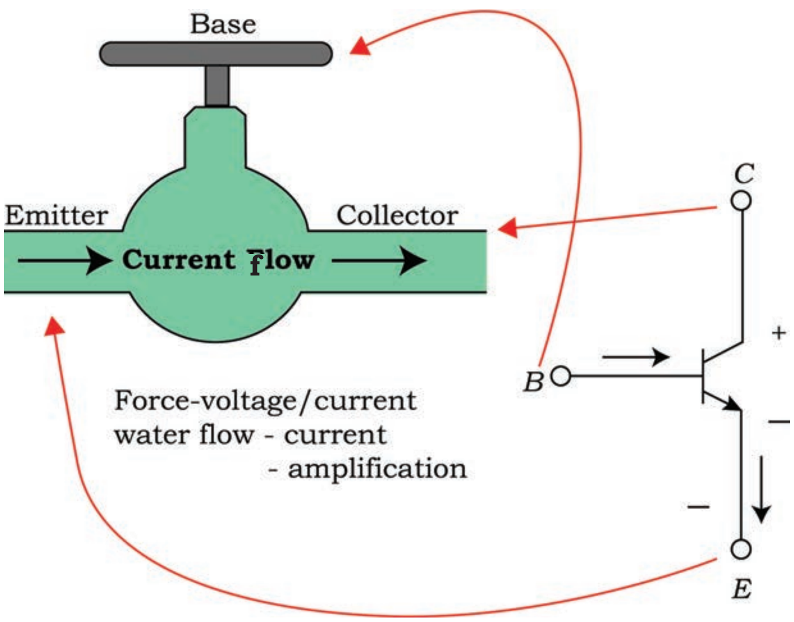


Fig. 2.27 Analogy of transistor

Identifying BJT terminals

Keep the transistor in such a way that the flat surface faces towards you as shown in Figs. 2.28(a) and (b).

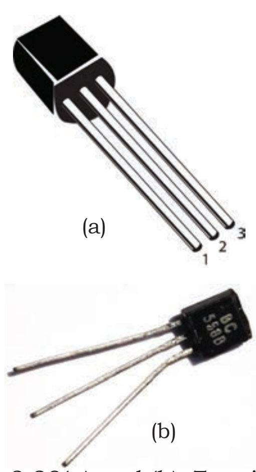


Fig. 2.28(a) and (b): Terminals of a transistor

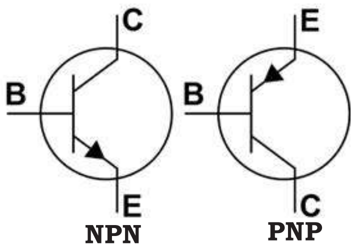


Fig. 2.29 BJT symbol

The bipolar junction transistor (BJT) has three terminals (Fig. 2.29).

1. Emitter (E)
2. Base (B)
3. Collector(C)

The schematic symbol of the BJT is given in Fig. 2.27.

Identifying BJT terminal using multimeter

NPN and PNP are the two types of BJT. Both are similar in physical appearance, and hence, cannot be differentiated. A multimeter is used to identify the type of BJT.

The following points illustrate the steps to identify BJT types.

- If we see a transistor internally, BJT has two junctions (NPN ≡ N - P - N ≡ NP junction + PN junction and PNP ≡ P - N - P ≡ PN junction + NP junction).
- Emitter to base is one PN junction (diode) and base to collector is another PN junction (diode) as shown in Fig. 2.30.

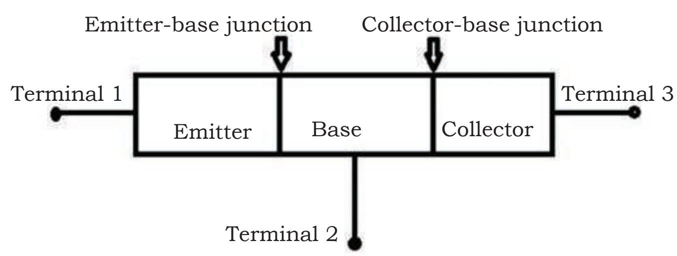


Fig. 2.30 Emitter-base (EB) and collector-base junction

- When a multimeter is set in the diode mode, it will show the voltage. If we keep the positive probe of the multimeter on to the anode of the diode and negative probe on to the cathode, then the multimeter will show forward voltage drop of diode.

Fig. 2.31 Diode in forward bias condition

- When the multimeter is set in the diode mode, it will not show the voltage. If we keep the positive probe of the multimeter on to the anode of the diode and negative probe on to the cathode, then the multimeter will not show any voltage.

Fig. 2.32 Diode in reverse bias condition

Practical Exercise 3

Identification of NPN-type transistor

Material required

Multimeter, transistor and connecting cords

Procedure

1. Connect the red cord to the voltage measuring point (Fig. 1).

Fig. 1

2. Connect the black cord to the common point (Fig. 2).

Fig. 2

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3. Turn the multimeter in the diode mode (Fig. 3).

Fig. 3

4. Touch the red probe to the centre pin (base) of the transistor, black probe to either of the two — pin 1 (emitter) or pin 3 (collector) of BJT (Fig. 4).

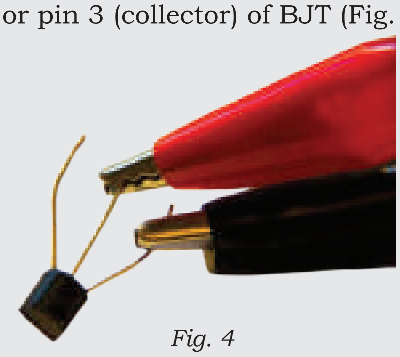


Fig. 4

5. Look at the display on the multimeter.
6. It will be NPN transistor. The logic behind this is, in NPN transistor
   - Emitter (E) – N-type material – Equivalent to cathode of the diode
   - Base (B) – P-type material – Equivalent to anode of the diode
   - Collector (C) – N-type material – Equivalent to cathode of the diode
7. If the multimeter positive probe is connected to the anode and negative probe to the cathode, then it will show the voltage. If the connections are interchanged, it will not show any value (Fig. 5).

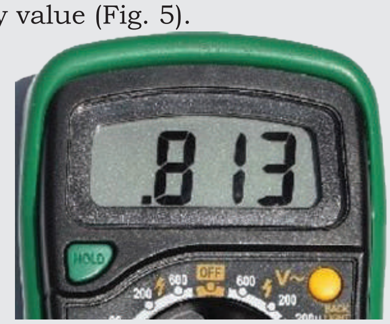


Fig. 5

Practical Exercise 4

Identification of PNP-type transistor

1. Connect the red cord to the voltage measuring point (Fig. 1).

Fig. 1

2. Connect the black cord to the common point (Fig. 2).

Fig. 2

3. Turn the multimeter in the diode mode (Fig. 3).

Fig. 3

4. Touch the black probe to the centre pin (base) of the transistor, red probe to either of the two — pin 1 (emitter) or pin 3 (collector) of BJT (Fig. 4).

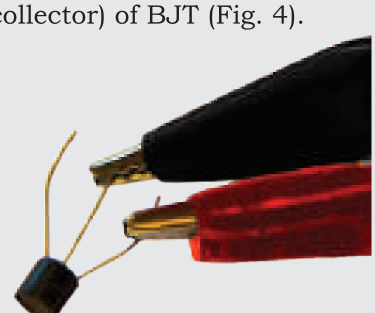


Fig. 4

Know more...

Switch is a device, which has two operations, i.e., ON and OFF. When a switch is closed (ON), current flows in the circuit. In this case, the circuit is said to be complete. When a switch is open (OFF), current does not flow in the circuit. In this case, the circuit is said to be incomplete.

Amplification is the process of increasing the level of voltage and current. A transistor is used in such a way that it increases the voltage and current level of the input signal. Transistors have three terminals. In transistors, the major current flows between any two terminals, while the third terminal is used for controlling the flow of current between the terminals.

NOTES

5. Look at the display of the multimeter.
6. It will be a PNP transistor.
   - Emitter (E) – P-type material – Equivalent to anode of the diode
   - Base (B) – N-type material – Equivalent to cathode of the diode
   - Collector (C) – P-type material – Equivalent to anode of the diode
7. If the multimeter positive probe is connected to the anode and negative probe to the cathode, then it will show the voltage. If the connections are interchanged, it will not show any value (Fig. 5).

Fig. 5

Transformer

A transformer is a static unit. It simply transforms the voltage level of an AC signal. It either steps up or steps down the AC voltage. It works on the principle of electromagnetic induction. A transformer does not change the frequency of applied signal. Transformers play an important role in electrical systems (Figs. 2.33 and 2.34).

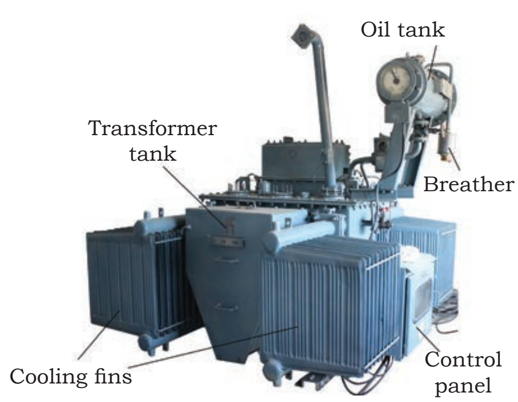


Fig. 2.33 Parts of a transformer

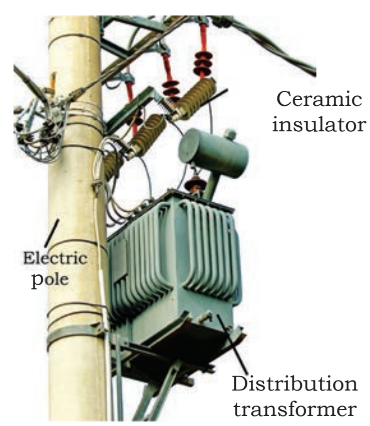


Fig. 2.34 Distribution transformer mounted on a pole

1. Transformers are available in a number of sizes, for example, the transformer used in a mobile charger is very small, whereas, those used in an electricity board substation are bulky or big.
2. High voltage is used for transmission in substations and low voltage in offices and homes.
3. Transformers are used to increase or decrease the AC voltage in transmission and distribution of electricity.
4. The basic construction of a transformer includes two coils wound on the magnetic frame or core.
5. Both the coils are magnetically coupled, whereas, they are electrically insulated from each other.
6. The primary or input coil is connected to the energy source, while secondary or output coil supplies power to load.
7. Electromagnetic induction is used in transformers. In power grids, large transformers are used. These transformers are used for the generation, distribution and transmission of energy (Fig. 2.35).

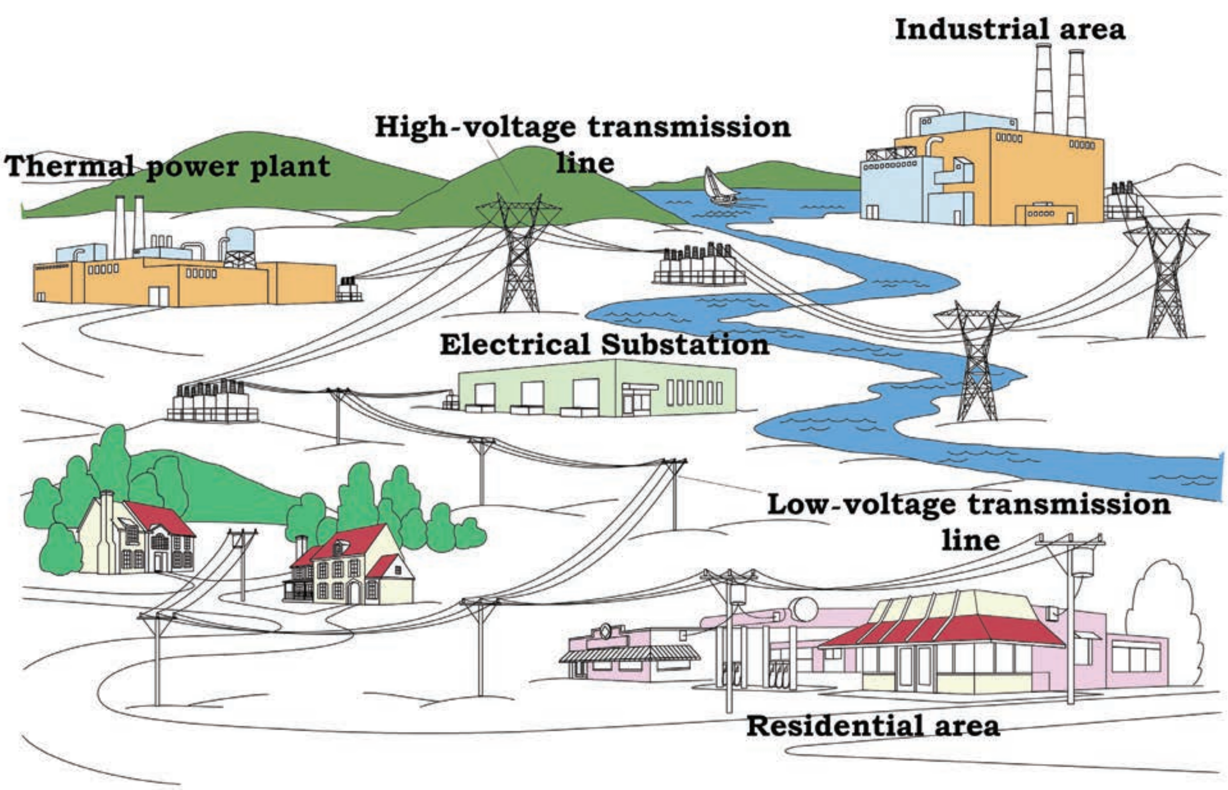
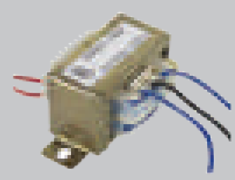


Fig. 2.35 Electrical network

Notes

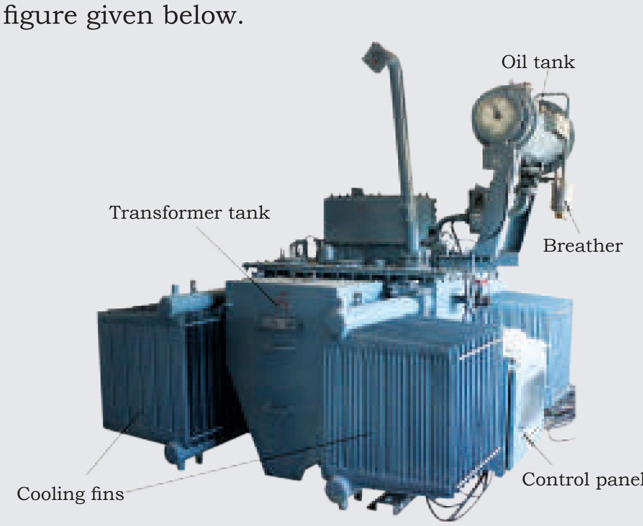
Assignment 5

Given below are different type of transformers. Read about the specifications of these transformers on the Internet and fill in the table given below.

Transformer	Name of transformer	Specification mentioned on the transformer
	Simple step down transformer	Input voltage: Output voltage: Operating frequency:
	Centre tape transformer	Input voltage: Output voltage: Operating frequency:
	High frequency transformer	Input voltage: Output voltage: Operating frequency:

Assignment 6

Visit your nearest power distributing substation. Identify and name the different parts of a high-voltage transformer as shown in the figure given below.



Practical Exercise 5

Perform an experiment to identify the primary and secondary winding of a transformer.

Material required

Transformer (220V to 12V), multimeter, input supply, 200-watt bulb, wire, wire stripper, wire cutter, insulation tape

Procedure

1. Connect a wire to the primary winding of the transformer.
2. Connect a wire to the secondary winding of the transformer.
3. Connect the primary winding wire to the input supply carefully.
4. Connect the secondary winding wire to the load.
5. Turn on the power supply.
6. Measure the voltage using a multimeter at the primary and secondary winding.
7. Note the reading displayed on the screen of the multimeter.

Integrated Circuit (IC)

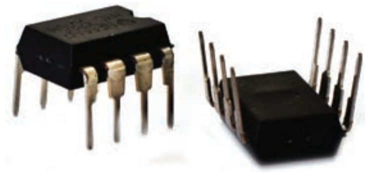


Fig. 2.36 Integrated Circuit

An integrated circuit is a combination of electronic components on a single piece (or chip) of semiconductor material as shown in Fig. 2.36. An integrated circuit has a large number of tiny transistors that are fit in a small chip to make circuits, which are smaller, cheaper and faster.

An integrated circuit has a number of pins. Each pin defines an input or output. A data sheet is required when working with an integrated circuit chip. It gives complete information about a particular integrated circuit. The internal structure of an IC is shown in Fig. 2.37.

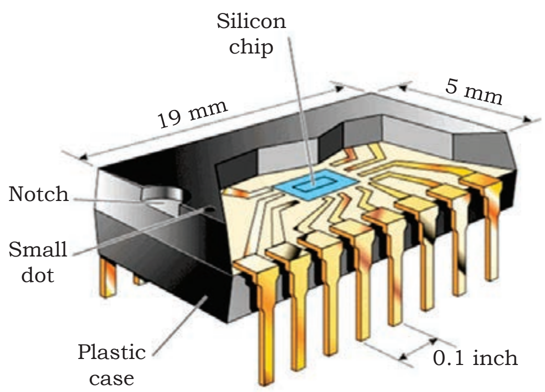


Fig. 2.37 Internal structure of IC

Light Emitting Diode

Light Emitting Diodes (LEDs) comprise several layers of semiconducting material. When the diode is utilised with DC, the active layer produces light. The LED emits light in a particular colour and this colour is dependent on the type of semiconductor material used in it. LEDs are made of semiconductor crystals as shown in Fig. 2.38.

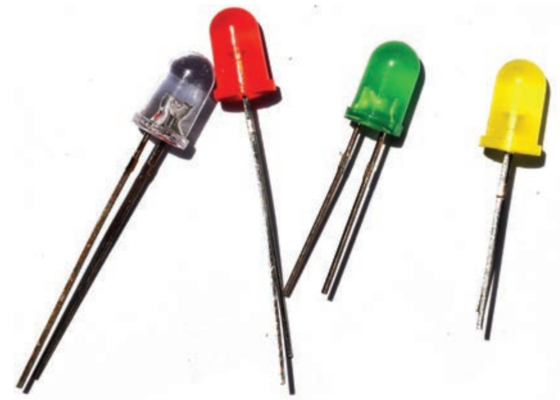


Fig. 2.38 Light Emitting Eiode

When current flows through them, they emit red, green, yellow or blue light, depending on the composition of the crystal compounds.

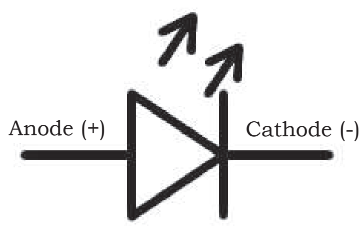


Fig. 2.39 LED symbol

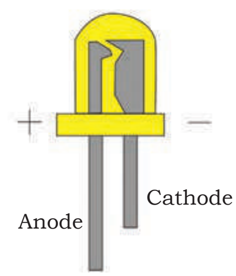
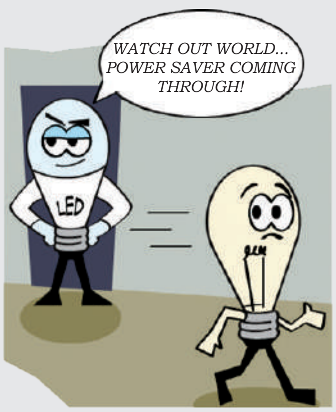


Fig. 2.40 LED light



Know more...

Why LEDs are a good choice?

1. Durable
2. High efficiency
3. Low energy use
4. Compact size
5. No UV issue

Check Your Progress

A. Multiple choice questions

1. A diode _________________________________.
   (a) is the simplest of semiconductor devices
   (b) has characteristics that closely match those of a simple switch.
   (c) is a two-terminal device
   (d) All of the above
2. Which of the following is a semiconductor material?
   (a) Silicon
   (b) Germanium
   (c) Both (a) and B
   (d) None of the above

3. An LED emits light when it is connected in ___________.
   (a) forward biased
   (b) reverse biased
   (c) unbiased
   (d) None of the above
4. Which of the following is a two-terminal semiconductor device?
   (a) Diode
   (b) Triode
   (c) Transistor
   (d) Integrated Circuit
5. Resistance of variable resistors can be changed, and hence, they are called ___________________.
   (a) rheostat
   (b) fixed resistor
   (c) variable resistor
   (d) None of the above
6. _____________ consists of a coil or wire loop.
   (a) Inductor
   (b) Capacitor
   (c) Resistor
   (d) Diode
7. A three-terminal semiconductor device is _________.
   (a) diode
   (b) transistor
   (c) IC
   (d) All of the above
8. Different colours emitted by an LED is because of ___________________.
   (a) applied voltage
   (b) forward or reverse bias
   (c) different compound formation
   (d) Power supply
9. An LED requires _____________ supply.
   (a) AC
   (b) DC
   (c) AC or DC
   (d) Non-linear supply
10. Transformer is used to _______________.
    (a) step up the voltage
    (b) step down the voltage
    (c) Both (a) and (b)
    (d) Non-linear supply
11. A transformer works on ____________________.
    (a) AC
    (b) DC
    (c) Both AC and DC
    (d) None of the above

NOTES

NOTES

12. A transistor has ____________ layers and ___________ junctions.
    (a) two, three
    (b) three, two
    (c) three, three
    (d) two, two
13. A diode is in forward bias condition when __________.
    (a) cathode is connected to the positive and anode to negative terminal of a battery
    (b) cathode is connected to the negative and anode to positive terminal of a battery
    (c) no specific polarity is required
    (d) None of the above
14. A diode is in reverse bias condition when ___________.
    (a) cathode is connected to the positive and anode is connected to negative terminal of a battery
    (b) cathode is connected to the negative and anode to positive terminal of a battery
    (c) no specific polarity is required
    (d) None of the above
15. Devices that store energy in the form of electric field are called ________________.
    (a) capacitors
    (b) inductors
    (c) resistors
    (d) diodes
16. Devices that store energy in the form of a magnetic field are called _______________.
    (a) capacitors
    (b) inductors
    (c) resistors
    (d) diodes
17. Resistance of a material affects the ________________.
    (a) length
    (b) temperature
    (c) thickness
    (d) All of the above
18. Pentavalent impurities in extrinsic semiconductor have ________ electrons in their outermost orbit.
    (a) 3
    (b) 5
    (c) 4
    (d) 2
19. Trivalent impurities in extrinsic semiconductor have _________ electrons in their outermost orbit.
    (a) 3
    (b) 5
    (c) 4
    (d) 2

20. The pure form of semiconductor is called ____________________.
    (a) intrinsic semiconductor
    (b) extrinsic semiconductor
    (c) Both (a) and (b)
    (d) None of the above
21. The impure form of semiconductor is called ______________.
    (a) intrinsic semiconductor
    (b) extrinsic semiconductor
    (c) Both (a) and (b)
    (d) None of the above
22. What are the two major categories for resistors?
    (a) Low and high power value
    (b) Commercial and industrial
    (c) Low and high ohmic value
    (d) Linear and non-linear
23. Carbon composition resistors are made of ________________.
    (a) germanium and lead
    (b) silicon and germanium
    (c) carbon and silica
    (d) lead and carbon
24. Which of the following is true for resistance?
    (a) Symbolised by R, measured in Ohm and directly proportional to conductance
    (b) Represented by the flow of fluid in the fluid circuit
    (c) Directly proportional to current and voltage
    (d) The opposition to current flow is accompanied by dissipation of heat
25. Carbon composition resistors are available in ______________ power rating.
    (a) 1/4 watt
    (b) 1/2 watt
    (c) 1 watt
    (d) All of the above
26. For fixed voltage, if resistance decreases, then current will _______________.
    (a) decrease
    (b) double
    (c) increase
    (d) remain the same
27. Resistance in a circuit is _______________.
    (a) the same as current
    (b) in opposition to current
    (c) the same as voltage
    (d) in opposition to voltage

Notes

NOTES

28. Which of the following is not a film resistor?
    (a) Carbon film resistor
    (b) Metal film resistor
    (c) Thin film resistor
    (d) Thick resistor
29. Which of the following is the temperature operating range of cracked carbon resistor?
    (a) 700–800 degree Celsius
    (b) 900–1000 degree Celsius
    (c) 500–600 degree Celsius
    (d) 600–700 degree Celsius
30. Which of the following is not a non-linear resistor?
    (a) Thermistor
    (b) Varistor
    (c) Photoresistor
    (d) Carbon film resistor
31. Which of the following is not a linear resistor?
    (a) Potentiometer
    (b) Trimmer
    (c) Wire wound resistor
    (d) Photoresistor

B. Fill in the blanks

1. Transformers work on ________________ voltage.
2. Extrinsic semiconductor is ____________ form of semiconductor.
3. Intrinsic semiconductor is ________________ form of semiconductor.
4. Capacitor stores energy in the form of ____________ field.
5. Inductor stores energy in the form of ______________ field.
6. Diode has ________________ terminals.
7. Silicon is ______________ material.
8. Transistor has _______________ terminals.
9. When LED is in forward bias condition, it will turn ________________.
10. A three-terminal semiconductor device is ___________.

C. State whether the following statements are True or False

1. Transformers are used only to step-up the voltage.
2. An LED emits light in a particular colour and this colour is dependent on the type of semiconductor material used in it.

3. A transistor is used as an amplifier and switch.
4. The electromagnetism in a transformer is the energy source for the transformer.
5. Low voltage is used for transmission and high voltage in office and home.
6. Transformer changes the frequency of applied signal.
7. The junction, where the emitter and base layer touch each other, is called emitter-base junction.
8. Amplification is the process of increasing the level of voltage and current.
9. The base unit of capacitance is Farad.
10. Trimmer is a miniature adjustable resistor.
11. Potentiometer is a variable resistor. Its resistance value can be changed using a rotating knob.
12. Negative and positive temperature coefficient are linear resistors.
13. When light is illuminated on a photo resistor, its resistance value decreases.
14. In non-linear resistors, current is directly proportional to the applied voltage.
15. In linear resistors, current is not directly proportional to the applied voltage.
16. In thick film resistors, resistive film is formed on the substrate of silicon to produce high resistance value resistor.
17. In film resistors, resistance value depends on the thickness of ceramic rod placed in it.
18. Linear resistors can be classified into fixed and variable.
19. Variable resistor includes carbon composition resistor, film resistor, wire wound resistor and cracked carbon resistor.
20. LDR stands for light dissipate resistor.

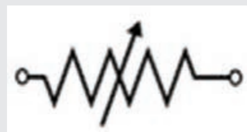
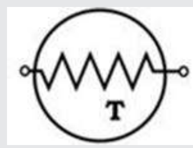
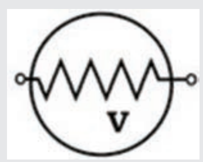
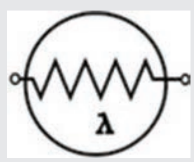
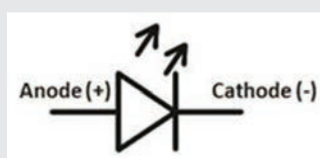
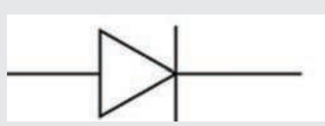
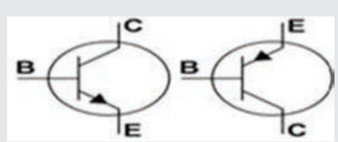
D. Short answer questions

1. Write short notes on— Diode, Transistor, LED, Capacitor, Inductor.
2. What is an extrinsic semiconductor?
3. What is an intrinsic semiconductor?
4. What are the applications of a transistor?
5. Write down the specifications of a capacitor.
6. What is inductance?

NOTES

Notes

E. Identify the symbols in the table given below

1. 	
2. 	
3. 	
4. 	
5. 	
6. 	
7. 	
8. 	

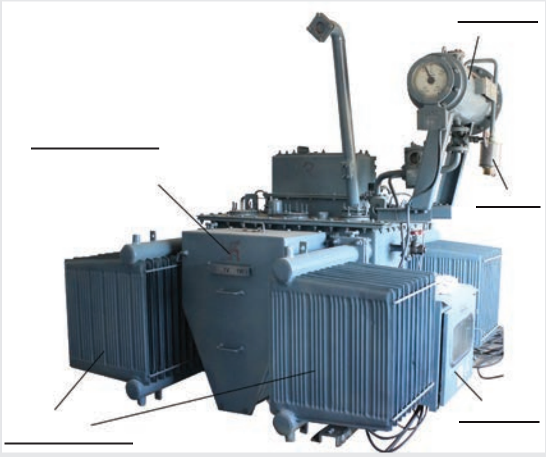
F. Calculate the value for the following

1. A 3-ohm resistor is connected to 12V battery. Determine the current in the circuit.
2. Calculate the capacitance value, when the amount of charge is 2C and 6V is applied across the capacitor.

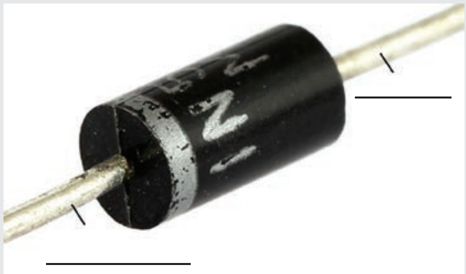
3. In an electric circuit, 10V is applied and current in the circuit is 2A. Calculate the value of resistor to be used.
4. Calculate the amount of charge when 220V is applied in a 2.5-microfarad capacitor.
5. Calculate the power consumed by the circuit when voltage and current are 220V and 0.8A, respectively.
6. Calculate the power consumed by a circuit when the applied voltage is 220V and resistance is 10 ohm.
7. Calculate the current in a circuit when power is 200W and resistance is 2 ohm.
8. Calculate the applied voltage when 880C charge is stored in a 4-farad capacitor.
9. What will be the amount of charge, when 440V is applied in a 2-farad capacitor?
10. Calculate the applied voltage, when the power consumed by a circuit is 20W and it has a resistance value of 20 ohm.

G. Label the following figures

1. Identify and name the parts of a transformer in the figure given below.



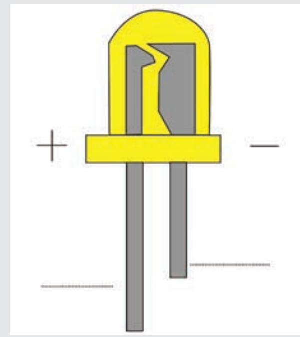
2. Identify and name the P-type and N-type terminal of the diode in the figure given below. Also, specify the anode and cathode terminals of the diode.



NOTES

Notes

3. Identify the parts of an LED in the figure given below.



4. Identify and name the different types of inductor listed in the following table.

Types	Name
(i) 	
(ii) Ferrite core 	
(iii) 	

H. Match the columns

A	B
(i) Semiconductor	(a) Magnetic field
(ii) Capacitor	(b) Opposition in the flow of current
(iii) Resistor	(c) Unidirectional device
(iv) Inductor	(d) Electric field
(v) Diode	(e) Three-terminal device
(vi) Transistor	(f) Trivalent and pentavalent

Unit 3

Components Value Identification

Introduction

Circuit designing and assembling is an interesting, innovative and responsible job. A large number of electrical and electronic components are available in market. For a beginner, it is difficult to identify these components. To get an idea about the components, we have to search for data sheets and books. This Unit will guide students to select the appropriate components. They will also learn to calculate the component value by reading a code mentioned on the component.

Component selection is a process of selecting a suitable component or a set of similar components from different suppliers for a designed circuit so that it performs its intended operation. A component engineer may have to first understand the circuit functionality or get the exact component with permissible tolerance. Most of the time, the design engineer invariably provides a list of critical parameters alone. But for the component engineer, the other non-listed parameters are also important. Therefore, it is important that the component engineer asks questions to the design team even for the smallest of doubts.

Notes

Only choosing the right component is not sufficient for product development but tracking and controlling every component's specifications throughout the supply chain and the product's life cycle is also significant. The life cycle of the component is yet another attribute that should be focussed upon while selecting a component. It is more relevant in case of semiconductor IC chips. The predicted life of the components inside the product constitutes to the life of the product itself in addition to other variables. The present 'availability' factor of the component is important but for how long is the component going to be available in future is more important. When replacing the components, there are unpredictable risks. Hence, one must always maintain a list of alternate components and sources.

The next important aspect to consider is the 'reliability' of the component, which is termed as the capacity of the component to perform its planned function for the specified time under defined environmental conditions.

Identification of resistor

Resistors are the fundamental components of electrical and electronics industry. A resistor opposes the flow of current in a circuit. The amount of opposition is measured in Ohm. The Ohmic value is mostly printed on the resistor in the form of a code. In a surface mount resistor, the Ohmic value is printed on the surface, whereas, in a carbon film resistor, it is printed in the form of bands of colour code. Learning the codes and by using a helpful mnemonic device, one can identify the value of resistors easily.

There are two methods for manually reading and identifying the value of a resistor. These are

1. Colour coded resistors (Axial resistors)
2. Alphanumerically coded resistors (surface mount resistors)

Colour coded resistors (axial resistors)

Axial resistors are cylindrical in shape with leads extending at each end. They are colour coded. The basic shape of an axial resistor is shown in Fig. 3.1(a). An axial resistor in colour coded form with four or five bands is shown in Fig. 3.1(b).

In case of a four-band resistor [Fig. 3.1(b)], the first two bands represent the significant digit, the third represents a multiplier and the fourth represents the tolerance. In case of a five-band resistor, the first three bands represent significant digits, the fourth represents a multiplier and the fifth represents the tolerance.

Resistors are colour coded mainly because of the difficulties in writing a value on the side of the resistor and the many errors that would occur.

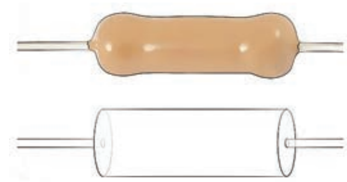


Fig. 3.1(a) Basic structure of an axial resistor

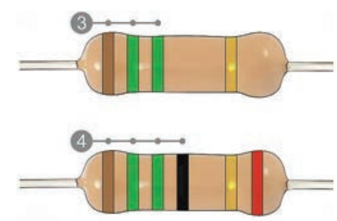


Fig. 3.1(b) Colour coded axial resistor

Specifications of four-band resistor

- The resistor is read this way—with the three colour bands on the left of the resistor and the single band to the right.
- The first band on a resistor is interpreted as the first number of the resistor value. For the resistor shown below, the first band is yellow, so the first number is 4 (Figs. 3.2 and 3.3).

Fig. 3.2 Four-band resistor

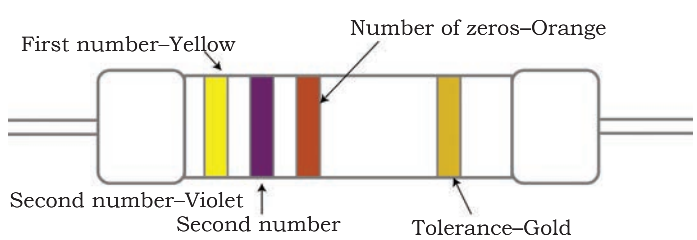


Fig. 3.3 Four-band resistor specification

- The second band is the second number. This is a violet band, making the second digit 7.
- The third band is called the multiplier and represents the number of zeros. In this case, it is orange, which is 3.

Colour	Number
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

Fig. 3.1(c) Colour code

- So the value of the resistor is 47000Ω or 47kΩ.
- The fourth colour represents the tolerance.
- Tolerance gives an upper and lower value that the resistor must be in. Take the following example for a 100Ω resistor.

Table 3.1 Tolerance value

Tolerance	Colour	Stated	Allowed upper value	Allowed lower value
+/-1%	Brown	100 Ω	101 Ω	99 Ω
+/-2%	Red	100 Ω	102 Ω	98 Ω
+/-5%	Gold	100 Ω	105 Ω	95 Ω
+/-10%	Silver	100 Ω	50 Ω	90 Ω

Colour	Significant figures			multiplier
Black	0	0	0	1Ω
Brown	1	1	1	10Ω
Red	2	2	2	100Ω
Orange	3	3	3	1KΩ
Yellow	4	4	4	10KΩ
Green	5	5	5	100KΩ
Blue	6	6	6	1MΩ
Violet	7	7	7	10MΩ
Grey	8	8	8	
White	9	9	9	
Gold				
Silver				

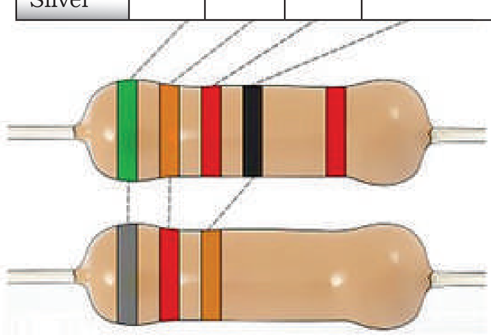


Fig. 3.4 Colour coding chart of a resistor

Calculation of resistor value

Read the colour bands from left to right. The colours on the first two or three bands correspond to numbers from 0 to 9, which represent the significant digits of the resistor's Ohmic value, the last band gives the multiplier (as shown in Fig. 3.4). For example, a four-band resistor with brown, brown, yellow and gold bands is rated at 11×10^4 or 110 kilo-Ohm with 0.1 tolerance. The code is as follows.

Brown: 1 significant digit

Brown: 1 significant digit

Yellow: Multiplier of 10^4

Gold: Tolerance of 1/10

Silver: Tolerance of 1/100

The last colour band represents the tolerance value of a resistor. To calculate the tolerance value of a resistor, read the colour on the last colour band, which is to the farthest right. This represents the tolerance of the resistor. If there is no colour band, the tolerance is 20 per cent. Some of the resistors have no, silver or gold band. In such cases, the tolerance band is of some other colour. The tolerance value for an axial resistor is given in Table 3.2.

Table 3.2: Tolerance value and colour of tolerance band

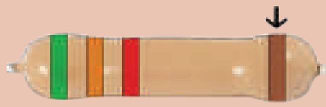
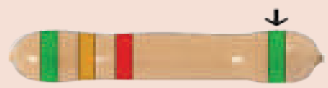
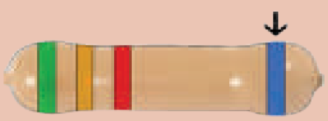
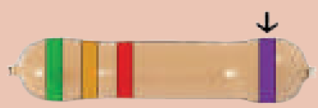
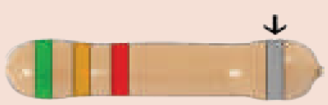
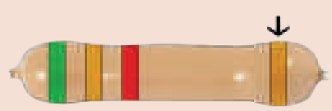
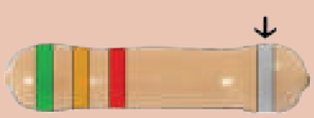
Brown: 1% tolerance  *Fig. a*	Red: 2% tolerance  *Fig. b*
Orange: 3% tolerance  *Fig. c*	Green: 0.5% tolerance  *Fig. d*
Blue: 0.25% tolerance  *Fig. e*	Violet: 0.1% tolerance  *Fig. f*
Grey: 0.05% tolerance  *Fig. g*	Gold: 5% tolerance  *Fig. h*
Silver: 10% tolerance  *Fig. i*	

Fig. 3.5 Memorising colour codes

Fig. 3.6 Colour codes

As one needs to memorise the colour code for resistors, it is important to choose a way so that it is not forgotten easily (Fig. 3.5). Remember that the first colour is black and so on. Each colour corresponds to a code in order from 0 to 9.

Some popular ways to memorise the sequence of colour code is as follows.

"**B. B. ROY** of **G**reat **B**ritain has a **V**ery **G**ood **W**ife".

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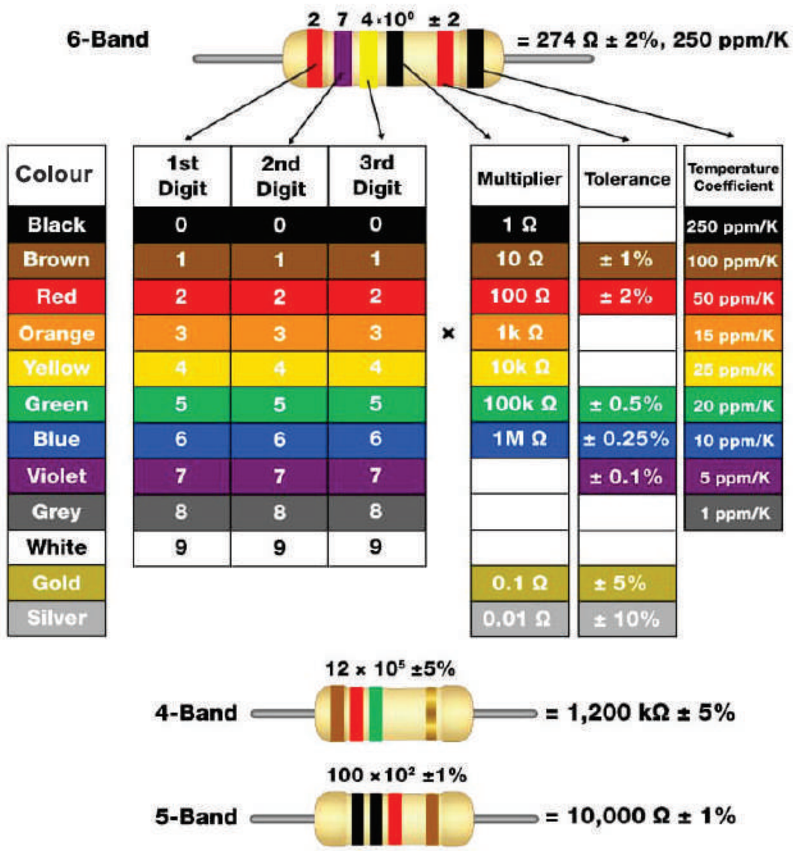


Fig. 3.7 How to read resistor colour codes

Alphanumerically coded resistors (surface mount resistors)

1.	Surface mount resistors are rectangular in shape. Surface mount resistors have emanating leads. These leads are used for mounting resistors on the PCB. Some surface mount resistors use plates on the bottom side.	
2.	The first two or three numbers printed on the surface mount resistor represents significant digits and the last digit represents the number of zero that should follow. For example, a resistor reading 1252 indicates a value 125200 Ohm. For tolerance value, use the letter at the end of the code.	

3.	Compare the letter at the end of the code with the tolerance it represents.	
4.	A: 0.05% tolerance	
5.	B: 0.1% tolerance	
6.	C: 0.25% tolerance	
7.	D: 0.5% tolerance	
8.	F: 1% tolerance	
9.	G: 2% tolerance	
10.	J: 5% tolerance	
11.	K: 10% tolerance	
12.	M: 20% tolerance	
13.	Check to see if there is a letter 'R' within the numeric code. This indicates a very small resistor, and the letter takes the place of a decimal point. For instance, a 5R5 resistor is rated at 5.5 Ohm.	

Notes

Assignment 1

Taking Fig. 1 as reference, find the resistance value of the following colour code.

1. Red-brown-green-silver
2. Black-brown-red-orange
3. Brown-orange-red-gold

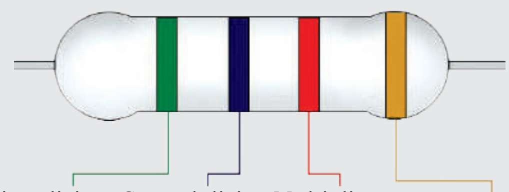


Fig. 1

Identification of capacitor

Reading a capacitor

Capacitor uses a wide variety of codes to describe its characteristics (Fig. 3.8). It is difficult to read the value of a small capacitor as it is printed in very small font size. For many low-voltage circuits, it is important to know the capacitance value and voltage rating of the capacitor. Capacitance is measured in Farad (F).

Measuring unit of capacitor

Capacitor values are, usually, tiny. To express those small values of capacitance, the metric system used is given below.

1 mF = 1 millifarad = 10–3 farad

1 µF = 1 microfarad = 10–6 farad

1 nF = 1 nanofarad = 10–9 farad

1 pF or µµF = 1 picofarad = 1 micromicrofarad = 10–12 farad

In general, millifarad and microfarad is used to measure the capacitance of household appliances.

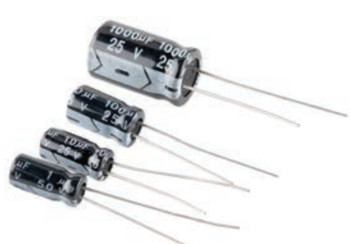


Fig. 3.8 Outer body of a capacitor

Reading capacitor value

It is important to read the capacitor values correctly. There will be some variation in the printing of the capacitance value. So, always look for the closely matched value of capacitance.

For example, the capacitor value printed in Mu may be treated as (µ) because the symbol for micro is difficult to typeset.

Sometimes the letter 'm' is used instead, resulting in micro-Farad being abbreviated as 'mF'. Technically, there is also 'milli-Farad'. But in practice, milli-Farad is almost never seen, with thousands of micro-Farad being more common.

For example, 'MF' is just a variation on 'mf'.

Abbreviation for farad is 'fd'. For example, 'mf' or 'mfd' is the same.

Single letter markings, such as '475m' are, usually, found on smaller capacitors for instructions. It represents the 475 milli farad.

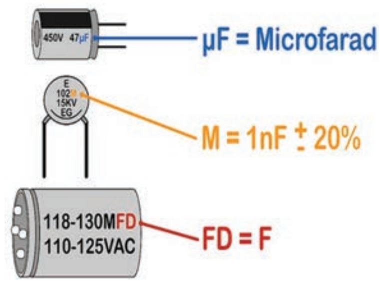


Fig. 3.9 Specification of a capacitor

Tolerance value of capacitor

Tolerance value of a capacitor is the maximum acceptable range of capacitance till the capacitor can work without damage. It is required to pay attention for a precise capacitor value. For example, a capacitor labelled '6000uF + 50%/-70%' could actually have a capacitance as high as 6000uF + (6000 × 0.5) = 9000uF, or as low as 6000 uF - (6000uF × 0.7) = 1800uF.

If tolerance percentage is not given, it can be calculated by using the alphabetic code printed on the capacitor (Fig. 3.10).

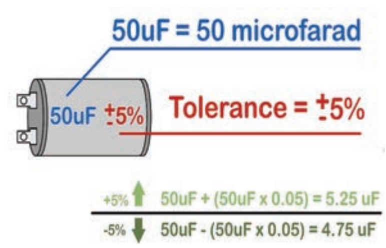


Fig. 3.10 Tolerance value of a capacitor

Voltage rating of capacitor

As the size of a capacitor is small, voltage is written as V, dc voltage rating as VDC, DC working voltage as VDCW and working voltage as wv. This is the maximum voltage of a capacitor (Fig. 3.11).

1 kV = 1,000 volt

If a capacitor is labelled with a single letter, such as V it can be assumed that it can work for both AC and DC voltage.

For example, to build an AC circuit, choose the capacitor rated specifically for VAC. The DC capacitor can only be used after converting it to AC.

A capacitor indicated with a minus (–) sign is an electrolytic capacitor. Such a capacitor is polarised. In such cases, make sure that the positive end of the capacitor is connected with the positive side of the circuit (Fig. 3.12). Otherwise, the capacitor may eventually cause a short circuit or even explode. The capacitor without + or – can be fixed in either way.

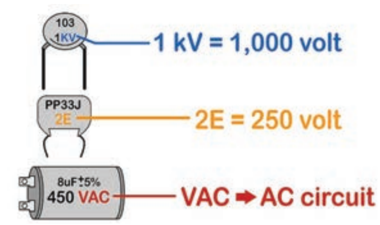


Fig. 3.11 Voltage rating of a capacitor

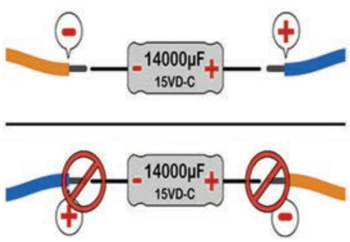


Fig. 3.12 Polarity of a capacitor

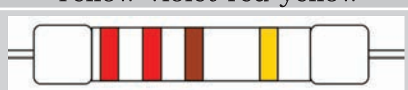
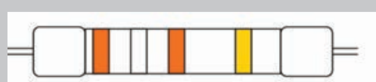
Fig. 3.13 Aluminium electrolytic capacitor

Fig. 3.14 Tantalum electrolytic capacitor

Some capacitors use a coloured bar or ring-shaped depression to show polarity. Traditionally, this mark designates the –ve end on an aluminium electrolytic capacitor as shown in Fig. 3.13. On tantalum electrolytic capacitors (which are very small) as shown in Fig. 3.14, this mark designates the +ve end.

Assignment 2

Analyse and write down the value of the resistors given below

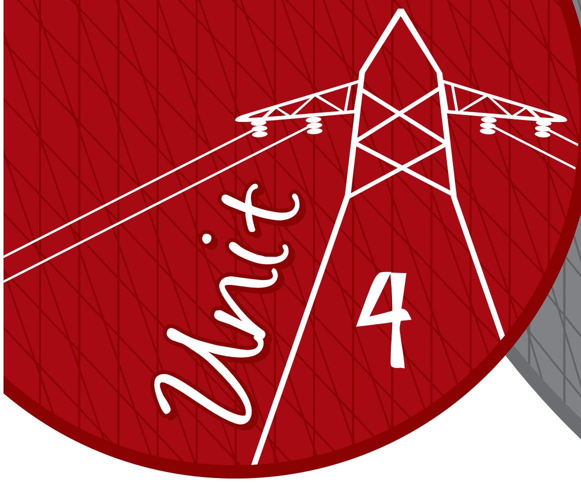
Resistor	Value
 Brown-black-yellow-yellow	
 Yellow-violet-red-yellow	
 Red-red-brown-yellow	
 Orange-white-orange-yellow	
 Green-blue-red-yellow	

Check Your Progress

A. Multiple choice questions

1. What are the two major categories of resistors?
   (a) Low and high power value
   (b) Commercial and industrial
   (c) Low and high Ohmic value
   (d) Fixed and variable
2. What is the Ohmic value for the colour code of orange, orange, orange?
   (a) 22 kilo Ohm
   (b) 33 kilo Ohm
   (c) 3300 Ohm
   (d) 44000 Ohm

3. Which of the following is true for resistance?
   (a) Symbolised by R, measured in Ohm and directly proportional to conductance
   (b) Represented by the flow of fluid in the fluid circuit
   (c) Directly proportional to current and voltage
   (d) The opposition to current flow accompanied by the dissipation of heat
4. Resistor tolerance is either printed on the component, or provided by __________________.
   (a) company
   (b) keyed containers
   (c) colour code
   (d) size
5. For a fixed voltage, if resistance decreases, then the current will __________________.
   (a) decrease
   (b) double
   (c) increase
   (d) remain the same
6. Resistance in a circuit is __________________.
   (a) the same as current
   (b) in opposition to current
   (c) the same as voltage
   (d) in opposition to voltage
7. A colour code of brown, brown, red, gold is for which Ohmic value?
   (a) 1.2k Ohm 5%
   (b) 1.1k Ohm 5%
   (c) 1.3k Ohm 5%
   (d) 1.5k Ohm 5%
8. A colour code of black, brown, green, gold is for which Ohmic value?
   (a) 1×10^5 5%
   (b) 1×10^4 5%
   (c) 1×10^5 10%
   (d) 1×10^4 10%
9. A colour code of brown, red, orange, silver is for which Ohmic value?
   (a) 12×10^3 10%
   (b) 21×10^3 10%
   (c) 14×10^3 5%
   (d) 12×10^2 5%
10. A colour code of red, yellow, grey, gold is for which Ohmic value?
   (a) 23×10^8 5%
   (b) 24×10^8 5%
   (c) 25×10^7 5%
   (d) 22×10^7 5%



Unit 4

Electrical Earthing System

Introduction

Earthing or grounding plays an important role in stable and safe operation of an installed electrical system. The concept of earthing is as old as the use of electrical power in electrical appliances and loads. In early days, when ungrounded (unearthed) electrical systems or appliances were used, there was always a risk of electric shock. In order to overcome this risk, the practice of earthing started. Earthing or grounding means connecting the electrical system or equipment to the ground by means of a suitable conductor. This conductor provides a return path for the faulty current. This faulty current passes to the ground or earth through the conductor.

Electrical earthing or grounding are commonly used words for earthing. Grounding is commonly used word for earthing in North American standards like Institute of Electrical and Electronics Engineers (IEEE), National Electrical Code (NEC), American National Standards Institute (ANSI) and Underwriter's Laboratories (UL), etc., while, earthing is used in European, Commonwealth countries and British standards like British Standard Institution (BSI) and International Electrotechnical Commission (IEC). Earthing or grounding in an electrical system is invisible physically but with its working we can feel its importance. Earthing is used to protect people from electric shocks by providing a path (protective conductor) for a fault current to flow into the earth.

Earthing is done for the safety of an electrical network. In an electrical network, all electrical parts are grounded. So, even if insulation inside an equipment fails, no dangerous voltage is present within.

Electrical earthing

The process of transferring immediate discharge of electrical energy directly to the earth with the help of a low-resistance wire is known as 'electrical earthing'.

Earthing refers to connection of the non-current carrying part of an equipment or neutral point of a power supply system to the earth or ground. It is done to avoid or minimise risks during the discharge of electrical energy.

Earthing provides a path to the leaking current. The short circuit current of the equipment passes to the earth, which has zero potential, thus, protecting the system and equipment from damage.

The metallic part of electric machinery and devices is connected to the earth plate or earth electrode (which is buried in the moist earth surface) through a thick conductor wire (which has very low resistance) for safety purpose. This set-up is known as **earthing** or **grounding**. The circuit symbol for electrical earthing is shown in Fig. 4.1

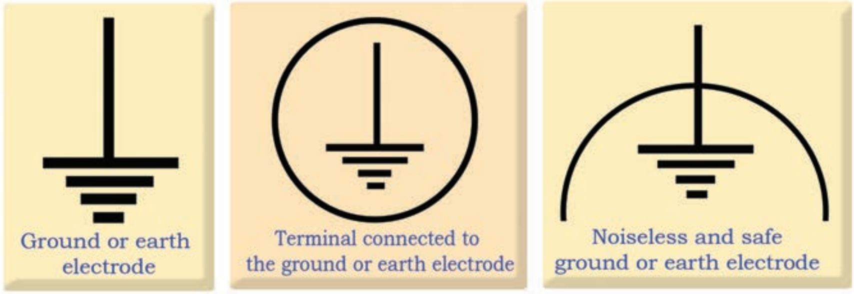


Fig. 4.1 Symbolic representation of grounding or earthing

Importance of earthing system

Every electrical equipment or appliance must be 'earthed' or 'grounded' for the safety of equipment, person and system as a whole.

Notes

Any fault occurring in electrical supply can directly impact the human body. Major accidents happen due to faulty earthing. The leaked current may pass through the human body, which may cause severe injury or even be fatal. Earthing plays an important role in safe generation, transmission, distribution and operation of an electric system as shown in Fig. 4.2. In large power stations, the earthing resistance value is 0.5 Ohm.

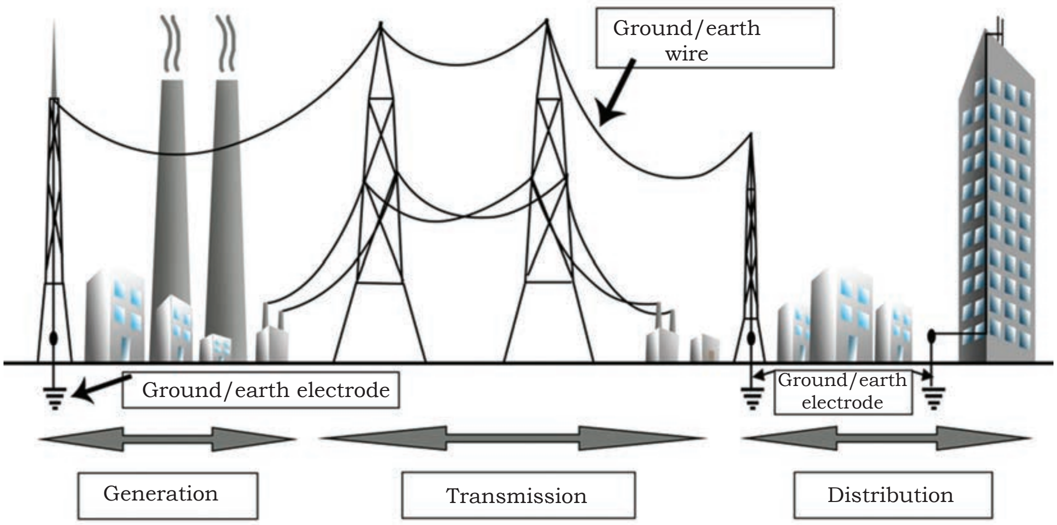


Fig. 4.2 Earthing in an electrical system

Earthing must be tested or checked at regular intervals. While testing the earthing connections, make sure that the resistance of earth connection is minimised. Record the results to improve the prescribed resistance value for better function.

Systems and purpose of earthing

The purpose of earthing can be better understood by two different systems, which are as follows.

- Ungrounded system
- Neutral grounded system

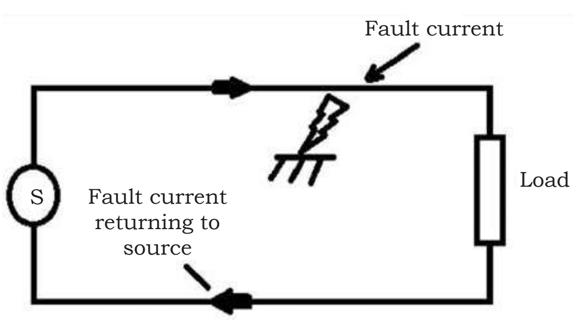


Fig. 4.3 Circuit with ungrounded system

Ungrounded system

In an ungrounded system, as shown in Fig. 4.3, the current flows from source to the load and returns to the source, thus, completing the circuit. As the circuit is not grounded, there is no path for fault current. Due to the absence of path for fault current, it will return to the source. This will damage the source and may harm the person in contact with the circuit. This type of system is not in practice anymore.

Neutral grounded system

The solution to the issue of ungrounded system is provided by a neutral grounded system. This system avoids the risk of developing the first fault and eliminates subsequent risks of short circuiting due to second fault in the circuit. In this type of grounding, one of the poles of the source is connected to the ground mass. This is called 'neutral', while the other pole that carries the charge to the load is called 'phase'. The neutral conductor always carries the return current from the load as shown in Figs. 4.4 and 4.5.

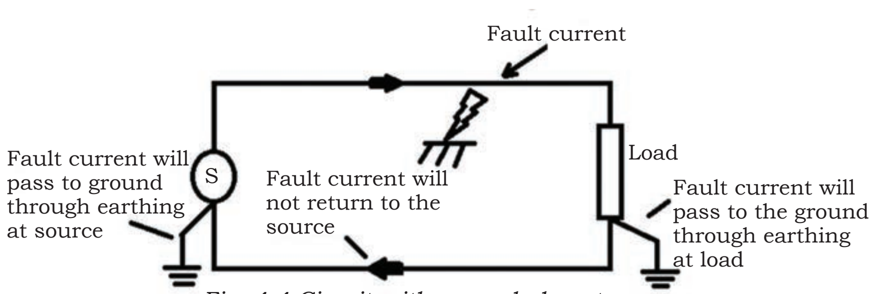


Fig. 4.4 Circuit with grounded system

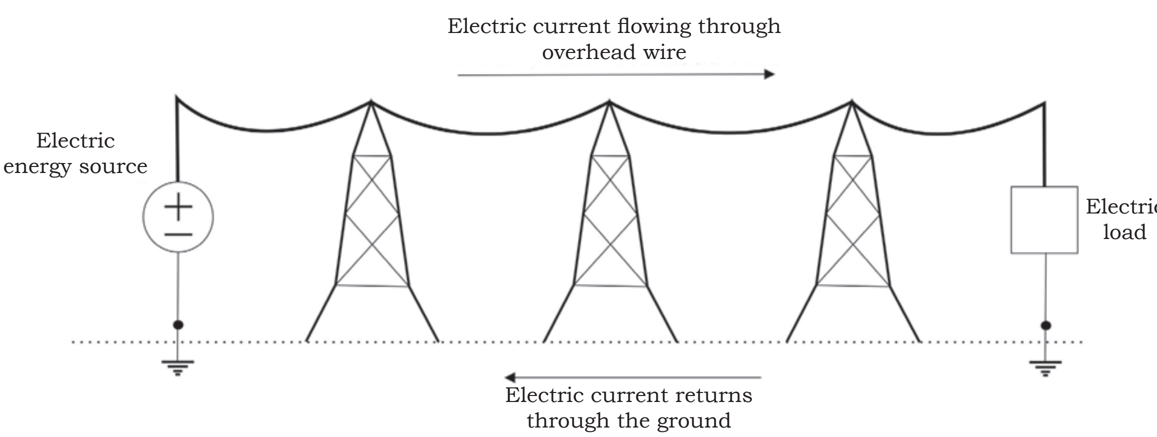


Fig. 4.5 Neutral ground system in electrical distribution system

In grounded or earthed system, neutral is connected to the earthed wire. In case of insulation failure in the phase conductor, the fault current can lead to damage in the machinery or equipment. Due to the availability of an earthed wire in the neutral line, excess fault current passes through the earthed wire to the ground surface. Through the ground path, this current safely returns to the source to complete the circuit (Fig. 4.5). Thus, by using grounded neutral, the risk of fault current gets bypassed. This way the risk of equipment damage can be avoided. In this type of system, neutral always provides the return current path from load to the source.

We handle various electrical appliances. These appliances have some external components, which do not carry current, and hence, we can touch these parts while using these appliances. For instance, we use an electric iron to press our clothes. While electric current flows through the iron, we can still hold its plastic coated handle. This is because of earthing done in our houses.

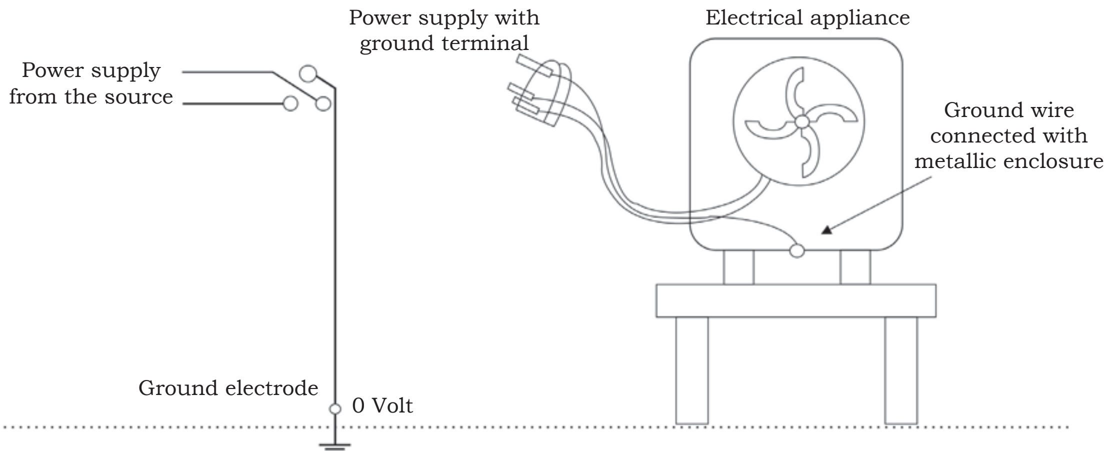


Fig. 4.6 Earthed three-pin socket of electrical appliances

The main purpose of earthing is to maintain zero potential or zero voltage of all non-current carrying metallic parts in an electrical system. When the metallic part of electrical appliances (part that can conduct or allow passage of electric current) comes in contact with a live wire due to failure of cable insulation, the metal can get charged and static charge accumulates on it. If such non-current carrying parts are not earthed, the person touching it will get electrocuted.

To avoid such an incidence, the power supply systems and parts of appliances must be earthed so as to transfer the charge directly to the earth. By earthing, the non-current carrying parts are connected to the earth and maintained at earth potential. It also prevents static charge buildup. Also, earthing is used to release the fault current from the electrical system.

Earthing can be done by connecting the respective parts, such as electrical conductors or electrodes placed near the soil or below the ground surface. The earthing mat or electrode under the ground level has a flat iron riser through which all non-current carrying metallic parts of the equipment are connected.

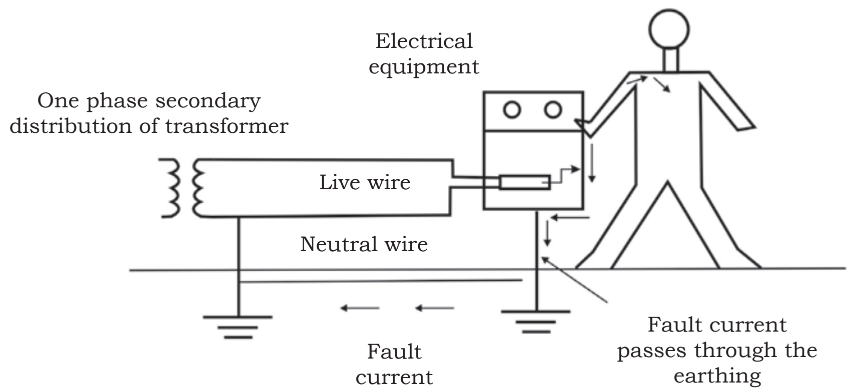


Fig. 4.7 (a) Electrical equipment with earthing

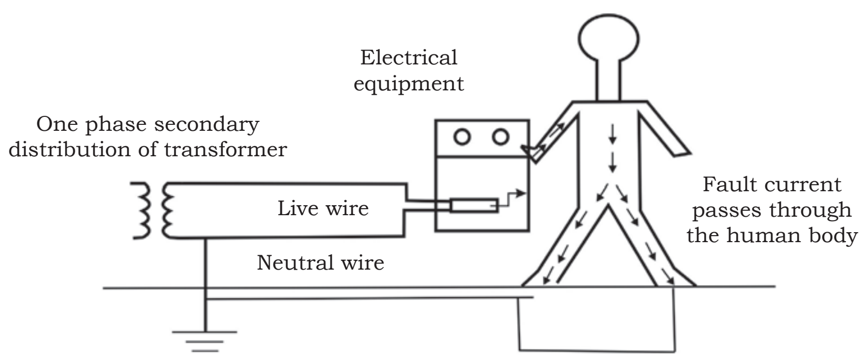


Fig. 4.7 (b) Electrical equipment without earthing

To understand the importance of earthing, let us observe a system with and without earthing as shown in Figs. 4.7(a) and (b). When a fault occurs, the fault current from the equipment flows through the earthing system to the earth, and therefore, protects the equipment from the fault current. The average resistance of human body is 500 to 1000 Ohm.

The contacting assembly is called 'earthing'. The metallic conductor connecting parts of the installation

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with the earthing is called 'electrical connection'. The earthing and the earthing connection together is called the 'earthing system'.

Types of earthing or grounding system on the basis of function

Equipment grounding

In an equipment grounding system, all non-current carrying metal parts are interconnected and connected to the earth. In this way, there is no potential or voltage between the non-current carrying parts and metal parts. Besides, there is no potential difference between the earth and non-current carrying metal parts. Non-current carrying metal parts include panel or enclosure body, metal race way, cable channel, equipment body or frame.

System grounding

In system grounding, a current carrying conductor is intentionally connected to the earthing system. This intentionally earthed current carrying conductor is called a 'grounded conductor'.

Components of earthing system

Electrical earthing system consists of the following basic components.

1. Earth continuity conductor
2. Earthing lead
3. Earth electrode

Earth continuity conductor or earth wire

Earth continuity conductor or earth wire is that part of the earthing system, which interconnects the overall metallic parts of an electrical installation. It includes conduit, ducts, boxes, metallic shells of switches, distribution boards, switches, fuses, regulating and controlling devices, metallic parts of electrical machines like motors, generators, transformers and the metallic framework, which contains electrical devices and components.

The resistance of the earth continuity conductor is very low. According to IEEE rules, the resistance between consumer earth terminal and earth continuity conductor (at the end) must not be more than 1Ω. It means, resistance of the earth wire should be less than 1Ω.

Size of the earth continuity conductor or earth wire depends on the cable size used in the wiring circuit. The cross sectional area of the earth continuity conductor must not be less than half of the cross sectional area of the thickest wire used in the electrical wiring installation.

Earthing lead or earthing joint

The conductor wire connected between earth continuity conductor and earth electrode or earth plate is called 'earthing joint' or 'earthing lead'. The point where the earth continuity conductor and earth electrode meet is known as the 'connecting point'.

Earthing lead is the final part of the earthing system that is connected to the earth electrode (which lies underground) through earth connecting point. There should be minimum joints in earthing lead and the connecting wires should be straight in position.

Generally, copper wire can be used as earthing lead. Copper strip is also used for high installation as it can handle high fault current due to its wider area than copper wire. A hard drawn bare copper wire is also used as earthing lead. In this method, all earth conductors are connected to a common (one or more) connecting point, and then, earthing lead is used to connect earth electrode (earth plate) to the connecting point.

To make the installation safe, two copper wires must be used as earthing leads to connect the device's metallic body to the earth electrode or earth plate, i.e., if we use two earth electrodes or earth plates, there would be four earthing leads. It must not be considered that the two earth leads are used as parallel paths to flow the fault current but both the paths must work to carry the fault current for safety purposes.

Earthing electrode or earth plate

A metallic electrode or plate, which is buried in the earth (underground) and is the last part of the electrical earthing system is known as the 'earthing electrode' or

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'earth plate'. In simple words, the final underground metallic (plate) part of the earthing system, which is connected with earthing lead, is called 'earth plate' or 'earth electrode'.

A metallic plate, pipe or rod, which has very low resistance and can carry the fault current safely towards ground (earth), can be used as an earth electrode.

Grounding resistance

A minimum ground electrode length must be of 2.5 metres (8 feet) must be in contact with the soil. There are four variables that affect the ground resistance of a ground system.

1. Length and depth of the ground electrode
2. Diameter of the ground electrode
3. Number of ground electrodes
4. Ground system design

Length and depth of ground electrode

One effective way of lowering ground resistance is to drive ground electrodes deeper. Soil is not consistent in its resistivity and can be highly unpredictable.

By doubling the length of the ground electrode, one can reduce the resistance level by an additional 40 per cent. There are occasions where it is physically impossible to drive ground rods in deeper areas that are composed of rock, granite, etc. In these instances, alternative methods, including grounding cement, are viable.

Diameter of ground electrode

Increasing the diameter of a ground electrode has a little effect in lowering the resistance. For example, one can double the diameter of the ground electrode and the resistance would only decrease by 10 per cent.

Number of ground electrodes

Another way to lower ground resistance is to use multiple ground electrodes. In this design, more than one electrode is driven into the ground and connected in parallel to lower the resistance. For additional electrodes to be effective, the spacing between additional rods needs to be at least equal to the depth of the driven rod. Without appropriate spacing between the ground electrodes, their spheres of influence will intersect and the resistance will not be lowered.

To assist students in installing a ground rod that will meet specific resistance requirements, they can refer to the table on ground resistance (Table 4.1). This is to be used only as a thumb rule because soil is in layers and is rarely homogeneous.

Ground system design

Simple grounding systems consist of a single ground electrode driven into the ground. Single ground electrode is the most common form of grounding used and can be found outside one's home or place of business. Complex grounding systems consist of multiple ground rods — connected, mesh or grid networks, ground plates and ground loops. These systems are, typically, installed at power generating substations, central offices and cell tower sites.

Complex networks dramatically increase the amount of contact with the surrounding earth and lower ground resistances (see Table 4.1).

Table 4.1 Ground resistance

Type of soil	Soil resistivity	Earthing resistance					
		Ground electrode depth (meters)			Earthing strip (meters)		
	M	3m	6m	10m	5m	10m	20m
Farming soil, clay soil	100 Ohm	33 Ohm	17 Ohm	10 Ohm	40 Ohm	20 Ohm	10 Ohm
Sandy clay soil	150 Ohm	50 Ohm	25 Ohm	15 Ohm	60 Ohm	30 Ohm	15 Ohm
Moist sandy soil	300 Ohm	66 Ohm	33 Ohm	20 Ohm	80 Ohm	40 Ohm	20 Ohm
Concrete 1:5	400 Ohm	-	-	-	160 Ohm	80 Ohm	40 Ohm
Moist gravel	500 Ohm	160 Ohm	80 Ohm	48 Ohm	200 Ohm	100 Ohm	50 Ohm
Dry sandy soil	1000 Ohm	330 Ohm	165 Ohm	100 Ohm	400 Ohm	200 Ohm	100 Ohm

Types of earthing on the basis of electrical system

There are four types of earthing, which are as follows.

Fig. 4.8 Copper plate used for plate earthing

Plate earthing

In plate earthing system (as shown in Figs. 4.8 and 4.9), a plate made of either copper with dimensions 60cm × 60cm × 3.18mm or galvanised iron (GI) of dimensions 60cm × 60cm × 6.35mm (2ft × 2ft × ¼ inch) is buried vertically into the earth (earth pit), which should not be less than 3m (10ft) from the ground level.

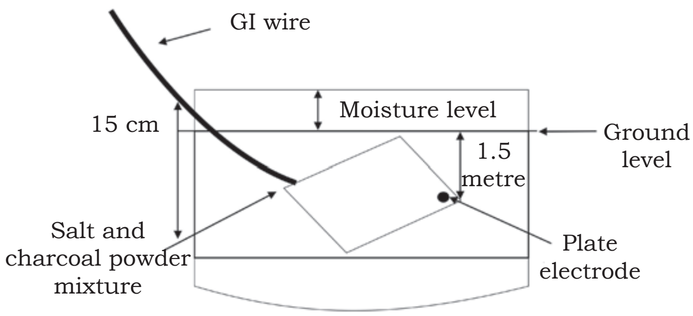

Fig. 4.9 Plate earthing

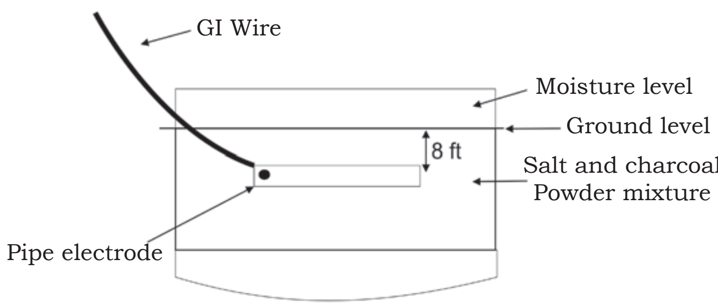

Fig. 4.10 Pipe earthing

Pipe earthing

In this kind of earthing system, a galvanised steel rod and perforated pipe of approved length and diameter is placed vertically into the wet soil. It is the most common system of earthing (as shown in Fig. 4.10).

The size of the pipe used depends on the magnitude of current and the type of soil. The dimension of the pipe is, usually, 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. A mixture of charcoal and salt of 10 kg each can be put into the pit to increase the conductivity of the soil. The moisture of the soil will determine the length of the pipe to be buried but, usually, it is 4.75m (15.5ft).

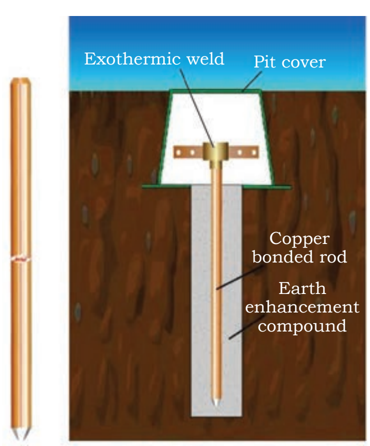

Fig. 4.11 Rod earthing

Rod earthing

Also known as 'fire earthing', it is the same as pipe earthing (Fig. 4.11). A copper rod of 12.5mm (1/2 inch) diameter or a rod 16mm (0.6in) diameter made of galvanised steel or hollow section, and 25mm (1inch) diameter of GI pipe of length above 2.5m (8.2 ft) are buried in upright position into the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

Strip or wire earthing

In this method of earthing, strip electrodes of cross section not less than 25×1.6mm (1×0.06 inch) is buried in horizontal trenches at a minimum depth of 0.5m. If copper with a cross section of 25×4mm (1×0.15 inch) is used for galvanised iron or steel, the dimension will be 6mm sq (Fig. 4.12).

If at all, round conductors made of galvanised iron or steel are used, their cross section area should not be too small, say less than $6mm^2$. The length of the conductor buried in the ground will give sufficient earth resistance and this length must not be less than 15m. This type of earthing is mostly used in transmission lines

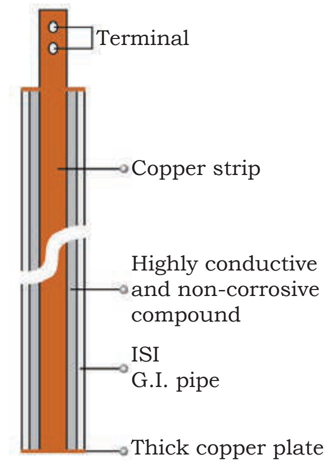

Fig. 4.12 Strip earthing

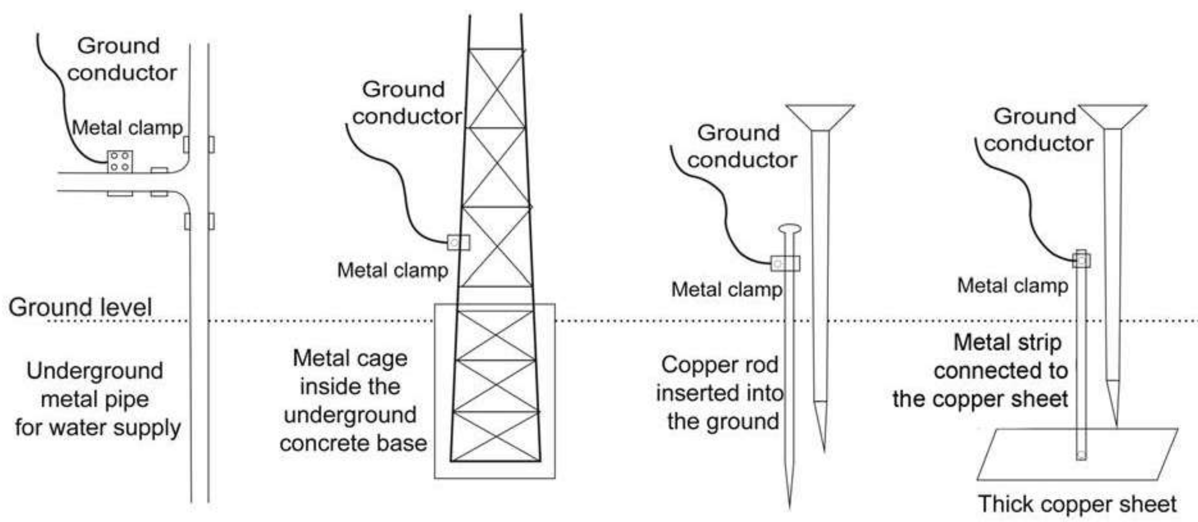

Fig. 4.13 Various ways of earthing

Lightning arrester

Lightning is a form of visible discharge of electricity between rain clouds or between a rain cloud and the earth. The electric discharge is seen in the form of an arc, sometimes several kilometres long, stretching between the discharge points.

When the electrical potential between two clouds or between a cloud and the earth reaches a sufficiently high value, the air becomes ionised along a narrow path and results in a lightning flash.

The possibility of discharge is high on tall trees and buildings rather than the ground. Buildings are protected from lightning by metallic lightning rods extending to the ground from a point above the highest part of the

Fig. 4.14 Lightning arrester

Notes

roof. A lightning arrestor has a pointed edge on one side and the other side is connected to a long thick copper strip, which runs down the building. The lower end of the strip is earthed. When lightning strikes, it hits the rod and current flows down through the copper strip. This rod forms a low-resistance path for the lightning discharge and prevents it from travelling through the structure itself.

The lightning arrestor protects the structure from damage by intercepting flashes of lightning and transmitting the current to the ground. Since lightning strikes tend to strike the highest object in the vicinity, the rod is placed at the apex of a tall structure. It is connected to the ground by low-resistance cables. In case of a building, soil is used as the ground, and in case of a ship, water is used. A lightning rod provides a cone of protection, which has a ground radius, approximately, equal to its height above the ground.

A lightning rod or lightning conductor is a metal rod mounted onto a structure and intended to protect the structure if lightning strikes. If lightning hits the structure, it will preferentially strike the rod and be conducted to the ground through a wire, instead of passing through the structure, where it could lead to a fire or cause electrocution. Lightning rods are also called 'finials', 'air terminals' or 'strike termination devices'.

In a lightning protection system, a lightning rod is a single component of the system. The lightning rod requires a connection to earth to perform its protective function. Lightning rods come in different forms, including hollow, solid, pointed, rounded, flat strips or even bristle brush-like. The main attribute common to all lightning rods is that they are all made of conductive material, such as copper and aluminium. Copper and its alloys are the most common material used in making lightning protection rods.

Features

- A lightning arrester can be used for safeguarding a structure from being struck by lightning.
- It can be installed at all corners of the building at every 7.5m distance from each other and at all periphery and elevated positions.

- All lightning arresters are interconnected by 25×6mm GI strip at every 7.5m.
- One down conductor GI strip of 25×6mm is routed to one dedicated earth pit and all earth pits must be interconnected by GI strip below the ground level.

Usage

Lightning arresters can be used in the following.

- Chimneys
- High-rise buildings
- Important places, such as monuments, etc.
- Residential building, hotels, etc.

NOTES

Check Your Progress

A. Multiple choice questions

1. What is the specification of GI earth plate?
   (a) 60 cm × 60 cm × 3 mm
   (b) 60 cm × 60 cm × 6 mm
   (c) 60 cm × 60 cm × 4 mm
   (d) 60 cm × 60 cm × 5 mm
2. What is the amount of charcoal and salt needed for GI pipe earthing?
   (a) Charcoal 5 kg, salt 8 kg
   (b) Charcoal 10 kg, salt 8 kg
   (c) Charcoal 10 kg, salt 10 kg
   (d) Charcoal 5 kg, salt 5 kg
3. The size of the earth or ground wire is based on __________________.
   (a) the maximum fault current being carried through the ground wire
   (b) the rated current carrying capacity of the service line
   (c) soil resistance
   (d) Both (a) and (c)
4. Earth or ground wire is made of _______________.
   (a) copper
   (b) aluminium
   (c) iron
   (d) galvanised steel
5. Generally, grounding is provided for ____________.
   (a) the safety of the equipment
   (b) the safety of the operating personnel
   (c) Both (a) and (b)
   (d) None of the above

NOTES

6. Ground resistance should be designed such that ________________.
   (a) grounding resistance is as low as possible
   (b) grounding resistance is as high as possible
   (c) grounding resistance is always zero
   (d) None of the above
7. The objective of earthing or grounding is __________.
   (a) to provide as low resistance as possible to the ground
   (b) to provide as high resistance as possible to the ground
   (c) to provide flow of positive, negative and zero sequence currents
   (d) None of the above
8. Moisture content in the soil ____________ the earth's soil resistance.
   (a) increases
   (b) decreases
   (c) does not affect
   (d) None of the above
9. Factors on which soil resistance depends is/are ______________.
   (a) depth of the electrode
   (b) moisture
   (c) NaCl (salt)
   (d) All of the above
10. What type of earthing is used by transmission lines?
   (a) Plate earthing
   (b) Rod earthing
   (c) Strip earthing
   (d) Both (a) and (c)
11. Average resistance of human body is ________________.
   (a) 200 Ohm
   (b) 1000 Ohm
   (c) 1500 Ohm
   (d) 2000 Ohm
12. Which type of earthing is also called 'fire earthing'?
   (a) Plate earthing
   (b) Rod earthing
   (c) Strip earthing
   (d) All of the above

B. Fill in the blanks

1. The algebraic sum of the resistances of earth continuity conductor, earthing lead, earth electrode and earth is called ______________.
2. The ______________ protects a structure from damage by intercepting flashes of lightning and transmitting the current to the ground.
3. The minimum distance between two earth electrodes must be ______________.

4. Collect all wires in a metallic pipe from the earth electrode. Make sure that the pipe is ________________ above the ground surface.
5. Strip electrodes of cross section not less than ________________ are buried in horizontal trenches of a minimum depth of 0.5m.

C. State whether the following statements are True or False

1. Soil resistance can be improved by using NaCl (salt).
2. An earth and ground wire is made of iron.
3. Earthing increases the resistance of the conductive path.
4. Earthing is used to provide supply voltage to an equipment.
5. The average resistance of the human body is 1500 Ohm.
6. In GI pipe earthing, 5 kg charcoal and 5 kg salt are required.
7. In transmission lines, plate earthing is used.
8. Strip earthing is also known as fire earthing.
9. For large power stations, the earthing resistance value is 0.5 Ohm.
10. The connection between electrical installation systems via conductor to the buried plate in the earth is known as earthing.

D. Short answer questions

1. What is earthing?
2. Why is earthing required?
3. Write down some applications of earthing.

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Unit 5

Cabling

Introduction

A cable is an assembly of a number of wires kept side-by-side and twisted or braided together. Cabling is the process of preparing cable and setting up a connection. An electrical wire is a path or way of connecting various accessories. Electrical energy is distributed from the energy meter board to appliances and devices, which consume energy, such as television sets, refrigerators, fans, lamps, etc. For distributing the energy, cabling is done by two or more wires running side-by-side and bonded, twisted or braided together to form a single assembly.

The role of a cable is to carry an audio or video signal from one device to another. Cables do not change the nature of the audio or video signal they carry. They do not convert or process the signal.

A conductor is a wire that carries the signal, while connector is a plug at the end of the cable that connects to a device. Cables are important components of a home stereo or home theatre set-up. If one uses appropriate cables for a job, then one could end up with a super sound or picture quality. If one uses cables that are damaged or junky, one could end up with a lousy experience.

Cabling is a secure and safe way to transmit data from one place to another. In cables, the inner conductor

Notes

is secured from the outer surrounding and pressure of earth. Cable insulation or shielding should be hard enough for the protection of the inner conductor. The use of correct data cabling and wiring (also referred to as network cabling and wiring) is imperative for successful business, government and academic network infrastructure installations. Structured cabling design and installation must be done under a set of network standards.

Choice of cabling and wiring system

It is necessary that one makes the right choice, while performing cabling and wiring at workplace. Choice for a cabling and wiring system is based on technical and economic factors. The selection of a cable and wire, primarily, depends on the work to be performed. Secondly, cost may be another factor involved in selecting the type of cable.

There are various characteristics or factors to be considered in cabling and wiring, which are as follows.

Cost of wiring

One of the important factors that must be considered for cabling and wiring is the cost of wiring. It must be economical.

Durability

The cabling and wiring material selected must be durable. Cables and wires selected must meet the required specifications. They must be able to withstand and carry maximum current without overload or damage to an equipment.

Permanency

The cabling and wiring must not get damaged by harsh weather, fumes, dampness, etc.

Accessibility

Panels and junctions used in cabling and wiring must be affordable and accessible when there is a need for alteration, extension or renewal.

Appearance

After cable and wire installation is complete, the wires and cables must be covered and tagged as per safety guidelines.

Mechanical protection

It is important to protect the cables and wires from mechanical damage during usage.

Safety

Safety is one of the most important factors that needs to be considered in cabling and wiring. Always prefer conduit wiring for cabling and wiring.

Maintenance cost

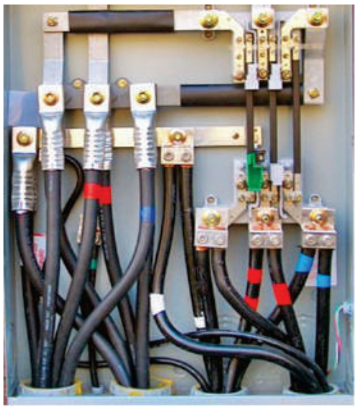

Fig. 5.1 Cabling and wiring

Cabling and wiring system employed must have low maintenance cost.

Load

The kind of cable used depends on the type of loads that consume electrical energy. Small diameter cables cannot be used for heavy loads as they may get damaged.

Types of cable

The cables used may be grouped according to

1. conductor,
2. number of cores,
3. voltage rating and
4. type of insulation used.

Based on conductor

On the basis of conducting material used, cables may be divided into two classes.

- Copper conductor cables
- Aluminium conductor cables

Based on number of cores

On the basis of the number of cores used, cables can be divided into three classes.

- Single-core cables
- Twin-core cables
- Three-core cables

Based on voltage rating

On the basis of voltage rating, cables may be of

- 240/440 volt
- 650/1100 volt

Based on type of insulation

On the basis of insulation used, cables may be categorised as:

- Vulcanised Indian Rubber (VIR) insulated cables
- Tough Rubber Sheathed (TRS) or Cab Tyre Sheathed (CTS) cables
- Polyvinyl chloride (PVC) cables
- Lead sheath cables
- Weather-proof cables
- XLPE cables
- Flexible cords and cables

Cable selection and application

It is essential to know cable construction, characteristics and ratings to understand the problems related to cabling systems. However, additional knowledge is required for assuring satisfactory cable operation. The following are five key factors.

- Cable installation
- Cable construction
- Cable operation
- Cable size
- Shielding

Cable installation

Depending on the distribution system and load, cables can be used for outdoor or indoor installation. After understanding the local site conditions, the maintenance personnel need to ensure that the selected cable system will operate satisfactorily in the desired installation site.

Many times, due to incorrect pulling tension, insulation gets damaged or weakened during installation. Therefore,

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designs of conduit systems are used to minimise the number of conduit bends.

Appropriate bend radius must be maintained in order to avoid unnecessary stress point. After completion of installation, routine inspection, testing and maintenance must be carried out on a regular basis to check the upkeep of the cable system.

Cable construction

Cable construction involves conductors, cable arrangement, insulation and finish covering. Selection and application of cable involves the type of cable construction needed for a particular installation.

Conductors

Conductor material, such as copper and aluminium, are used for power distribution.

Cable arrangement

Cables can be arranged in the following way.

- Single conductor cable
- Three conductor cable

Single conductors are easier to install and splice, and allow the formation of multiple cable circuits. Overheating of the cable must be prevented.

Insulation and finish covering

The selection of cable insulation and finish covering is normally based on the type of

- installation,
- ambient operating temperature,
- service conditions, and
- load served.

Cable operation

In normal and abnormal operating conditions, insulation of the cable must be able to withstand voltage stresses. Therefore, cable insulation must be selected on the basis of applicable phase-to-phase voltage and general system.

Cable size

The selection of cable size is based on these factors.

- Current carrying capacity
- Voltage regulation
- Short circuit rating

The above mentioned factors must be considered before selecting a cable size. In many instances, voltage regulation and short circuit rating factors are overlooked. This can cause danger to a property and personnel, as well as, damage to the cable.

Current carrying capacity

It is the amount of current, which a cable can carry safely. The current carrying capacity of a cable is also based on its thermal heating.

Voltage regulation

Voltage regulation defines the voltage rating of the cable and wire.

Short circuit rating

It is the rating on components and assemblies representing the maximum level of short circuit current that a component can withstand.

Shielding

When working with medium voltage, a cable should be selected based on shielded or non-shielded type. The conditions under which shielded cable is to be selected and applied are explained in the following paragraphs.

The application of shielded cable involves the following considerations.

- Type of insulation system
- Whether the system neutral is grounded or ungrounded
- Safety and reliability requirements of the system

In power systems, where electric field is intense, such as in case of high and medium voltage, surface discharges will take place and cause ionisation of air

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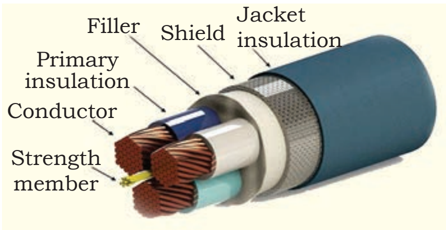


Fig. 5.2 Power cable internal interfacing

particles. The ionisation of air particles causes ozone generation, which can damage certain insulations and coverings. To prevent this shield, cables are used.

There are five fundamental constituents that make a cable—conductor, insulation, shield, filler and strength member (Fig. 5.2).

Commonly used cables

LT (PVC or XLPE) cable

Low tension (LT) cables are heavy duty cables. These are used for working voltage from 650 to 1100 Volt. These cables are used for underground, as well as, overhead transmission of electric power. These power cables are used in power plants, industries, interconnection of process control, communication and panel control systems, projects and all other electrical installations [Fig. 5.3 (a and b)].

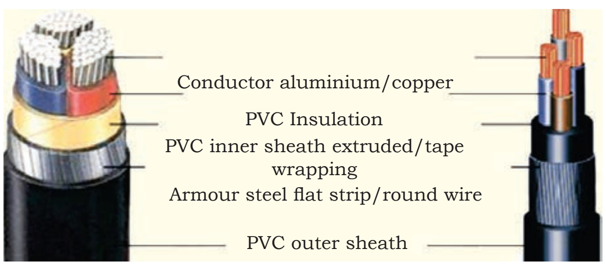


Fig. 5.3 LT cable of three and four cores

PVC

Polyvinyl chloride (PVC) is a thermoplastic material. It is used for making power cables. It acts as an insulator and can be used for covering the conductor in the cable.

XLPE

Cross linked polyethylene (XLPE) is the most commonly used thermoset material. It is used for making power cables. It acts as an insulator and protecting cover for the power cable.

PVC or XLPE

Single core	Red, black, yellow or blue
Two cores	Red and black
Three cores	Red, yellow and blue
Four cores	Red, yellow, blue and black
Five cores	Red, yellow, blue, black and grey
Six cores and above	Two adjacent cores blue and yellow, and remaining grey

Construction of LT power cable

Conductor: Aluminium or copper
Insulation: PVC or XLPE
Inner sheath: PVC
Armour: Galvanised steel wire or strip
Sheath: PVC

PVC	XLPE
Polyvinyl chloride	Cross linked polyethylene
Under short circuit conditions, it can withstand temperatures up to 160 degrees Celsius.	Under short circuit conditions, it can withstand temperatures up to 250 degrees Celsius.
Low moisture resistance	High moisture resistance
Low overloading capacity	High overloading capacity

Coaxial cable

Fig. 5.4 Coaxial cable internal interfacing

Coaxial cable is used to carry radio frequency signals and is widely used in the communication system. It is mostly used as it is shielded from external electromagnetic field interference. When carrying high-frequency signal, these cables do not radiate signal in the medium. No leakage of signal is possible because of shielding in the coaxial cable (Fig. 5.4).

Coaxial cable consists of an inner wire called core, which is surrounded by a second wire and the braid that encloses it entirely. But these two wires are electrically isolated from each other. Various types of coaxial cable are available with single or multi stranded cores. The outer sheath may consist of a solid tube, or in most cases, a conductive sheath made of braided wires (hence, the outer sheath is often referred to as the braid) or foil tape (Figs. 5.5 and 5.6).

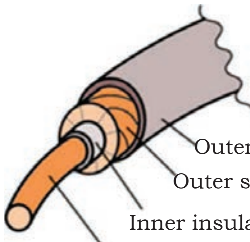


Fig. 5.5 Insulation layers of coaxial cable


Fig. 5.6 Coaxial cable

Optics fibre cable

Fibre optics is the science of light transmission through fine glass or plastic fibre. Optics fibre cables (Fig. 5.7) have various applications due to their inherent advantage over copper conductors.

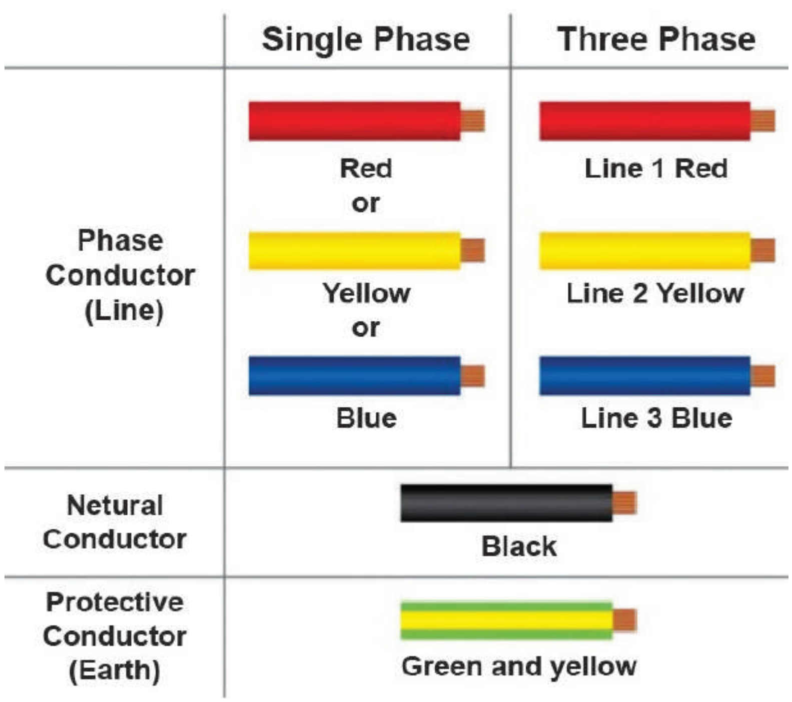

Fig. 5.7 Optics fibre cable

These cables are available in single mode and multi mode.

- Single mode optics fibre cables have a small core diameter (i.e., around 8–10 micrometre) through which only one ray of light can be transmitted.
- Multi mode optics fibre cables have a wider core diameter (i.e., around 50–100 micrometre) through which one or more rays of light can be transmitted.

Colour coding and marking

For a wireman, it is important to be able to identify wires on the basis of colour. By looking at the wire colour, the percon can identify the phase, neutral and earth wires. Therefore, the wireman needs to understand the colour coding of wires. Colour coding of a wire represents the purpose for which it is to be used (Fig. 5.8).



Code	Wire colour
B	Black
P	Pink
BR	Brown
R	Red
G	Green
SB	Sky blue
GR	Grey
SI	Silver
L	Blue
V	Violet
LG	Light green
W	White
O	Orange
Y	Yellow

Fig. 5.8 Colour code for electrical wires

The wireman must be aware of the specifications of the wires, printed on the outer sheath of the cable. The specification on the outer sheath indicates the type and size of the wire. Wires of different colours present inside the sheath serve different purposes.

Black wire

It is used for neutral wire.

Red wire

It is used as phase wire. It contains line voltage and is also called ‘hot’ or ‘line’ or ‘live’ wire.

Yellow wire

It is used as phase wire. It contains line voltage, and is also called hot or line or live wire. Generally, it is included in three-phase supply.

Blue wire

It is also used as phase wire. It contains line voltage and is also called hot or line or live wire. Generally, it is also included in the three-phase supply.

Green wire

Green or green with yellow stripe wires are used as earth wire.

Routing cables

It is the way of placing cables. Routing protect the cables from harsh weather conditions. Fig. 5.9 shows the routing of cables. While routing cables, one must do the following.

- Route the cable to the longest distance first.
- Use the diagram to plan the routing of the cables.
- Cut the unlabeled cable. Label all cables before routing them, else one may lose track.
- Make sure that the cable is not stretched or pinched.
- Make sure to leave the corners of the cable uncut. One must leave ample slack.
- Use electrical tape to attach the two cable ends and the end of the pull string together.

Fig. 5.9 Routing of cables

Bending of cables

Bend radius is the minimum radius at which one can bend a cable without making any kink or causing damage. The smaller the bend radius, the greater will be the flexibility of the material. Fig. 5.10 represents the bending of cables.

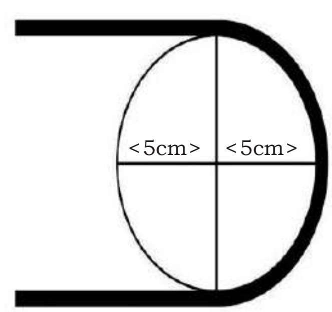


Fig. 5.10 Bending of cables

The minimum bend radius is of utmost importance at the time of handling optics fibre cables. The bending radius varies with different cable designs. If no minimum bend radius is given, a minimum low stress radius not less than 15 times of the cable diameter is assumed to be safe.

The following table represents minimum permissible bending radius of different cables.

Table 5.1: Bending radius of different cables

Voltage rating (kV)	**Paper insulated lead cables (PILC)**		**Polyvinyl chloride (PVC) cables**		**Cross linked polyethylene (XLPE) cables**	
	Single core	Multi core	Single core	Multi core	Single core	Multi core
	Micrometre (µm)	Micrometre (µm)	Micrometre (µm)	Micrometre (µm)	Micrometre (µm)	Micrometre (µm)
Up to 1.1	20 µm	15 µm	15 µm	12 µm	15 µm	12 µm
1.1 to 11	20 µm	15 µm	15 µm	15 µm	15 µm	15 µm
Above 1.1	25 µm	20 µm	20 µm	15 µm	20 µm	15 µm

Assignment 1

1. Identify different types of cable, i.e., PVC, coaxial cable, optics fibre cable.
2. Use stripping tools to strip these cables and identify the material used for making the cables.
3. Discuss the application of these cables.

Check Your Progress

A. Multiple choice questions

1. Thickness of the layer of insulation on the conductor in cables depends on ____________________.
   (a) reactive power
   (b) power factor
   (c) voltage
   (d) current carrying capacity
2. Which of the following protects a cable against mechanical injury?
   (a) Bedding
   (b) Sheath
   (c) Armour
   (d) None of the above

3. Which of the following insulation is used in cables?
   (a) Varnished cambric
   (b) Rubber
   (c) Paper
   (d) All of the above
4. PVC stands for ____________________.
   (a) Polyvinyl chloride
   (b) Post varnish conductor
   (c) Pressed and varnished cloth
   (d) Positive voltage conductor
5. Which of the following colour codes is used for live wire?
   (a) Grey
   (b) Red
   (c) Green
   (d) Black
6. In cables, sheaths are used to ____________________.
   (a) prevent the cable from moisture
   (b) provide strength
   (c) provide insulation
   (d) None of the above
7. Material used for armouring on the cable is _______________.
   (a) steel tape
   (b) galvanised steel wire
   (c) Both (a) and (b)
   (d) None of the above
8. Which colour wire is used as neutral?
   (a) Red
   (b) Black
   (c) Green
   (d) White
9. Which colour wire is used as earth?
   (a) Red
   (b) Black
   (c) Green
   (d) White
10. Which cable uses light for transmission?
   (a) Coaxial cable
   (b) Optics fibre cable
   (c) PVC cable
   (d) XLPE cable

B. Fill in the blanks

1. Green or green with yellow stripes is used as ________________ wire.
2. Blue wires are also used as hot wires. They contain line voltage and are also called ________________ wire.
3. Black wire is used for ________________.

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4. ________________ optic cables have very narrow diameter core (i.e., around 8–10 micrometre).
5. Coaxial cable is commonly used to carry ________________ signals.
6. Low-tension cables are heavy duty. They are used for working voltage from ________________.
7. ________________ is the most common thermoset material used as protecting cover of power cable.
8. Multi core optics fibre cable has a wider diameter core, i.e., around ________________ micrometre.
9. Fibre optics is the science of ________________ transmission through a very fine glass or plastic fibres.
10. Cross linked polyethylene is the most commonly used ________________ material.

C. State whether the following statements are True or False

1. Bend radius is the minimum radius at which one can bend a cable without making any kink or causing damage.
2. In selecting and applying cables at medium voltage, a major consideration involves whether the cable should be shielded or non-shielded.
3. Many times, cable insulation is damaged or weakened during installation by applying incorrect pulling tension.
4. Conductors, such as copper and aluminium, are used for power distribution.
5. Coaxial cable is used for radio communication.
6. Black wire is used for earth.
7. Red wire is used as neutral wire.
8. Green wire is used for earthing.
9. PVC is not used as an insulator in wire.
10. Optical fibre uses light as a medium of transmission.

D. Short answer questions

1. List the various types of cable.
2. What is a PVC power cable?
3. What is XLPE power cable?
4. Write the difference between PVC and XLPE power cable.
5. What do you understand by colour coding of cables?
6. What is the importance of bending in cabling?
7. On what factors does the cable size depend?
8. What is optics fibre cable?
9. Define single core and multi core fibre cable.
10. Which factors affect cable selection?
11. What steps must be followed for cable routing?

Unit 6

Electrical Safety

Introduction

It is important to follow occupational health and safety standards while dealing with electrical components and appliances. Electric current has enough power that if exposed to, it can be fatal. All electrical systems can cause harm. Electric current may cause the following.

1. Cardiac arrest
2. Muscle, nerve and tissue destruction
3. Thermal burns
4. Falling or injury

Electricity can travel through the body and can interfere with regular electrical signals between the brain and our muscles. This can lead to situations, where the heartbeat, breathing and other body functions may stop. Arc flashes can cause major burns or lead to intense lightning that can cause blindness.

Electrical safety at workplace is regulated by health and safety regulations, which state that every employer is responsible for ensuring that all employees are safe from injuries and other risks at the workplace.

A group, comprising employers and workers, must be formed to identify hazards associated with electrical

Know more...

Electrocution refers to death or severe injury caused by electric shock. When current passes through a human body, it causes electric shock.

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equipment. Assessing the risk is imperative to reduce the risk or severity of an injury. Electricity safety training can provide employees with the required knowledge and skill to identify and eliminate risks.

Safety in electrical system

Safety of personnel is important. Therefore, it is necessary to get acquainted with the safety procedures and practices to be followed in all major and minor electrical installations, such as generating stations, transmission and distribution lines, industrial establishment, etc. To get familiar with the safety rules and regulations governing the workplace, it is necessary to know the following rules and regulations.

1. The Electricity Act, 2003
2. The Factories Act, 1948
3. The Workman's Compensations Act, 1923
4. The Payment of Wages Act, 1936

Classes of safety

Following electrical safety measures is the most important thing that must be taken care of while working with an electrical circuit or appliance. Based on some basic factors like earthing, grounding, insulation in the appliance, classes of safety are categorised as follows.

Class 0

- Appliances under this class do not use appropriate earthing connection and have a single level of insulation between live parts and exposed metal work.
- Due to inappropriate earthing, Class 0 safety appliances are used in dry areas only.

Class 1

- In Class 1 safety, the chassis of an appliance must be earthed. If live wires touch the chassis of the appliance, current will flow through the ground or earthed wire.

- A fault in the appliance, which causes a live conductor to contact the casing, will cause the current to flow in the earth conductor.

Class 2

- Class 2 or double insulated electrical appliances are designed in such a way that they do not require a safety connection into the earth (ground).

Class 3

- Class 3 appliances are supplied power from a separate or extra low voltage source.
- Application of safety standards is intended to reduce the risk of injury or damage due to:
  - electric shock,
  - energy related hazards,
  - fire,
  - heat related hazards,
  - mechanical hazards,
  - radiation and
  - chemical hazards.

Work and safety standards

Following the safety standards are important for a company that seeks continuous improvement at the workplace. Standards for operational and safety procedures provide the company with baseline references, which are essential for the business to grow. The standard operating procedures (SOPs) provide a stable platform for performance measurements. A wireman must adhere to the work standards so as to meet the desired targets and achieve sustainability at the workplace. SOPs describe the way of doing a task step-by-step. They document the existing best practices and ensure that they are implemented every time during a task. Every process or machine operation has SOPs and technicians are advised to adhere to the SOPs at all times.

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Work standards

In industries, work standards are the thumb rules. Safety standards are designed to ensure the safety of people, products, processes, activities, and so on.

The general guidelines for electrical safety must be followed by the wireman to ensure personal, as well as, co-worker safety. The points given below are some of the general guidelines that must be followed at the workplace.

- Always follow the correct procedures to ensure zero accidents at work.
- Always follow the correct wiring diagram.
- Obey the safety signs, stickers and tags on the control panel.
- Always uses appropriate tools for carrying out a work.
- Never leave a running panel unattended.
- Always read the labels and instructions given on the components.
- Always wear appropriate clothing and remove metal objects before starting a work.
- Use prescribed protective safety equipment only.
- Always follow electrical safety rules when working with electrical machinery or equipment.
- Report all unsafe acts or conditions to the supervisor.

Personal protective equipment

There are some common personal protective equipment (PPE) that must be used at the workplace. Common PPE at the workplace include gloves, helmet, goggles, safety boots, hearing protectors, high-visibility clothing, and so on (Fig. 6.1). Also, there are some special safety equipment available, such as fire extinguishers.

Selection of PPE and other safety equipment must be such that they are suitable for a job and offer the required protection. Items for personal safety are shown in Fig. 6.1. One of the important safety equipment in the electrical and electronic industry is fire extinguisher (fire is a serious hazard in the industry). If there is a fire in an electrical unit, fire extinguishers are brought into use.

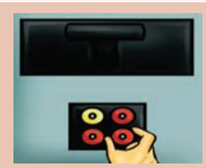
Fig. 6.1 Personal protective equipment

Did You Know?	
Current in milli ampere	**Effect on human body**
0.5–3	Tingling sensation
3–10	Muscle contraction and slight pain
10–40	Let-go threshold
40–75	Respiratory paralysis
100–200	Ventricular fibrillation
200–500	Heart clamp
1500+	Inflammation (burning)

Electricity makes life easier but may also lead to fire. Therefore, all electrical appliances, wires and cables and electric equipment must be handled cautiously. Electrical safety can be achieved by following some basic rules (Table 6.1).

Table 6.1: Electrical safety

Electrical safety is an important aspect that needs to be taken care of while working on an electrical system. Always follow the required safety standards while working with house wiring.	
Electrical house wiring needs undivided attention of people working with the electrical installation system. Do not work in a hurry. Make sure that the work is planned. Make a suitable stopping point. In case of an emergency, one can stop working at that defined stopping point.	
Shut down power to the circuit where work is going on. Use a phase tester and multimeter for testing the circuit in order to make sure that the power is off.	

Always keep a torch or flashlight near the electrical panel, in case of power shutdown.	
Always use wooden or bamboo ladders to carry out an electrical work. Wooden or bamboo ladders are non-conductors. Do not use an aluminium ladder.	
Never work in a wet or damp location. Do not work in rain as it may cause electric shock, and hence, dangerous.	
Always wear shoes having rubber sole, and never work barefoot or with only socks or slippers on. Concrete is conductive, particularly, when damp.	
After shutting off the line to the control panel, always put electrical 'danger' signboard in the panel before starting work. This will be a visual indication for a person approaching towards the panel and the person immediately becomes alert.	
Work with fuse panels instead of breaker panels. When removing a fuse, use only one hand to remove it. Put the other hand either in pocket or behind the back. The reason for doing so is that use of two hands provides a path for electricity to flow through the body.	
Electricity can still flow through one hand and one foot, and pass through the body. But if one follows the precautions as discussed in the Unit, one can minimise exposure to this hazard.	

Protecting oneself

Electricity is a form of energy and this energy cannot be seen with the naked eye. One must be aware of the risks, such as

1. electrocution, which defines electric shocks
2. inflammation, combustion or smoke and gas generation (Fig. 6.2).

Use insulation to prevent electrocution (electric shocks). One must not use spongy material, which can absorb water as water is a good conductor of electricity. The material chosen must be 'plastic', which is nearly waterproof.

Fig. 6.2 Inflammation while connecting a cord

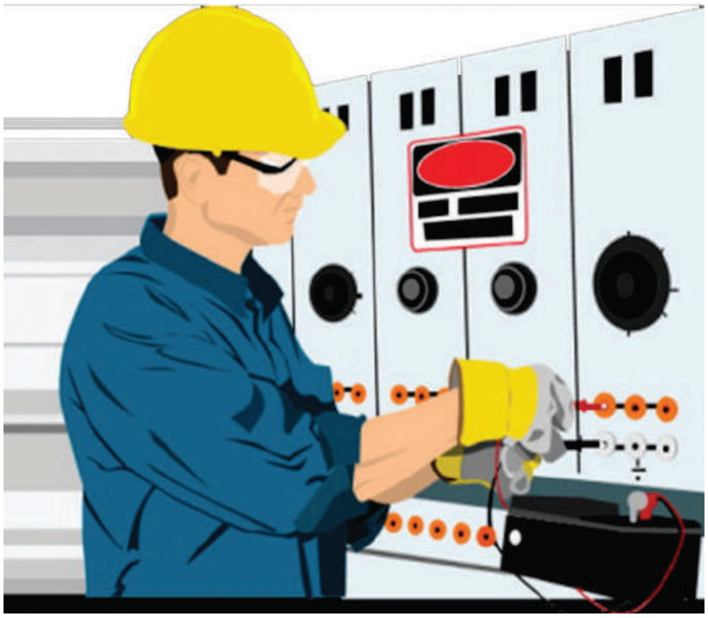


Fig. 6.3 Wireman testing a panel

Use a wire that helps prevent inflammation. Electric energy needs metal wire to transfer from one pole to another. This results in 'current'. This transfer of energy can sometimes heat up the wire, which may cause fire. The heat may cause the wire to become so hot that it

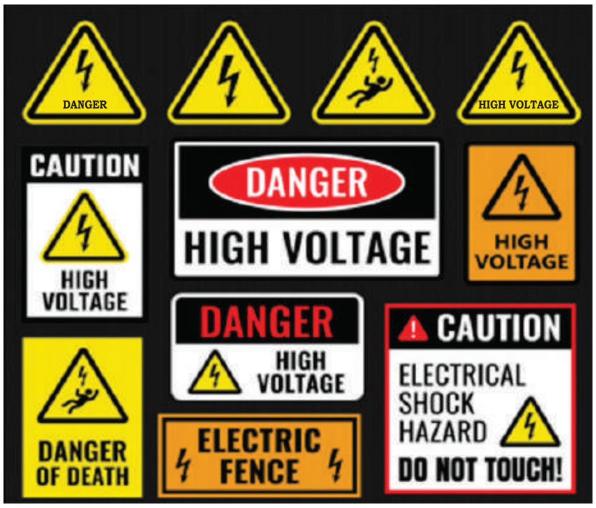


Fig. 6.4 Electrical warning signs

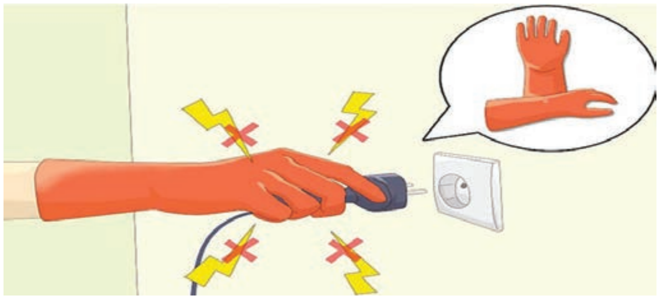


Fig. 6.5 Take precaution while plugging (wear rubber gloves)

may melt and burn anything around. Therefore, the insulation also starts melting. Melted insulation will produce smoke and poisonous gas (as shown in Fig. 6.6).

This heating problem can be eliminated by using the appropriate size of wire (Fig. 6.7).

Fig. 6.6 Melted wire produce smoke and poisonous gas

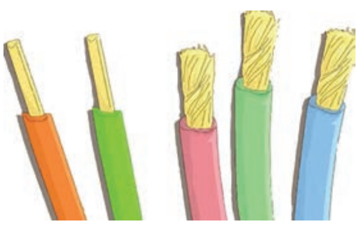


Fig. 6.7 Different size of wires

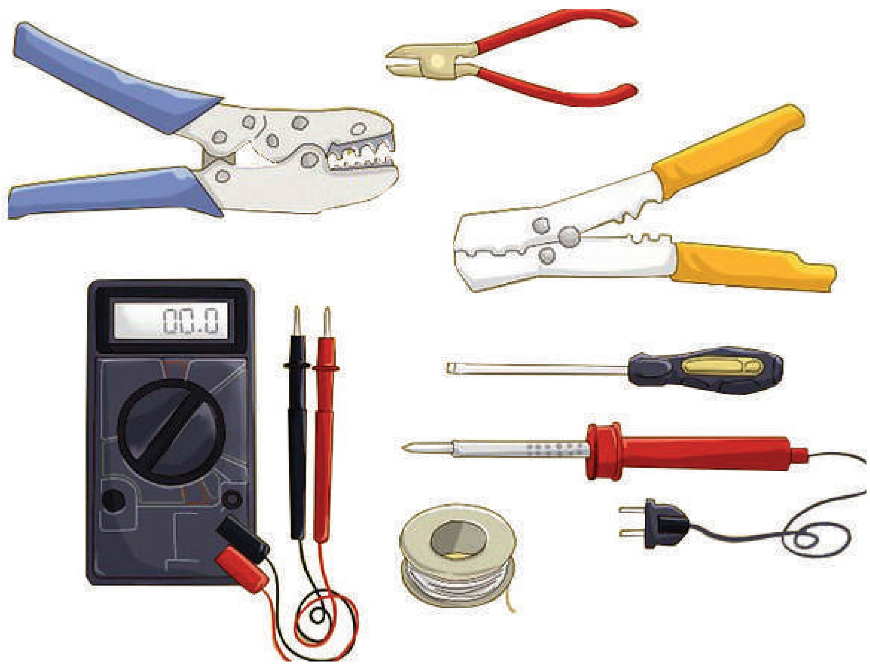


Fig. 6.8 Components found in a tool kit

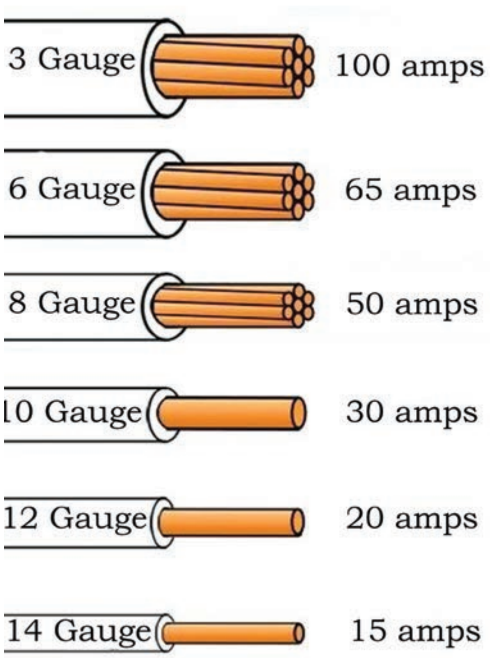


Fig. 6.9 Gauge and amperage of wire

Make sure to use the right tool(s). Always carry necessary tools in the utility box, such as wire cutter, wire stripper, fully insulated screwdrivers, multimeter and soldering station with solder (Fig. 6.8). Add one extra pair of probe wires with 2.5 mm² cross section and one long probe wire of 0.2 mm² cross section with a clamp additional to the multimeter probes, which come with the purchase. This will enable to measure the required value of the probe wires without fire hazard from the electric wires.

For choosing the right dimension of wire, one must consider the gauge and amperage of the wires as shown in Fig. 6.9. Selecting the appropriate dimension of wire is necessary to avoid burning of the insulation, short circuiting, etc.

Electrostatic discharge (ESD)

Electrostatic discharge refers to sudden build-up of static electricity when two differently charged objects are brought together. While manufacturing electronic products, electrostatic discharge is one of the issues that arises as it can cause damage to electronic devices and components. Fig. 6.10(a) represents some causes of ESD.

Fig. 6.10(b) represents some of the ESD prevention guidelines that must be followed to reduce the risk of electrostatic discharge damage to the electric components.

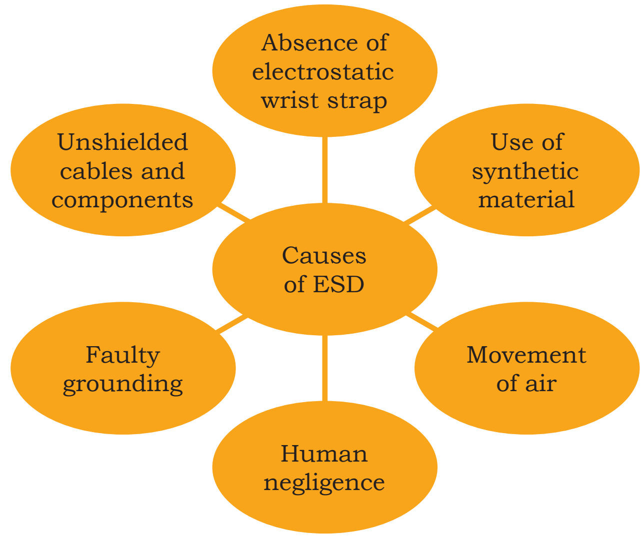


Fig. 6.10(a) Causes of ESD

Causes of ESD

- Faulty grounding
- Movement of charges takes place between the connecting points or printed circuit board
- Human negligence

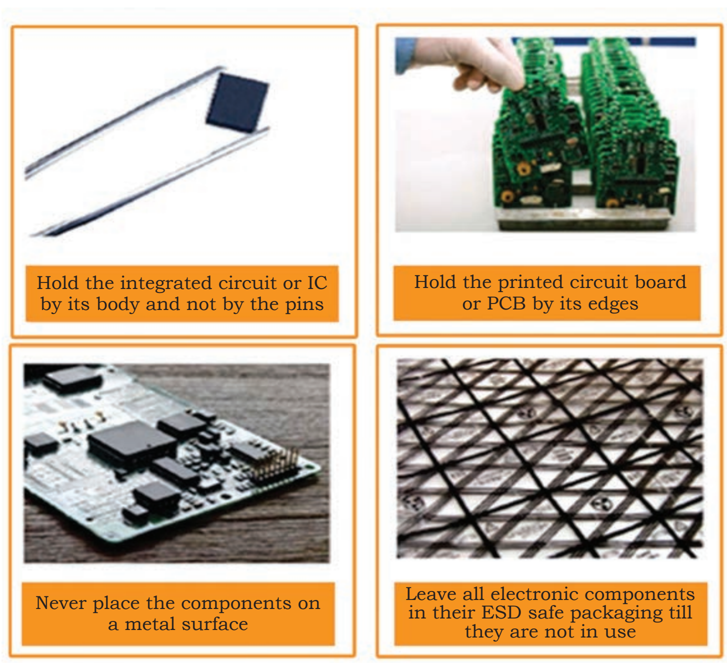


Fig. 6.10(b) ESD prevention guidelines

Electrical conductivity

An electric current results from the motion of electrically charged particles in response to forces that act on them from an applied electric field. In solid material, current arises due to the flow of electrons, which is called 'electronic conduction'. In all conductors, semiconductors and many insulated material, only electronic conduction exists and electrical conductivity is dependent on the number of electrons available to participate in the conduction process. Most metals are good conductors of electricity because of the presence of a large number of free electrons. In water and ionic material like $H_2\,SO_4$, Nacl, HCl, etc., a net motion of charged ions can occur. This phenomenon produces electric current and is called 'ionic conduction'.

> **Know more...**
>
> Pure water is distilled water. During distillation, all impurities and ions present in the water are removed. This type of water is not healthy, and hence, unfit for consumption.

Water conductivity

Pure water is not a good conductor of electricity. However, as electric current is transported via ions in the solution, its conductivity increases and the concentration of ions increases.

Electrical conductivity of water is its ability to conduct electric current. Salt or other chemicals like ammonia, hydroflouric acid, etc., that dissolve in water can break down into positively and negatively charged ions. These free ions mixed in water conduct electricity. So, the electrical conductivity of water depends on the concentration of ions. Salinity and total dissolved solids are used to calculate the electrical conductivity of water, which helps to indicate its purity. Higher the purity of water, lower is the conductivity. To give a real-life example, distilled water is almost an insulator, but saltwater is an efficient electrical conductor.

Fuse

A fuse is a short length of wire. It is designed to melt and separate from the circuit in an event of excessive current. Fuses are always connected in series with component(s) to be protected from over current. So, when a fuse blows (opens), it opens the entire circuit and stops the current through the component(s). A fuse connected in one branch of a parallel circuit will not affect current through any of the other branches.

Fig. 6.11 Circuit breaker in the form of fuse

Normally, a thin piece of fuse wire is contained within a safety sheath to minimise hazards in case of an arc blast. The fuse wire opens when electric current flows through it. Sheath is made of a transparent material so that the fusible element can be visually inspected. Residential wiring and glass fuse are commonly used.

Circuit breakers

Circuit breakers are, especially, designed switches. They automatically open to stop the current in case of over current. Small circuit breakers, such as those used in residential, commercial and small industrial areas are thermally operated. They contain a bimetallic strip. A bimetallic strip is a thin strip of two metals bonded back-to-back carrying circuit current, which bends when heated. When enough force is generated by the bimetallic strip due to over current heating of the strip, the trip mechanism operates and the breaker opens. Larger circuit breakers are automatically operated. They are operated by the strength of the magnetic field. This magnetic field is produced by current carrying conductors within the breaker. Relays can also be used for tripping the circuit breaker. As the circuit breaker is operated automatically by electrical circuit, it does not fail in case of over current. All fuses need to be replaced with miniature circuit breaker (MCB) for safety and control purposes. MCBs are used, primarily, as alternative to fuse in most circuits. A wide variety of MCBs with varied breaking capacity are available in market and used in all areas of domestic, commercial and industrial applications as a reliable means of protection.

Miniature circuit breaker (MCB)

Fig. 6.12 Miniature circuit breakers

It is an electromagnetic device that automatically operates or breaks a circuit, if current in the circuit reaches a predetermined amperage value. It is enclosed in an insulating material. The main function of an MCB is to switch the circuit OFF, i.e., to open the circuit (which has been connected to it) automatically. However, the MCB needs to be switched on manually. When the current passing through it (MCB) exceeds the value for which it is set, then the MCB will get tripped. It can be manually switched 'on' and 'off' similar to a normal switch. MCBs are popularly used for load break, protection and isolation of a sub-circuit, including motor sub-circuits, lighting circuits and control circuits. The main usage area of MCBs is in low-voltage sites, i.e., mainly in domestic, small industrial or commercial applications. These are manufactured in one, two, three and four pole versions of different current and voltage ratings. Similar to fuses, these are used for performing two major functions—over current and short circuit protection. MCBs can replace conventional wire fuse in a distribution board and are designed to operate accurately under both overloading and short circuit conditions. MCBs can be reset quickly by an operator. But in case of a fault, a wire fuse reclosing is not possible quickly. The tripping of an MCB can easily be identified under overload or short circuit condition as its operating knob moves from 'on' to 'off' position.

MCBs are rated up to 100 amperes. However, the trip current is, normally, not adjustable. It gives a better service for protection because it can operate 5–15 per cent excessive overloads.

Generally, MCBs are used for 230V AC for single phase, 440V AC for three phase or 220V for DC supply. An MCB rated at 10A current, operating on thermal magnetic trip, is the most common type used in modern domestic consumer units and commercial electrical distribution boards.

Construction of MCB

MCB designs are of single pole construction for use in single phase circuits. The complete system is housed within a plastic casing. MCBs are fitted with arc chute stack consisting of various arc chutes (metal plates), which are held in position by an insulating material. It is not necessary that arc chute stack always surrounds the contacts (bimetallic strip). Hence, in some designs, arc runners are provided to move the arc into the arc chutes.

The thermal tripping mechanism consists of a thermal-magnetic arrangement, where thermal action is provided by a bimetallic strip, and in some cases, by a heater. The tripping mechanism is activated by the deflection of the bimetallic strip. A low-resistance bimetal is used for a high current MCB and a higher resistance bimetal for a low current MCB. A heater may be incorporated around the bimetal to generate sufficient heat for low current MCBs. The magnetic tripping mechanism consists of a coil, which is wound around a tube. This tube has a spring-loaded slug and the slug movement operates the tripping mechanism. The magnetic field generated by the coil during high fault current overcomes the spring force holding the slug in position. So, the movement of slug actuates the tripping mechanism. The coil is made of a thin wire with many turns for low rating MCBs and a thicker wire with

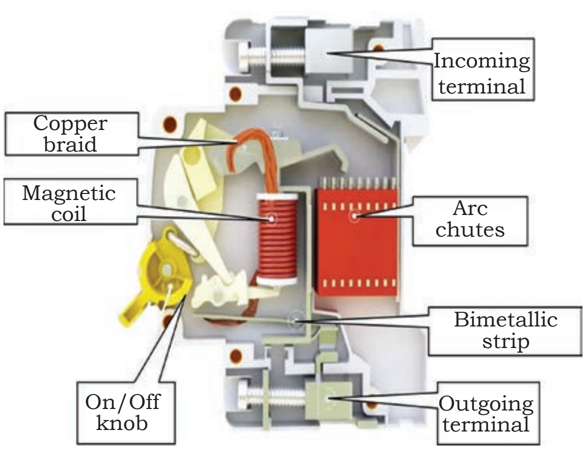


Fig. 6.13 Internal parts of an MCB

fewer turns for higher rating MCBs. Depending on the required characteristics, the magnetic tripping is set by the manufacturer.

Notes

Specification of MCB

Company logo

It defines the name of the manufacturing company.

Type number

It defines the type of MCB.

Current rating

It is the current value above which overload protection trips.

Rated voltage AC

It defines the maximum voltage, which can be applied across the terminals of the MCB.

Breaking capacity

It defines the maximum current, which an MCB can withstand without damage.

EN/IEC

It defines the international standard of an MCB.

Energy limiting class

It refers to an energy limiting class number (1, 2 or 3) marked on circuit breakers. It defines the thermal and mechanical stress during operation.

Pin number

It defines the number of MCB terminals.

Poles

It defines the numbers of poles of the MCB.

Pole interlock

It defines the interlocking of poles.

Thermal protection

It defines the thermal protection in the MCB. This protects the MCB or circuit from high thermal energy produced by current.

Magnetic protection

It defines magnetic protection in the MCB. This will protect the MCB or circuit from magnetic effects of current.

NOTES

Knob

It is used for turning the MCB 'on' or 'off'.

Label

It can be inserted in the holder fitted with a transparent cover. It helps to name multiple circuits on the distribution board.

True contact indication flag

It defines the MCB's indication of whether it is open or close. Red or green colour flag provides a clear visual indication of the contact status inside.

Earthing pit

Nowadays, earth pits are the preferred method for earthing, especially, for electrical works. Electricity always follows the path of least resistance. To divert maximum current away from a circuit, earthing pits are designed. The size of the pit plays a vital role in earthing. Earthing or grounding an electrical network is an essential safety measure, which can protect equipment from electrical faults and save human beings and animals from electric shocks.

Need for earthing electrical networks

Electrical networks are earthed for three main purposes, which are as follows.

1. An earthed circuit reduces the risk of death or injury by providing an alternative path for current to discharge into the ground. Equipment, appliances and property are protected against faults, leaks and fires resulting from short circuits and sparking.
2. Earthing also provides protection against power surges, accidental connection with high-voltage lines and even lightning strikes, allowing the energy to flow into the ground, with minimal effect.
3. Ground offers a common point of reference for calculating the relationship between different voltage sources. It has been used as a universal standard since the introduction of distribution system.

Practical Exercise

Notes

Practical Exercise 1

Demonstration of earthing

Material required

Tools for excavation, charcoal and salt, GI pipe, copper, GI wire

Procedure

1. An area of 1.5×1.5m is excavated to a depth of 3m.

Fig. 1 Making a pit for earthing

2. The pit is half filled with a mixture of charcoal and salt.
3. A $500 \times 500 \times 10$mm plate (earth plate) is placed in the centre of the pit.

Fig. 2 Copper plate set in the pit

4. Connections between the earth plate and surface are installed for system earthing. The rest of the pit is filled with charcoal, sand and salt mixture.

Fig. 3 Copper plate and surface are connected with a pipe

NOTES

5. To connect the earth plate to the surface, two GI strips with a cross section of 30×10mm can be used. Additionally, the top of the pipe can be covered with a T-section to prevent mud, sand and stones from clogging it. In summers, the pit must be watered to prevent it from drying out.

Fig. 4 Pit filled with mud, sand and stones

Check Your Progress

A. Multiple choice questions

1. Appliances of which class have no protective earth connection and feature only a single level of insulation between live parts and exposed metal work.
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
2. Sudden build-up of static electricity when two differently charged objects are brought together is called ________________.
   (a) electrostatic energy
   (b) electron motion
   (c) electrostatic discharge
   (d) electrostatic potential
3. Which tool is used for removing insulation from the wire?
   (a) Screwdriver
   (b) Pliers
   (c) Nose pliers
   (d) Stripper
4. ESD stands for ________________.
   (a) Electrostate display
   (b) Electrostatic display
   (c) Electrostatic discharge
   (d) Electrostate discharge

5. Double insulated or ________________ electrical appliance is one, which is designed in a way that does not require a safety connection into the earth (ground).
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
6. ____________ appliance is designed to be supplied from a separated or safety extra-low voltage power source.
   (a) Class 0
   (b) Class 1
   (c) Class 2
   (d) Class 3
7. Which of the following dimensions is used for copper plate in plate earthing?
   (a) 600 × 600 × 12mm
   (b) 600 × 600 × 6mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
8. Which of the following dimensions is used for galvanised iron plate in plate earthing?
   (a) 600 × 600 × 12mm
   (b) 600 × 600 × 6mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
9. Which of the following dimensions is used for cast iron plate in plate earthing?
   (a) 600 × 600 × 6mm
   (b) 600 × 600 × 12mm
   (c) 600 × 600 × 3.5mm
   (d) 600 × 600 × 15mm
10. What will be the impact on the conductivity of water if it gets purified?
   (a) Conductivity of water will increase
   (b) Conductivity of water will decrease
   (c) Conductivity of water will remain the same
   (d) Conductivity of water does not depend on purity

B. Fill in the blanks

1. Electricity always follows the least _____________ path.
2. Bimetallic strip is a part of ________________.
3. A miniature circuit breaker has two states, i.e., open and _______________.
4. Pure water is bad ______________ of electricity.
5. ESD stands for __________________.
6. Electrical safety at workplace reduces ____________.
7. Class 0 safety is used only in ____________ area.
8. One must follow the safety ____________ and tags on the control panel.

Notes

Notes

9. Current of 40–75 mA will cause ___________.
10. Heating problem can be eliminated by using the _______________ of wire.

C. State whether the following statements are True or False

1. A wireman should always follow the correct wiring diagram.
2. A wireman must follow the safety signs, stickers and tags on the control panel.
3. It is not necessary to read labels and instructions given on the components.
4. A wireman wears appropriate clothing and removes all metal objects before working.
5. One must use only the prescribed protective safety equipment.
6. Always follow the safety rules when working with electrical machinery or equipment.
7. Electrostatic discharge can cause damage to the electronic devices and components.
8. When removing a fuse, use only one hand.
9. After shutting off a line, always put danger signboards in panels before starting a work.
10. Distilled water is a good conductor of electricity.

D. Short answer questions

1. What can be the causes of electrostatic discharge?
2. What is electrocution?
3. List the tools required for carrying out electrical work.
4. What will be the hand position of a wireman while working with a fuse panel?
5. What testing can be performed for confirming that power of a device is off?
6. Which ladders are used at workplace?
7. What are the general guidelines that a wireman needs to follow at the workplace?

Unit 7

Tools and Equipment

Introduction

An ammeter measures current, a voltmeter measures the potential difference (voltage) between two points and an ohmmeter measures resistance. A multimeter combines these functions and possibly some additional ones as well into a single equipment. Various tools and equipment, such as screwdriver, phase tester, stripper and pliers are used to carry out electrical panel installation. In this Unit, students will learn about these tools and equipment.

Multimeter

Multimeters are test instruments. By operating a multi-position switch on a multimeter, it can be easily set to be a voltmeter, an ammeter or ohmmeter. A multimeter has several settings (called ranges) for each type of meter and the choice of AC or DC. Some multimeters have additional features, such as transistor testing, and ranges for measuring capacitance and frequency. Multimeters are available in digital and analogue types.

Fig. 7.1 Digital multimeter

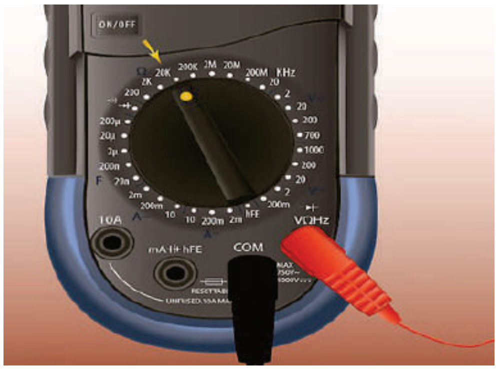


Fig. 7.2 Twisting the selector knob

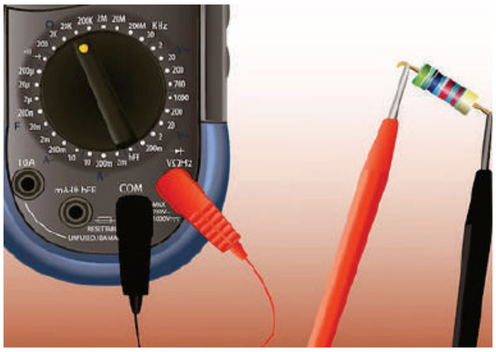


Fig. 7.3 Touching the tips of the probes

Fig. 7.4 Multimeter reading

Measuring resistance using digital multimeter

A digital multimeter has two probes. Resistance can be measured using these probes.

- Insert the black probe into the common terminal and the red probe into the terminal marked for measuring Volt and Ohm. The terminal may also be marked for testing diodes.
- Twist the selector knob to set the multimeter to measure resistance. This may be represented by the Greek letter Omega (Ω), which stands for Ohm, the unit of measurement for resistance.
- Touch the tips of the probes to each side of the resistor.
- Read the display and carefully take note of the units. A reading of 10 may indicate 10 Ohm, 10 kilo-Ohm or 10 mega-Ohm.

Measuring AC and DC voltage using digital multimeter

- Resistance can be measured using the two digital multimeter probes. Put the black probe in the common terminal and the red probe in the terminal marked for measuring Volt and Ohm.
- Set the multimeter for voltage to be measured. You can measure volts DC (direct current), millivolts DC or volts AC (alternating current). If the multimeter has an auto-range function, it is not necessary to select the voltage you are measuring.
- Measure AC voltage by placing the probes across the component. In case of AC, it is not necessary to observe the polarity.
- Observe the polarity when measuring DC voltage or millivoltage. Place the black probe on the negative side of the DC

source and the red probe on the positive side of the DC source.

- Read the display, carefully to note the units. You can also use the touch-hold feature to keep the reading on display after removing the probes. The multimeter will beep each time a new voltage is detected.

Fig. 7.5 Digital multimeter probes

Measuring AC and DC current using multimeter

- Choose either the terminal marked for measuring 10 amps or the one marked for measuring 300 milliamps (mA). If not sure of the current, start in the 10 amp terminal until confident that the current is less than 300 milliamps.
- Set the multimeter to measure current. This may be represented by the letter 'A'.
- Turn off power to the circuit.
- Break the circuit. To measure current, you must place the multimeter in series with the circuit. Place the probes on either side of the break, observing polarity, such as black probe on the negative side and red on the positive.
- Turn the power on. The current will run through the circuit up the red probe and through the multimeter, then out of the black probe and into the circuit.

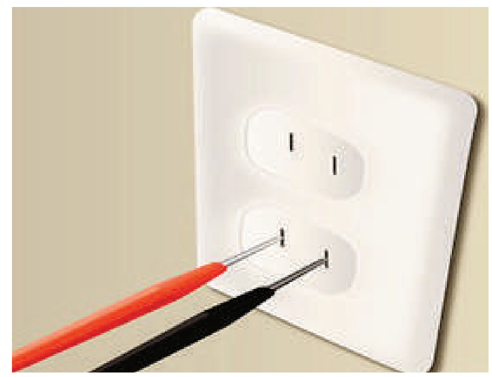


Fig. 7.6 AC voltage measurement

Fig. 7.7 DC Voltage measurement

Fig. 7.8 AC voltage value

Fig. 7.9 Probes of multimeter connected to current measurement slot

Fig. 7.10 Switch on the selector knob to measure current

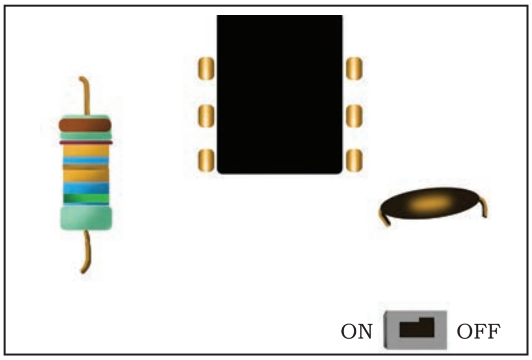


Fig. 7.11 Turn off the current using switch

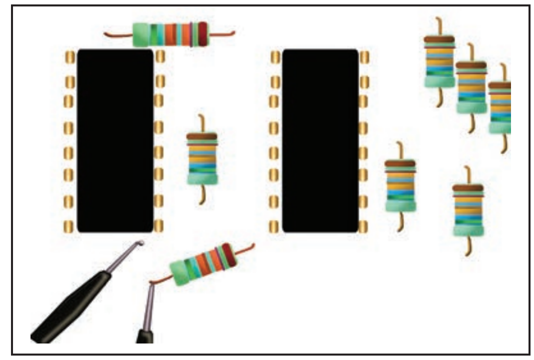


Fig. 7.12 Place the multimeter probe terminals to current measuring point

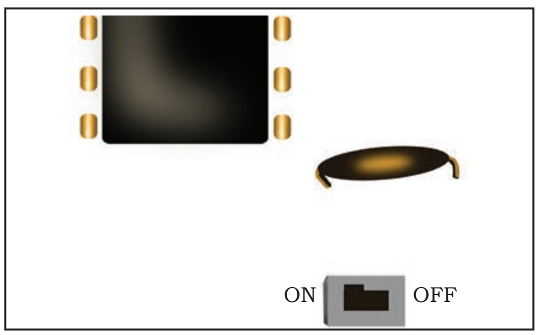


Fig. 7.13 Turn on the circuit using switch

Fig. 7.14 Current value on multimeter display

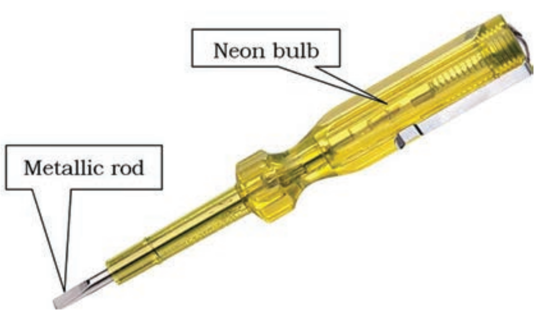


Fig. 7.15 Phase tester

- Read the display. Remember whether you are measuring amps or milliamps. You can use the touch-hold feature, if required.

Line or phase tester

Phase or line tester is used to identify or test the phase of a socket. Line tester is also called 'neon screwdriver' or 'test pin'.

Construction of phase or line tester

The following are the main parts of a typical phase or line tester.

Metallic rod and mouth

It is a cylindrical metal rod. The flat end (mouth) is used as a screwdriver or touch electrical conductor or wire to find phase or live wires, and the other end is connected to resistance, neon bulb, element and metallic cap screw.

Body and insulation

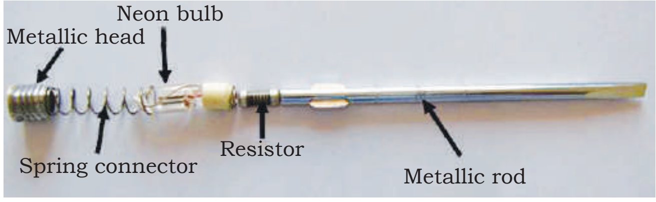


Fig. 7.16 Parts of a phase tester

Components, such as resistance, neon bulb, element or metallic spring and metallic cap screw are covered in a transparent insulated body made of plastic. The flat end of the cylindrical metal rod is also covered with transparent insulated plastic for insulation purpose, except the mouth.

Resistor

It is an element, which opposes the flow of current through a phase tester. In the phase or line tester, the resistor is connected between the cylindrical metal rod and neon bulb. This resistor controls the current passing through the neon bulb. Without a resistor, high current may damage the neon bulb. Moreover, it would not be safe to use the phase tester without a resistor.

Neon bulb

Neon bulb is connected between the resistor and metallic spring. It is used as a phase indicator bulb. When a small current flows through it, it glows. Due to the presence of the neon bulb, a phase or line tester is also called a neon screwdriver.

Element (metallic spring)

It is used to make connection between the neon bulb and metallic cap screw.

Metallic cap screw and clip

The screw is used for tightening all components in the phase tester. The screw is connected to the spring (element) and the spring (element) to the neon bulb. The metallic clip is used for holding the phase tester in pocket.

Screwdriver

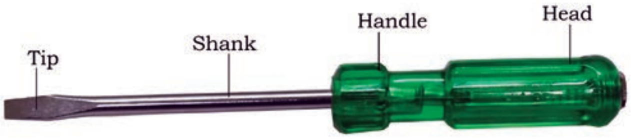


Fig. 7.17 Screwdriver

A screwdriver is the basic tool used in electrical panel installation. It is manual or powered, and is used for inserting and removing screws. A screwdriver has a handle and a shaft. A user puts the end tip of the screwdriver into the screw before turning the handle. The shaft is, usually, made of tough steel. It is used to resist bending or twisting. The tip may be hardened to resist wear. Handles are made of wood, metal or plastic. The handle is, usually, hexagonal, square or oval in cross section to improve the grip. This is helpful when twisting the screwdriver and also helps prevent the tool from rolling on the head of the screw. Some manual screwdrivers have interchangeable tips that fit into a socket at the end of the shaft and are held mechanically or magnetically. These often have a hollow handle that contain different types and sizes of tips.

Fig. 7.18 Clamp meter

Clamp meter

It is a tool for measuring current in a wire. As compared to the multimeter, a clamp meter does not need to be connected to a circuit in order to read the current. It does not require breaking the circuit to measure current. The clamp on the device is placed around a live wire. This allows one to measure the current in the wire without interrupting the operation of the electrical appliance. The clamp meter uses digital technology to bring instantaneous readings.

Steps for measuring AC or DC current using clamp meter jaws

Choose an electrical conductor

The clamp meter can measure the current on a load without disconnecting the electrical conductor from the circuit. To get a reading, the electrical wire needs to be connected to an operational electrical appliance.

Choose appropriate function and range

Set the rotary switch on the clamp meter to appropriate function and range. Measuring current that is higher than that specified in the range can damage the device. If not sure about the range of the current to be measured, choose a high range clamp meter.

Clamp the conductor

Push the trigger on the device to open the jaw. Clamp the device around the conductor and close it. If the electrical conductor is not yet connected to a power source, connect it. Note the reading on the display of the clamp meter.

Use an AC line separator

When measuring AC current, the device may give false reading. Current in hot and neutral wire cancel each other, which causes the device to display nothing on the LCD screen. To correct the problem, connect the AC line separator between the electrical conductors, i.e., phase and neutral.

Measure voltage

Set the clamp meter to the voltage symbol 'V' to read the voltage on the conductor. Plug the probes to the meter as well. Connect the black probe to the common jack and the red to the voltage omega jack. Select the appropriate range of voltage. Remember that voltages above the maximum range on the clamp meter are not measured. Touch the tips of the probes with the electric conductor to get a voltage reading. Read the voltage on the LCD screen. The clamp meter will help save time during an electrical repair work, increase efficiency in carrying out wiring projects and protect a person or wireman from accidents.

Plier and wire stripper

A combination plier, as the name suggests, performs various operations. It enables to perform a combination of operations, i.e., cutting and gripping. Some combination pliers have other additions, especially, if they are designed for use in particular industries or for specific tasks.

Fig. 7.19 Combination plier

Handles

The handles of combination pliers, usually, have a plastic coating, for comfort and grip. The size and length of the handles depend on the size of the pliers. Pliers

Fig. 7.20 Chuck key

Fig. 7.21 Turn the chuck key counter clockwise

Fig. 7.22 Slide the drill bit out

Fig. 7.23 Insert new drill bit

designed for use by electricians and linemen have insulated handles.

Jaws

The jaws of the combination plier opens and closes along with the handles. They have flat edges for general gripping, which are often serrated for extra grip. Sometimes, they are smooth but they, usually, have squared tips.

Cutter

The cutters built into the jaws of the combination plier are, usually, designed to cut cables and wires.

Pipe grip

The pipe grip is a rounded cutout in the jaws of the plier. It is, primarily, used for gripping rounded stock like pipes and cables.

Pivot point

It is a kind of hinge that allows the handles and tips to open and close so that the jaws can grip or cut, and then, be opened again.

Drill bits

Drill bits are cutting tools used to make holes. These are used in circular motion. They come in many sizes and shapes. Different size of holes can be made by using different size of bits. In order to make holes, drill bits are, usually, attached to a drill machine, which powers them to cut through a work piece, typically, by rotation.

One must insert the chuck key. If a drill is with a chuck key, one needs to use it in order to loosen the chuck. To insert the chuck key, one must line up the teeth so that they match the teeth on the chuck and insert the tip into one of the holes on the side of the chuck. Then, the person must turn the chuck key counter clockwise (Fig. 7.21). As the key is turned, the jaws on the chuck will begin to open. One must continue turning until the chuck opens enough to easily slide the drill bit out. The jaws are the three or four pieces in the mouth of the chuck that extend to hold the bit in place.

Now, the person needs to remove the bit. Once the chuck is loosened, the person must pull the bit out using the thumb and index finger. If the chuck is opened wide and the drill is turned downwards, it may fall out.

Now, inspect the bit for damage. If the bit is dull, it must be replaced. If it is bent or shows signs of cracking, it must be thrown away.

One must insert a new bit. While the jaw on the chuck is wide open, the new bit must be inserted. Hold the bit with the thumb and index finger so that the smooth part of the bit (shank) faces the jaws of the chuck and insert it.

Keep the fingers on the bit and the chuck as the bit is not secure and may fall.

Fig. 7.24 Soldering kit

Soldering

Soldering is the process of melting a metal onto other metal components in order to bind them. Soldering differs from welding. In welding, the component pieces are melted together, whereas, in soldering, a softer metal with a lower melting point is used to connect them. Since soldering does not melt components, it is useful for delicate applications, such as electronics work or plumbing. The purpose of soldering is to bind two components together. Solder can be thought of as a sort of 'metal glue'. It can be used to fill in the gaps or hold the pieces in place but does not serve any other complicated purpose. Since solder is metallic, it conducts electricity. That is why, it is commonly used for connecting electronic components.

Megger meter

Insulation resistance (IR) quality of an electrical system degrades with time and environment conditions, i.e., temperature, humidity, moisture and dust particles. It also gets impacted negatively due to the presence of electrical and mechanical stress. So, it becomes necessary to check the IR of the equipment at regular intervals to avoid incidences of electrical shock. A megger meter is used as a measuring equipment for insulation resistance tester.

Uses of megger meter

This device is used to measure electrical leakage in a wire. The results are reliable as electric current passes through the device while testing goes on. The equipment is used for verifying the electrical insulation level of devices, such as motors, cables, generators, windings, etc. This test need not show us the exact area of electrical puncture but shows the amount of current leakage and moisture level within the electrical equipment or winding or system.

Fig. 7.25 Electronic megger meter

Types of megger meter

There are mainly two types of megger meter.

- Electronic megger meter (battery operated)
- Manual megger meter (hand operated)

But there is another of megger meter, which is motor operated and does not use battery to produce voltage. It requires an external source to rotate an electrical motor, which in turn, rotates the generator of the megger.

Electronic megger meter

The important parts of an electronic megger meter are as follows.

Digital display

It shows the IR value in digital form.

Wire lead

It connects the megger with the electrical external system to be tested.

Selection switch

It is used to select electrical parameters ranges.

Indicators

It is used to indicate various parameters status, i.e., ON or OFF. For example, power, hold, warning, etc.

Manual megger meter

The important parts of a manual megger meter are as follows.

Analog display

It is provided on the face of the tester for IR value recording.

Hand crank

It is used to generate voltage, which runs through electrical systems through desired RPM (rotation per minute).

Wire leads

These are used for connecting the tester with the electrical system as in an electronic megger meter.

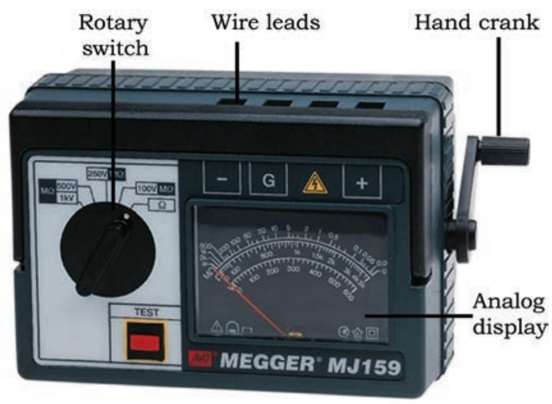


Fig. 7.26 Manual megger meter

Fig. 7.27 Wire lugs

Wire lugs

These are connecting terminals used to connect the conductor wire to a circuit. Wire lugs are a class of electrical connector, which are used to transfer electrical current from a power or grounding source to a user. After which terminals are terminated by using crimping or soldering technique.

Wire stripper

A wire stripper is often considered an important tool for electricians and other related personnel.

It is a portable handheld tool, especially, used by electricians for removing the protective coating of

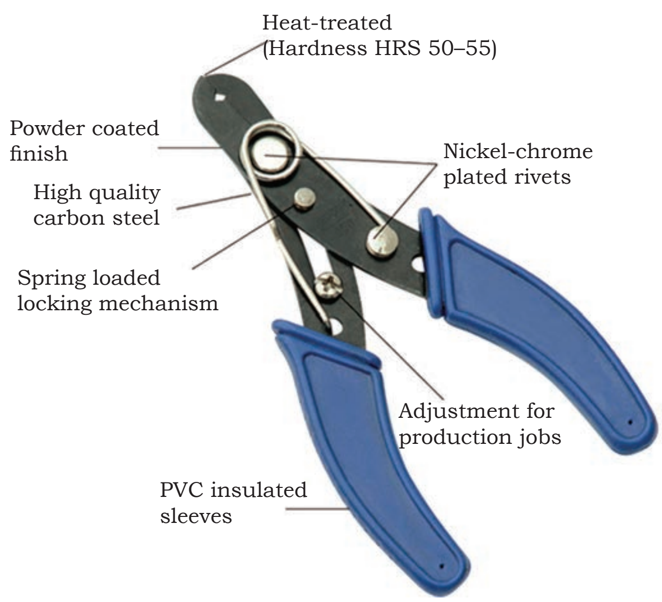


Fig. 7.28 Wire stripper

an electric wire in order to replace or repair it. It also enables stripping the end portions of the wire in order to connect them to other wires or terminals.

Wire strippers can be categorised into two types — manual and automatic. A manual wire stripper is considered the most versatile. To use it, the user needs to manually rotate it while applying pressure around the insulation in order to cut or adjust the wires. In case of an automatic wire stripper, one side is held tight, and simultaneously, the other side is cut and removed. An automatic wire stripper can help even a novice cut and strip most wires quickly. However, it only works for certain size range of wires. It can break small wires. Large wires may not fit into its jaws.

Wire strippers are available in various shapes and sizes and are, usually, made of steel. They, usually, have serrated teeth, which are useful in stripping the wires. The handles can be either straight or curved, and in most cases, are covered with rubber coating to provide a secure grip. Wire strippers often have a wire cutter as well.

Wrench

Also called 'spanner', it is used for rotating soft iron pipes and fittings with a rounded surface. The design of the wrench's adjustable jaws allows it to lock in the frame, such that any forward pressure on the handle tends to pull the jaws tighter together. Teeth angled in the direction of turn dig into the soft pipe. They are not intended for use on hardened steel hex nuts or other fittings because they may damage the head of the hex nuts. However, if a hex nut is soft enough that it becomes rounded beyond use with standard wrenches, a pipe wrench is sometimes used to break the bolt or nut free. Pipe wrenches are classified by the length of the handle. They can be available in any size from as small as 3 inches up to 48 inches or even bigger. They are, usually, made of cast steel. Aluminium is also used to construct the body of the wrench, while the teeth and jaw are of steel. Teeth

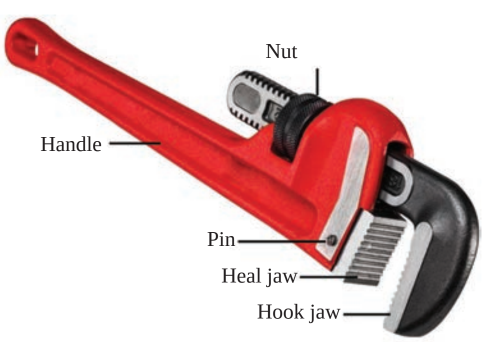


Fig. 7.29 Pipe wrench

and jaw kits, which also contain adjustment rings and springs can be bought to repair broken wrenches as it is cheaper than buying a new wrench.

Hammer

It is a tool, consisting of a metal piece with a flat end that is fixed onto the end of a long, thin, usually, wooden handle used for hitting things, shaping metal sheets, etc.

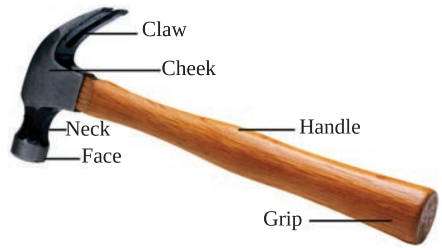


Fig. 7.30 Hammer

Ladder

A ladder is a vertical or inclined set of steps. There are two types of ladder. Rigid ladders are self-supporting or may be leaned against a vertical surface, such as a wall, whereas, rollable ladders like those made of rope or aluminium that may be hung from the top. The vertical members of a rigid ladder are called 'stringers' or 'rails'. Rigid ladders are, usually, portable, but some types are permanently fixed on to a structure, building or equipment. They are commonly made of metal, wood, fiberglass or plastic.

Fig. 7.31 Ladder

Check Your Progress

A. Multiple choice questions

1. Which of the following quantities can be measured using a multimeter?
   (a) Voltage
   (b) Current
   (c) Resistance
   (d) All of the above
2. Which of the following tools is used for shaping a metal into a sheet?
   (e) Hammer
   (a) Screwdriver
   (b) Stripper
   (c) Wrench

NOTES

3. Pipe wrenches are available in sizes from ___________ to ___________ inches.
   (a) 1, 50
   (b) 3, 48
   (c) 4, 58
   (d) 1, 45
4. Wire stripper is categorised as _______________ and _______________
   (a) vertical, horizontal
   (b) straight, aligned
   (c) manual, automatic
   (d) fix, movable
5. Which of the following is used as a wire connector?
   (a) Lug
   (b) Screwdriver
   (c) Stripper
   (d) Hammer
6. Which of the following meter is used for insulation resistance testing?
   (a) Ammeter
   (b) Voltmeter
   (c) Wattmeter
   (d) Megger meter
7. Which of the following equipment is used to measure AC voltage?
   (a) Tachometer
   (b) Multimeter
   (c) Ammeter
   (d) Megger meter
8. Which of the following meters is used to measure insulation resistance?
   (a) Tachometer
   (b) Multimeter
   (c) Ammeter
   (d) Megger meter
9. Which of the following tools is used for turning soft iron pipes and fittings with a rounded surface?
   (a) Wrench
   (b) Plier
   (c) Wire stripper
   (d) Screwdriver
10. Which of the following tools is used for the removing the insulation of a wire?
   (a) Plier
   (b) Wrench
   (c) Wire stripper
   (d) Hammer

B. Fill in the blanks

1. Combination plier is used for ________________ and ________________.
2. Pipe wrenches are available in size from _____________ to ________________ inches.
3. The process of melting a metal onto other metal components in order to bind them together is called ________________.
4. Megger meter is classified as ________________ and ________________.
5. Soldering is also known as ________________.
6. Ladder is classified as ____________________ and ________________.
7. In line tester, ________________ bulb is used for the indication of live wire.
8. In drilling practice, ________________ is used for making a hole in the wall or wood.
9. A multimeter is used for the measuring of resistance, voltage and ________________.

C. State whether the following statements are True or False

1. Soldering is known as metal glue.
2. A clamp meter is used to measure current flowing inside an electric wire.
3. A multimeter is used for the testing of diode.
4. A combination plier is used for stripping insulation in a wire.
5. A line tester is used for testing diode.
6. A multimeter can measure AC and DC voltage.
7. Lugs are used as wire connectors.

D. Short answer questions

1. Write short notes on the following.
   (a) Screwdriver
   (b) Megger meter
   (c) Multimeter
   (d) Combination plier
   (e) Line tester

NOTES

Unit 8

Electromechanical Assembly

Introduction

Electromechanical assembly converts electrical signals to mechanical movements and vice versa as shown in Fig. 8.1. Electromechanical devices perform electrical operations by movement of different parts. An electromechanical assembly includes electrical and mechanical components. They also involve mechanical and electrical process. A manually operated switch is an electromechanical component, which causes an electrical output due to mechanical movement. Electromechanical assembly is a term, usually, used to refer to devices that involve an electrical signal to create mechanical movement or vice versa. Electromechanical assembly follows electromagnetic principles. For example, in relays, voltage can be controlled by switching the contact using electromagnetic force.

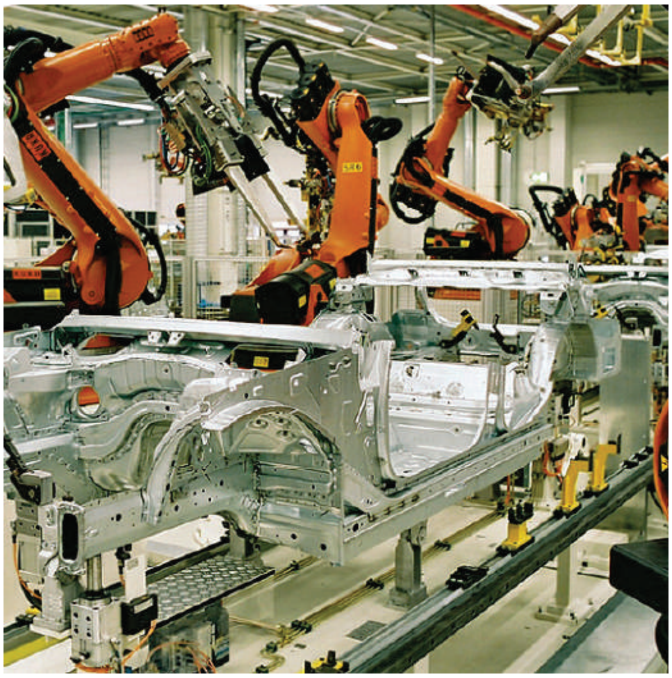


Fig. 8.1 Assembly line in the automobile industry uses electromechanical assembly

Fig. 8.2 Assembly line uses robotic arm for manufacturing unit

Electromechanical system

The term electromechanical indicates conversion of an electrical signal to mechanical movements and vice versa.

Electromechanical systems engineering focusses on things that make electrical and mechanical systems work together. Here, comes the concept of electromechanical assembly, which combines both electrical and mechanical components, and sometimes, electronic components as well.

Electromechanical systems engineers work on ways to make electricity work well with machines. Common electromechanical components, such as electric motors and solenoids are used in combination with mechanical parts to provide actuation or movement. An actuator is a device that converts an electrical signal to mechanical actions. It can create a force to manipulate itself, other mechanical devices or the surrounding environment to perform useful functions.

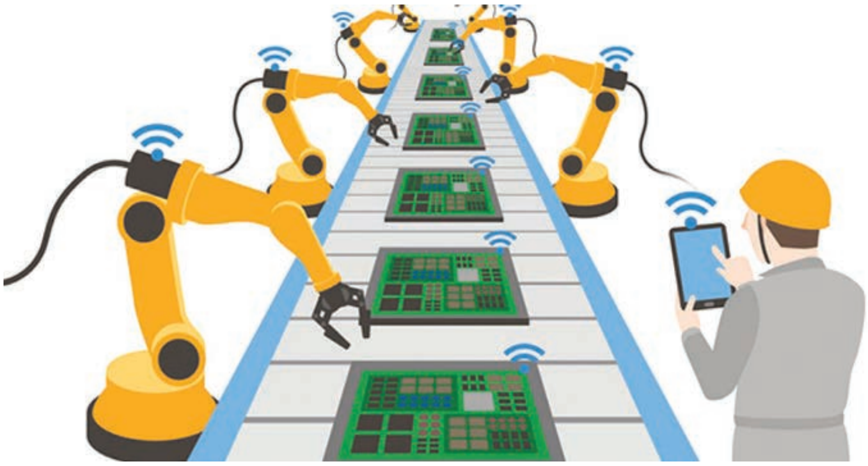


Fig. 8.3 Industrial electromechanical assembly

Fig. 8.4 Electrical control panel cabinet

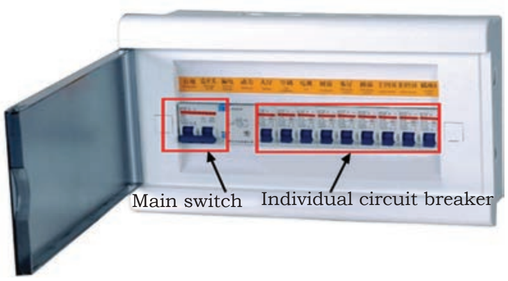
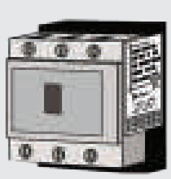


Fig. 8.5 Distribution box

Electromechanical devices or systems, such as electric typewriters and clocks are extensively used in complicated systems, Figs. 8.3 and 8.4 represent an assembly of industrial equipment and an electrical control panel cabinet. Some of the devices and appliances that use electromechanical system are motor vehicles, lifts, cranes, escalators, etc.

Know more...

A control relay is the simplest electrical control device. It has a coil that can be energised (logical 1) and de-energised (logical 0) by voltage (120V, 24V DC) and contacts that change logic state based on its coil (logic input) state. Control relays are used to turn other devices like contactors, pilot lights, etc., on and off.



Assignment 1

- From your daily life, give three examples of appliances that use electromechanical system.

Electromechanical assembly

Electromechanical assemblies provide a customised solution for doing a specific job and having the required output. For example, distribution board of electricity supply (Fig. 8.5) is an electromechanical assembly that contains cables and electromechanical components, such as circuit breakers, fuses, switches, and so on. Some of the common components used in electromechanical assembly are as follows.

- Switch-sensor assembly
- Power supply assembly
- Panel assembly
- Transformer assembly
- Indicator assembly

Components of an electromechanical assembly

Components of an electromechanical assembly are relay, switch, contactor, motor, generator, transformer, PLC, diode, resistor, capacitor, transistor, and so on. Few components, such as circuit boards, control box, relays, switches, enclosures, gauges, and so on, are to be assembled together to make an electromechanical device.

Motor as shown in Fig. 8.6 and Miniature Circuit Breaker (MCB) as shown in Fig. 8.7 are also examples of electromechanical assembly.

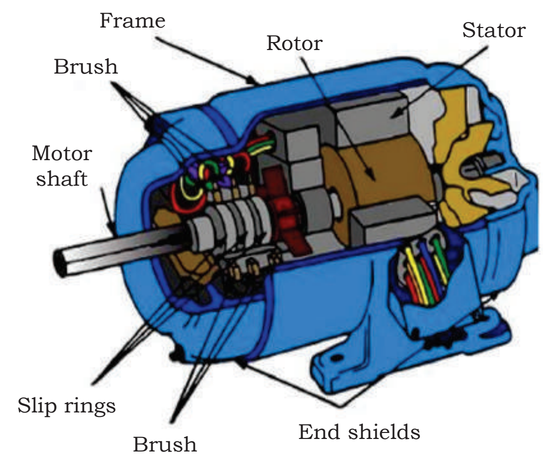


Fig. 8.6 Motor as an electromechanical assembly

Types of assembly

Cabinet assembly

Cabinet assemblies are used in food, pharmaceutical, wastewater treatment and mining industries. Control cabinets provide a compact design for a large number of functions as shown in Fig. 8.9. These serve as decentralised cabinets with all the required components at a specific station to provide identical solutions for identical processes. The control panel as shown in Fig. 8.8 shows an example of cabinet assembly.

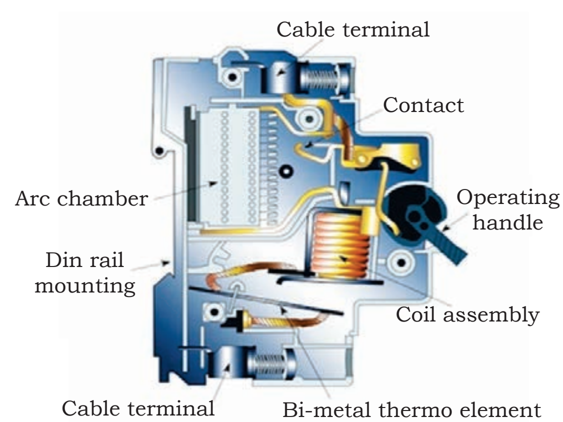


Fig. 8.7 MCB as an electromechanical assembly

Fig. 8.8 Switch gear cabinet in control panel

Fig. 8.9 Control cabinet in control panel

Fig.8.10 Motor control centre in control panel

Bucket assembly

Bucket assemblies are, generally, used for motor control centres (MCC), lever cylinders, and so on. The components of MCC bucket assembly are soft starters, frequency drives, video servers, motor control units, and so on. Figs. 8.10 and 8.11 represent MCC bucket assembly and its internal unit.

Fig. 8.11 MCC bucket centre assembly in control panel

Door or shelf assembly

It consists of one or multiple doors to assemble the components. Figs. 8.12 and 8.13 represent door panels.

Cable assembly

In a cable assembly, wires and cables are grouped together to work as a single unit. The number of cables in an assembly depends on the process of wiring. Colour coded wiring is used to locate problems or faulty wires in the cables. Fig. 8.14 represents a cable assembly.

Fig. 8.12 One-door control panel

Fig. 8.13 Multi-door control panel

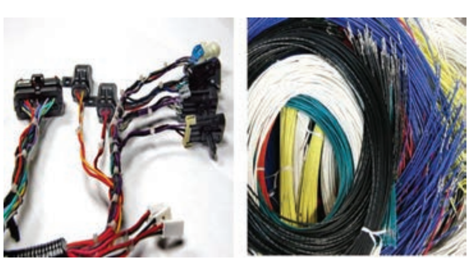


Fig. 8.14 Cable assembly

Wiring instructions and guidelines for assemblies

There are various types of wiring method that can be used for an industrial control panel assembly. The objective is to have a logically arranged panel assembly that is easy to maintain. Following are some of the best practices that can be followed at the time of control panel assembly wiring.

1. The wires that are used must be of adequate amperage capacity and stranded.
2. Use screws or bolts and not adhesive for anchoring a hinge and wrap the wires running over the hinges.
3. Use the least number of cables or wire ties while wiring, except if it is a temporary one (as shown in Fig. 8.15).

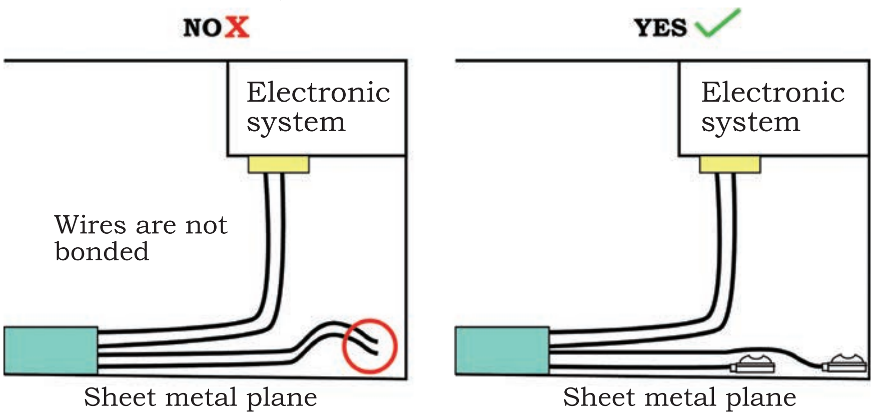


Fig. 8.15 Metal sheet

4. Avoid looping of wires unless needed.
5. Measure the length needed for the wire before cutting it.
6. Always bond the ends of the free conductors.
7. Keep the wire labels in the same direction.
8. Strip the insulation of wires to make joints and connections.
9. Bend and form the bend of a delicate wire gradually.
10. While working with shielded twisted pair cable, strip some amount of the jacket to ensure that every conductor can be accessed for removal and testing.
11. Wires must exit from the terminal without bending.
12. Mount the electrical enclosures cautiously.
13. Eliminate electrostatic discharge by applying appropriate procedure and taking precautions.

Notes

14. Considerations for a panel layout are as follows.
    (a) Put Programmable Logic Controller (PLC) input/output (I/O) racks in specified space of the wiring duct so that high-density wires can be easily connected to them. Make sure to route all wires to keep various voltages separated.
    (b) Keep some space between the device and wireways or any other obstruction.
        - Minimum 2 inches for 220V AC and less
        - Minimum 4 inches for 440 Volts

Working with panel assembly


Fig. 8.16(a) Correct raceway (routing) of cable

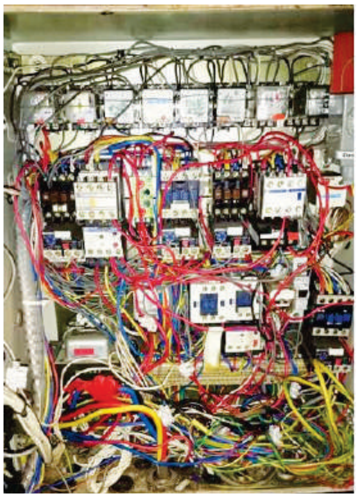


Fig. 8.16(b) Incorrect raceway (routing) of cable

The process of panel assembly includes setting up of side panels, integrating the required components and sub-assemblies on a board, wiring them, putting the board with components in the panel and setting up the wiring according to the wiring diagram. Following points have to be remembered during the panel assembly process.

1. Shielded cables must be used for low-powered signals to ensure less interference.
2. Panels that are conductive in nature, such as steel, must be used. It offers protection against electromagnetic radiation.
3. Use specified connectors and devices to secure the components should be used.
4. Different raceways for different types of cable must be used and precautions be taken while using high and low power devices in the panel to avoid malfunction. Fig. 8.16 (a and b) show correct and incorrect raceways of cables.
    - Prepare the components and enclosures required for assembly operations.
    - Devices, such as frequency converter and variable speed drive, have low radiation within the panel. If they are encapsulated in a metal enclosure, it must be connected to the back side panel, i.e., earthing plane.

- Ensure that the components are not damaged and are free from foreign objects. Dirty cables affect the performance of an appliance, device or equipment adversely.
- Ensure that the tools and equipment are in usable and safe condition and are within the calibration date.
- Do not make loops with cables and wires inside the panels, if not needed. Current flowing through them may create inductive winding. Current identical to the original one will pass through the electrical equipment in the loop. If winding is formed by a power cable, there will be significant amount of energy loss.
- Fig. 8.18 (b) represents the correct way of wiring. Mark the sides of the panels. Do soldering and drilling for attaching the board and components, and for cabling.
- Cut the control wires to the required length, strip the cable insulation, add markers to the wires for easy identification and add ferrules at the ends of the wires.
- Knowledge of approved techniques for mounting electrical components in the panel board and using them safely is required.

Fig. 8.17 Another way of cabling and wiring

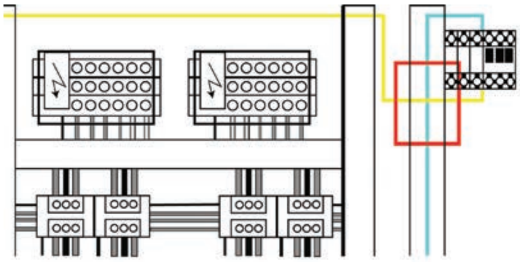


Fig. 8.18(a) Loop of wires

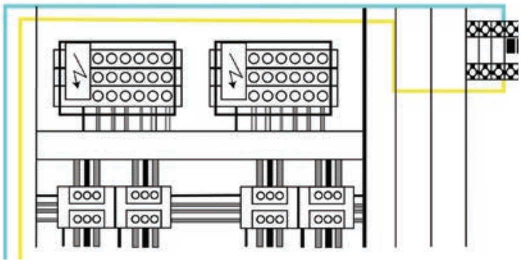


Fig. 8.18(b) Correct way of wiring

- If you use controls, make adjustments or try any procedure other than the specified ones as it may cause an injury. Assemble the components as indicated in the guide. In case of doubt, consult a qualified person.

Note: Ferrule is a cap, usually, made of metal. It is used to shield the cables from external damages and prevent the terminals from splitting.

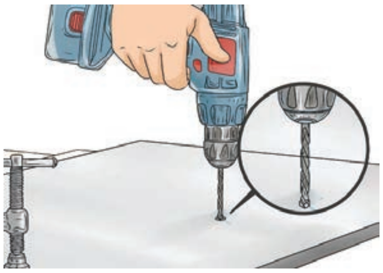


Fig. 8.19 Drilling the panel board

Steps of making panel assembly

The steps of making a panel assembly are as follows.

Step 1

Drill the panel board as shown in Fig. 8.19.

Step 2

Place the components that need to be installed in their respective places as shown in Fig. 8.20. Also, place the power source in its place.

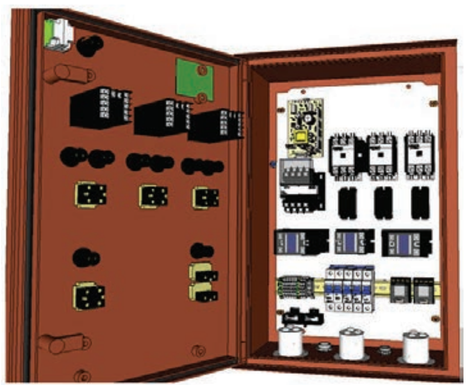


Fig. 8.20 Different components placed on the board

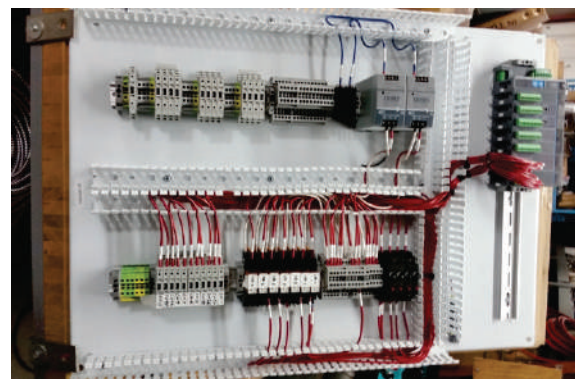


Fig. 8.21 Wireways or cable ways placed on the board

Step 3

Put wire ways or cable ways on the board as per the design and secure them with screws (as shown in Fig. 8.21).

Step 4

Connect the components with wires according to the wiring diagram as shown in Fig. 8.22.

Step 5

Label each component with device tags as shown in Fig. 8.23.

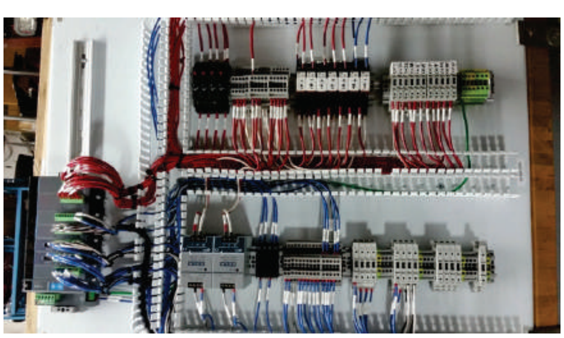


Fig. 8.22 Connect the components with wires

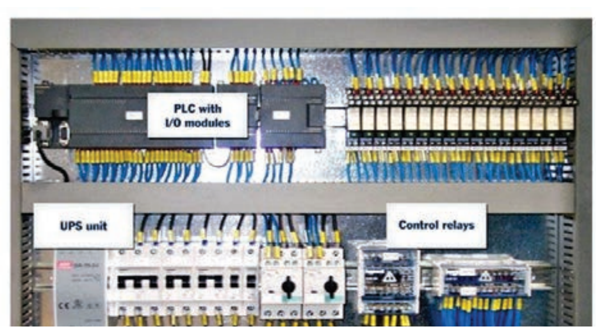


Fig. 8.23 Components with tags

Fig. 8.24 Wires having numbers on the laminated labels

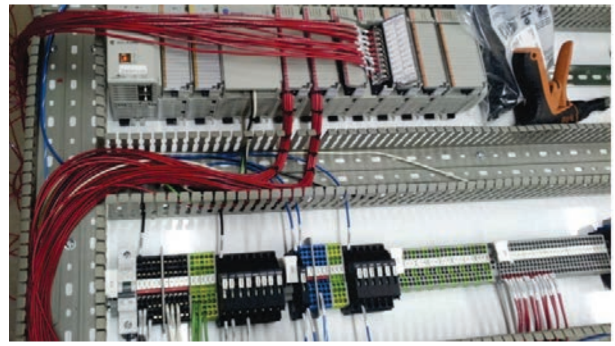


Fig. 8.25 Wires are clipped together

Step 6

Each wire has a number on the label laminated on it as shown in Fig. 8.24. Mark the cable terminals and place the wires and cables on the board in the wireways and cable ways.

Fig. 8.26 Board inside the panel

Step 7

Clip the wires together that run out of the wireways as shown in Fig. 8.25.

Step 8

Place the board integrated with the components inside the panel as shown in Fig. 8.26.

Check Your Progress

A. Multiple choice questions

1. When working at 120V AC, the minimum space between the device and wireways or any other obstruction is ______________
   (a) 1 inch
   (b) 2 inches
   (c) 4 inches
   (d) 5 inches
2. Which type of assembly is used in food, pharmaceutical, wastewater treatment and mining industries?
   (a) Cabinet
   (b) Door
   (c) Bucket
   (d) All of the above
3. Name the cap, usually, made of metal that is used to shield cables from external damages and prevent the terminals from splitting.
   (a) Clip
   (b) Clutch

NOTES

(c) Ferrule
(d) MCB

4. Which of the following cables is used for low-power signals to ensure less interference?
   (a) Unshielded
   (b) Shielded
   (c) Twisted pair
   (d) Coaxial
5. When working at 440V AC, the minimum space between the device and wireways or any other obstruction is _______________
   (a) 1 inch
   (b) 2 inches
   (c) 4 inches
   (d) 5 inches
6. Which of the following assemblies are, generally, used for motor control centres (MCC), lever cylinders, etc.?
   (a) Bucket
   (b) Door
   (c) Cabinet
   (d) All of the above
7. MCC stands for _______________.
   (a) Motor Control Centre
   (b) Machine Control Centre
   (c) Maintenance Control Centre
   (d) Machine Centre Connection
8. Motor is an example of _______________.
   (a) Electrostatic assembly
   (b) Electromechanical assembly
   (c) Electrical assembly
   (d) Electrodynamics assembly
9. PLC stands for _______________.
   (a) Programmable Logic Controller
   (b) Programmable Legal Act
   (c) Protect Legal Assembly
   (d) Project Logic Assembly
10. Electromechanical assembly converts _______________.
   (a) electrical energy to mechanical movement
   (b) nuclear energy to mechanical movement
   (c) mechanical movement to electrical signal
   (d) Both (a) and (c)

B. Fill in the blanks

1. Strip the wires correctly to make _______________.
2. Motor is an example of ___________ assembly.
3. While working with ___________ cable, strip some amount of the jacket to ensure that every conductor can be accessed for removal and testing.

4. Wires must exit from the terminal without any _____________.
5. Mount the _____________ enclosures cautiously.
6. Eliminate _____________ by applying appropriate procedure and taking precautions.
7. The wires that are used must have adequate _________________ capacity and _______________.
8. PLC stands for Programmable ______________ Controller.
9. Colour coded wire is used to locate _____________ in the cable.
10. On each wire, _____________ is used for marking.

C. State whether the following statements are True or False

1. Bucket assemblies are used in food, pharmaceutical, wastewater treatment and mining industries.
2. In a cable assembly, wires and cables are grouped together to work as a single unit.
3. Colour coded wiring is used to locate problems or faulty wires in cables.
4. Cabinet assemblies are, generally, used for motor control centres (MCC) and lever cylinders.
5. Ferrule is a cap, usually, made of metal, used to shield cables from external damages and prevent terminals from splitting.
6. Use different raceways for different type of cables and take precautions while using high and low power devices in the panel to avoid malfunction.
7. Avoid looping of wires unless needed.
8. Use screws or bolts and not adhesive for anchoring of hinges and wrapping the wires running over the hinges.

D. Short answer questions

1. What is an electromechanical assembly?
2. List different types of assembly.
3. Discuss the instruction and guidelines followed in the assembly process.
4. What are the components on a panel assembly?
5. List the places where electromechanical assembly is used.
6. What can be the industrial application of electromechanical assembly?

NOTES

Unit 9

Wire Preparation Methods

Introduction

Wire preparation is done through cutting, stripping, slitting, marking, crimping, and so on based on electrical connection, length accuracy, cross sectional width and amperage. The tools required for this purpose are different type of wire strippers, wire cutters, and so on. Electrical wiring must be installed in accordance with the electrical regulations and safety standards. If electrical wiring is carried out incorrectly or without adhering to the required safety standards, devices may get damaged and it may also lead to reduced device durability.

The following points must be considered for wire preparation.

- Choose a wire depending on the colour code mentioned by various standards, such as red for phase wire, black for neutral, green for earth, and so on.
- Various electrical tools are required for installation work. Some of these tools include cutters, strippers, testers, pliers, etc.
- Choose the components, such as electrical boxes, switches and receptacles based on their size and rating.

Wire conductors are available in many forms, ranging from single solid insulated conductors to highly integrated multiple conductors. Different type of tools are needed for preparing different kind of wires.

Wire preparation steps

In an electrical network, wiring plays an important role. Therefore, a wireman must know the steps for wiring installation. The basic step for wiring is wire preparation. Wire preparation includes the basic techniques and tools, which must be used for wiring. Wiring process relates to the preparation of wires or cables. The following steps need to be considered for wire preparation.

- Wire stripping
- Wire cutting
- Wire marking

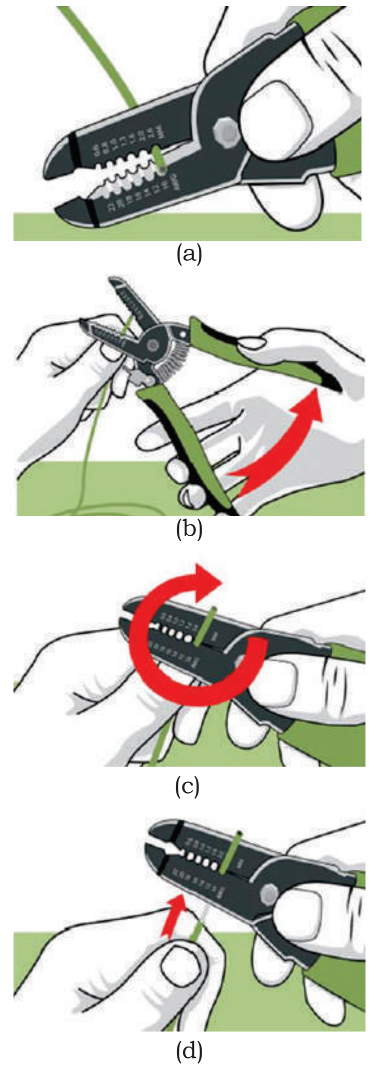


Fig. 9.1 (a–d) Insulation removal steps

Wire stripping

Electric wire is coated with an insulating material. The wire inside the insulating material consists of a metal conductor, which carries the current. Insulation removal is an essential step of wire preparation. Stripping is the process of removing the insulation. Stripper is a hand tool used to remove wire insulation. There are several techniques that are used to strip the insulation of wires. There are various type of wire strippers available in market for insulation removal. Fig. 9.1(a–d) shows the steps to remove wire insulation with the help of a stripper.

Hand-operated strippers are of several types, such as

- adjustable,
- hand-held automatic, and
- non-adjustable

Adjustable hand stripper

This tool uses V-shaped jaws for cutting the insulation of a wire. It is like a pair of scissors with a little notch to cut the insulation. There is a stop screw that can be adjusted back and forth. By adjusting the screw

Fig. 9.2(a) Adjustable hand stripper

Fig. 9.2(b) Different sections of an adjustable hand stripper

Fig. 9.3(a) Hand-held automatic stripper

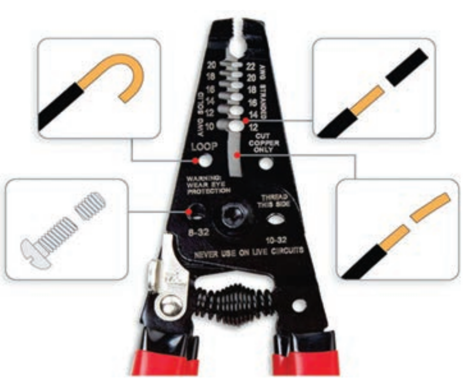


Fig. 9.3(b) Different sections of a hand-held automatic stripper

the jaws can be opened according to the wire size. The screw should be moved in such a way that only the insulation of the wire gets cut and not the conductor. Adjustable screw allows the hand stripper to cut wires of various diameters. Fig. 9.2(a) shows an adjustable hand stripper. Use a piece of wire to test whether the jaws of the hand stripper are appropriately adjusted or not. After removing the insulation, check if any damage is caused to the wire.

An adjustable hand stripper contains three sections, which are as follows.

- The first section is used for stripping the wire.
- The second is used for cutting the wire.
- The third is used for bending the wire.

Hand-held automatic stripper

The word automatic denotes the self-adjusting feature of the stripper. In an automatic stripper, there is no need to move the screw manually to adjust the opening of the jaws. The automatic stripper has predefined holes as per the gauge standard of a wire. Wire that has to be stripped has some standard gauge. This wire is inserted in the appropriate hole, having the same gauge value of automatic stripper. Use the apt size of the cutting hole when using a hand-held automatic stripper as shown in Fig. 9.3(b). A hand-held automatic stripper contains various sections, which are as follows.

- One section is used for stripping the wire.
- One section is used for cutting the wire.
- One section is used for making threads in the bolts.
- One section is used for bending the wire.

Non-adjustable stripper

This tool can be adjusted according to the length of the wire to be stripped. The jaws are designed in such a way that they can grip the insulation of the wire without leaving any mark on it as shown in Fig. 9.4(b).

Fig. 9.4(a) Non-adjustable stripper

Fig. 9.4(b) Stripping a wire using a non-adjustable stripper

Wire cutting

Sometimes there is a need to cut the wire to get the required length, which means the wire is first cut, and then, stripped to connect to the components. A wire cutter is used for cutting the wire. Fig. 9.5 shows wire cutting.

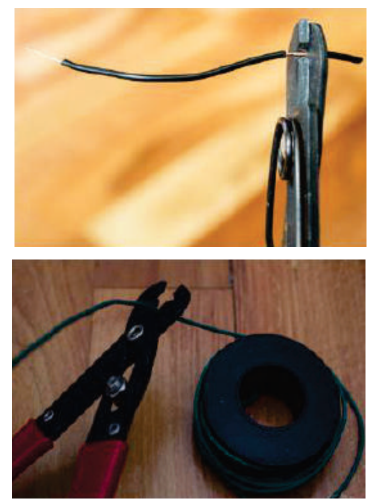


Fig. 9.5 Wire cutting

Wire marking

Wires are marked with different colours (Fig. 9.6). Colours indicate the purpose for which the wires are to be used. They must also be labeled to provide indications of their usage and other safety information.

Fig. 9.6 Wire marking

Cable stripper

Wires, usually, have a small diameter. This limits the range of transmission and distribution. A wire with a small diameter can carry only a small amount of current in its conductor. For high current and voltage transmission, a thick conductor with a thick layer of insulation is required. The conductor and insulation combine to form a cable. Different type of cables are available in market. They have more than one protective layer. These layers play an important role at the time of stripping.

Stripping of cables is done by a cable stripper. The outer coating of multicore cables needs to be removed without damaging the inner core. There is a spring in

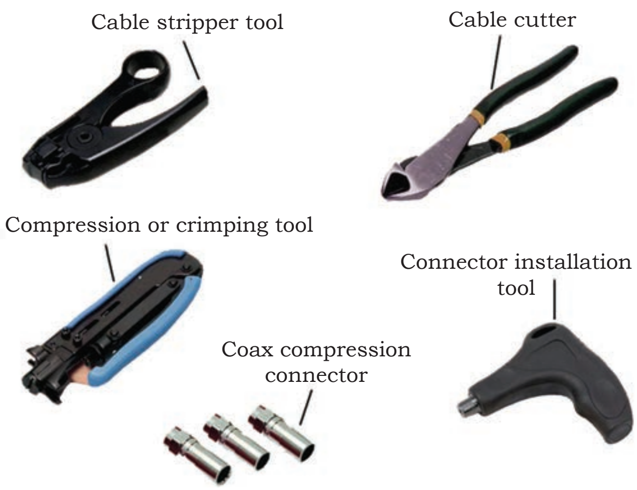


Fig. 9.7 Tools required for stripping a cable

the cable clamp and the cutter can be adjusted according to the thickness of the outer sheath.

Cable stripping operation

The steps to strip a cable are as follows.

Step 1

In order to strip a cable, the following tools are required as shown in Fig. 9.7.

Coax compression connector

There are several type of connectors available. Compression connectors provide the best connection and finish to a cable. Another type of connectors are 'crimp' connectors. Avoid using push-on or twist connectors.

Compression or crimping tool

It is used to crimp the connectors mounted on the conductor. Ensure that it is compatible with the compression or crimping connector.

Cable stripper tool

It is used to strip the insulation of coaxial cable.

Cable cutter

It is used to cut the cable insulation and conductor.

Connector installation tool

This tool is used for pushing the connector firmly onto the stripped cable.

Fig. 9.8 Cable cutter

Step 2

Use the cutting tool to make a straight cut at the end of a cable. After cutting, use fingers to push the end of the cable back into a circle (Fig. 9.8).

Fig. 9.9 Adjustable knob for stripper

Step 3

Adjust the stripper to work on the cable. If the wire stripper is not adjusted, the ground wire may get stripped, damaging the cable.

Step 4

Strip the end of the cable. Place the end of the cable into the stripper. Spin it around two to three times so that insulation at the end of the cable can be removed as shown in Fig. 9.10.

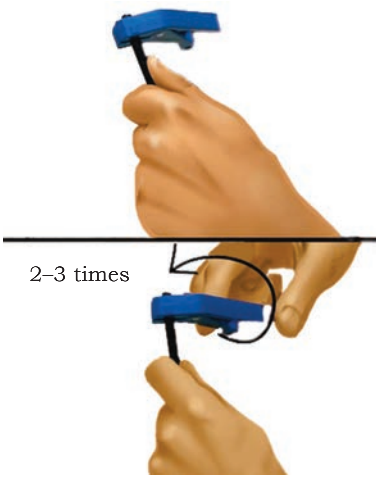


Fig. 9.10 Rotate the stripper for insulation removal

Step 5

Pull off the outer shield of the cable as shown in Fig. 9.11. After stripping the cable, two segment cuts can be seen. Pull the outermost segment off of the cable. This will reveal the centre conductor wire.

Step 6

Pull off the second segment or inner cut of the cable as shown in Fig. 9.12. This will reveal the foil that insulates the cable. Find the edge of the foil and peel it off the cable. This will leave a single layer of foil around the white insulation.

Fig. 9.11 Pull the outer shield of the cable

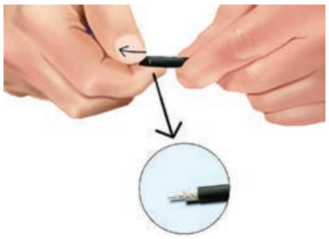


Fig. 9.12 Pull the inner cut of the cable

Fig. 9.13 Fold the ground wire of the cable

Step 7

When the cable jacket is pulled off, a lot of loose ground wires can be seen. Fold these back against the cable such that the connector touches all wires when installed as shown in Fig. 9.13.

Fig. 9.14 Cut the wire using a wire cutter

Step 8

Cable stripper tools will leave the correct length of a conductor wire exposed but check before proceeding. Cut the conductor using a wire cutter, if necessary as shown in Fig. 9.14.

Fig. 9.15 Insert a connector in the cable conductor

Step 9

Insert a connector into the stripped end of the cable conductor as shown in Fig. 9.15.

- Avoid bending the bare conductor wire when installing the connector.
- Twist the cable while pushing with the tool to connect it firmly.

Fig. 9.16 Crimp the connector using a cable crimper

Fig. 9.17 Cable after crimping

Step 10

Compress or crimp the connector. The process for compressing or crimping the connector varies, depending on the type of connector being used. Some require press down on the cable end of the connector piece, while others require pushing the front end of the connector piece into each other as shown in Fig. 9.16.

Step 11

After compressing the connector, inspect it for loose connections. Loose connections can lead to poor signal or non-functional cable.

Damages during insulation removal

Some damages that may be caused at the time of removing insulation are:

- dents or scratches in solid conductors,
- stripped plating and scores in solid metal conductors and
- twisting of wire with other wires.

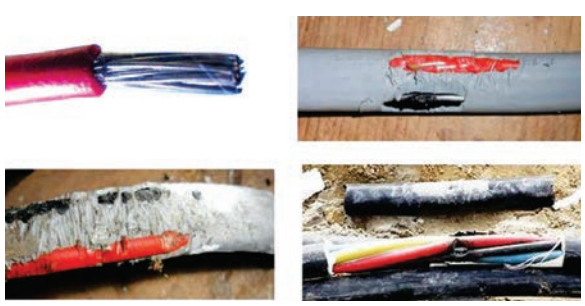


Fig. 9.18 Cuts in wires

Cuts in wire

Cuts weaken the wire mechanically and also reduce its current carrying capacity. Cuts hamper the functioning of an equipment as the wire gradually breaks. Cuts can also lead to electric shocks. Always put insulation tape over damaged wires. Fig. 9.18 shows some of the damages (cuts) that can occur during insulation removal.

Fig. 9.19 Wire stripper

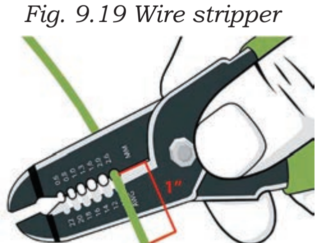


Fig. 9.20 Wire in the notch of a wire stripper

General principles of wiring and stripping of wire

A wire stripper has a number of notches in its jaws. It looks like a pair of pliers as shown in Fig. 9.19. Different types of wire and gauges can be put in the notches. These notches can vary in size.

Place the wire in the notch according to the size of wire, and then, gently close the jaws of the stripper. Line it up so that the jaws are about an inch (two to three centimetres) from the end of the wire as shown in Fig. 9.20.

Use pressure to remove the insulation as shown in Fig. 9.21. Do not press too hard as it may damage the wire beneath the insulation, and hence, make it unsuitable for an electrical project. Use notch with the right gauge to cut the insulation without damaging it.

After closing the stripper's jaws around the wire, cut the circumference of the insulator by using the cutting tool. Carefully rotate the tool around the wire as shown in Fig. 9.22.

Keep the tool's jaws closed to slide it off the wire to remove insulation from the tip. Pull the tool towards the short end of the wire or the end that is only about an inch (two to three centimetres) away from the jaws as shown in Fig. 9.23.

Fig. 9.21 Press the handles of the stripper to remove insulation

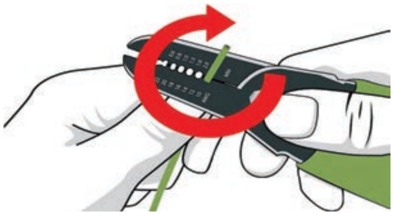


Fig. 9.22 Rotate the stripper around the wire

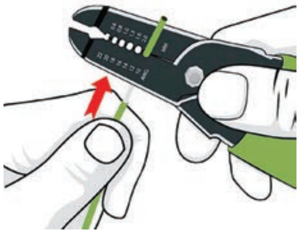


Fig. 9.23 Pull the insulation of wire

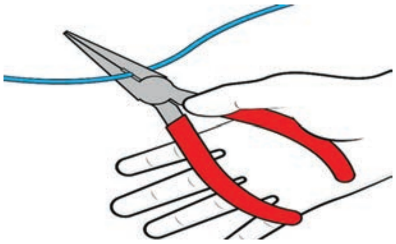


Fig. 9.24 Hold the wire using a pair of pliers

Fig. 9.25 Cut the damaged part of the wire

Hold the plier in one hand. Bring the wire to be stripped between its jaws and press its handles together to close the jaws as shown in Fig. 9.24.

Observe if the wire is twisted or broken. If so, then that part of the wire must be removed because it may cause discontinuity in carrying electricity. Use a wire stripper to cut the twisted and damaged part of the wire as shown in Fig. 9.25.

Fig. 9.26 Place a utility knife on the wire that needs to be cut

Wire insulation removal using utility knife

Place the wire on a flat work surface. Use one hand to hold the utility knife about an inch (2–3 cm) from one end of the wire. Do not do any cutting and let the knife rest on the exact spot you want to cut as shown in Fig. 9.26.

Hold the knife with one hand. Roll the wire with the other hand so that the blade scrolls all the way around the insulation sheathing as shown in Fig. 9.27. Do not press hard with the knife. Apply appropriate pressure for removing the insulation.

Fig. 9.27 Roll the wire with one hand

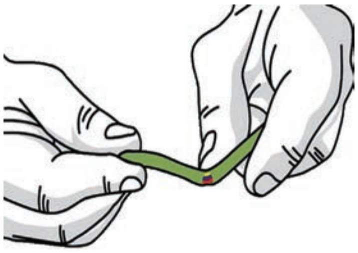


Fig. 9.28 Put a cut mark around the wire and bend it up and down to break

Put a cut mark around the insulation sheathing that needs to be removed. Bend the tip of the wire up and down to break as shown in Fig. 9.28. Slide off the insulation at the marked line.

Wire bending

- To bend the wire, mark it with a marker or pencil. A thicker wire may require larger tools and specialised machinery as shown in Fig. 9.29.
- For bending the wire at 90 degrees, use a pair of pliers with wide jaws as shown in Fig. 9.30.


Fig. 9.29 Marking on the wire for bending

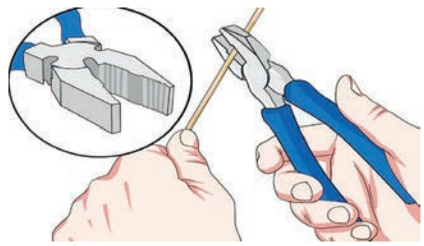


Fig. 9.30 Use a pair of pliers for bending the wire

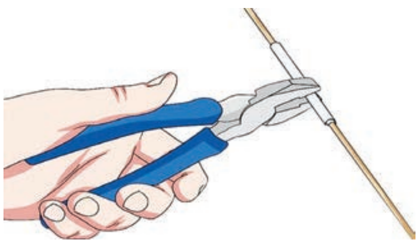


Fig. 9.31 Wrap a piece of cloth around the wire

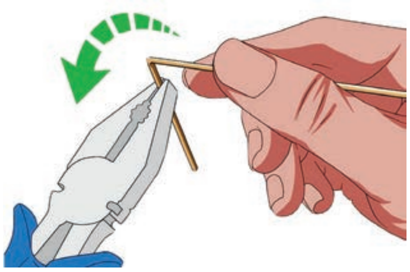


Fig. 9.32 Using the pair of pliers to bend the wire

- Grip the wirewith the pair of pliers. To prevent the wire from developing marks from the pliers, wrap a piece of cloth around it or grip it with two small pieces of wood on either side as shown in Fig. 9.31.
- Make the bend by turning the pliers to the direction needed as shown in Fig. 9.32.
- Another way to bend the wire is to use a vice. Use a block of wood to ensure even bending as shown in Fig. 9.33.

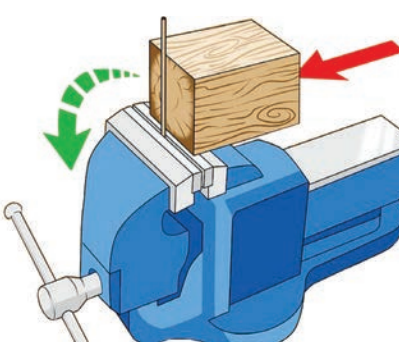


Fig. 9.33 Use a vice to bend the wire

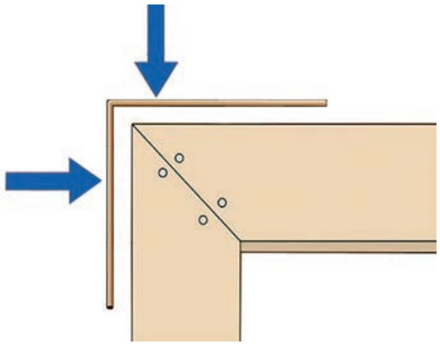


Fig. 9.34 Check for correct wire bending using a square frame

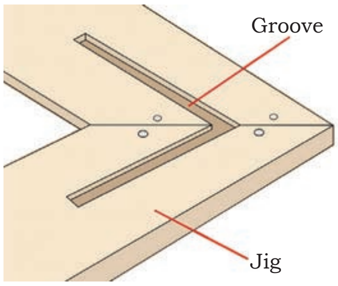


Fig. 9.35 Groove formation using a jig

- Check the angle of the wire using a square frame as shown in Fig. 9.34.
- Use a jig to form grooves on the wooden frame at 90 degrees as shown in Fig. 9.35. The simplest method to make one of these is to drill two crossing holes through a piece of wood. By cutting the wood at 90 degrees through the centres of the holes, you will end up with two pieces of wood with crossing grooves as shown in Fig. 9.35.

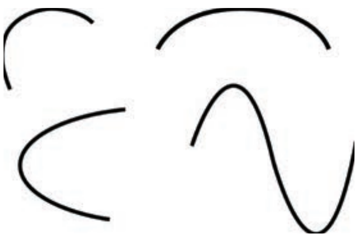


Fig. 9.36 Curves of different shapes

Making regular curves of wires

- A regular curve is a line, which follows the curvature of one specific circle as shown in Fig. 9.36.

Fig. 9.37 Free hand curve template

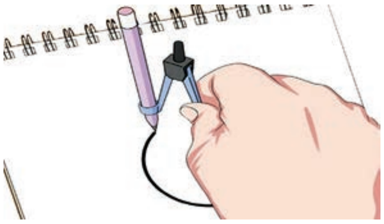


Fig. 9.38 Curve template drawn using a compass

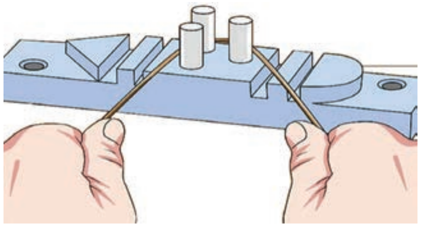


Fig. 9.39 Making a curve in a wire using a machine

- Make a template of circle or curve as shown in Fig. 9.37 and 9.38.
- To make the template, draw a curve on a paper and cut it. Now, put the paper template on a wooden or plywood board and cut as per the template to get the curve.
- Use specialised machines for bending wires and tubings as shown in Fig. 9.39.

Fig. 9.40 Observing the material of wire conductor

Straightening of wire

- A wire can be straightened in many ways, taking into account the properties of the wire as shown in Fig. 9.40.
- Straighten thin and soft wires by hand as shown in Fig. 9.41.
- Straighten thick and strong wires on an anvil or similar surface as shown in Fig. 9.42.

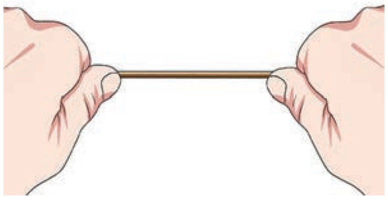


Fig. 9.41 Straightening the wire using hands

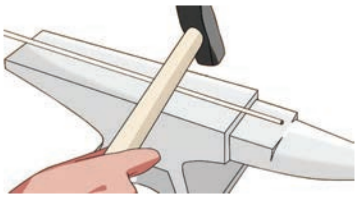


Fig. 9.42 Straightening the wire using a hammer

The hammer must be made of harder material than the wire. Use it gently as there is a risk of flattening or damaging the wire in the process. Wood or brass hammer is a good choice.

- Straightening thin and soft aluminium or copper wire is the easiest with two pieces of wood and a vice.
- Sandwich the wire between the wood and secure it in the vice. Do not put much pressure. It can be done by pulling the wire through the two pieces of wood as shown in Fig. 9.43.
- Another option is securing one end of the wire in a vice, and then, pulling along the wire with two pieces of wood.

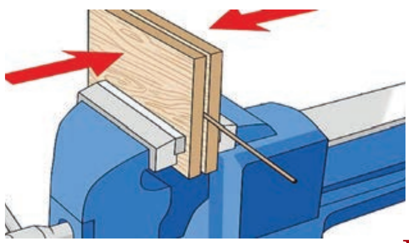


Fig. 9.43 Straightening the wire using wooden pieces

Making loop of wire

- Use pliers with round jaws (Fig. 9.44). Conical jaws will make nooses (loop) of varying diameter.
- Square pliers can be used to make square nooses.
- Choose the gripping point on the pliers according to the diameter of the noose (Fig. 9.45).
- Adjust the wire in the jaws of the round nose plier as shown in Fig. 9.46.
- After that, rotate the pliers so that the bent part is not gripped by the jaws as shown in Fig. 9.47.
- Repeat the previous step until the circle is complete as shown in Fig. 9.48.

Fig. 9.44 Round nose plier

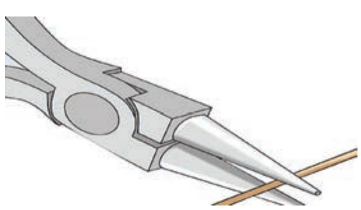


Fig. 9.45 Placing the wire in the round nose plier

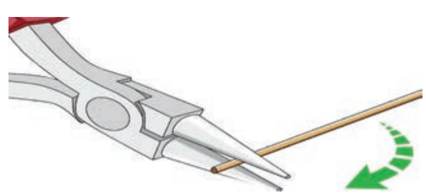


Fig. 9.46 Adjusting the wire in the jaws of round nose plier

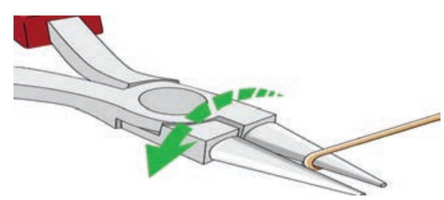


Fig. 9.47 Rotating the round nose plier

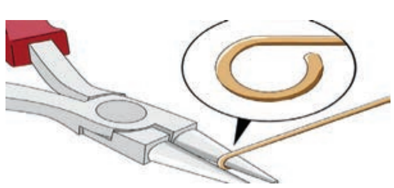


Fig. 9.48 Turning the wire in circular shape

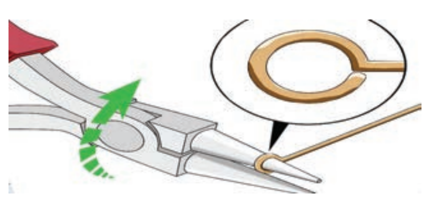


Fig. 9.49 Bending the noose of wire using a nose plier

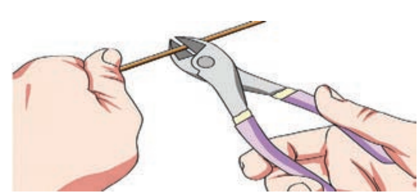


Fig. 9.50 Cutting the extra wire with a wire cutter

- Bend the noose back as shown in Fig. 9.49.
- Cut off the excess wire with the help of a wire cutter. A specialised chisel or a hacksaw can also be used as shown in Fig. 9.50.
- Make the end of the wire smooth. Make necessary adjustments to the noose as shown in Fig. 9.51.
- Flatten the noose to give it finishing touches it as shown in Fig. 9.52.

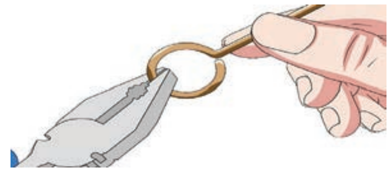


Fig. 9.51 Making adjustment in the noose using a pair of pliers

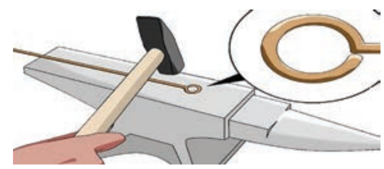


Fig. 9.52 Flattening the wire using a hammer

Wire joints

Western union joint

It is a straight joint used for small solid cables. To form a western union joint, the following points have to be considered.

- Remove the insulation.
- Bring the two conductor wires to a crossed position, and then, make a long bend or twist in each wire.
- Wrap the end of one of the wires around the straight portion of the other wires, and then, do the same for the other wire. Repeat this for about four to five times.
- Press the ends of the wires down close to straight portions of the wires to prevent the ends from intruding through the insulation tape (as shown in Fig. 9.53)
- Insulate the joint using the tape.

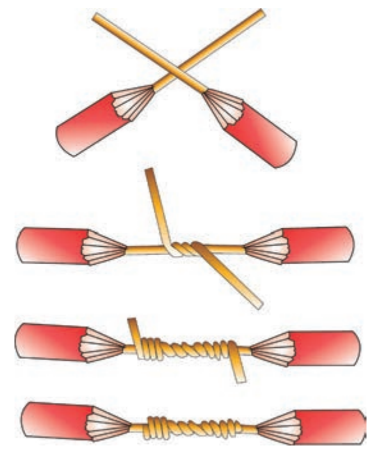


Fig. 9.53 Wire joints

Fixture joint

It is a type of branch joint, connecting a small diameter wire with a large diameter conductor, such as those used in lighting fixtures as shown in Fig. 9.54. To form a fixture joint, the following points have to be considered.

- Remove the insulation.
- Now, wrap the fixture wire around the branch wire.

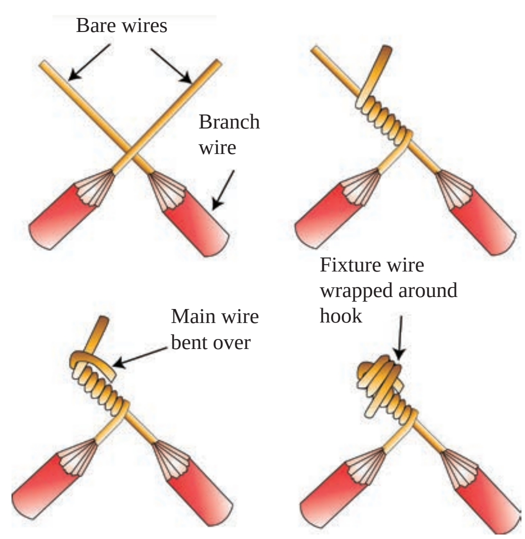


Fig. 9.54 Fixture joints

Know more...

Rattail joint splice, also known as 'twist splice', this joint is formed by taking two or more wires and wrapping them together symmetrically around the common axis of both the wires.

- Bend the branch wire over the completed turns.
- Wrap the remaining fixture wire over the bent branch wire.
- This can be followed by soldering and taping, or simply taping of the joint.

Knotted tap joint

It is used to connect a branch wire to the main wire as shown in Fig. 9.55. To form a knotted tap joint, the following points have to be considered.

- Remove about 1 inch of insulation from the main wire and about 3 inches from the branch wire.
- Place the branch wire behind the main wire so that three–fourth of its bare wire extends above the main wire.
- Bring a branch wire over the main wire. Then, turn the branch wire in a way that it forms a knot over the main wire. Wrap the branch wire around the main wire. Knots of the branch wire on the main wire should be short and tight. Trim the remaining terminal of the branch wire.

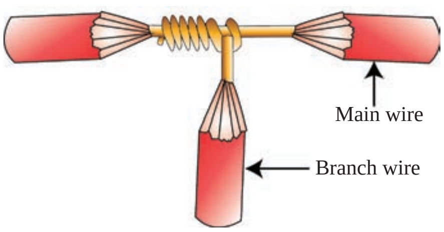


Fig. 9.55 Knotted tap joint

Joints using wire nut and split bolt

A wire nut replaces a rattail joint splice. The nut is, usually, housed in a plastic insulating casing. The process to make a joint using a wire nut and split bolt are as follows.

- Strip the conductors.
- Place the two wires to be joined into the wire nut.
- Twist and tighten the nut to form a joint.

Fig. 9.56 Split bolt connector

Split bolt connector

A split bolt is used to joint large conductors as shown in Fig. 9.56. This replaces the knotted tap joint and can be used to join three ends or a branch wire with a continuous conductor. The bare wires are placed in the space between the two bolts, after which the nut is tightened to ensure a sound joint.

Crimping

Crimping refers to joining two metal pieces together. Generally, a wire and connector are connected together by deforming one of them, and enabling the other one to hold it. The resultant deformity is known as 'crimp'.

For crimping, do not use a pair of pliers as the deformity cannot be formed. If air is trapped between the crimp and the connector, it collects moisture. This eventually causes corrosion in the wire and can even lead to connection failure.

Crimping tool

Crimping tools are used for punching the connector on a metallic conductor. There are two types of crimping tool.

- Mechanical crimping tool
- Hydraulic crimping tool

Fig. 9.57 Mechanical crimping tool

Mechanical crimping tool

This tool (as shown in Fig. 9.57) is used for crimping wires. The diameter of a wire must range from 2.5 to 16mm.

Hydraulic crimping tool

This tool is used to crimp copper or aluminium cable lugs. Connectors can also be crimped onto the cable for cable connection. Cables having a diameter from 35 to 1000mm can be crimped as shown in Fig. 9.58.

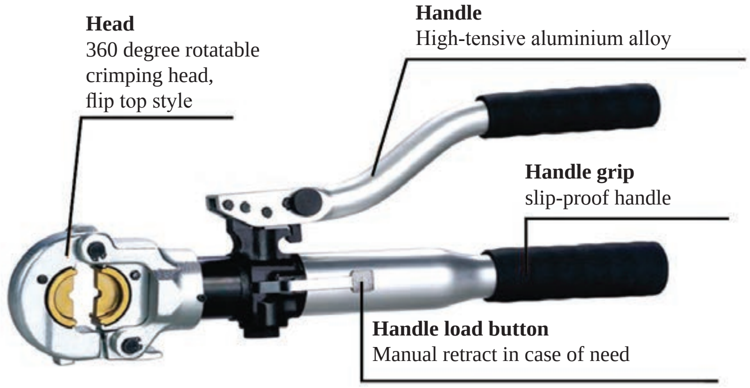


Fig. 9.58: Parts of a hydraulic crimping tool

Die

A crimping tool die is designed for reliable and controllable electrical connection. Dies, which can be attached to a hydraulic crimping tool, are available in different sizes as shown in Fig. 9.59.

Fig. 9.59 Different size of dies used in hydraulic crimping tool (diameter of 95–300mm)

Care and maintenance

Cleaning: Dust, sand, environmental influences like high salt index, in particular, and dirt, in general, are harmful for hydraulic crimping tools. It is important to clean these tools carefully.

Storage: Appropriate storage is important to prevent damage to the tools because of dust, etc.

Checking the oil level: The oil level in hydraulic crimping tools must be checked at regular intervals. If it is not oiled for a long time, fill oil at the top end of the handle as shown in Fig. 9.60. While refilling, take some precautions, such as

- Use only the specified oil.
- Never use old oil.
- The oil must be clean and non-contaminated.


Fig. 9.60 Fill oil in the hydraulic crimping tool

Steps of crimping

The steps of the crimping process are as follows.

Step 1

Strip the insulation of a wire as shown in Fig. 9.61.


Fig. 9.61 Strip off the insulation

Step 2

Make the tip of the wire firm by twisting the conductor material to enable better connection for the connector as shown in Fig. 9.62.


Fig. 9.62 Twist the conductor

Step 3

Place the wire into the connector in such a way that the bare part of the wire touches the bare part of the connector as shown in the Fig. 9.63.

Fig. 9.63 Connector connected into the wire

Step 4

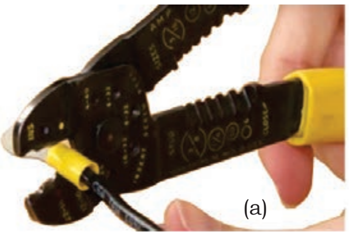
Enter the wire along with the connector into the crimping tool.

Step 5

Squeeze the tool with force as shown in Fig. 9.64.

Step 6

After completion of the process, check that the wire and the connector are together even after applying force, as shown in Fig. 9.65. If you are able to pull off the connector from the wire, crimping has not been done properly.



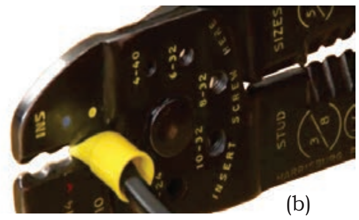


Fig. 9.64 (a and b) Squeeze the handle of the crimper to crimp the connector

Lug (Connector)

Lug (electrical connector) is an enclosure tied to an electric cable. It is used for supporting the connection of a cable. Lug is made of aluminium or copper. It helps tighten the connection. It is a solderless electrical connection. Lugs are punched on to the cable using crimping tools as shown in Fig. 9.66.

Fig. 9.65 Wire after crimping

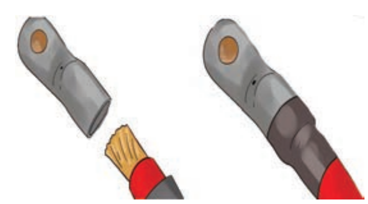


Fig. 9.66 Lugs connecting to the wire

Cable preparation

- Select appropriate pressing dies for the (connector) lugs to be crimped.
- The size of the dies varies from 35 to 400 mm diameter as shown in the Fig. 9.67.
- Insert the dies in the tool head. Half circled pressing dies are used in crimping. A half circled die is made of two parts with identical external measurements, so that they can be inserted into the piston or the head.
- The step for inserting pressing dies is identical to the mounting of both piston and head.
- The dies are inserted via guides until they come to a stop at the blocking pin.

Fig. 9.67 Dies of various size

- Then, the pin is retracted using the release button and the die is inserted further until it is held by the pin and is in place.
- When inserting into the piston, one must ensure that the crimper push button is pushed far enough forward for the release button to be visible and accessible.

Fig. 9.68 Hydraulic crimping tool

- To remove the dies, in both instances, the relevant release button must be activated. Then, allow the dies to slide out. To remove the inserts at the piston, the steps listed above must be carried out in reverse order. A hydraulic crimping tool is shown in Fig. 9.68

Start

- Bring the tool to working position.
- Select appropriate pressing dies for the connector (lugs) to be crimped.
- Insert the pressing dies in the tool head.
- Insert the conductor into the connector.
- Place the connector firmly between the two pressing dies.
- Hold the tool securely and press the mobile lever arm to move the piston forward quickly until the pressing dies meet the connector to be compressed.

Fig. 9.69 Fixing the dies in crimper

Fig. 9.70 Inserting the cable into the crimper

Fig. 9.71 Pressing the crimper

Fig. 9.72 Crimped cable with crimper

Fig. 9.73 Dies removed from crimper

- As soon as the pressing dies start to compress the connectors, the system automatically switches from closing to working feed.
- Press until the pressure limiter can be heard or the pressing dies meet and a perceptible discharge of the pump occurs.
- To bring the piston to its basic position, activate the release lever on the tool. Releasing the pressing dies, return the piston to the basic position.
- The above mentioned step can also be used during crimping if you have made an error in the selection of connector or die.

Coaxial cable

Stripping of a coaxial cable depends on the type of connectors. You need to adjust the slide of the cutter according to the type of the cable. You can also use a knife to strip a coaxial cable. Stripping of a coaxial cable is shown in Fig. 9.74.

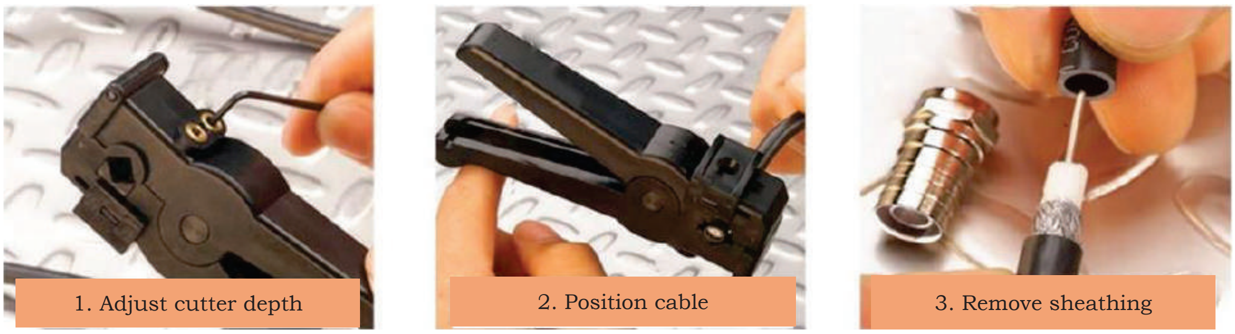


Fig. 9.74 Insulation stripping of a coaxial cable

Securing cables

For securing the cables, you need to ensure that

- the cables are supported in a way that they are not exposed to any mechanical strain.
- the termination of the cables must be free from undue mechanical strain.
- the cables are supported by appropriate means at regular distances to secure them from damage because of their own weight.
- clips are used to organise and group the cables.
- the hook and loop straps must be used to secure the cables (as shown in Fig. 9.75).
- the cable stress caused by tension in a tightly clinched bundle is minimised. Cable bindings for tying multiple cables must be irregularly spaced and loosely fitted so that it can be moved easily.
- the bends are made gradually while routing electrical cables. Sharp bends in the cable must be avoided.

Fig. 9.75 Securing of cables

Preparing three-core cable

To prepare a three-core cable, the following steps must be considered.

- Remove the sheathing and wiring armour.

- Separate the wire armour and bend the wires away from the cable. Place a support ring under the armour at each side of the joint.
- Cut back the cable insulation.
- Remove the insulation from each conductor.

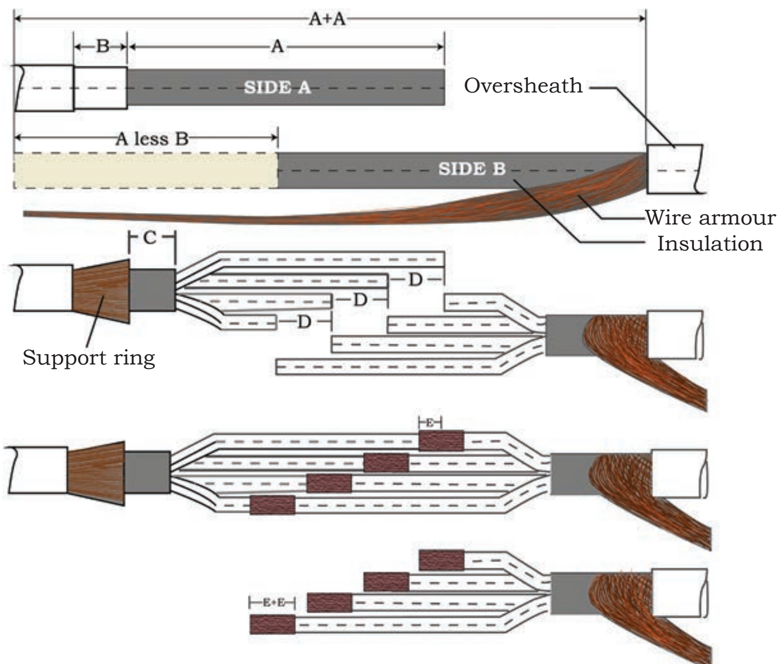


Fig. 9.76 Preparing three-core armoured cable

Crimping and insulating the cable

For crimping and insulating the cable, the following points must be considered (Fig. 9.76).

- Once the cable is ready, connect each end of the three conductors to a suitable mechanical connector or crimp.
- Tightly fix the matching connectors and test the connection.
- Tape the crimped connectors. Wrap around and extend to cover at least 25mm of the cable insulation of the conductor entering the connectors.

Binding the cables


Fig. 9.77 Taped, crimped connectors on individual cables

Bind the wires tightly, and then, tape them together. When insulating both individual cables and the whole bunch, fill in the voids to create even taped ends as shown in Fig. 9.77.

Restoring the armour and applying mesh tape


Fig. 9.78 Wires taped together

- Tightly wrap the cable from armour (metal covering) to armour while applying adequate tension around the insulation.
- Join the wire armour from one end to another and cut excess wire to the correct length. Ensure that the armour is spread evenly over the entire joint.

- Wrap the cable with mesh tape. Then, use standard vinyl/PVC tape to wrap over the mesh to provide mechanical barrier against stray wire ends. For the branch joint, bring both the main and branch cables together before wrapping. Next, use standard vinyl or PVC tape to wrap over the constant force springs placed over the under-armour rings. The tape provides a barrier against sharp edges as shown in Fig. 9.79.

Fig. 9.79 Wrapping the cable with mesh tape

Re-establishing the outer sheath

- Use a self-fusing tape to wrap over the cable and establish the outer sheath. Start in the centre and apply one layer of tape to one end, wrapping over the jacket for at least 25mm. Apply the tape from the end towards the centre so that you have two layers on each side.
- For branch joints, wrap over the insulation for both the main and branch cable by at least 50mm. Bring the two together and fill it with insulating putty from both sides. Do this up to 25 mm away from the point where the branch and main cables are joined.
- Put the two cables together and bind the main and branch cables tightly over the filling. Finally, wrap the crotch while pulling the branch away from the main cable as shown in Fig. 9.80.

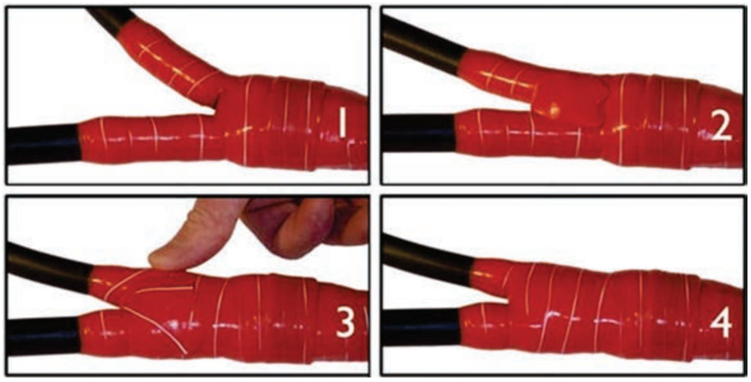


Fig. 9.80 Restoring the outer sheath on a branch joint

Check Your Progress

A. Multiple choice questions

1. Which of the following is used as electrical connector for an electric cable?
   (a) Lug
   (b) Plastic jacket
   (c) Clip
   (d) Tape

NOTES

2. Which of the following tools is used for insulation removal in a coaxial cable?
   (a) Cutter
   (b) Stripper
   (c) Mechanical crimping tool
   (d) Hydraulic crimping tool
3. The size of dies varies from ____________ to ____________ diameter connectors.
   (a) 25 mm, 300 mm
   (b) 25 mm, 400 mm
   (c) 35 mm, 400 mm
   (d) 15 mm, 400 mm
4. Which of the following tools is required for crimping of a 70mm cable?
   (a) Mechanical crimping tool
   (b) Hydraulic crimping tool
   (c) Both (a) and (c)
   (d) Stripper
5. Which of the following tools require oil for its smooth operation?
   (a) Stripper
   (b) Hydraulic crimping tool
   (c) Plier
   (d) Cutter
6. Lugs are made of ____________ and ____________.
   (a) Aluminium and silver
   (b) Silver and copper
   (c) Copper and zinc
   (d) Aluminium and copper
7. Which of the following precautions must be taken while refilling oil in a hydraulic crimping tool?
   (a) Use only the specified oil
   (b) Never use old oil
   (c) Oil must be clean and non-contaminated
   (d) All of the above
8. Which of the following tools is used for wire bending?
   (a) Plier
   (b) Screwdriver
   (c) Stripper
   (d) Cutter
9. Which of the following tools is required for making noose (loop) in a wire?
   (a) Round nose plier
   (b) Cutter
   (c) Stripper
   (d) Hammer

10. Which of the following is not a type of joint?
    (a) Western union joint
    (b) Fixture joint
    (c) Knotted tap joint
    (d) Axial joint

B. Fill in the blanks

1. Insulation can be removed from an electric wire by using a _____________.
2. Electrical connectors are called _____________. These are used for crimping of electrical cables.
3. The oil level in a tank must be checked at regular intervals in _____________.
4. Lugs are made of _________________ and ______________.
5. Non-adjustable stripping tool can be adjusted according to the length of the _____________.
6. There is a spring in the cable clamp and the cutter can be adjusted according to the thickness of the _____________.
7. The size of a wire must match the correct __________ of the stripper.
8. Lugs are punched onto a cable using ___________ tool.
9. Clips are used for organising and _____________ of cables.
10. Lugs are _____________ connection.

C. State whether the following statements are True or False

1. Hook and loop straps must be used to secure the cables.
2. Lugs are made of zinc and iron.
3. The size of dies varies from 35 to 400mm diameter connectors.
4. Hydraulic crimping tools are used to crimp copper and aluminium cable lugs or connectors onto cables.
5. Crimping tool die is designed for reliable and controllable electrical connection.
6. A wire cutter is used for making markings on the wire.
7. Non-adjustable stripping tool can be adjusted according to the length of the strip.
8. Bends are made gradually while routing electrical cables. Sharp bends in the cable must be avoided.
9. Use standard vinyl or PVC tape to wrap over the armour rings.
10. Knives cannot be used for stripping of coaxial cable.

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D. Short answer questions

1. Write down the uses of a screwdriver and crimping tool.
2. What are the steps of crimping?
3. Write short notes on the following.
   - Hydraulic crimping tool
   - Die
   - Lug
4. What steps need to be taken for the care and maintenance of a hydraulic crimping tool?
5. Name the different type of joints used for cables.
6. List the steps for cable preparation.
7. What are the type of hand-operated strippers?

Unit 10

Hazards with Panel Assembly and Wiring

Introduction

While assembling panel components, one may have to deal with hazards associated with the panel assembly process. Therefore, one must be aware of the hazards associated with wiring a control panel or while assembling the components in a panel assembly. Many hazards can be avoided by taking appropriate precautions. This will ensure safety at workplace. Points that may lead to hazards are as follows.

- Exposure to high electromagnetic fields
- Electrical fires due to faulty and outdated wiring and use of faulty components
- Electric shock due to faulty grounding of electrical equipment
- Defective or inadequate insulation on electrical cables

To avoid electrical hazards, follow these precautions.

- Ensure the power tools to be used in the assembly process include extension cord of appropriate rating.
- Do not use damaged electric tools.
- Inspect and test the installed electrical equipment and system at regular intervals.

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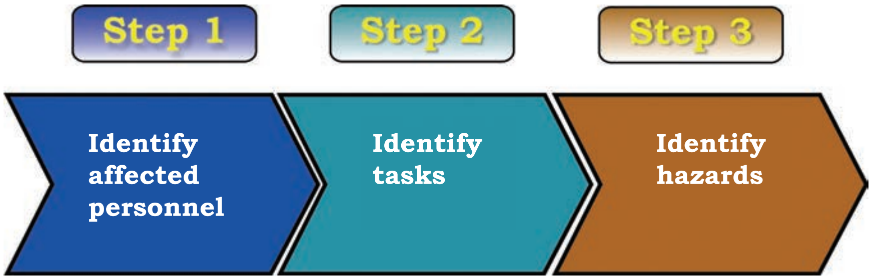

Fig. 10.1 People, task and hazard identification

- Check the rating and physical condition of the components and cables.
- Use standard techniques for assembling the components.
- Use personal protective equipment for safety purpose.

Handling heavy and hazardous material

Handling loads manually may cause cumulative disorders, such as back pain, musculoskeletal disorders, and so on, due to continuous lifting or handling of heavy machines and equipment.

The following points must be taken into account to reduce risks associated with handling of heavy and hazardous loads.

- Identify the hazard
- Assess the risk
- Select appropriate measures to control or reduce the risk

Common injuries that can be caused due to lifting heavy loads include backache, neck strain, wrist sprain, back sprain, shoulder pain, and so on. Similarly, some common injuries associated with handling of hazardous material include dermatitis, occupational respiratory and lung ailments, and so on. Therefore, it is mandatory to follow the standard safety procedures while handling equipment, hazardous material or tools.

The following measures are some of the key points that must be taken care of while handling hazardous material.

- Use machines to lift or carry hazardous material.

- Use personal protective equipment, such as boots, gloves, helmets, goggles, and so on.
- Work in a team while handling heavy loads.

Maintaining correct posture while working

A wireman must maintain the correct posture while working, whether in squatting, standing or bending position. When trying to pick up a tool or equipment while wiring at a height, one tends to stretch the body. This stretch may cause injuries. Moreover, when wiring a control panel in racks and cabinets, one is required to work in uncomfortable positions, which may harm the back, neck and limbs. Therefore, it becomes important to take precautions while working to ensure that no harm is caused to the body (Fig. 10.2).

Some of the precautions that one must take while working include the following.

- Follow the correct posture while working on a table for wiring or soldering as shown in Fig. 10.3.

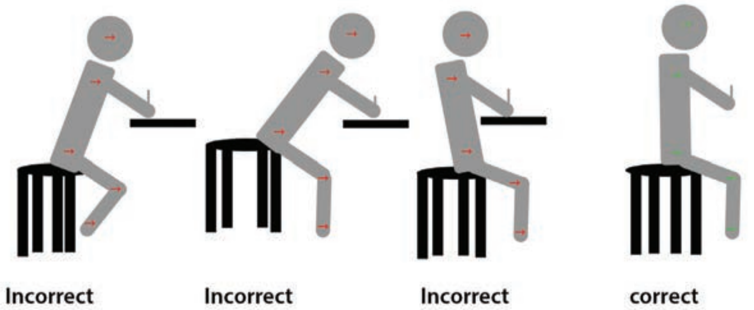

Fig.10.3 Incorrect and correct postures while working on a table

- Keep stretching the arms, legs, neck and back while working to ensure that they are not strained.
- Follow the correct way for lifting heavy boxes or other material as shown in Fig. 10.4.

How electricity works

The wireman must know the way electricity flows through a circuit. The person must also have the knowledge of the material and equipment used for insulation. The first step in preventing a dangerous

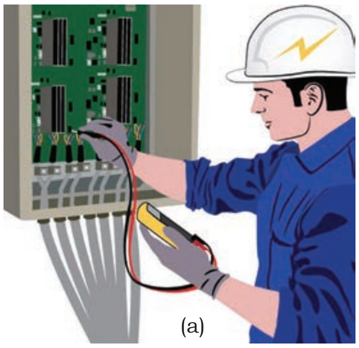

Fig. 10.2 (a and b) Wiremen working in different positions

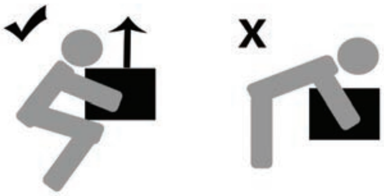

Fig. 10.4 Correct and incorrect way of bending and lifting

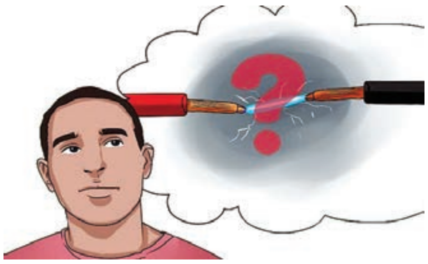

Fig. 10.5 Remember the cause of shock in an electrical system

situation is to understand the cause of an electric shock (Fig. 10.5).

- Natural current follows the least resistive path, and flows to the earth or ground through the material that conducts electric current.
- Due to the presence of sodium and water in human and animal body, current can easily flow through them. When electric current passes through a human body, the person experiences electric shock. Material like wood and glass are poor conductors of electricity, whereas, seawater and metals are good conductors.
- Incidence of experiencing electric shock often happens when a person is exposed to direct source of electricity. Electric current may flow in a human body through water, metallic rod or pole, etc.

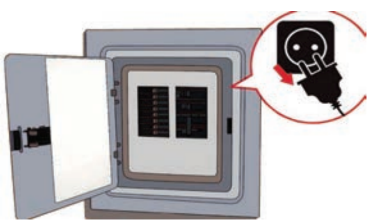

Fig.10.6 Control panel board

Electric appliances used in homes have their own electrical specifications. Therefore, one needs to know about the type of circuit breakers, fuses and light bulbs required in our homes (Fig. 10.6). One must replace them with the right parts when needed. Using unspecified parts may hamper an equipment's functioning. It may create an unsafe condition that may lead to fire, injury or even death.

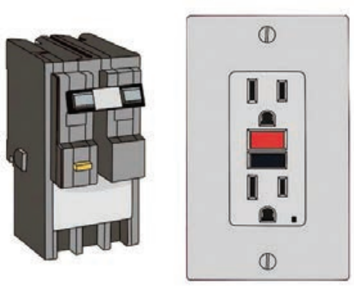

Fig.10.7 Types of circuit breaker

Preventing electric shock at workplace

Install breakers

Ground fault circuit interrupter (GFCI) device is used to measure the imbalance occurring in an electric appliance.

Avoid common mistakes

Avoid making common mistakes when trying to install electrical system or working on the electric system. Avoid touching a bare wire that may be carrying electric current or a wire with bare handle.

Fig. 10.8 Mistakes made while installing a socket

Replace damaged equipment

Inspect electrical devices at regular intervals and maintain them. Some signs that indicate a need for repair are:

(a) sparking
(b) experiencing minor shocks
(c) frayed or damaged cords
(d) heat from electrical outlets
(e) frequent short circuit

These are the few signs of wear and tear in an equipment or appliance. If something unusual is noticed, contact an electrician immediately.

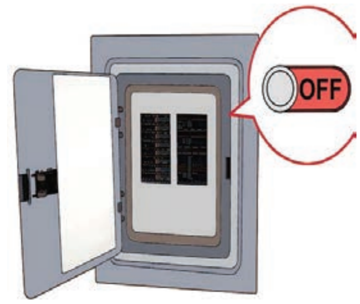

Fig. 10.9 Turn off the control panel

Turn off the power source

Whenever a project involves exposure to electrical equipment or electricity, check whether the power is off before starting the work (as shown in Fig. 10.9). Again, there should be a main electric panel for the entire facility. Find out this panel and turn the switch off.

Wear protective gear

Use rubber sole shoes and gloves. Also, put a rubber mat on the floor. Putting all these is an effective precaution as rubber does not conduct electricity and will prevent a person from getting electric shock (Fig. 10.10).


Fig. 10.10 Rubber shoes and gloves prevent a person from electric shock

Exercise caution when operating power tools

Make sure that all tools have a three-pronged plug (as shown in Fig. 10.11) and look for signs of damage in the tools. Always turn off the switch of power tools before connecting them to the socket. Always keep the electric power tools away from water. Besides, when using an electric power tool, keep the work area free from flammable gases, vapour and solvents.


Fig. 10.11 Three-pin plug

Double up

It is always wise to have a second person around to assist you when installing the panel (Fig. 10.12). This person can double check to ensure that all necessary precautions are being followed. Also, if something goes wrong and the person working gets an electric shock, this second person can immediately provide help.

Make sure to communicate well with the other person. Many electrical accidents occur because of


Fig. 10.12 The second person conducts a check

Fig.10.13 Calling a electrician

miscommunication. The person must carefully listen when the second person says the power of the control panel is OFF or ON.

Even if you trust this person, it is important to double check and make sure that the power is off. Never assume anything when dealing with electricity as a small lapse may result in a major accident.

Call a professional for major works

Working with electricity is dangerous and complicated. If a person is not confident, rope in an electrician to complete the job as shown in Fig. 10.13.

Fig.10.14 Checking the weather report

Preventing electric shock in lightning storm

Check the weather report

When working outside, one must make sure that the weather is clear. Also, check the weather forecast for ensuring safety (Fig. 10.14). Even if one has an afternoon work, the weather can change in no time and the best precaution is preparedness. Check for chances of thunderstorm in an outdoor area you plan to install the panel. One must change the plan accordingly, if needed and wait for the weather condition to become normal.

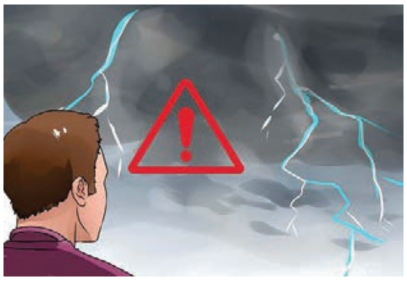

Fig.10.15 Watch out for signs of storm

Watch out for signs of storm

Regularly monitor the changes in temperature, increase in wind speed or darkening of the sky (Fig. 10.15). If it looks like a storm rolling in, cover the panel and stop the work immediately and look for shelter.

Fig. 10.16 Do not touch the victim with bare hands

Do not touch a victim with bare hands

Shock victims, usually, do not hold electricity in their bodies for very long time. However, always be cautious when touching the victim of electrocution as the person may still be carrying the current (Fig. 10.16). Use a non-conductive material to touch the victim like rubber gloves, wooden stick, etc.

Turn off the power supply

If possible, turn off the power supply. But, one must make sure that one is cautious and takes necessary precautions to avoid getting an electric shock. Move the victim away from near the power source with the help of a non-conductive material like a wooden stick as shown in Fig. 10.17(b).

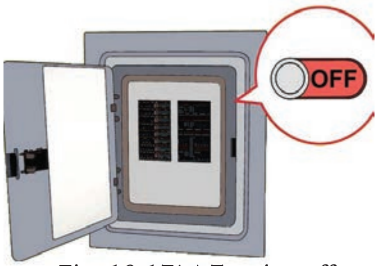

Fig. 10.17(a) Turning off the power supply

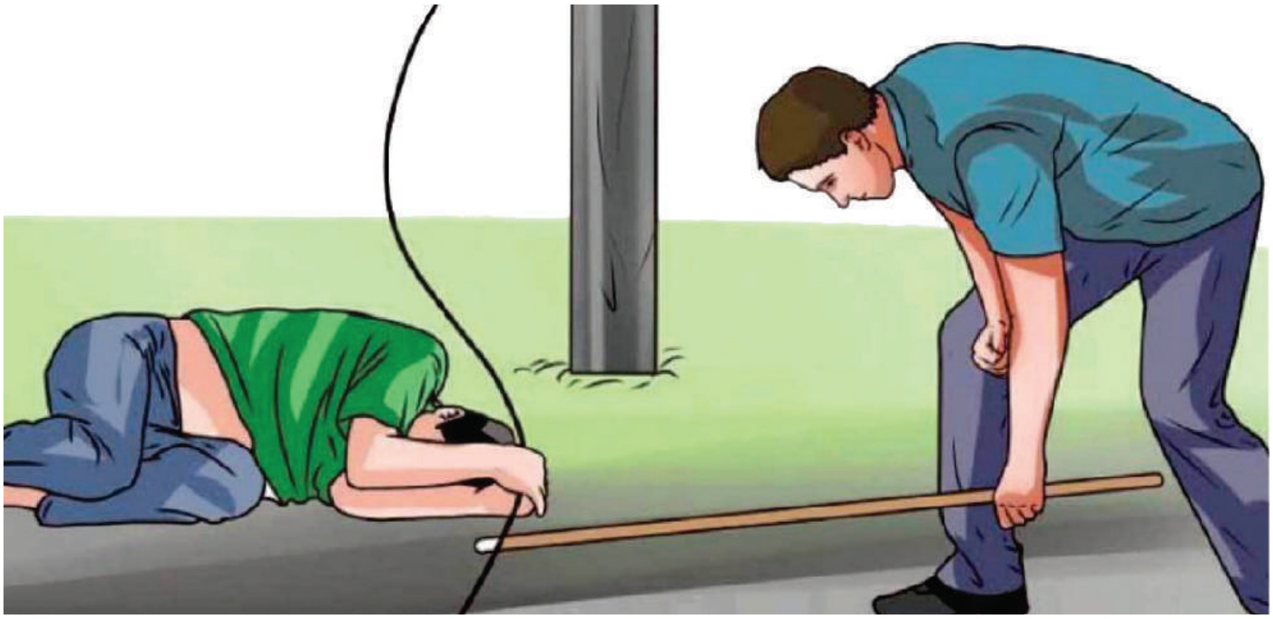

Fig. 10.17(b) Using a wooden stick to move away a live wire from a victim

Fire extinguisher

Often used in emergency situations, a fire extinguisher is an equipment used to extinguish or control small fire. It is a cylindrical pressure vessel, containing an agent, which can be discharged to cease or control fire. The equipment must always be available in areas involving work with electrical equipment. The extinguishers used to douse electrical fires are labeled as class 'C', 'BC' or 'ABC'. Fig. 10.18 shows the parts of a fire extinguisher.

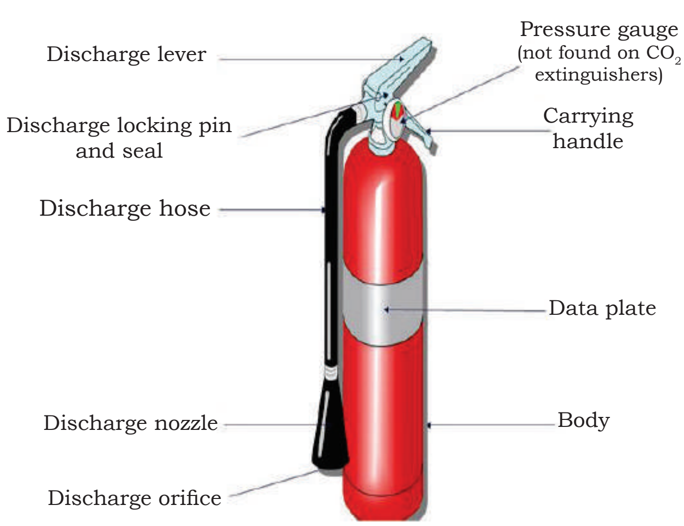

Fig.10.18 Fire extinguisher

The steps to operate a fire extinguisher in case of an emergency has been shown in Fig. 10.19.

Step 1	Identify the safety pin of the fire extinguisher, which is, generally, present in its handle.
Step 2	Break the seal and pull the safety pin from the handle.
Step 3	Use the fire extinguisher by squeezing the lever.

Fig. 10.19 Steps to open the seal and safety pin

The steps to use a fire extinguisher can easily be memorised by the word PASS as shown in Fig. 10.20.

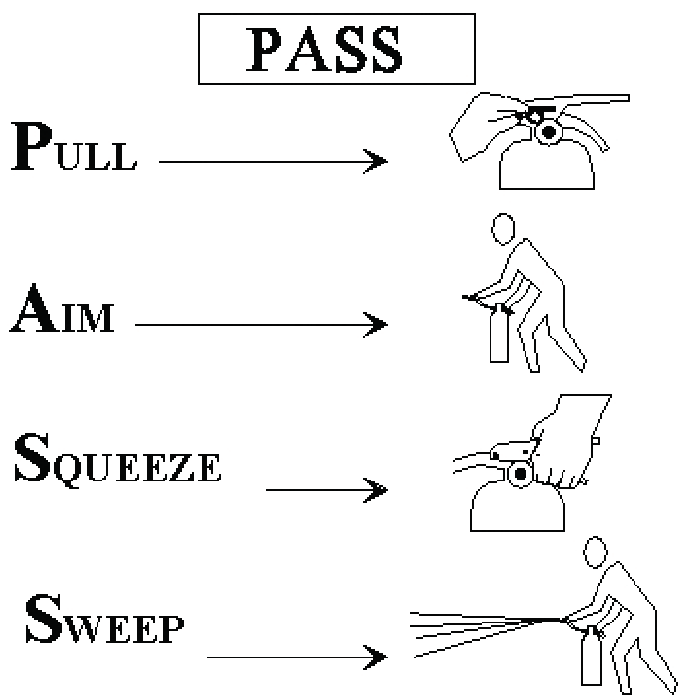

Fig. 10.20 Steps to use a fire extinguisher

Precautions

One must follow some safety or precautionary measures to ensure that the work area is safe. Some of the precautions that one must follow while working include the following.

- Observe if there is a risk of fire in or near the work area.
- Be alert and keep the work area free from untidy things so that if a fire breaks out, it can be easily noticed, and hence, controlled.
- Ensure that all exit gates are clear and easily accessible during emergency evacuation.
- Observe and immediately report, if any fire-fighting equipment, such as a sand bucket or fire extinguisher is missing or not working.
- Ensure that all safety equipment are maintained. Cases of negligence must be reported immediately.
- Ensure that people do not smoke near electrical equipment or machinery or any other material, which may catch fire easily.

First aid

First aid is of prime importance in the event of an accident. Hence, everybody must have the knowledge of the basic first aid practices, which may include the following.

- Bring the affected person to a noise-free, less crowded and open place. Ensure that the person does not feel suffocated.
- Keep the affected body parts of the victim in straight position and lay down the person on the spot, if required.
- In case of head injury, lay down the person in a way that the head rests in an upward position.
- If the victim is having trouble in breathing, then the person must be kept in sitting position.
- If the victim is in an epileptic condition, then lay the person down ensuring that the head is below the level of the body.

NOTES

Fig. 10.21 Basic first aid kit

- If the victim has wounds, then take water in a small bucket and add four drops of iodine to it to make it anti-bacterial. Now, wash the wounds neatly and carefully, and allow it to dry. Then, apply iodine on the wounds and wrap them with medicated or anti-bacterial cotton.

Note: In case of an emergency, try to remain calm. A person can act effectively with calmness.

The following medicines or items must be kept in the first aid box.

- Dressing cotton
- Yellow or dressing pad for burn injuries
- Clean and sterilised cotton pads
- Tincture iodine
- Potassium permanganate
- Adhesive plaster
- Eye drops
- Boric powder
- Tourniquet
- Three-angle bandage (in case of broken bone)

- Safety pins
- Soda-bi-carbon
- 2 or 3 wooden plaques
- Aspirin tablets
- Bottle of antiseptic liquid
- Bottle of spirit
- Scissor, knife, etc.

NOTES

Types of injury

Workplace injuries can occur in all kinds of work environment. Some of the injuries are as follows.

Bleeding

There can be four types of bleeding through injuries, which are as follows.

- Minor bleeding
- Bleeding through the arteries or main blood circulatory system
- Bleeding from the veins
- Internal bleeding

In case of minor bleeding or bleeding from the veins, tightly wrap the body part above and below the wound for the bleeding to stop. Internal bleeding, such as in stomach, from brain or lungs, etc., cannot be seen. However, it can be seen in the vomit or spit of the injured person. Internal bleeding is dangerous as compared to external bleeding. In such a situation, give the injured person cold water or ice and arrange for immediate medical help. Excessive bleeding after injury may even cause death. Hence, medical help must be arranged without delay.

Bone injury

In case of accidents, sometimes the bones of the body may break, and the tip of the broken part may be visible in the wound. In such cases, first try to stop bleeding without touching the wounded part. Wrap the broken body part by resting it on wooden plank and take the injured person to a hospital as soon as possible.

Fig. 10.22 Monitoring the breathing of an unconscious person

If the bones of legs are broken, then the injured person must be taken on a stretcher.

Unconsciousness

If the person loses consciousness, open the airway and monitor the person's breathing. If breathing becomes difficult, call other people for help to admit the person to a hospital immediately. Put your hands over the person's ears to keep the head aligned. Roll the victim over gently, making sure that you keep the neck and back aligned at all times, joining the hands of all team members like a stretcher.

Fig. 10.23 Burn injury

Burns

Severe burns may affect all layers of the skin or cover a large area of the body (Fig. 10.23). The aim of first aid treatment for severe burns is to cool the affected area rapidly with cold water, placing cold wet towels on the area, or applying cooling lotions to reduce the burning sensation, prevent loss of body fluids and other damages. Try to reduce the pain and injury using first aid as any negligence may harm the tissues and internal body parts. If the person is injured on a larger part of the body, the person must immediately be shifted to the hospital.

If the person's clothing catches fire, immediately bring the victim to the ground and use a blanket, rug or coat to douse the flames. Immerse the burnt part of the person's body in cool water or cover it with cold wet towels for at least 10 minutes. If the burn injuries are due to acid action, then the wound must be washed and cleaned with baking soda water. If the burn injury is caused due to carbolic acid, it must be cleaned and washed with spirit.

Tips

- Do not apply any ointment on the burns unless recommended by a doctor.

- Do not touch the burns or burst the blisters.
- Do not put ice on the burnt part.
- Do not apply iodine on such wounds.

Electrocution

When a worker is electrocuted, the following measures must be taken.

- First disconnect the power supply. If possible, send someone for disconnecting the supply.
- If the person is in contact with a live wire or a faulty equipment, one must not touch the victim with bare hands even if one is standing on a wooden plank as current may pass through the victim's body and the moisture present in the wooden plank may cause electric shock to the rescuer as well.
- If the person comes in contact with a low-tension transmission line, then the rescuer must wear rubber gumboots and gloves while carrying out the rescue work. If electric shock is due to high-tension transmission line, then the safety gear used for separation must have the capacity to resist high voltage. In case, appropriate safety gear is not available, do not touch the victim. However, confirm that the things used for such operations are dry and insulated.
- After removing or isolating the electrocuted person from live wire or equipment, first loosen the person's clothes. Remove material, such as tobacco, betel nuts or artificial teeth from the victim's mouth. If the respiration system has failed, try to give artificial respiration immediately to the person.
- If the electrocuted person becomes unconscious, do not give any drink, water, etc., to the person.
- Apply ointments like Burnol or Soframycin on the burnt area and put on a bandage. The wound must not come in contact of air.
- Keep the person warm by wrapping a blanket or coat. If possible, both the feet of the victim should be kept in warm water.

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Notes

After the person gains consciousness, do the following things.

- Call the doctor immediately and continue with artificial respiration.
- Offer adequate water mixed with sodium bicarbonate to the electrocuted person.
- Give the victim salt to inhale.
- If the victim's throat is injured or the person has pain in the throat, no drink or water must be given unless advised by the doctor.
- If the person passes urine, keep the urine sample for pathological tests.
- Do not do anything, which can cause mental or physical stress to the person till doctor is available.
- If the person becomes normal, allow the person some rest.

Tips

In case of electrocution:

- take remedial measures immediately without any delay.
- a delay may even cause the death of the victim.
- timely aid and remedial measures may save the life of an electrocuted person.
- the heart muscles remain alive for up to half-an hour. Hence, artificial respiration may help save the life of the person.
- continue artificial respiration till doctor or medical help arrives.

Artificial respiration (cardiopulmonary resuscitation)

Artificial respiration is given when a person's respiration fails. These are some of the methods used for giving artificial respiration.

Mouth-to-mouth method

In this method, stand up near the head of the electrocuted person or sit on your knees. The person's head must be kept in downward position by pushing it with one hand, and with the other hand lift the person's lower jaw. Take a deep breath and keep your open mouth onto the mouth of the electrocuted person. Close both the nostrils of the person with one hand and exhale. Observe whether the chest of the person expands or not (Fig.10.24).

Fig. 10.24 Mouth-to-mouth respiration

Keep your mouth away and again inhale. Repeat the procedure as mentioned above. Try to repeat such artificial respiration for 10 to 12 times in a minute. If there is some difficulty in doing so, try to push the person's head and again pull the lower jaw. If you again find it difficult to give this treatment, see whether the lips of the person are open and try to see if the teeth are jammed. If so, then use mouth-to-nose method.

Mouth-to-nose method

In case giving mouth-to-mouth respiration is difficult, try mouth-to-nose method. In this process, stand near the head of the person or sit on your knees. Push the victim's head downwards and pull up the lower jaw. Then, take a deep breath. Put one hand on the forehead of the electrocuted person, and with the other hand, close the mouth of the person tightly and exhale through the mouth into the nose of person slowly so that air enters the person's lungs. See if the chest expands. The same procedure must be repeated 10 to 12 times in a minute (Fig. 10.25).

When the person starts breathing on one's own, give this breathing in a synchronous way and see if the chest expands. When the person comes to a comfortable position, allow the person some rest. Put the person on a stretcher and observe if there is any difficulty in respiration. The person's body must be wrapped in a blanket and kept warm. The person who fell unconscious due to electric shock may even get immediate cardiac problem. Thus, every worker must know this method and try to get training in carrying out the procedure.

Fig.10.25 Mouth-to-nose respiration

NOTES

Tips

1. If mouth-to-nose respiration is done, air will travel slowly to the electrocuted person's lungs. In case, the nose of the electrocuted person is very narrow, then the system of mouth-to-mouth should be preferred.
2. If it is observed that the throat of the person is very narrow or clogged, then it must be cleaned.
3. In case, the teeth of the person are jammed, then use the mouth-to-nose method.
4. If possible, keep a thin handkerchief on the mouth of the person for mouth-to-mouth procedure.
5. For infant or young children, blow air from your mouth. At least 20 times per minute respiration is required.
6. In case the victim is in contact with an electric pole and artificial respiration has to be given, one must first safeguard oneself from the live parts and also avoid coming in contact with the victim. One must stand carefully on the pole by using a safety belt so that one is able to place the mouth onto the mouth or nose of the electrocuted person.

Holger Nelson method

In this procedure, first lay down the person in a downward position and keep the person's hands at the back in crossed position. Keep the neck on one side and apply light pressure. Keep your right knee near the head of the person and feet near the person's elbow. Put your palms on the back of the affected person in such a way that the thumbs of both your hands rest on the backbone of the person. Then, start giving light pressure with both the palms on the back of the affected person. Keep this position for 2–5 seconds, and then, start releasing the pressure slowly from the back. Now, hold the arms of the person, and put the person's hands in upward position and pull them forward. The procedure must be repeated 10 to 12 times per minute till the person starts breathing on one's own.

Schaefer's method

Fig.10.26 (a) Exhalation

Fig. 10.26 (a and b) Schaefer's respiration method

In this method, lay down the injured person in such a way that the stomach is in contact with the surface. Put pillow or clothes below the person's head. Now, slowly turn the person's head in either right or left direction. The rescuer must sit down on one's knees in crossed-legged position so that the person covers the victim. Next, the rescuer must put both the thumbs on the back side of the injured person. The rescuer must place the other fingers on the back side of the victim's forearm from both the side and apply constant pressure on the back. Then, the pressure must be relased. One must do this step 15 times per minute. This leads to the expansion and contraction of lung muscles of the victim, which helps ensure continuous respiration. One thing that must be followed is that pressure must be given slowly to ensure inhaling and exhaling action in the victim. The amount of pressure must be synchronised with the breathing of the affected person. This procedure must be continued until the victim starts breathing on one's own. This exercise may take half-an-hour or more. The pressure needs to be of 20–25 pounds for adult males, 10–15 pounds for adult females and children.

Sylverester's method

Lay down the electrocuted person in upward position. Loosen the clothes on the person's chest and stomach. A pillow must be placed below the person's shoulder in such a way that the neck and head of the affected person are in downward position. Then, pull out the victim's tongue. The person administering the treatment must sit on the knees near the affected person. Keep the hands of the person below the elbow and pull the victim's hands till they become parallel to the earth. This treatment must be given for 3 seconds. After that, bring both the hands of the person below the chest and press the chest lightly. This action must be done for 2 seconds. The procedure must be repeated 10 to 12 times per minute. In this system, since the head of the affected person remains in upward position, the effect of artificial respiration can be seen immediately.

Tips

For men, give 20 to 25 pound pressure for 10 to 12 times. In case of women and children, the pressure should be 10 to 15 pounds for 10 to 12 times per minute. For very young children or infants, a pressure of 10–15 pounds should be 15 times per minute. This procedure should be continued till the affected person starts breathing.

Electrical emergencies

Electrical accidents cause countless injuries and claim many lives every year. Fig. 10.27 shows some of the impacts of electrical accidents

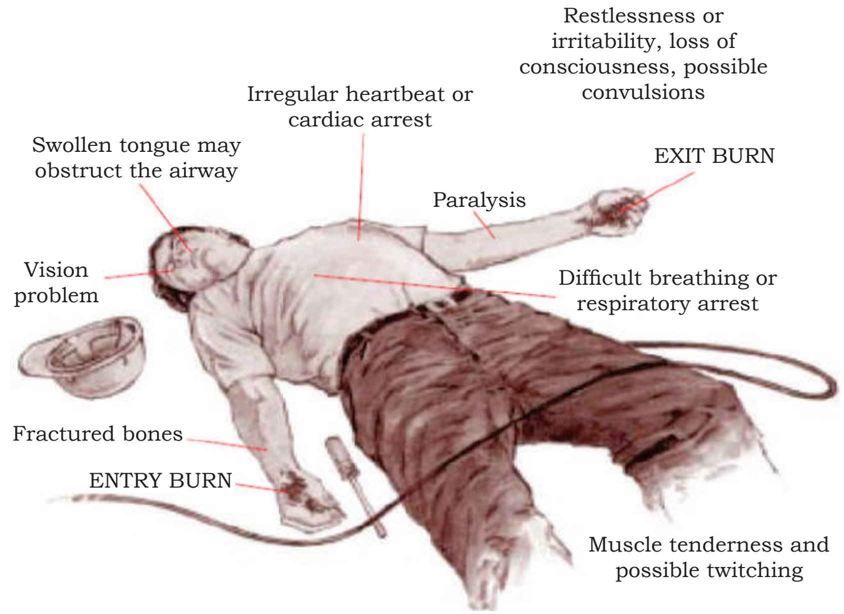

Fig.10.27 Health problems a worker suffers from after an electrical injury

The injuries could be minimised and many lives could be saved if appropriate rescue techniques and treatments are practised. Electrical accidents may occur at any time or place. Timely response and treatment of victims is a major concern. One must be able to judge the electrical emergency and the type of treatment that needs to be given to the victim. Do you know the actions to take? Do you know what dangers could be encountered? When an electrical accident occurs due to muscle clamp, a victim is often incapable of moving or releasing the electrical conductor. Attempts to rescue the victim may pose a hazard for the rescuer as well. Caution must be a primary consideration in case of an electrical accident or emergency. There must always be an emergency response plan for scheduled electrical maintenance or work.

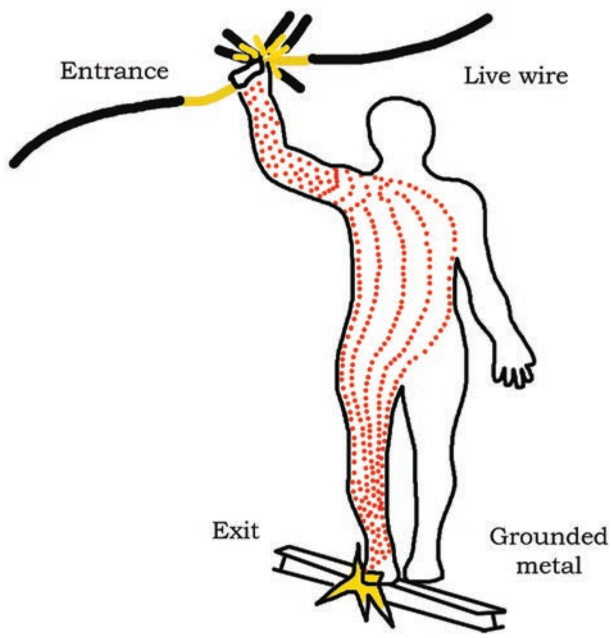

Fig. 10.28 Effects of electric current on human body

Rescue techniques

Approaching the accident

- Never rush to an accident situation.
- Get help of a trained electrical personnel, if possible.
- Approach the accident scene cautiously.

Examining the scene

- Visually examine victims to find out if they are in contact with energised conductors.
- Metal surfaces or objects near the victim or the earth itself may be energised.
- A person may get an electric shock, if one touches an energised victim or conductive surface. Therefore, do not touch the victim or conductive surfaces while they are energised.
- Stand on a dry rubber blanket or other insulating material.
- Do not touch the victim or conductive material near the victim until the power is turned off.
- Once power is off, examine the victim to determine if the person needs to be moved. Provide necessary first aid.


Fig. 10.29 Risk of electric shock in the control panel

NOTES

Methods to de-energise

- De-energise electrical circuits as soon as possible.
- An extension or power cord probably powers portable electrical equipment. Unplug portable electrical equipment to stop the power supply.
- Open a disconnecting device or circuit breaker to de-energise fixed electrical equipment.

Hazards and solutions

- Be alert for hazards, such as stored energy, heated surfaces and fire.
- If one is unable to de-energise the power source, one must be careful while on the job.
- One must ensure that the hands and feet are dry.
- Wear personal protective equipment, such as rubber gloves and rubber shoes. Stand on a clean dry non-conductive surface.
- Use non-conductive material to rescue the victim in contact with a conductor.

High-voltage rescue

- Special training is required for carrying out rescue work if high-voltage is present.
- Protective equipment, such as rubber gloves and rubber shoes must be worn.
- use special insulated tools.

Insulated tools

- Insulated tools, with high-voltage ratings, are a lifesaver.
- Use devices, such as hot or shotgun sticks to remove the victim from energised conductors.
- In some cases, non-conductive rope or cord may be used to remove the victim from a conductor.

Check Your Progress

A. Multiple choice questions

1. Which of the following is not a type of artificial respiration?
   (a) Mouth-to-mouth
   (b) Mouth-to-nose

(c) Silverester's method
(d) Clear breathing

2. Which of the following human organs is the most affected from an electric shock?
(a) Nervous system
(b) Heart
(c) Kidney
(d) Stomach

3. In case of an electric shock, an unconscious man must be given ____________ pressure for 10 to 12 times.
(a) 20 to 25 pound
(b) 15 to 25 pound
(c) 10 to 15 pound
(d) 25 to 30 pound

4. In case of an electric shock, an unconscious woman or child must be given __________ pressure for 10 to 12 times per minute.
(a) 20 to 25 pounds
(b) 15 to 20 pounds
(c) 10 to 15 pounds
(d) 5 to 10 pounds

5. Which of the following is used to heal a burn injury in case of electrocution?
(a) Burnol
(b) Soframycin
(c) Both (a) and (b)
(d) None of the above

6. Which of the following is not a type of bleeding?
(a) Minor bleeding
(b) Bleeding through the artery or main blood circulatory system
(c) Bleeding from the veins
(d) External bleeding

7. A first aid box must contain which of the following medicines?
(a) Tincture iodine
(b) Potassium permanganate
(c) Sol-violate spirit
(d) All of the above

8. What is/are the step(s) for using a fire extinguisher?
(a) Identify the safety pin of the fire extinguisher, which is, generally, present in its handle.
(b) Break the seal and pull the safety pin from the handle.
(c) Use the fire extinguisher by pressing the lever.
(d) All of the above

9. When do we use a fire extinguisher?
(a) In case of flood
(b) In case of electric shock
(c) In case of fire
(d) In case of burn injury

Notes

NOTES

10. Which of the following is a safety gear that a wireman must not have while working?
    (a) Safety boots
    (b) Gloves
    (c) Helmet
    (d) Belt
11. Which of the following is a poor conductor of electricity?
    (a) Aluminium
    (b) Copper
    (c) Wood
    (d) Silver
12. Which of the following safety gear is used for protecting the eyes?
    (a) Gloves
    (b) Helmet
    (c) Rubber shoes
    (d) Goggles
13. Which of the following safety gear must be worn while tripping a circuit breaker?
    (a) Gloves
    (b) Helmet
    (c) Rubber shoes
    (d) Goggles
14. Which of the following equipment have a discharge nozzle?
    (a) Control panel
    (b) Fire extinguisher
    (c) MCB
    (d) Switch
15. Which of the following provides the least resistive path for an electric current?
    (a) Earthing
    (b) Resistance
    (c) Capacitor
    (d) Inductor

B. Fill in the blanks

1. While working on electricity, the technician must wear _________ gloves and shoes.
2. Keep stretching the arms, legs, neck and back while working to ensure that they are not _________.
3. Unconsciousness due to electric shock may cause damage to the __________.
4. An electrocuted person must be given adequate water mixed with ____________.
5. If a burn injury is due to __________, it must be cleaned and washed with spirit.
6. In case of electric shock, an infant must be given a pressure of __________.

7. Exhale from the mouth into the nose of a person needing artificial respiration slowly so that air enters the person's _________.
8. One of the causes of electric shock may be due to faulty ____________ of electrical equipment.
9. Defective or inadequate insulation may cause ___________.
10. Faulty current can be transferred to the ground by ___________.
11. While working on a control panel, make sure that power is _________.
12. GFCI stands for Ground ___________ Circuit Interrupter.
13. Copper is a _________ conductor of electricity.
14. Earthing is necessary in ____________ and __________ equipment.
15. Do not touch the electrical panel with ________ hands.

C. State whether the following statements are True or False

1. Fire extinguishers for use on electrical fires will have a C, BC or ABC on the label.
2. Apply Burnol or Soframycin on the burnt body part of an electrocuted person and bandage it.
3. In Silverester's method, give 20 to 25 pound pressure for 10 to 12 times to a female.
4. Artificial respiration is Cardiopulmonary Resuscitation.
5. The body parts of an affected person must be kept straight and the person must be laid down on an uneven surface.
6. Fire extinguisher consists of a hand-held cylindrical pressure vessel, containing an agent, which can be discharged to extinguish a fire.
7. Check the rating and physical condition of the components and cables.
8. The aim of first aid treatment is to cool down the affected area rapidly to minimise damage and loss of body fluids.
9. Rubber is a good conductor of electricity.
10. Fire extinguisher is used in case of an earthquake.

D. Short answer questions

1. What are the factors that result in a hazard?
2. List the various preventive measures that need to be taken care of at a workplace to prevent electric shock.
3. How will you protect yourself from electric shock in a lightning storm?

Notes

NOTES

4. List the various items that a first aid box must contain.
5. What is Sylverester's method?
6. What precautions are required to be taken during mouth-to-nose respiration?
7. How to perform artificial respiration?
8. How will you reduce the risk associated with handling of heavy and hazardous loads?
9. Write the names of different methods of artificial respiration.
10. List the first aid treatment that needs to be given in case of a burn injury.
11. Write down the steps for correct way of operating a fire extinguisher in case of a fire emergency.

Answer Key

Unit 1: Basics of Electricity and Electronics

A. Multiple choice questions

1. (b)	2. (d)	3. (c)	4. (d)	5. (a)
6. (a)	7. (c)	8. (b)	9. (c)	10. (a)
11. (b)	12. (b)	13. (a)	14. (c)	15. (a)
16. (b)	17. (a)	18. (a)	19. (c)	20. (b)

B. Fill in the blanks

1. series	2. parallel
3. work	4. switch
5. positive	6. power
7. Georg Simon Ohm	8. 1000, 3600
9. opening and Closing	10. negative

11. voltage, resistance and resistance, voltage, current.

C. State whether the following statements are True or False

1. F	2. F	3. T	4. F	5. T
6. F	7. F	8. T	9. T	10. T

Unit 2: Electrical and Electronic Components

A. Multiple choice questions

1. (d)	2. (c)	3. (a)	4. (a)	5. (c)
6. (a)	7. (b)	8. (c)	9. (b)	10. (c)
11. (a)	12. (b)	13. (b)	14. (a)	15. (a)
16. (b)	17. (d)	18. (b)	19. (a)	20. (a)
21. (b)	22. (d)	23. (c)	24. (d)	25. (d)
26. (c)	27. (b)	28. (c)	29. (b)	30. (d)
31. (d)				

B. Fill in the blanks

1. AC	2. impure
3. pure	4. electric
5. magnetic	6. two
7. semiconductor	8. three
9. on	10. transistor

C. State whether the following statements are True or False

1. F	2. T	3. T	4. T	5. F
6. F	7. T	8. T	9. T	10. T
11. T	12. F	13. T	14. F	15. F
16. T	17. F	18. T	19. F	20.F

E. Identify the symbols in the table given below

1. Resistor	2. Variable resistor
3. Thermistor	4. Varistor
5. Photo resistor	6. Light Emitting Diode
7. PN-junction diode	8. Bi-polar junction transistor

NOTES

F. Calculate the value for the following

1. 4 ampere
2. 0.33 farad
3. 5 ohm
4. 0.00055 coulomb
5. 176 watt
6. 4840 watt
7. 10 ampere
8. 220V
9. 880 coulomb
10. 20 V

G. Match the columns

1. (f)
2. (d)
3. (b)
4. (a)
5. (c)
6. (e)

Unit 3: Component Value Indentification

A. Multiple choice questions

1. (d)	2. (b)	3.(d)	4. (c)	5. (c)
6. (b)	7.(b)	8. (a)	9. (a)	10.(b)

Unit 4: Electrical Earthing System

A. Multiple choice questions

1. (a)	2. (c)	3. (d)	4. (d)	5. (c)
6. (a)	7. (a)	8. (b)	9. (d)	10. (c)
11. (b)	12. (b)			

B. Fill in the blanks

1. earth resistance
2. lightning arrestor
3. 5 metre
4. 1 feet (30 cm)
5. 0.5m

C. State whether the following statements are True or False

1. T	2. F	3. F	4. F	5. F
6. F	7. F	8. F	9. T	10. T

Unit 5: Cabling

A. Multiple choice questions

1. (c)	2. (c)	3. (a)	4. (a)	5. (b)
6. (a)	7. (c)	8. (b)	9. (c)	10.(b)

B. Fill in the blanks

1. earth
2. phase or line or live
3. neutral
4. single core fibre
5. radio frequency
6. 650 to 1100 volts
7. cross linked polyethylene
8. 50-100
9. light
10. thermoset

C. State whether the following statements are True or False

1.T	2. T	3. T	4. T	5. T
6. F	7. F	8. T	9. F	10. T

Unit 6: Electrical Safety

A. Multiple choice questions

1. (a)	2. (c)	3. (d)	4. (c)	5. (c)
6. (d)	7. (c)	8. (b)	9. (b)	10.(b)

B. Fill in the blanks

1. resistance	2. Miniature Circuit Breaker
3. close	4. conductor
5. Electrostatic Discharge	6. hazards
7. dry	8. stickers
9. respiratory paralysis	10. appropriate gauge

C. State whether the following statements are True or False

1. T	2. T	3. F	4. T	5. T
6. T	7. T	8. T	9. T	10. F

Unit 7: Tools and Equipment

A. Multiple choice questions

1. (d)	2. (a)	3. (b)	4. (c)	5. (a)
6. (d)	7. (b)	8. (d)	9. (a)	10. (c)

B. Fill in the blanks

1. cutting and gripping	2. 3, 48
3. soldering	4. electronic and manual
5. metal glue	6. rollable and rigid
7. neon	8. drill bits
9. current	

C. State whether the following statements are True or False

1. F	2. T	3. T	4. F	5. F
6. T	7. T			

Unit 8: Electromechanical Assembly

A. Multiple choice questions

1. (b)	2. (a)	3. (c)	4. (b)	5. (c)
6. (a)	7. (a)	8. (b)	9. (a)	10.(d)

B. Fill in the blanks

1. connections	2. electromechanical
3. shielded twisted pair	4. bending
5. electrical	6. electrostatic discharge
7. amperage	8. Logic
9. faulty wires	10. label

C. State whether the following statements are True or False

1. F	2. T	3. T	4. F	5. T
6. T	7. T	8. T	9. T	10. T

NOTES

NOTES

Unit 9: Wire Preparation Methods

A. Multiple choice questions

1. (a)	2. (b)	3. (c)	4. (b)	5. (b)
6. (d)	7. (d)	8. (a)	9. (a)	10. (d)

B. Fill in the blanks

1. stripper	2. lugs
3. hydraulic crimping tool	4. aluminium and copper
5. strip	6. outer sheath
7. notch	8. crimping
9. grouping	10. solderless

C. State whether the following statements are True or False

1. T	2. F	3. T	4. T	5. T
6. F	7. T	8. T	9. T	10. F

Unit 10: Hazards with Panel Assembly and Wiring

A. Multiple choice questions

1. (d)	2. (b)	3. (a)	4. (c)	5. (c)
6. (d)	7. (d)	8. (d)	9. (c)	10.(d)
11. (c)	12. (d)	13. (a)	14. (b)	15. (a)

B. Fill in the blanks

1. rubber	2. strained
3. heart	4. Sodium bicarbonate
5. Carbolic acid	6. 10–15 times per minute
7. lungs	8. grounding
9. electric shocks	10. earthing
11. off	12. Fault
13. good	14. electrical, electronic
15. wet	

C. State whether the following statements are True or False

1. T	2. T	3. F	4. T	5. F
6. T	7. T	8. T	9. F	10. F

Glossary

Access control: *It refers to regulating the flow of people through an entry and exit door.*

Actuator: *It is a component of a machine that is responsible for moving and controlling a mechanism or system.*

Air spaced PE: *It refers to a coaxial cable that uses air injected into plastic as a dielectric spacer between conductors. It is also known as 'foam dielectric'.*

Alloy: *It is a metal formed by mixing two or more metals together or by mixing metal with another substance. For example, brass is an alloy of copper and zinc.*

Alternating Current (AC): *It refers to an electric current that reverses direction at regular intervals. The abbreviation AC is commonly used.*

Aluminium conductor: *It is a part of a wire, which carries electric current.*

Ampacity: *It refers to the maximum current, in amperes, that a wire can carry safely without over heating.*

Amperage: *It refers to the strength of an electrical current. It is measured in amperes.*

Ampere (amp): *Named after Andre-Marie Ampere, it is a unit used to measure electric current.*

Ampere/hour (AH): *It is the measurement of a battery's capacity. One ampere of current flowing for one hour equals one ampere/hour.*

Amplitude: *It is the maximum absolute value reached by a voltage or current waveform.*

Anode: *It is the positively charged electrode by which electrons leave an electrical device.*

Arc blast: *It occurs from high-amperage currents arcing through air. This abnormal current flow is initiated by contact between two energised points.*

Arcing: *It refers to luminous electrical discharge or electrical sparking through the air that occurs when high voltages exist across a gap between conductors.*

Armour: *Generally, placed over the outer sheath, it is an outer braid of metal or spiral steel tapes, primarily, for the purpose of mechanical protection.*

Bandwidth: *It is the range or band of frequencies that an electronic signal uses on a given transmission medium. Bandwidth is expressed in terms of the difference between the highest and lowest frequency signal components.*

Bare conductor: *Such a conductor is not covered with an insulating material.*

Battery: *It is an electrochemical cell that can be charged electrically to provide static potential for power or released electrical charged*

Notes

when needed. A battery consists of an anode, a cathode and electrolyte. It is used for powering devices, such as flashlights, mobile phones and electric cars.

Breather: *It is a device present in a transformer to filter out moisture. A breather consists of silica gel, which absorbs moisture from air.*

Bend cable: *It refers to two or more cables, which have been joined together by stainless steel strapping.*

Bend radius: *The radius of curvature that determines how tightly a cable can bend without damaging its electrical performance.*

Bending loss: *It is a loss that takes place in a fibre optic system caused by the bending of cable.*

Biasing: *It is the method of establishing predetermined voltages and currents at various points in a circuit to set the appropriate operating point.*

Bipolar: *It relates to a device capable of using two polarisations, such as a transistor that uses positive and negative charge carriers.*

Block diagram: *It is a diagram that shows the relationship between various devices in a system. Blocks used to represent each piece of equipment are arranged in a system diagram that shows their physical or operational relation with each other.*

Bonding: *It refers to the joining of electrical parts to assure a conductive path.*

Bonding jumper: *It is a reliable conductor that ensures the required electrical conductivity between metal raceways, which is required to be electrically connected.*

Boring tool: *This tool is used for drilling and boring. They are used to make holes in material like wood.*

Braid: *It refers to a group of small wire strands interwoven to form a cylinder surrounding a dielectric.*

Braid coverage: *It refers to the braided filament cover in the inner part of a cable. Tighter mesh material offer a higher percentage of coverage.*

Breadboard: *It is a thin plastic board full of holes that is used to hold components wired together. It is commonly used for prototyping and experimenting with circuit designs.*

Breakdown (puncture): *It refers to a disruptive discharge through insulation.*

Bridge rectifier: *It is a rectifier with four elements connected as a bridge circuit with direct voltage secured from one pair of opposite junctions when alternating voltage is applied to the other pair.*

Burns: *These are caused when a person touches an electrical wire or equipment that is not installed correctly or is ill-maintained. Burn injuries caused by electricity, typically, occur on the hands.*

Buzzer: *It is an electric signalling device that produces a buzzing sound as a signal.*

Cable: *Alternatively referred to as a cord, connector or plug, a cable consists of one or more wires covered with plastic. A cable transmits power or data to devices or locations.*

Cable attenuation: *Expressed in decibels (dBs), it is the loss or reduction in signal strength. Attenuation is a naturally occurring effect when transmitting signals over distance.*

Cable core: *It is the portion of an insulated cable lying under a protective covering or jacket. It contains the conductor part of a cable.*

Cable sheath: *It is used to help bundle several conductors together if a cable consists of multiple wires.*

Capacitor: *It is a device used in electrical circuits. A capacitor stores an electrical charge for a short duration, and then, returns it to the circuit. Common types of capacitor includes tantalum, electrolytic, ceramic and film capacitors.*

Capacitance: *It is the property of a capacitor to hold charge. It is measured in Farad.*

Cathode: *A cathode is a type of electrode through which electrons move.*

Central conductor: *It is a wire in the centre of a coaxial cable, the diameter of which is based on the American Wire Gauge (AWG), a standardised gauge system.*

Ceramic capacitor: *It is a capacitor made of alternating layers of metal and ceramic, with the ceramic material acting as the dielectric.*

Channel lock pliers: *These are used for grabbing and pinching things. Their gripping jaws provide a strong grip on an object. They are made of high-carbon steel.*

Circuit breaker: *It is a device that protects an electrical circuit from damage caused by excess current due to overload or short circuit. It automatically stops electric current if it becomes dangerous.*

Circuit: *It is a complete path of wires and equipment along which electric current flows.*

Closed circuit: *It is an electric circuit that provides an uninterrupted path for the flow of current.*

Closed position: *Relating to switches, it is a position in which current can flow.*

CMOS: *It is the abbreviation for Complementary Metal Oxide Semiconductor. It is a class of integrated circuits.*

Coaxial adapter: *It is a connector used to join a coaxial cable to different cables.*

Coaxial cable: *Also called coax cable, it is a type of electrical cable that has an inner conductor surrounded by a tubular insulating layer, which is further surrounded by a tubular conducting shield. Many coaxial cables also have an insulating outer sheath or jacket.*

Coaxial connector: *It is a connector used to join two coaxial cables.*

Notes

NOTES

Coil: *It refers to a series of circles formed by the winding of an insulated wire, which creates a magnetic field when electric current passes through the circles.*

Colour code: *Colour code is used for purposes of identification of wires in a multi-conductor cable.*

Composite cable: *It is a cable consisting of two or more types or sizes of wire or cable.*

Conductor: *It is a substance that allows electricity or heat to pass through it.*

Conduit: *It is a pipe, channel, tube or trough for protecting electrical wires or cables from environmental effects.*

Connector: *It is a device that joins two or more conductors and terminals of equipment.*

Continuity: *Such a situation is established when a complete path for current exists.*

Control box: *It is a metal sheet enclosure that contains electronic and electromechanical controls and circuit.*

CPR: *Abbreviation for Cardiopulmonary Resuscitation, it refers to an emergency procedure that involves giving artificial breathing and heart massage to someone who is not breathing or does not have a pulse.*

Critical resistance value: *It refers to the maximum nominal resistance value at which a rated power can be loaded without exceeding the maximum working voltage. The rated voltage is equal to the maximum working voltage in critical resistance value.*

Current: *It is the amount of electric charge flowing through a wire at a specified point of circuit in one second. It is represented by the symbol 'I'.*

De-energise: *It is the process of shutting down the energy sources to circuits and equipment and depleting any stored energy.*

Desoldering tools: *These tools are used to remove soldered wires and components on printed circuit boards for repair and troubleshooting, usually, when there is a fault in the connections.*

Dielectric: *It is an insulating or non-conducting material between outer and inner conductors in a coaxial cable.*

Dielectric withstanding voltage: *It refers to the rated voltage that can be applied to a designated point between a resistive element and the outer coating, or the resistive element and the mounting surface without causing dielectric breakdown.*

Diode: *It is an electronic device, in which electric current passes in one direction only, e.g., silicon chip.*

Direct current (DC): *It refers to electric current flowing in one direction only (i.e., current produced using a battery). The abbreviated form DC is commonly used.*

Double Pole Double Throw switch (DPDT): *It is a switch that has two inputs and four outputs. Each input has two corresponding outputs.*

Double Pole Single Throw switch (DPST): *It is a four-terminal switch or relay contact arrangement that simultaneously opens or closes two separate circuits or both sides of the same circuit (two input and two output).*

Dual In-line Package (DIP): *In microelectronics, a Dual In-line Package (DIP or DIL) or Dual In-line Pin Package (DIPP) is an electronic component package with a rectangular housing and two parallel rows of electrical connecting pins.*

Duty cycle: *It is the percentage of time or operating time of a device. For example, a device that is ON for one minute and OFF for nine minutes, it is operating at a 10 per cent duty cycle.*

Earth continuity conductor: *It is a conductor wire connected with different electrical devices and appliances like distribution board, plugs, etc. Hence, the wire between earthing lead and electrical device or appliance is called 'earth continuity conductor'. It may be in the shape of a metal pipe (fully or partial), cable metallic sheath or flexible wire.*

Earth electrode: *When a conductor or conductive plate is buried in the earth for electrical earthing system, it is known as an 'earth electrode'. Earth electrodes come in different shapes like conductive plate, conductive rod, metal water pipe or any other conductor with low resistance.*

Earth resistance: *This is the total resistance between earth electrode and earth (measured in Ohms). Earth resistance is the algebraic sum of the resistances of earth continuity conductor, earthing lead, earth electrode and earth.*

Earth: *It is the connection between electrical installation systems via a conductor to the buried plate in the ground.*

Earthed: *When an electrical device, appliance or wiring system is connected to the earth through earth electrode, it is known as earthed device or 'earthed'.*

Earthing lead: *It refers to a conductor wire or conductive strip connected between earth electrode, electrical installation system and devices.*

Electricity: *It is a form of energy produced from charged elementary particles, usually, supplied as electric current through cables, wires, etc., for lighting, heating, driving machines, etc.*

Electrolytic capacitors: *It is a polarised capacitor, whose anode or positive plate is made of a metal that forms an insulating oxide layer through anodisation. This oxide layer acts as a dielectric of the capacitor.*

Electromagnet: *It is a coil of wire, usually, wound on an iron core, which produces a strong magnetic field when current is passed through the coil.*

NOTES

Notes

Electromagnetic Interference (EMI): *Also called Radio Frequency Interference (RFI) when in the radio frequency spectrum, it is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling or conduction.*

Electromechanical: *It indicates conversion of an electrical signal to mechanical movements and vice versa.*

Electromechanical assembly: *It combines both electrical and mechanical components, and sometimes, electronic components as well.*

Electromotive force (EMF): *It is the measurement of energy that causes current to flow through a circuit. It can also be defined as the potential difference in charge between two points in a circuit.*

Electron: *It is a negatively charged subatomic particle. It can be either free (not attached to an atom) or bound to the nucleus of an atom.*

Energised: *It is defined as the presence of energy in a circuit, equipment, device or component.*

Energy meter: *Also called an electricity, electric or electrical meter, it is a device that measures the amount of electric energy consumed by a house, business or device.*

Electric starter: *It is a device that controls the use of electrical power in an equipment, usually, a motor. As the name suggests, an electric starter starts the motor and can also stop, reverse and protect it from technical glitch.*

Electrostatic discharge: *It is a form of current that is left within an insulating body after the power source is removed.*

Farad: *Represented by (F), Farad is the SI derived unit of electrical capacitance, which refers to the ability of a body to store an electrical charge. It is named after the English physicist Michael Faraday.*

Fault current: *It refers to current that does not travel in its intended path.*

Ferrite core: *It is a type of magnetic core made of ferrite, on which the windings of electric transformers and other wound components, such as inductors are formed.*

Filled cable: *In telecommunication, a filled cable is a cable that has gel or oil inside the jacket or sheath.*

Fixed wiring: *Such a wiring is permanently installed in homes and other buildings.*

Flexible wiring: *These are electrical cables, especially designed to cope with the tight bending radii and physical stress associated with moving applications, such as inside cable carriers.*

Frequency: *It is the rate at which a sound or electromagnetic wave vibrates per unit of time. It is expressed in Hertz (Hz).*

Fuse: *It is a small wire or device inside a piece of electrical equipment that breaks or stops the current if the flow of electricity is too strong.*

Notes

Gain: *Also called 'amplification', it refers to an increase in signal power, voltage or current by an amplifier, expressed as the ratio of output to input.*

Gauge: *It denotes the physical size of a wire.*

Germanium: *It is a chemical element with the symbol 'Ge' and atomic number 32. It is a lustrous, hard, brittle and greyish-white metalloid.*

Ground fault: *It refers to inadvertent contact between an energised conductor and ground or equipment frame.*

Ground potential: *It refers to the potential of earth, which is used in circuit parameter calculation.*

Ground Fault Circuit Interrupter (GFCI): *Also called Residual Current Device (RCD), it is a type of circuit breaker, which shuts off electric power supply when it senses imbalance between outgoing and incoming current.*

Grounding: *Also known as 'earthing', it is the process of passing fault current from an equipment into the earth surface.*

Heat sink: *It is a passive heat exchanger that transfers heat generated by an electronic or mechanical device to a fluid medium, air or some liquid coolant, allowing regulation of the device's temperature.*

Hertz (Hz): *It is the unit to measure the frequency of sound waves.*

High pass filter: *It refers to a filter that blocks low frequencies and allows high frequencies to pass through.*

High-tension wire: *It is a wire used for transmitting electrical energy having high voltage over long distances. High-tension wires need to be of low resistance so as to minimise heat loss and withstand high voltages.*

IC: *It is the abbreviation for Integrated Circuit. It is a microscopic array of electronic circuits diffused or implanted onto the surface of a single chip of semiconducting material, such as silicon.*

IEC: *It is the abbreviation for International Electrotechnical Commission, similar to International Standards Organization (ISO).*

IEEE: *It is abbreviated form of the Institute of Electrical and Electronic Engineers.*

Impedance: *It is the measurement of total resistance of a piece of electrical equipment, etc., to the flow of an alternating current, arising from the combined effects of Ohmic resistance and reactance. It is represented by the symbol 'Z'.*

Inductance: *It refers to the property of an electric conductor or circuit that causes an electromotive force to be generated by a change in the current flowing.*

Inductor: *Also called coil, choke or reactor, it is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor, typically, consists of an insulated wire wound onto a coil around a core.*

NOTES

Infrared (LEDs): *Also called infrared light emitting diode, it is a solid state lighting (SSL) device that emits light in the infrared range of electromagnetic radiation spectrum. Infrared LEDs allow for cheap and efficient production of infrared light, which is electromagnetic radiation in 700 nm to 1 mm range.*

Insertion loss: *It is the loss of power signal due to the insertion of a device in a transmission line or optical fibre. It is expressed in decibels (dB).*

Insulation: *It refers to the act of protecting something with a material that prevents heat, sound or electricity from passing through. It is used for protecting wire, cable and tools.*

Insulator: *It s a material or device used to prevent heat, electricity or sound from escaping something. In other words, it is a material whose internal electric charges do not flow freely. Little electric current will flow through it under the influence of an electric field. This is opposite to other material, semiconductors and conductors, which conduct electric current easily.*

Inverter: *It is a device used to convert direct current into alternating current. It is also a type of logic gate with a single input.*

Isolation: *It refers to a condition where there is no electrical connection between two or more circuits.*

Jacket: *It is an insulating layer made of plastic or rubber covering a cable or bundle of wires.*

Jumper: *It refers to an electrical wire or group of wires in a cable, with a connector or pin at each end.*

Junction: *It is a point in a circuit, where two or more wires are connected.*

Junction box: *It is a protective enclosure for connecting circuitwires.*

K Ohm: *It is the symbol for one thousand ohms.*

Kilowatt-hour: *It is used to measure electrical energy equivalent to power consumption of one thousand watt for one hour.*

Lamp: *It is a glass bulb or tube that emits light produced by electricity (such as incandescent light bulb or fluorescent lamp).*

Leakage current: *It is a current that does not return through the intended path but, instead, 'leaks' into the ground.*

Live circuit: *It is a circuit with applied voltage.*

Load: *It refers to electrical power consumed by a device.*

Loop resistance: *Consider a cable having two conductors. Strip both the ends of the cable. After stripping, there are two conductor terminals at each side of the cable. Take any one end and twist it together with the two stripped conductors. Measure the resistance of both the wires by connecting the remaining two terminals with the multimeter. This resistance value is called loop resistance.*

Low pass filter: *It is a filter designed to transmit electromagnetic frequencies below a certain value, while excluding those of a higher frequency.*

Lumen: *It is the unit of luminous flux. It is represented by the abbreviation 'lm'. It is used to measure the total visible light emitted by a source per second.*

Maximum overload voltage: *It is the maximum voltage that the insulation strength or internal construction of a component can stand. It comes into consideration for components that have high rating. So, their wattage or dissipation ratings do not exceed before insulation breakdown.*

Maximum working voltage or maximum limiting element voltage: *It is the maximum voltage a resistor can withstand constantly without arcing. Maximum working voltage is often expressed as 'Vrms'.*

Microwave frequency: *It is the range of frequency utilised by a microwave equipment. It ranges from 300 MHz to 300 GHz.*

Milliampere (milliamp or mA): *It defines 1/1,000 of an ampere.*

Multimeter: *It is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current and resistance.*

N-type semiconductor: *It is a semiconductor to which doping material is added to increase the number of free charge carriers.*

National Electrical Code (NEC): *It is a standard for safe installation of electrical wiring and equipment.*

Non-polar: *Also called non-polarised capacitor, it is a type of capacitor that has no implicit polarity. It can be connected in either way in a circuit. Ceramic, mica and some electrolytic capacitors are non-polarised.*

Nose pliers: *This tool comes handy in gripping components with short leads that need to be soldered onto or desoldered from the PCB but cannot be held with bare hands.*

Ohm: *It is the unit of electrical resistance and impedance, abbreviated with the symbol omega. Resistance is the opposition offered by a substance to the passage of electrical current.*

Ohm's law: *It was propounded by German scientist G. S. Ohm. It defines the relationship, between voltage, current and resistance of a circuit. It states current is directly proportional to applied voltage.*

Open circuit: *It is a circuit, which is broken. In such a circuit, current will not flow.*

Operating temperature: *It refers to a temperature range, in which a device will perform within its specified designed tolerances. It may be measured in degrees Fahrenheit (F) or degrees centigrade (C).*

Operating voltage: *It is the actual voltage drawn by the equipment for operation.*

Notes

NOTES

Operational amplifier: *It refers to an amplifier with high gain and high input impedance (usually, with external feedback) used, especially, in circuits for performing mathematical operations on an input voltage.*

Over current: *It refers to current in excess of the rated current or ampacity. It may result from overload, short circuit or ground fault.*

Over current protection device: *It is a device that prevents a cable, wire or an appliance from over current.*

Overload: *It is the load beyond the capacity of a circuit.*

P-type semiconductor: *It is a semiconductor to which doping material is added to decrease the number of electrons.*

PE: *It is the abbreviation for Polyethylene, a thermoplastic insulator with electrical properties.*

Pliers: *These are multi-purpose tools used for cutting, gripping and stripping of wires.*

PN junction: *It refers to a boundary or interface between two types of semiconductor material — p and n-type — inside a single crystal of semiconductor.*

Polarity: *It refers to the positive or negative orientation of a signal or power source.*

Polyvinylchloride: *It is a family of insulating compounds, whose basic ingredient is either polyvinylchloride or its co-polymer with vinyl acetate in combination with appropriate plasticisers, stabilisers, fillers and pigments.*

Potentiometer: *It is a variable resistor.*

Power rating: *In electrical and mechanical engineering, the power rating of an equipment is the highest power input allowed to flow through the particular equipment. The word 'power' refers to electrical or mechanical power.*

PPE: *It is stands for Personal Protective Equipment.*

Primary winding: *It refers to transformer winding that receives energy from a supply circuit.*

PTFE: *It is the abbreviation for Polytetrafluoroethylene, also known as Teflon. PTFE is a fluoropolymer insulation or jacketing material.*

Rated power: *It refers to the maximum amount of power that can be continuously applied to electrical and electronic components at rated ambient temperature.*

Rated voltage: *It refers to the maximum value of DC or AC voltage (rms) capable of being applied continuously to electrical and electronic components at rated ambient temperature*

Regulated power supply: *It refers to power supply that provides constant output regardless of input voltage.*

Relay: *It refers to an electrically controlled device that opens and closes electrical contacts to affect the operation of other devices in same or another electrical circuit.*

Reliability: *It is the probability that a device will perform its desired function.*

Reset time: *It is the time required to return the output to its original condition.*

Resistance: *The electrical resistance of an object is a measure of its opposition to the flow of electric current. 'R' is the symbol for resistance.*

Resistor tolerance: *It is expressed as deviation from nominal value in per cent and is measured at 25 °C only with no appreciable power applied.*

Resistor: *It is a component that resists electric current by producing a drop in voltage.*

RF (Radio Frequency): *It is the band of frequencies suitable for telecommunications, satellite and radar.*

Rotor: *It is the rotating part of an electric generator and motor.*

Screwdriver: *It is a manual or powered tool with a narrow blade that is especially shaped at the end and is used for turning screws. A screwdriver has a handle and a shaft, ending in a tip.*

Semiconductor: *It is a solid material, whose electrical conductivity at room temperature is between that of a conductor and insulator. The most common semiconductor material is silicon.*

Series circuit: *It refers to a circuit, in which current runs sequentially through each component.*

Shielding: *It is a metallic layer surrounding a conductor(s) to prevent electromagnetic interference within the cable and devices outside the cable.*

Shock: *It refers to electrical current that passes through a part of a person's body. Electric shock occurs when the human body becomes part of a path through which electrons are flowing.*

Short circuit: *It is an electrical circuit that allows current to travel along an unintended path with no or very low electrical impedance. This results in excessive current flowing through the circuit.*

Side cutting pliers: *These tools are used for cutting wires, screws and nails. They are also called 'diagonal cutting pliers' because the cutting blades are at an angle to the handles.*

Silicon: *It is a chemical element with the symbol 'Si' and atomic number 14. It is a hard, brittle crystalline solid with a blue-grey metallic lustre. It is a tetravalent metalloid and semiconductor.*

Sine wave: *Also called sinusoid, sine wave is a mathematical curve that describes smooth periodic oscillation. A sine wave is a continuous wave.*

Soldering iron: *It is a hand tool used for soldering. It supplies heat to melt solder to form an electrical and physical connection between two surfaces. A soldering iron is made of a heated metal tip and an insulated handle.*

NOTES

NOTES

Soldering station: *A soldering station is a multipurpose power soldering device designed for soldering electronic components.*

Solenoid: *It is a type of electromagnet. The purpose of a solenoid is to generate a controlled magnetic field through a coil wound onto a tightly packed helix.*

Spike: *It refers to momentary increase in electrical current. Spikes can damage electronic equipment.*

Static electricity: *It is a form of current that is left within an insulating body after the power source is removed.*

Stator: *It is a stationary part of a rotary system found in electric generators and motors.*

Stray capacitance: *It refers to undesirable capacitance between circuit wires, components and chassis, or between wires and chassis in an electronic equipment.*

SWG: *It stands for Standard Wire Gauge. It is used to measure the size of wires.*

Switch: *It is a small device that is pressed up or down in order to turn a light or piece of electrical equipment on and off. It also connects or breaks connections in an electrical circuit.*

Tantalum capacitor: *It is an electrolytic capacitor, which consists of a pellet of porous tantalum metal as anode, covered by an insulating oxide layer that forms the dielectric, surrounded by liquid or solid electrolyte as cathode.*

Temperature rating: *It is the maximum allowable temperature at which an electric equipment may be used.*

Terminal: *It is a position in a circuit or device at which a connection is normally established or broken.*

Thermistor: *A combination of 'thermal' and 'resistor', it is a type of resistor, whose resistance is dependent on temperature, more so than in standard resistors.*

Tolerance: *Normally expressed in a percentage, it is the maximum allowable deviation of electrical, environmental or dimensional parameters.*

Transformer: *It is a unit for converting an alternating electrical current from high to low potential voltage or vice versa. Transformers work on AC.*

Transistor: *It is a small electronic device, containing a semiconductor and at least three electrical contacts used in a circuit as an amplifier, detector or switch.*

Trip: *It refers to automatic opening (turning off) of a circuit by a circuit breaker.*

Utility knife: *It is one of the essential tools used in carrying out electrical works as it can cut through most material.*

Variable capacitor: *It is a capacitor, whose capacitance can be altered by changing the effective area of the plates or the distance between the plates.*

Variable resistor: *It is type of resistor, in which resistance value can be varied manually. It is also known as 'potentiometers'.*

Volt: *It is the unit of electric potential and its symbol is 'V'.*

Voltage divider: *It is a passive linear circuit that produces an output voltage that is a fraction of its input voltage. Voltage division is the result of distributing input voltage among the components of the divider.*

Voltage drop: *It refers to the decrease in electrical potential along the path of current flowing in an electrical circuit.*

Voltage regulator: *It is a circuit, which maintains a constant voltage across a load irrespective of variable input voltage.*

Watt: *It is the unit of an electric power. Its symbol is 'W'.*

Watt hour: *It is a measure of electrical energy equivalent to power consumption of one watt for one hour.*

Wave form: *It is the representation of a wave in graph-form achieved by plotting wave against time.*

Wire duct: *It is used to route, protect and organise electrical cables and wires, typically, within a control panel.*

Wrench: *It is a tool used to turn objects, usually, rotary fasteners like nuts and bolts or to keep them from turning.*

XLPA: *It stands for Cross-Linked Extruded Polyalkene.*

XLPE: *Also abbreviated as XLP, it stands for Cross-Linked Polyethylene.*

Notes

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Unit 1

Fig.1.1(a), Fig.1.2, Fig.1.3, Fig.1.4(a), Fig.1.4(b), Fig.1.5, Fig.1.6, Fig.1.7, Fig.1.9, Fig.1.12, Fig.1.13, Fig.1.14, Fig.1.16(a), Fig.1.16(b), Fig.1.17, Fig.1.18, Fig.1.19, Fig.1.20, Fig.1.21(a), Fig.1.21(b), Fig.1.22(a), Fig.1.22(b), Fig.1.23(a), Fig.1.23(b), Fig.1.24, Fig.1.25, Fig.1.26, Fig.1.27, Fig.1.28, Fig.1.29, Fig.1.30, Fig.1.31, Fig.1.32, Fig.1.33, Fig.1.34, Fig.1.35, Fig.1.36

Assignment 3

Fig.1, Fig.2

Assignment 5

Fig.1, Fig.2

Assignment 6

Fig.1

Check Your Progress

Fig.1, Fig.2, Fig.3, Fig.4

Key Concepts

Fig.1(a), Fig.1(b)

Practical Exercise 1

Fig.1, Fig.2

Practical Exercise 2

Fig.1

Practical Exercise 3

Fig.1, Fig.2, Fig.3, Fig.4, Fig.5

Practical Exercise 4

Fig.1, Fig.2, Fig.3

Practical Exercise 5

Fig.1, Fig.2

Practical Exercise 6

Fig.1

Unit 2

Fig. 2.1, Fig. 2.2, Fig. 2.3(a), Fig. 2.3(b), Fig. 2.4, Fig. 2.5 (a and b), Fig. 2.6 (a and b), Fig. 2.7 (a and b), Fig. 2.8, Fig. 2.9 (a and b), Fig. 2.10, Fig. 2.11, Fig. 2.12, Fig. 2.13, Fig. 2.14, Fig. 2.15, Fig. 2.16, Fig. 2.17, Fig. 2.18, Fig. 2.19, Fig. 2.20, Fig. 2.21, Fig. 2.22, Fig. 2.23, Fig. 2.24, Fig. 2.25, Fig. 2.26, Fig. 2.27, Fig. 2.28 (a and b), Fig. 2.29, Fig. 2.30, Fig. 2.31, Fig. 2.32, Fig. 2.33, Fig. 2.34, Fig. 2.35, Fig. 2.36, Fig. 2.37, Fig. 2.38, Fig. 2.39 and Fig. 2.40

Table 2.1 Different types of inductor

Fig.1, Fig. 2, Fig. 3

Practical Exercise 1

Fig. 1

Practical Exercise 2

Fig. 1

Practical Exercise 3

Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5

Practical Exercise 4

Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5

Assignment 1

Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5

Assignment 4

Fig. 1, Fig. 2, Fig. 3, Fig. 4

Assignment 5

Fig. 1, Fig. 2, Fig. 3

Assignment 6

Fig. 1

Check Your Progress

Fig. 1, Fig. 2, Fig. 3

Unit 3

Fig. 3.1(a), Fig. 3.1(b), Fig. 3.1(c), Fig. 3.2, Fig. 3.,3Fig. 3.4, Fig. 3.5, Fig. 3.6, Fig. 3.7, Fig. 3.8, Fig. 3.9, Fig. 3.10, Fig. 3.11, Fig. 3.12, Fig.3.13, Fig.3.14

Alphanumeric coded resistor

Fig.1, Fig.2, Fig.3, Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, Fig.9, Fig.10, Fig.11, Fig.12

NOTES

Assignment 1

Fig.1

Assignment 2

Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5

Table 3.1

Fig.1

Table 3.2

Fig. 3.7(a), Fig. 3.7(b), Fig. 3.7(c) , Fig. 3.7(d), Fig. 3.7(e), Fig. 3.7(f), Fig. 3.7(g), Fig. 3.7(h), Fig. 3.7(i)

Unit 4

Fig. 4.1(a), Fig. 4.1(b), Fig. 4.1(c), Fig.4.2, Fig.4.3, Fig.4.4, Fig. 4.5, Fig.4.6, Fig.4.7 (a), Fig.4.7 (b), Fig.4.8, Fig.4.9, Fig.4.10, Fig.4.11, Fig.4.12, Fig.4.13, Fig.4.14

Unit 5

Fig. 5.1, Fig. 5.2, Fig. 5.3, Fig. 5.4, Fig. 5.5, Fig. 5.6, Fig. 5.7, Fig. 5.8, Fig. 5.9, Fig. 5.10

Unit 6

Fig. 6.1(a), Fig. 6.1(b), Fig. 6.2, Fig. 6.3, Fig. 6.4, Fig. 6.5(a), Fig. 6.5(b), Fig. 6.6, Fig. 6.7, Fig. 6.8, Fig. 6.9, Fig. 6.10(a), Fig. 6.10(b), Fig. 6.11, Fig. 6.12, Fig. 6.13

Practical Exercise 1

Fig.1, Fig.2, Fig.3, Fig.4, Fig.5

Table 6.1 Electrical Safety

Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9, *Fig. 10*

Unit 7

Fig.7.1 (a), Fig.7.1 (b), Fig.7.2, Fig.7.3, Fig.7.4, Fig.7.5 (a), Fig.7.5(b), Fig.7.5(c), Fig.7.6, Fig.7.7, Fig.7.8(a), Fig.7.8(b), Fig.7.9, Fig.7.10, Fig.7.11, Fig.7.12, Fig.7.13, Fig.7.14, Fig.7.15, Fig.7.16, Fig.7.17, Fig.7.18, Fig.7.19, Fig.7.24, Fig.7.25, Fig.7.26, Fig.7.27, Fig.7.28, Fig.7.29, Fig.7.30, Fig.7.31

Unit 8

Fig.8.1, Fig.8.2, Fig.8.3, Fig.8.4, Fig.8.5, Fig.8.6, Fig.8.7, Fig.8.8, Fig.8.9, Fig.8.10, Fig.8.11, Fig.8.12, Fig.8.13(a), Fig.8.13(b), Fig.8.14, Fig.8.15, Fig.8.16, Fig.8.17, Fig.8.18, Fig.8.19, Fig.8.20, Fig.8.21, Fig.8.22, Fig.8.23, Fig.8.24, Fig.8.25, Fig.8.26

Unit 9

Fig.9.1, Fig.9.2(a), Fig.9.2(b), Fig.9.3 (a), Fig.9.3 (b), Fig.9.4 (a), Fig.9.4 (b), Fig.9.5, Fig.9.6, Fig.9.7, Fig.9.8, Fig.9.9, Fig.9.10, Fig.9.11, Fig.9.12, Fig.9.13, Fig.9.14, Fig.9.15, Fig.9.16, Fig.9.17, Fig.9.18, Fig.9.19, Fig.9.20, Fig.9.21, Fig.9.22, Fig.9.23, Fig.9.24, Fig.9.25, Fig.9.26, Fig.9.27, Fig.9.28, Fig.9.29, Fig.9.30, Fig.9.31, Fig.9.32, Fig.9.33, Fig.9.34, Fig.9.35, Fig.9.36, Fig.9.37, Fig.9.38, Fig.9.39, Fig.9.40, Fig.9.41, Fig.9.42, Fig.9.43, Fig.9.44, Fig.9.45, Fig.9.46, Fig.9.47, Fig.9.48, Fig.9.49, Fig.9.50, Fig.9.51, Fig.9.52, Fig.9.53, Fig.9.54, Fig.9.55, Fig.9.56, Fig.9.57, Fig.9.58, Fig.9.59, Fig.9.60, Fig.9.61, Fig.9.62, Fig.9.63, Fig.9.64, Fig.9.65, Fig.9.66, Fig.9.67, Fig.9.68, Fig.9.75, Fig.9.76, Fig.9.77, Fig.9.78, Fig.9.79, Fig.9.80, Fig.9.81

Unit 10

Fig.10.1, Fig.10.2(a), Fig.10.2(b), Fig.10.3, Fig.10.4, Fig.10.5, Fig.10.6, Fig.10.7, Fig.10.8, Fig.10.9, Fig.10.10, Fig.10.11, Fig.10.12, Fig.10.13, Fig.10.14, Fig.10.15, Fig.10.16, Fig.10.17 (a), Fig.10.17 (b), Fig.10.18, Fig.10.19 (a), Fig.10.19 (b), Fig.10.19(c), Fig.10.20 Fig.10.21, Fig.10.22 Fig.10.23 Fig.10.24 Fig.10.25 Fig.10.26 (a), Fig.10.26 (b, Fig.10.27, Fig.10.28, Fig.10.29

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Fig.1.8(c)	http://www.atulgroup.com/wp-content/uploads/2014/10/Generators.jpg
Fig.1.15	http://www.atulgroup.com/wp-content/uploads/2014/10/Generators.jpg
Fig.1.10	http://www.atulgroup.com/wp-content/uploads/2014/10/Generators.jpg
Fig.1.11	https://i.ytimg.com/vi/DkaCfoyNAD4/maxresdefault.jpg
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Fig. 2.9 (b)	https://www.wikihow.com/Identify-Resistors
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Fig.7.21	https://www.wikihow.com/Change-a-Drill-Bit
Fig.7.22	https://www.wikihow.com/Change-a-Drill-Bit
Fig.7.23 (a)	https://www.wikihow.com/Change-a-Drill-Bit
Fig.7.23 (b)	https://www.wikihow.com/Change-a-Drill-Bit

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