**Draft Study Material**

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**(Qualification Pack: Ref. Id. PSS/Q0102)**

**Sector: Power**

## (Grade XII)



**PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION**
**(a constituent unit of NCERT, under Ministry of Education, Government of India)**
**Shyamla Hills, Bhopal- 462 002, M.P., India**

# Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.



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Date: 20 June 2024

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# Table of Contents

# MODULE 1 BASIC ELECTRICITY – II

| Module Overview |
| --- |
| This module covers the basics of electricity and electronic components. It includes fundamental electrical quantities and their importance. Constant voltage and current sources, along with measuring instruments, are explained. The module also introduces active and passive components with their types and features. Simple circuit connections and resistor value calculations are included. |

| Learning Outcomes |
| --- |
| After completing this module, you will be able to:<br>1. Explain basic electrical quantity.<br>2. Describe constant voltage and current source<br>3. Describe measuring equipments for electrical quantity<br>4. Explain importance of various electrical quantity<br>5. Explain electronic components<br>6. Describe active components<br>7. Describe passive components<br>8. Explain type and feature of components<br>9. Describe importance of electronic components<br>10. Drawing of simple series and parallel circuits<br>11. Explain series, parallel and series parallel connection<br>12. Explain calculation of value of resisters |

| Module Structure |
| --- |
| Session 1: Basic Electrical Quantity<br>Session 2: Electrical Components<br>Session 3: Draw and design basic circuits |

During the past decades, electricity became more important to man as the time passed. Today, in our homes, we depend on it for light, heat, running many appliances and music. Outside of the home, we also depend on electricity for many things. The use of domestic appliances is a good example and uses electricity for lights, music and heat energy

The word "electricity" comes from the Greek word "elektron" which means amber. When a piece of amber is rubbed with a woollen cloth, the amber would attract lightweight items like dust, straws, feathers, and lint. This is because the amber becomes electrically charged.

Electricity is a form of energy called electrical energy. However, the electric energy cannot be seen, heard, touched or smelled. The effect of electricity can be seen –lightening of incandescent lamp, heard- ringing of doorbell, touched- shock due to high voltage, smelled- burning of insulation of wire carrying electrical current. In 19th century the use of electricity has widen using for electronic equipment's. In this century there is revolution in electronics. At present all the equipment's are controlled through electronics.

## Session 1

## Basic electrical quantity

### Electron Theory

The basic building block of any matter which has a mass and occupies space such as solid, liquid and gas is atom. The atom is a smallest particle in which element or substance can be divided without loosing their properties. There are about 100 elements which makes all the matters in this world. Each element has different type of atoms and thus determines their electrical properties.

### Atomic Structure

An atom is the smallest particle of any element that still retains the characteristics of that element. Atoms are composed of three types of particles: protons, neutrons, and electron as shown in Fig.1.

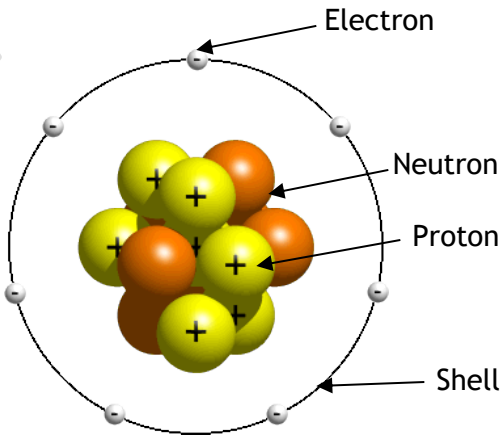


Fig. 1 Atomic

The nucleus is at the centre of the atom is made up of positively charged particles called protons and neutrons which are neutral. The nucleus is surrounded by one or more lightweight negatively charged particles called electrons. An atom is held together by forces of attraction between the electrons and protons. The neutrons help to hold the protons together.

### Atoms and Electrical Charges

If an atom has the same number of electrons and protons, it will be balanced and have a neutral charge (no charge).

If an atom gains an electron or has more electrons than protons, it will be unbalanced and be negatively charged ion. If an atom loses an electron or has fewer electrons than proton, the atom will be positively charged ion. The Fig.2 shows an atom of helium in three different states

of charge. Positive ions attract electrons from neighbouring atoms to become balanced. This causes electron flow.

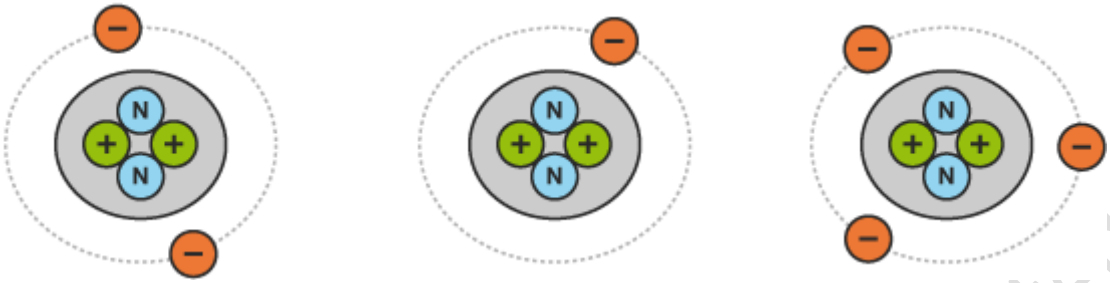



**Fig.2 Helium atom - electrically balanced with positive charge with negative charge**

### Electron Flow

Depending upon the atom it can have many orbits or shells. The atom of the copper is shown in Fig.3 and has 4 shells. The atoms in the inner shells are locked by its attraction to the positive charge of the protons in the nucleus and are called bound electrons. The outer shell of any atom is called the valence shell and the electrons present in the shell are called valence electron. Valence electrons are the electrons of the atom which are weakly held by the positive proton charges and can be transferred to or shared with one or more other atoms. Valence electrons are bound until they are freed by some outside force or reaction. When the valence electron in any atom gains sufficient energy from some outside force such as heat, light, pressure, chemical action or magnetic action, it can break away from the parent atom and become what is called a free electron. These free electrons move from one atom to the next and the stream of free electron forms an electric current. The electron motion is shown in Fig.4.

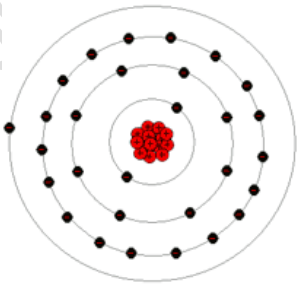


**Fig.3 Copper**

| Negative | Electron flow | Positive |
|---|---|---|
| Excess of electron | Through Conductor | Lack of electrons |

**Fig.4 Electron motion**

### Conductors, Insulators and Semiconductors

The electrical properties of different materials are governed by the number of electrons in the outer shell.

***Conductors:*** Materials having 1 to 3 electrons in the outer shell makes good conductors. Metals such as copper and aluminium are good conductors of electricity and are used in automobile wiring. The electrical current easily flows in the conductors.

***Insulators:*** Materials having 5 to 8 electrons in the outer shell are insulators, because the outer shell is almost filled with electrons. Large amount of force is required to free the electrons in these materials. They do not allow the electricity to flow. Glass, rubber, porcelain and plastic are insulators. Electric wires used in automobile are covered with plastic to avoid short circuiting.

***Semiconductors:*** Materials with exactly 4 atoms in outer shell of the atom are called semiconductors. They are neither good conductors, nor good insulators. Carbon and silicon are semiconductors.

**Voltage, Current and Resistance**

Electricity cannot be measured or weighed, but certain electrical action can be. Voltage, current, resistance and power are electric actions to describe electricity.

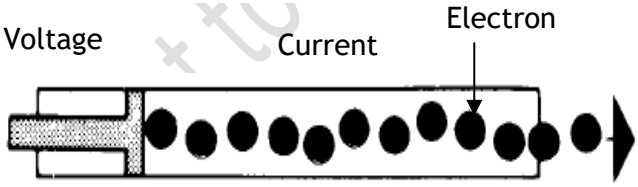


Fig.5 Current flow

**Current:** 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 a *current*, and it is often referred to in terms of "flow," just like the flow of a liquid through a hollow pipe. Current flows in a wire pushed by voltage as shown in Fig.5. Current (I) is measured in Ampere and is designated by the symbol "A".

**Ampere:** if one columb charge cross over the area of cross section of the conductor per on second then the value of current through the conductor is called 'One Ampere'

***Voltage:*** The force motivating electrons to "flow" in a circuit is called voltage. The voltage is electrical pressure, a potential force or difference between electrical charges between two points. Voltage pushes the current in a wire as shown in Fig.6. Voltage exists between positive and negative terminals of a battery. Voltage (E or V) is measured in Volts and is abbreviated by the symbol "V".

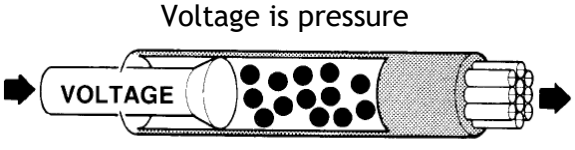


Fig.6 Voltage causes current to flow

**One Volt** means the force move one coulomb of electrons in one second

***Resistance:*** Free electrons tend to move through conductors with some degree of friction, or opposition to motion. This opposition to motion is more properly 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. The resistance (R) is measured in Ohms and is designated by the symbol "Ω".

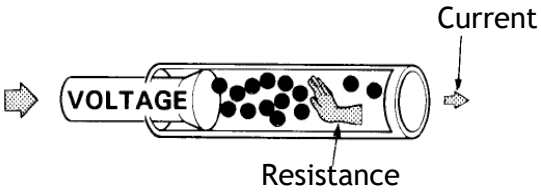



**Fig.7 Resistance slows flow of current**

**One Ohm** When a conductor having 1 V potential between the two end points, one ampere current will flowing through conductor and the resistance value of conductor is 1 Ohm (Ω)

**Power:** It is measured in watts and instrument measuring electric power is watt meter. The electric power is calculated as a product of voltage and current. 'W' stands for watts. For example, lamps are available in 25W, 40W and 60W etc.

W = VI Watts

**Energy:** It is measured in Kilo Watts Hours. (1 kilo watt hour = 1000-watt hour = 1 Unit). A meter which measures energy consumption is known as energy – meter or KWH meter. The electricity board provides meters in every house to record the consumption of electrical energy. KWH is also expressed as Unit of power. Energy is calculated by the equation:

Energy = WT KWH

Energy = VIT KWH

**Ohms Law**

To make a current flow through a resistance there must be a voltage across that resistance. Ohm's Law shows the relationship between the voltage (V), current (I) and resistance (R). It can be written in three ways:

$$V = I \times R \text{ or } I = \frac{V}{R} \text{ or } R = \frac{V}{I}$$

Where:

V = voltage in volts (V)
I = current in amps (A)
R = resistance in ohms (Ω)

or

V = voltage in volts (V)
I = current in milliamps (mA)
R = resistance in kilohms (kΩ)

**Statement-** At constant temperature, current flowing through circuit is directly proportional to the voltage and inversely proportional to resistance

When the resistance is constant, if we increase the voltage then current increases and if decrease the voltage then current decreases

The main limitations of ohm's law: it is valid for the conductors whose physical dimensions are not change with the variation of temperature.

**Kirchhoff's Laws**

Kirchhoff's circuit laws are two equalities that deal with the conservation of charge and energy in electrical circuits, and were first described in 1845 by Gustav Kirchhoff

Kirchhoff's Current Law to be restated as:

At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.

Or

The algebraic sum of currents in a network of conductors meeting at a point is zero. This law is a statement of charge conservation alternating current.

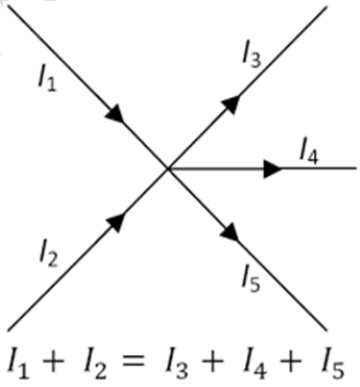



Fig- Illustration of Kirchhoff's junction rule

Most of the domestic lighting and heating systems make use of alternating current. We have some appliances which work on DC. Before connecting the supply, we must make fig sure whether the appliance can work on Ac only or DC only. Sometimes an appliance may work both on Ac and DC. In an AC supply the terminals are identified as phase and neutral. The phase wire can be identified by placing a neon tester on it. The supply voltage of AC is 230 volts in our houses.

In DC supply the terminals are identified as positive and negative. The appliance working on DC is also marked for its polarity. The positive from the supply must be connected to the positive terminal of appliance. If we interchange the connection, it may damage the appliance. The AC supply is usually given by electricity board and DC source is an available in DC generator, batteries and cells.

Electricity is highly dangerous to work on as electric shock is deadly. Moreover it is invisible and even little negligence may cause accidents. But we need not be in panic if we follow certain procedures to ensure safety. The procedures are known as safety procedures.

While working, we have to consider the personal safety of the operator or mechanic. But in addition to this we must consider the safety of others, safety for tools and equipment also. It is

essential that we do not damage tools and cause accidents which may disrupt the workshop itself.

It is not enough to know about safety procedures. We should be able to apply these in work situations and make safety as a habit while working. We can list the safety procedures in terms of what we should do and what we should not do. These procedures are as follows

1. Never touch a current carrying wire or conductor.
2. Never pull out a flexible cable while removing the plug from the mains.
3. Switch off the supply while checking any electrical appliance.
4. Never play with tools.
5. Handle tools carefully and be alert while working.
6. Never switch on supply unless you are sure about working of an appliance.
7. Ensure that proper earthing is provide for the appliance.
8. Seek guidance of your teacher in case of any doubt and do not try to experiment yourself.
9. Report and damage/breakdown to your teacher immediately.

**Electromagnetic Induction and Magnetism**

Cranking of an engine require mechanical energy. It is done by supplying electrical energy to a starter motor from the vehicle battery. Mechanical energy from the engine is used to drive the generator, produce electricity. Magnetism is the connecting link between mechanical energy and electrical energy.

***Magnetism:*** Magnetism is an invisible force that attracts iron and steel. A particular type of stone called magnetite that is a natural magnet. For commercial use magnets are made from iron and steel by artificial means. We are familiar with bar- and horseshoe-shaped magnets which are permanent magnets made from steel.

If a bar magnet is suspended by a thread, it will swing into a north-south direction with its ends pointing to the earth's magnetic poles. The end of the magnet toward the north is known as the north pole and the end to the south the south pole. If we bring in contact the north pole of the second bar magnet with north pole of the suspended magnet, the suspended magnet will move away from its position. Upon bringing the south pole of the second magnet in contact with the north pole of the suspended magnet, the ends of both magnets will stick with each other. Therefore, like poles repel and unlike poles of the magnet attract each other.

The surrounding space around a magnet that is affected by the magnet's invisible force is known as a magnetic field. The magnetic field is demonstrated by sprinkling some iron filings on a piece of paper placed on a tabletop. A bar magnet is dropped into the center of the paper and the filings are attracted by the magnet.

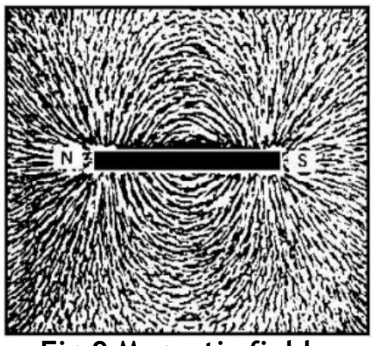



Fig.9 Magnetic field

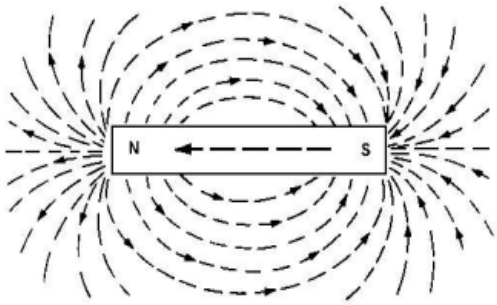



Fig.10 Magnetic lines of force

Upon tapping the table, the iron filings get arranged in a definite pattern as shown in Fig.8, the magnetic field.

The lines formed about the magnet are known as lines of force as shown in Fig.9.

***Electromagnetic Induction:*** Electromagnetic Induction refers to generation of electricity or passage of current through a conductor when it placed in a changing magnetic field or the conductor is in motion in a stationary magnetic field.

As shown in Fig.10, a permanent magnet is being moved in and out of a small coil, and "induced" current flows in the coil. But it is only while the magnetic field in the coil is changing that any induced current flows. The magnetic field is being produced by the magnet and it is changing due to its motion.

The principle finds numerous applications in electric generators and motors, transformers, microphones, and engine ignition systems. The current produced by the generator or alternator of the automobile is due to electromagnetic induction. The ignition coil produces a very high voltage to cause a spark in the spark plug is also due to electromagnetic induction.

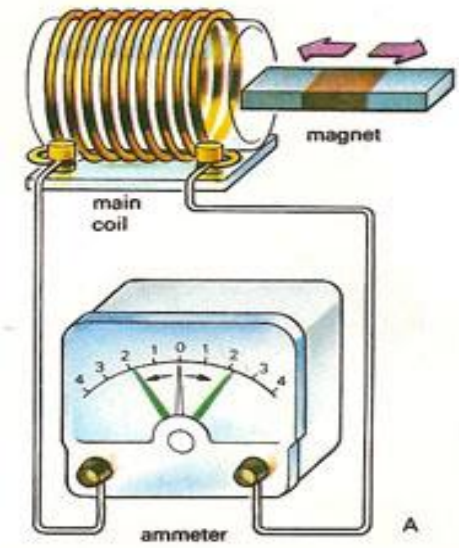



**Fig.11 Electromagnetic induction**

The word “electronics” is derived from electron mechanics, which means the study of the behaviour of an electron under different conditions of externally applied fields.

Electronics are divided into two parts.

1. Analog Electronics.

2. Digital Electronics.

## 1. Analog Electronics

Analog Signals: - The signals, which are continuous and can have any value in a limited range are known as analog signals.

The electronics circuit, which is used to process analog signal, is called Analog circuits.

The systems built around this kind of operation are known as analog systems i.e. Radio, TV, Deck, Tape etc. The branch of electronics in which we study Analog circuit is called Analog Electronics.

## 2. Digital Electronics

The term "digital" refers to any process that is accomplished using discrete units. e.g. -Fingers, Toes, Rocks, Elephants etc. A discrete signal is called a Digital Signal. Digital Signal has two discrete values or levels. One of these may be called as LOW level and the other one as HIGH level. The signal will always be of one of the two levels.

The circuits, which are used to process these signals (digital signals), are known as digital circuits.

Digital Signal has two discrete levels. Using the terms can represent these levels

**LOW / 0 / 0 volts / OFF / FALSE / - ve**

**HIGH / 1 / 5 volt/ ON / TRUE / + ve**

The branch of electronics in which we study Digital circuit is called Digital Electronics. Digital circuit performs only a few basic operations. These operations are AND, OR, NOT, and flip-flop. AND, OR, and NOT operations are called logical operation and FLIP-FLOP is a basic memory element which is used to store binary information.

**Exercise**

**A. Answer the following**

1. Explain the following
   - Voltage
   - Current
   - Resistance
2. A circuit has two lamps of 100 each 3 tube lights of 40 Watt each, 3 tube lights of 40 watt each, 2 ceiling fans of 80 watt each. Calculate the total wattage?

**B. Multiple Choice Questions**

1. The smallest particle of an element is known as

a) Atom
b) Molecule
c) Nucleus
d) Electron

2. The atom is composed of

a) Electron only
b) Proton only
c) Neutrons only
d) Electron, Proton, neutrons

3. The supply for domestic purpose is
a) 110- 120 V
b) 120- 130 V
c) 220- 230 V
d) 400- 440 V

**C. Tick T if you think statement is true; Tick F if you think statement is false**

1. The signals, which is continuous and can have any value in a limited range, is known as analog signal **(T/F)**

## Session 2

## ELECTRONIC COMPONENTS

Electronic components are divided into two parts.

1. Passive Component

2. Active Component.

**1. Passive Component: -** These components are not capable of amplifying or processing an electrical signal. Examples are Resistors, Capacitors, Inductors.

**2. Active Component: -** These components capable of amplifying or processing an electrical signal. Examples are Tube devices, Semiconductor devices.

**Resistors:**

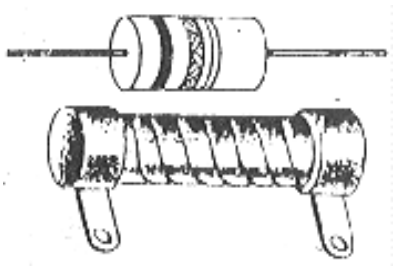
The flow of charge (or current) through and material, encounters an opposing force similar in many respects to mechanical friction. This "opposing force" is called the resistance of the material. It is measured in ohms, for which the symbol is "Ω" (the Greek capital letter omega) shown in the figure.

**Types of Resistors:**

A. Fixed resistor

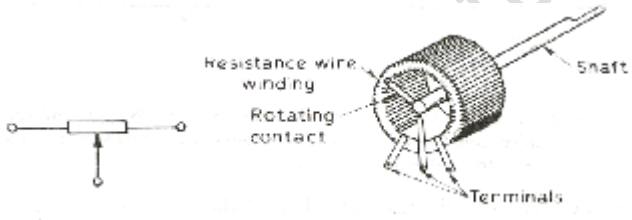
B. Variable resistor.

**A. Fixed resistors: -** Many types of resistors are used having different uses and construction. The most common types have a fixed value of resistance so are often called fixed resistors. The most common of the low wattage, fixed-type resistors is the molded -carbon composition resistors. The resistive material is of carbon-clay composition. The leads are made of tinned copper. Resistors of this type are readily available values ranging from few ohms to about 22 M Ohms, having a tolerance range of 5 to 20%.



Fixed Resisters

**B. Variable resistors: -** In electronic circuits, sometimes it becomes necessary to adjust the values of currents and voltages. For example, it is often desired to change the volume (or loudness) of sound, the brightness of a television picture, etc. Using variable resistors can do such adjustments.




There is two type of Variable Resistance: -

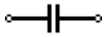
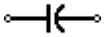
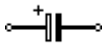
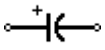
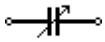
### 1. Capacitors

Capacitor is an electronic component that stores electric charge. The capacitor is made of 2 close conductors (usually plates) that are separated by a dielectric material. The plates accumulate electric charge when connected to power source. One plate accumulates positive charge and the other plate accumulates negative charge.

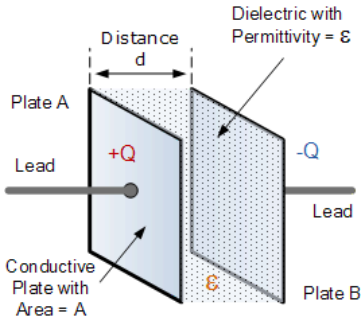
The capacitance is the amount of electric charge that is stored in the capacitor at voltage of 1 Volt.

The capacitance is measured in units of Farad (F).

Capacitor symbols

| | | |
|---|---|---|
| Capacitor |  |  |
| Polarized capacitor |  |  |
| Variable capacitor |  | |

The capacitance of a parallel plate capacitor is proportional to the area, A of the plates and inversely proportional to their distance or separation, d (i.e. the dielectric thickness) giving us a value for capacitance of C = k (A/d) where in a vacuum the value of the constant k is 8.84 x 10-12F/m or 1/4. π.9 x 109, which is the permittivity of free space. Generally, the conductive plates of a capacitor are separated by air or some kind of insulating material or gel rather than the vacuum of free space.




**Capacitance**

The capacitance (C) of the capacitor is equal to the electric charge (Q) divided by the voltage (V):

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

C is the capacitance in farad (F)

Q is the electric charge in coulombs (C), that is stored on the capacitor

V is the voltage between the capacitor's plates in volts (V)

**Capacitance of plates capacitor**

The capacitance (C) of the plates capacitor is equal to the permittivity (ε) times the plate area (A) divided by the gap or distance between the plates (d):

$$C = \varepsilon \times \frac{A}{d}$$

C is the capacitance of the capacitor, in farad (F).

ε is the permittivity of the capacitor's dialectic material, in farad per meter (F/m).

A is the area of the capacitor's plate in square meters ($m^2$].

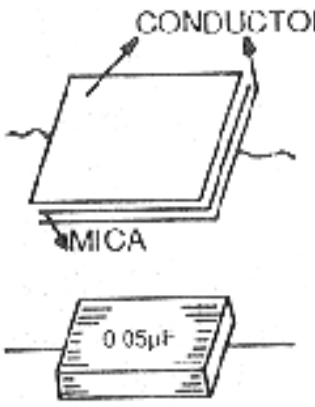
d is the distance between the capacitor's plates, in meters (m).

A capacitor is basically meant to store electrons (or electrical energy), and release them whenever desired. capacitor's ability to store charge. It is measured in farads (F). However, the unit farad being

too large, practical capacitors are specified in microfarads (mF), or Pico farads (pF). A capacitor offers low impedance to ac, but very high impedance to dc.

Capacitors, like resistors, can be either fixed or variable. Some of the most commonly used fixed capacitors are mica, ceramic, paper, and electrolytic. Variable capacitors are mostly air-gang capacitors.

**Mica capacitors:** Mica capacitors are constructed from plates of aluminum foil separated by sheets of mica as shown in Figure. The plates are connected to two electrodes. Available capacitance ranges from 5 to 10 000 pF. Mica capacitors are usually rated at 500 V. Its leakage current is very small ($R_{leakage}$ is about 1000 MF).




Mica capacitor


**Ceramic capacitors:** A ceramic disc is coated on two sides with a metal, such as copper or silver. These coatings act as the two plates. During the manufacture of the capacitor, tinned wire leads are also attached to each plate. Then the entire unit is coated with plastic and marked with its capacitance value-either using numerals or a colour code.

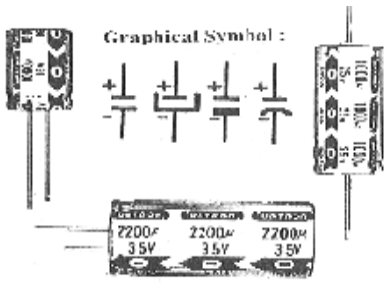
**Ceramic Capacitors**

The colour coding is similar to that used for resistances. Ceramic capacitors are very versatile. Their working voltage ranges from 3 V (for use in transistors) up to 6000 V. The capacitance ranges from 3 pF to about 2mf. Ceramic capacitors have a very low leakage currents ($R_{leakage}$ is about 1000 MF) and can be used in both dc and ac circuits.

**Paper capacitors:** The basic construction of a paper capacitor is shown in Figure. Since paper can be rolled between two metals foils, it is possible to concentrate a large plate area in a small volume. The capacitor consists of two metal foils separated by strips of paper. This paper is impregnated with a dielectric material such as wax, plastic or oil.


**Paper capacitor**

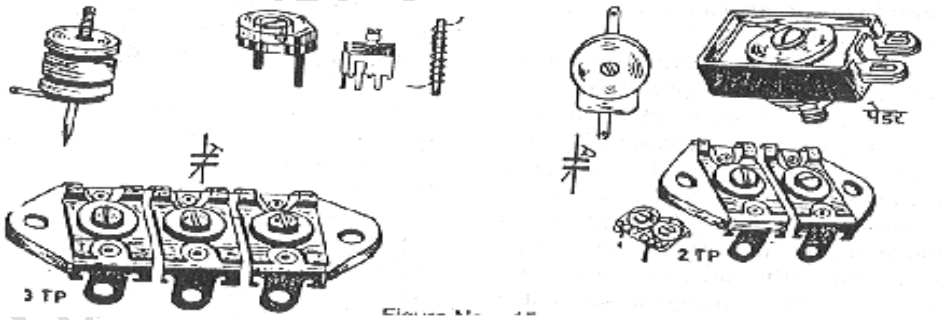
Paper capacitors have capacitance ranging from 0.0005 mF to several mF, and are rated from about 100 V to several thousand volts. They can be used for both dc and ac circuits. Its leakage resistance is of the order of 100 MF.




**Electrolytic capacitors:** Electrolytic capacitors are extremely varied in their characteristics. The capacitance value may range from 1 mF to several thousand microfarads. The voltage ratings may range from 1 V to 500 V, or more. These capacitors are commonly used in situations where a large capacitance is required. Various types of electrolytic capacitors are shown in Figure.

**Electrolytic Capacitors**

The electrolytic capacitor consists of an aluminum foil electrode, which has an aluminum-oxide film covering on one side. The aluminum plate serves as the positive plate and the oxide as the dielectric. The oxide is in contact with a paper or gauze saturated with an electrolyte. The electrolyte forms the second plate (negative) of the capacitor. Another layer of aluminum without the oxide coating is also provided for making electrical contact between one of the terminals and the electrolyte. In most cases, the negative plate is directly connected to the container of the capacitor. The container then serves as the negative terminal for external connections. The aluminum oxide layer is very thin. Therefore, the capacitor has a large capacitance in a small volume. It has high capacitance-to-size ratio. It is primarily designed for use in circuits where only dc voltages will be applied across the capacitor. Ordinary electrolytic capacitors cannot be used with alternating currents.




A new type of electrolytic capacitor is the tantalum capacitor. It has an excellent capacitance-to-size ratio.

**Variable capacitors:** In some circuits, such as a tuning circuit, it is desirable to be able to change the value of capacitance readily. This is done by means of a variable capacitor. The most common variable capacitor is the air-gang capacitor, shown in Figure. The dielectric for this capacitor is air. By rotating the shaft at one end, we can change the common area between the movable and fixed set of plates. The greater the common area, the larger the capacitance.

In some applications, the need for variation in the capacitance is not frequent. One setting is sufficient for all normal operations. In such situations, we use a variable capacitor called a trimmer (sometimes called padder). Both mica and ceramic are used as the dielectric for trimmer capacitors.

**Reading Colour Code in Capacitors:** The Colour code in Capacitor is similar to Resistance Colour code but in Capacitor, there are two types of Colour code systems, there are:

1. E.I.A. (Electronics Industrial Association)
2. J.A.N. (Joint Army Navy) or A.W.S. (American Ware Standard)

**E.I.A. Colour code system:** The value of Colour code is in pF.

| **Three Point E.I.A. Colour Code** | | | |
|---|---|---|---|
| Colour | First Number | Second Number | 3rd Number(Multiplier) |
| Black | 0 | 0 | 1 |
| Brown | 1 | 1 | 10 |
| Red | 2 | 2 | 100 |
| Orange | 3 | 3 | 1,000 |
| Yellow | 4 | 4 | 10,000 |
| Green | 5 | 5 | - |
| Blue | 6 | 6 | - |
| Violet | 7 | 7 | - |
| Gray | 8 | 8 | - |
| White | 9 | 9 | - |
| Golden | - | - | 0.1 |
| Silver | - | - | 0.01 |

| **6-point E.I.A. Colour Code** | | | | | | |
|---|---|---|---|---|---|---|
| Colour | 1st Colour | 2nd Colour | 3rd Colour | 4th Colour Multiplier | 5th Colour Tolerance | 6th Colour Working Voltage |
| Black | 0 | 0 | 0 | 1 | 1% | - |
| Brown | 1 | 1 | 1 | 10 | 2% | 100 |
| Red | 2 | 2 | 2 | 100 | 3% | 200 |
| Orange | 3 | 3 | 3 | 1,000 | 4% | 300 |

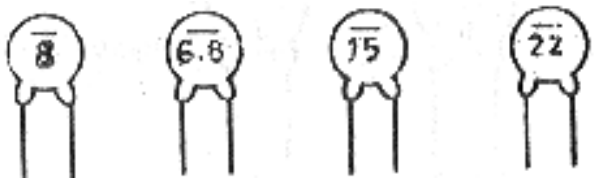
| | | | | | | |
|---|---|---|---|---|---|---|
| Yellow | 4 | 4 | 4 | 10,000 | - | 400 |
| Green | 5 | 5 | 5 | - | - | 500 |
| Blue | 6 | 6 | 6 | - | - | 600 |
| Violet | 7 | 7 | 7 | - | - | 700 |
| Gray | 8 | 8 | 8 | - | - | 800 |
| White | 9 | 9 | 9 | - | - | 900 |
| Golden | - | - | - | - | 5% | 1,000 |
| Silver | - | - | - | - | 10% | 2,000 |
| No Colour | - | - | - | - | 20% | 500 |

| **6-point J.A.N. Colour Code** | | | | | | |
|---|---|---|---|---|---|---|
| Colour | 1st Colour | 2nd Colour | 3rd Colour | 4th Colour Multiplier | 5th Colour Tolerance | 6th Colour T.C. |
| Black | 0 | 0 | 0 | 1 | 1% | - |
| Brown | 1 | 1 | 1 | 10 | 2% | ±1000 |
| Red | 2 | 2 | 2 | 100 | 3% | ±500 |
| Orange | 3 | 3 | 3 | 1,000 | 4% | ±200 |
| Yellow | 4 | 4 | 4 | 10,000 | - | ±100 |
| Green | 5 | 5 | 5 | - | - | - |
| Blue | 6 | 6 | 6 | - | - | - |
| Violet | 7 | 7 | 7 | - | - | - |
| Gray | 8 | 8 | 8 | - | - | - |
| White | 9 | 9 | 9 | - | - | - |
| Golden | - | - | - | - | 5% | - |
| Silver | - | - | - | - | 10% | - |
| No Colour | | - | - | - | 20% | - |

**Rule to calculate the value of simple capacitors:**

**Rule 1:** If on any capacitor number of one or two digit is written without any code or unit then that number is the value of capacitor in Pico farad (pF).

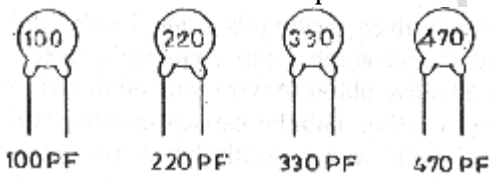
**Example:**




**8pF 6.8pF 15pF 22p**

**Rule 2:** If on any capacitor, a number of three digits is written with last digit as zero without any code or unit then that number is the value of capacitor in Pico farad (pF).

**Example:**



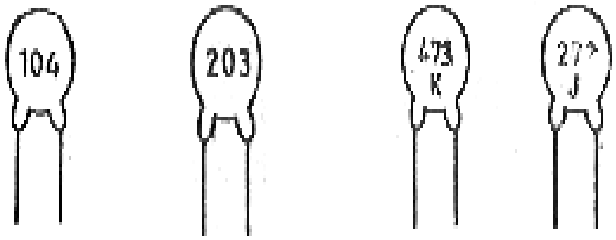

**Rule 3:** If on any capacitor, a number of three digits is written with last digit other than zero then its value is calculated by colour code method i.e. the 3rd digit is multiplier and the value is in pF. In these types of capacitors, if English alphabet is written after the number then that alphabet shows its tolerance. These alphabets are:

**F = ± 1%** **G = ± 2%**

**Example:**

**J = ± 5%** **K = ± 10%**

**M = ± 20%**

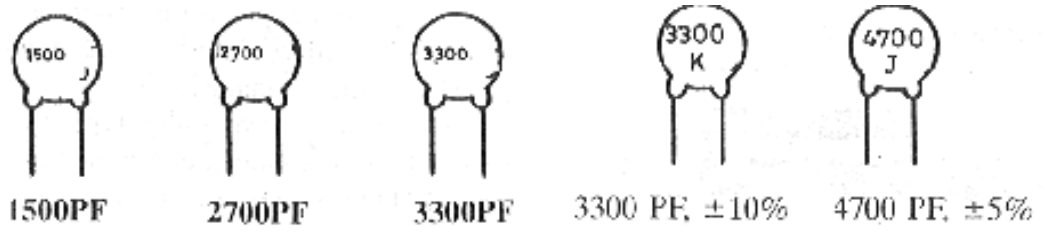



**10,0000pF 20,000pF 47,000pF 27,00pF**

**± 10% ± 5%**

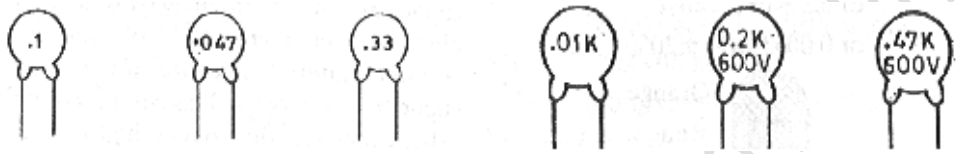
**Rule 4:** If any capacitor, a number of four digits is written with zero as a fourth digit than the given number is the value of that capacitor in Pico farad (pF). If an English alphabet is also written on the capacitor along with, the four digits number than that alphabet represents its tolerance (same as Rule 3).

**Example:**




**Rule 5:**If a number is written on the capacitor after the decimal than that number is the value of capacitor in microfarad (uF). If on these types of capacitors, an English alphabet is written then that alphabet shows capacitor's tolerance (same as on Rule 3).

**Example:**




**0.01uF 0.047uF 0.33uF 0.01uF±10% 0.2uF±10%0.47uF ± 10%**

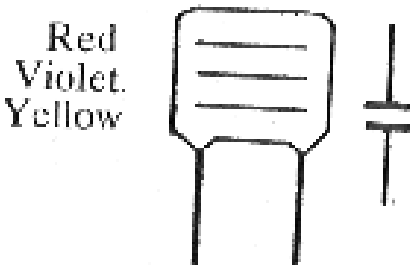
**600V 600V**

**Colour code Reading from Flat Ceramic Capacitor:**

Read colour code from bottom to top, i.e.

Yellow – Violet – Red

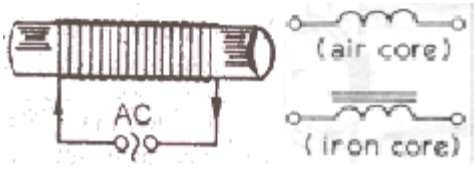
4700pF or 4.7 KpF or 0.0047 uF



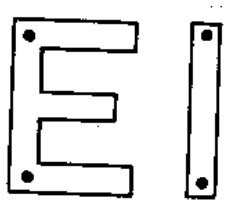

**Code Identification of Capacitor**

**Inductors**

When current flows through a wire that has been coiled, it generates a magnetic field. This magnetic field reacts to oppose any change in the current. This reaction of the magnetic field, trying to keep the current flowing at a steady rate, is known as inductance; and the force it develops is called induced e.m.f. The electronic component producing inductance is called an inductor. The symbols of an air-core and an iron-core inductor are shown in figure. The inductance is measured in Henry (H).



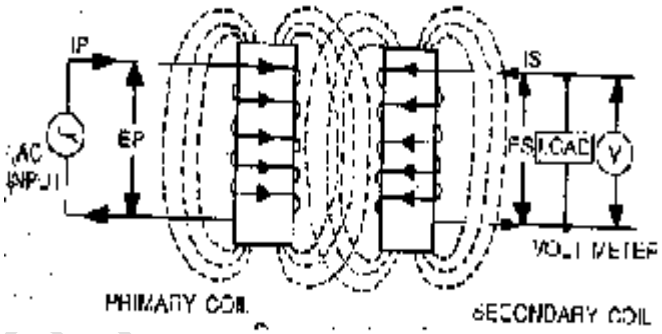
**Inductor and symbols**



Filter chokes are the inductors used in smoothing the pulsating current produced by rectifying ac into dc. A typical filter choke has many turns of wire wound on an iron core. To avoid power losses, the core is made of laminated sheets of E-and I-shapes shown in the figure. Many power supplies use filter chokes of 5 to 20 H, capable of carrying current up to 0.3 A.

**E & I Laminated Core**

Audio-frequency chokes (AFCs) are used to provide high impedance to audio frequencies (say, 60 Hz to 5 Hz). Compared to filter chokes, they are smaller in size, and have lower inductance. Chokes having still smaller inductance are used to block the radio frequencies. Such chokes are called radio-frequency chokes (RFCs).




A transformer is quite similar in appearance to an inductor. It consists of two inductors having the same core (Fig.1.17). One of these inductors, or windings, is called primary. The other is called secondary.

When an alternating current is applied at the primary, an induced voltage appears in the secondary. In a step-up transformer, the number of turns in the secondary is more than that in the primary. The secondary voltage is more than the primary. If the number of turns in the secondary is less than that in the primary, the voltage will be stepped-down. The transformer is then called a step-down transformer. The transformer of suitable turns-ratio is often used in electronic circuits for impedance matching.

**Introduction to Various Semiconductor Devices**

Let us now study some of the important semiconductor devices. Following table is the names of some of these devices.

| S.No. | Semiconductor Device |
|---|---|
| 1. | Semiconductor Diodes |
| 2. | Point Contact Diodes |
| 3. | Junction Diodes |
| 4. | Zener Diodes |
| 5. | Tunnel Diodes |
| 6. | Transistors |
| 7. | Junction Transistors |

8. Field Effect Transistors

9. Surface Barrier Transistors

10. PNPN Devices

11. Integrated Circuits

12. Light Sensitive Semiconductors

13. Uni-junction Transistor

## 1. SEMICONDUCTOR DIODES:

These are two terminal devices, which perform the function of rectification. Various types of semiconductor diodes are –

a) Rectifier diode
b) Single diode
c) Zener diode
d) Varactor diode
e) Hot carrier or Schottky diode
f) Tunnel diode
g) Light Emitting diode
h) Photo sensitive diode

### (a) RECTIFIER DIODE:

These diodes are used to convert AC into DC. These are used as half wave rectifier or full wave rectifier. Three points must be kept in mind while using any type of diode.

1. Maximum forward current capacity
2. Maximum reverse voltage capacity
3. Maximum forward voltage capacity

The number and voltage capacity of some of the important diodes available in the market are as follows:

Diodes of number IN4001, IN4002, IN4003, IN4004, IN400S, IN4006 and IN4007 have maximum reverse bias voltage capacity of 50V and maximum forward current capacity of 1 Amp. Diode of same capacities can be used in place of one another. Besides this diode of more capacity can be used in place of diode of low capacity but diode of low capacity cannot be used in place of diode of high capacity.

For example, in place of IN4002, IN400l or IN4007 can be used but IN4001 or IN4002 cannot be used in place of IN4007.

The diode BY125 made by company BEL is equivalent of diode from IN4001 to IN4003. BY126 is equivalent to diodes IN4004 to IN4006 and BY 127 is equivalent to diode IN1007.

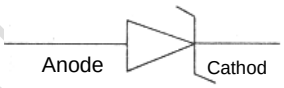
**b) SINGLE DIODE or CAT WHISKER or POINT CONTACT DIODE:**

The diode is used in the microwave field for signal detection. These diodes are made in the glass and red coloured ring is printed on their cathodes. 0A70, 0A79, 0A85, IN34, IN4148 etc. are such diodes. The symbol of these types of diodes is same as that of ordinary diode.

**c) TUNNEL DIODE:**

The diode which keeps the features of negative resistance and which is used for switching at the level of microwave frequency is known as tunnel diode.

**d) ZENER DIODES**:




The Zener Diode is used in electronic circuits to maintain constant voltage in the circuit. A Zener diode keeps the voltage level in the circuit at a constant level although the current in the circuit may vary.

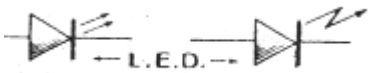
**e) HOT CARRIER OR SCHOTTKY DIODE:**

The special feature of these diodes is getting output during forward biasing. Because of this property, these diodes are used for modulation and detection of V.H.F., U.H.F., and microwave level. High level switching is also done with the help of' these diodes.

**Example:** IN5825 is a hot carrier diode (Schottky diode) which gives 5A of current in the output on forward bias of just 0.38V. However, as soon as this forward biasing is removed current also stops flowing through it.

**f) LIGHT EMITTING DIODE (LED):**

We know that in each diode there in a recombination of electrons and holes. This recombination of electrons and holes releases some energy, which is invisible in most of the diodes, but in some diodes, it is visible in the form of light.

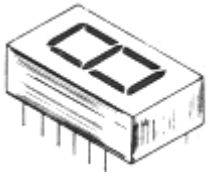



When light is emitted on forward biasing of a diode than it is known as Electro-luminance. In this way, the frequency of emitted light from the diode may be in visible spectrum or in invisible spectrum.

Emitted light from the diode can be divided into two parts; (i) light which is visible to human and (ii) light which is invisible to human.

The frequency range visible to a normal man is 400nm (nanometer) to 700nm, the frequency range of light below 400nm are known as ultraviolet and frequency of light is greater than 700nm are known as infrared.

Colour LED generally used as indicator and Infra-red and ultraviolet LED's are used for transmitting invisible signals.



A seven-segment display unit as shown in the figure is made by using a number of LED's. By activating suitable combination of LED's in this unit, any digit from 0 to 9 can be displayed by it.

The LED's are work on low voltage (1 or 2 V) and currents (5 to 10 mA) and thus consume less power.

**g) VARACTOR DIODE:**

The meaning of varactor diode is variable capacitance diode and these are mostly used for signal modulation and demodulation.

**Terminals identification of semiconductor diode with the help of multimeter**

It is essential to note that the polarity of analogue multimeter leads is reversed on the resistance ranges, so the black lead is positive (+) and red is negative (-)

1. Pick up the diode the read the number encoded on the body
2. Refer to manual to know the identification of body
3. Confirm the identification and test by using a multimeter as follows
4. Adjust multimeter for resistance between two terminals of the diode
5. Measure the resistance between two terminals of diode
6. Reverse the diode terminals and again measure
7. Note down the resistance given in two cases. It should be low in one case and high in other cases, if it is not so that means diode is faulty
8. Low reading corresponds to forward bias and high resistance to reverse bias
9. Now mark the anode (A) to the diode terminal where black probe of multimeter is connected and mark another terminal of diode as cathode (K) where, red probe of multimeter is connected

**By visual inspection**

1. In many diodes, leads identified by colour ring at the one end of the diode. Ring indicate cathode

**USE OF DIODES IN RECTIFIERS:**

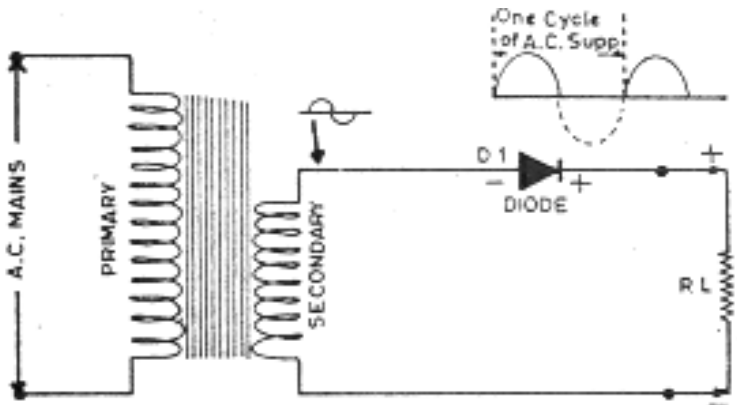
In any type of electronic circuit, DC power is needed. The supply, which is obtained from the secondary winding of the transformer, is AC. In order to convert this AC supply in DC, rectifier circuit is used. In this way, the section, which converts AC supply into DC supply, is known as rectification section. The components used in this section are known as rectifier Diode. In this, diodes are used in all the rectifier circuits as the basic components. The specialty of the diode

is that it always conducts in one direction. This part of the equipment is called **Power Supply**. Rectifier circuits can be divided into two parts:

(i) Half-wave Rectification
(ii) Full-wave Rectification

### 1. Half-wave Rectification:

In this circuit, a diode is connected at the secondary of the single winding transformer. When primary winding of the transformer gets the AC supply, then the voltage developed in the secondary comes to the negative end of the diode. This diode conducts only when positive half cycle of AC is fed to the negative end, because this positive half cycle forward biases it (diode) and diode passes supply only during forward bias. During the negative, half cycle of AC, no current passes through diode because then diode is reverse biased. In this way, the DC, which obtained at the two ends of load resistance, is in the form of half pulses, means a gap between the two positive pulses. Thus, this type of DC is known as half wave DC and the circuit from which it is obtained is known as half wave rectifier circuit.



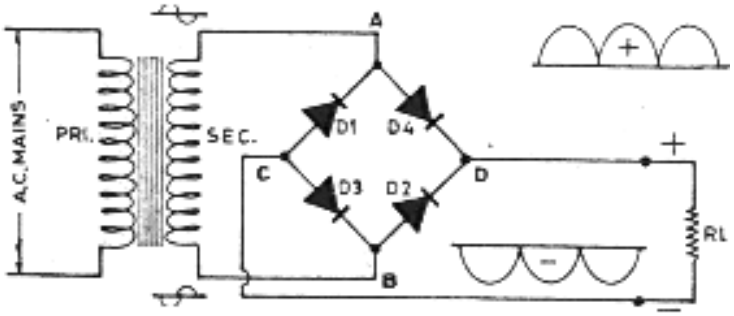

### 2. Full-wave Rectification

In this rectifier circuit, two diodes are used and each one is connected on the two ends of secondary winding of double winding transformer (centre Tapped transformer) as shown in the figure.

According to the circuit, positive ends of both the diodes are connected with each other. Diode D1 conducts only when positive half cycle comes on its negative end. Similarly, diode D2 conducts only when positive half cycle of AC comes on its negative end. On both of these diodes positive half cycles come alternately which means, when positive half cycles of AC come on diode D1 then diode D2 gets negative half cycle and when diode D1 gets negative half cycle then diode D2 gets positive half cycle. In this way, diodes D1 & D2 conducts alternately using every half cycle of AC. As a result of this, DC is obtained at the output ends with no gap remaining between the two continuous pulses.

**Full-wave Rectification using four diodes**

Full wave rectifier made by connecting four diodes on the secondary winding of single winding transformer as shown in the figure is known as Bridge Rectifier. It is considered as best among all other rectifiers, so it is widely used.




Following way can also make the circuit of bridge rectifier:

**Filtration Section:**

The DC supply obtained from the rectifier section cannot be directly given to any electronic device because this DC supply is in the form of pulses and thus known as pulsating DC, whereas the supply obtained from battery or cell does not have pulses in it, so it is known as smooth DC. Thus, when DC supply is obtained from AC, it must be made smooth before giving it to any circuit. This function is performed by the filtration section, which removes the AC pulses. Coils and capacitors are mainly used in the filtration circuit. Besides this in some filter circuits resistance is also used. Resistance produces same effect on the supplies i.e. AC & DC. Its main function is to control the current. These components remove AC pulses from pulsating DC to some extent, however the DC supply thus obtained cannot be considered as ideal DC supply.

**TRANSISTORS**

Great American scientists Mr. Vardon and Mr. Bradone invented the Transistor in 1947. After the invention of transistor, there was a great revolution in the Electronics field. The Transistor is an electronic device, which is generally made of Semiconductor materials Germanium or silicon.

Transistor is a three-terminal device, Transistors have three leads, known as base (B), emitter (E), and collector (C). A very small emitter-base current allows a much larger collector-emitter current to flow. Therefore, transistors may amplify the signal, or act as a switch.

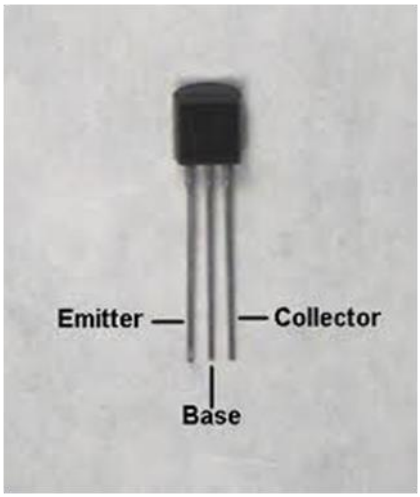



Fig- Transistor

Based on the construction, there are two types of transistor

(1) P-N-P type

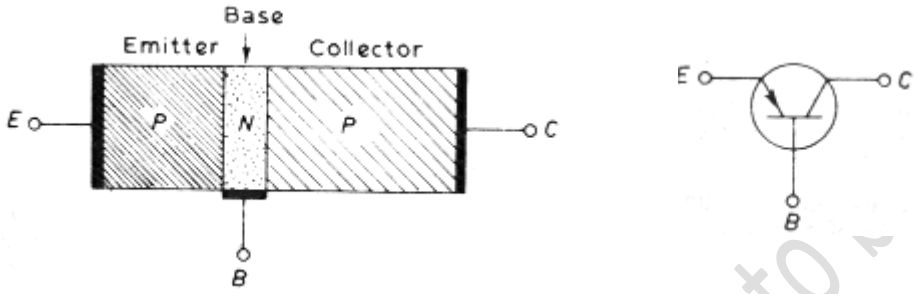
(2) N-P-N type.

In both types there are their terminals namely, emitter, base and collector. The terminal, which emits the charge, called an emitter and that which collects charge is called

collector. The middle layer between the Emitter and Collector is called base, the junction between base and emitter is called the Emitter junction and that between the base and the collector is called the Collector junction. The function of base is to control the collector current.

**(A)P-N-P Type transistor:**

It is made of two P-type layers and one N-type layer. In this type, we add two P-type layers, on either side of an N-type layer. In this way, we get a P-N junction and an N-P junction. We can compare a P-N-P transistor with two diodes in which N type semi conductor material is joined in between. The two diodes are called emitter-base diode or emitter diode and the collector base or collector diode.

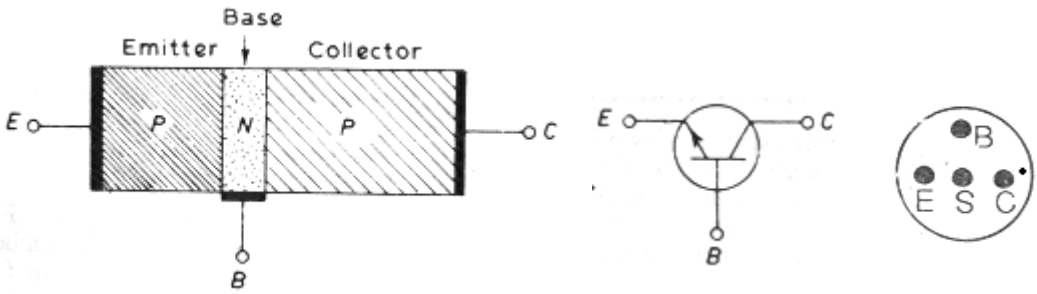



The schematic structure and graphical symbol of Transistor

**(B) N-P-N Transistor:**

It is made of two N-type and one P-type semiconductor layer. In this transistor, between the two layers of N-type semiconductor material, there is a layer of P-

type material and the properties of the N-P-N transistor are completely opposite to P-N-P transistor. The figure shows the schematic representation of NPN transistor.

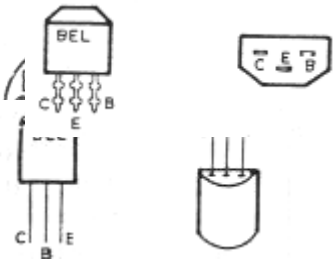



Schematic structure symbolic representation

Structure and symbolic representation of N-P-N transistor.

**Identify the terminals of Transistor:** Generally, there are three terminals in transistors, called Emitter, Base and Collector, but in high frequency transistor there is an additional terminal called shield and this terminal is generally connected to the body of transistor. To identify the terminals of transistors, we follow the following points:

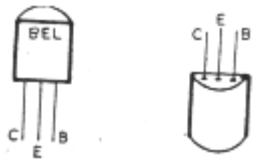
1. Terminals are in straight line, emitter and base are closer, whereas base and collector are more apart. Terminal configuration is shown in the figure.




2. The shapes of all transistors are semi-circular and terminals are in straight line. To identify the terminals, we take transistors in hand in a way that the portion of transistor on which the numbers are written, remain towards us and terminals remain on the lower side. The left- terminal is collector, right terminal is emitter and middle terminal is base. These transistors are called Si planer transistors. These transistors are- BEL 188, BEL 187, BEL 147, BEL 148, BEL 158, BEL 157 etc. Some transistors have four terminals, shield(S), base (B), emitter (E) and collector(C). All terminals are in straight line and the terminal which is away from the other terminals is the collector terminal. Example: AF115.
3. Some transistors have four terminals and three terminals are in straight line. These are emitter (E), shield(S) and collector(C) and fourth terminal is base(B). Example 2SA324.
4. Some transistors of special shapes, made by BEL Company, are called Epitexial transistors. Numbers of that transistors starts with BC and we identify the terminals according to figure. Few examples of this transistors are :BC147, BC148, BC149, BC157, BC158.

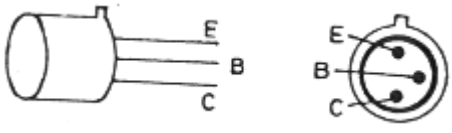

5. Some Epitaxial transistors of BEL Company whose numbers starts with BF and we identify the terminals of thattransistors are done according to figure.

   Few of this transistors are BE167, BF195, BFJ97.The terminals of some planer transistor like BEL195 and BEL 194 etc. are different than other planer transistors of BEL. There the base and emitter are interchanged and the terminals can be identified according to figure.



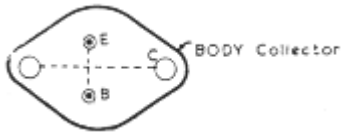

6. In some transistors, the terminals are arranged in a triangle fashion and there is a coloured dot near terminals. This dot shows collector terminal. The middle one is called base and rightmost is called emitter. It is shown in figure. The numbers of some that type transistors are AC127, AC128, AC187, AC188


7. Some transistors have metallic body and a metallic tip, near the terminal. That terminal which is nearer to tip is called emitter middle terminal is called base and leftmost terminal is called collector, as shown in figure. Numbers of some that type of transistors are: BD115, 2N2905, CL1OO, SK1OO, BC109, BO150, 2SC2193, 2SC2131, 2SC1820.




8. Some power transistors have special shape. Generally, there are only two terminals and the body of that transistor itself works as collector. The other terminals are identified

according to figure. Numbers of some this type of transistors are AD149, AD161, AD162 BU105, BU108, BU205, BU207, 2N3055 etc. There are two holes on the body of these transistors. There are 2 pins for the emitter and base. The distance of pins of one hole is less than the distance from the other hole. By putting the former hole towards us, we find that right terminal is base and left one is emitter. These transistors are used in different black and white TVs.




**Identification of transistor by visual inspection**

Pick up the terminals pointing towards you and the flat side pointing away from you, the right terminal is the emitter the middle is always a base and the left terminal is the collector

**Identification of N-P-N and P-N-P Transistor with the help of Multimeter**

1. Put the multimeter in the ohm (W) range

2. Measure resistance emitter-base and base-collector

3. Connect black probe of multimeter to transistor base and connect red probe to emitter and collector respectively

4. If pointer of meter shows low resistance then transistor is N-P-N

5.When we connect red probe to base and connect black probe to emitter and collector respectively and if meter shows low resistance then transistor will P-N-P

6. Each transistor will be either P-N-P or N-P-N. so meter shows low resistance once only checking.

**Measuring Instrument**

Many testings, measuring and indicating instrument have been developed to aid engineers and technicians in their work. For better understanding of electronic principles, a student is expected to do some experimental exercises. Some of the basic instrument needed in an electronics laboratory is:

- Energy Meter
- Ammeter
- Voltmeter
- Multimeter
- CRO

**ENERGY METER**

An energy meter is an instrument used for recording the energy consumed by a consumer in the form of 'UNIT' or 'KWH'. It is also known as Kilo Watt Hour meter. One kilo watt hour power means a thousand watts of power have been consumed in one hour. It is usually fixed in main

supply lines for Supply Company at domestic installation. Usually the meter is sealed by Supply Company. The old dial type of meters has now been replaced by new cyclometer type energy meters. The new cycle type energy meter is direct reading meter, which shows the total number of kilo watt hours of electric power consumed. In this type of meter, first to fifth position umber form the left are for units and extreme right under indicates fraction of a unit. The total units consumed over a certain period can be calculated from present reading and previous reading in KWH Units. The difference between previous and present reading will give the KWH of power consumed. Connection of energy meters are done in domestic installation by electricity supply company as shown in Fig.

**Ammeter**

An **Ammeter** is a measuring instrument used to measure the electric current in a circuit. Electric currents are measured in amperes (A), hence the name is ammeter. Instruments used to measure smaller currents, in the milliampere or microampere range, are designated as milliammeters or microammeters.

**Construction of Ammeter**

- U shaped permanent magnet
- Rectangular copper coil
- Suspension wire
- Iron core
- Pointer
- Shunt
- Instrument used to measure current in the circuit.
- Always connected in series with the circuit and carries the current to be measured.
- This current flowing through the coil produces the desired deflecting torque.
- It should have low resistance as it is to be connected in series.

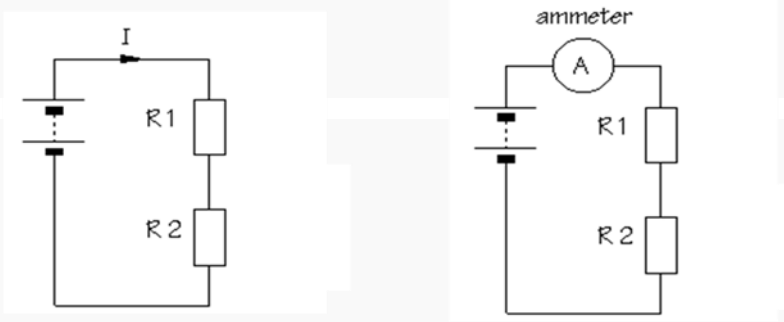



Fig- Ammeter connection in circuit

All the current flowing in the circuit must pass through the ammeter

**Voltmeter**

A **voltmeter** is an instrument used for measuring electrical potential difference between two points in an electric circuit.

Voltmeters have two types

1- Analog
2- Digital

Analog **voltmeters** move a pointer across a scale in proportion to the voltage of the circuit

Digital **voltmeters** give a numerical display of voltage by use of an analog to digital converter.

- Instrument used to measure voltage between two points in a circuit.
- Always connected in parallel.
- Current flowing through the operating coil of the meter produces deflecting torque.
- It should have high resistance.

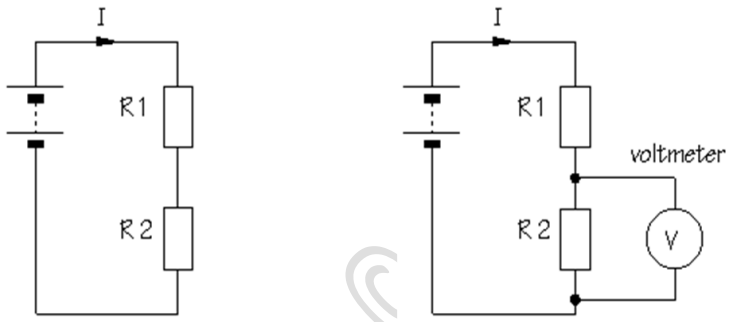



Fig- Voltmeter connection in circuit

**Advantages**

- The instruments are suitable for use in AC and DC circuits.
- The instruments are robust, owing to the simple construction of the moving parts.
- The stationary parts of the instruments are also simple.
- Instrument is low cost compared to moving coil instrument.
- Torque/weight ratio is high, thus less frictional error.

**Errors**

- Error due to variation in temperature.
- Error due to friction is quite small as torque-weight ratio is high in moving coil instruments.
- Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.
- Error due to variation of frequency causes change of reactance of the coil and also changes the eddy currents induced in neighboring metal.
- Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material.

**Difference between Ammeters and voltmeters**

| Parameters | Ammeter | Voltmeter |
|---|---|---|
| Connection | It is to be connected in series mode | It is to be connected in parallel mode |
| Resistance | It has comparatively low resistance | It has high resistance |
| Uses | It is used to find the amount of current flowing in the circuit | It is used to find the potential difference in the circuit |
| Circuit | Circuit must be disconnected in order to attach the ammeter | Circuit does not need to be disconnected |
| Accuracy | Considered as less accurate | Considered as more accurate compared to ammeter |

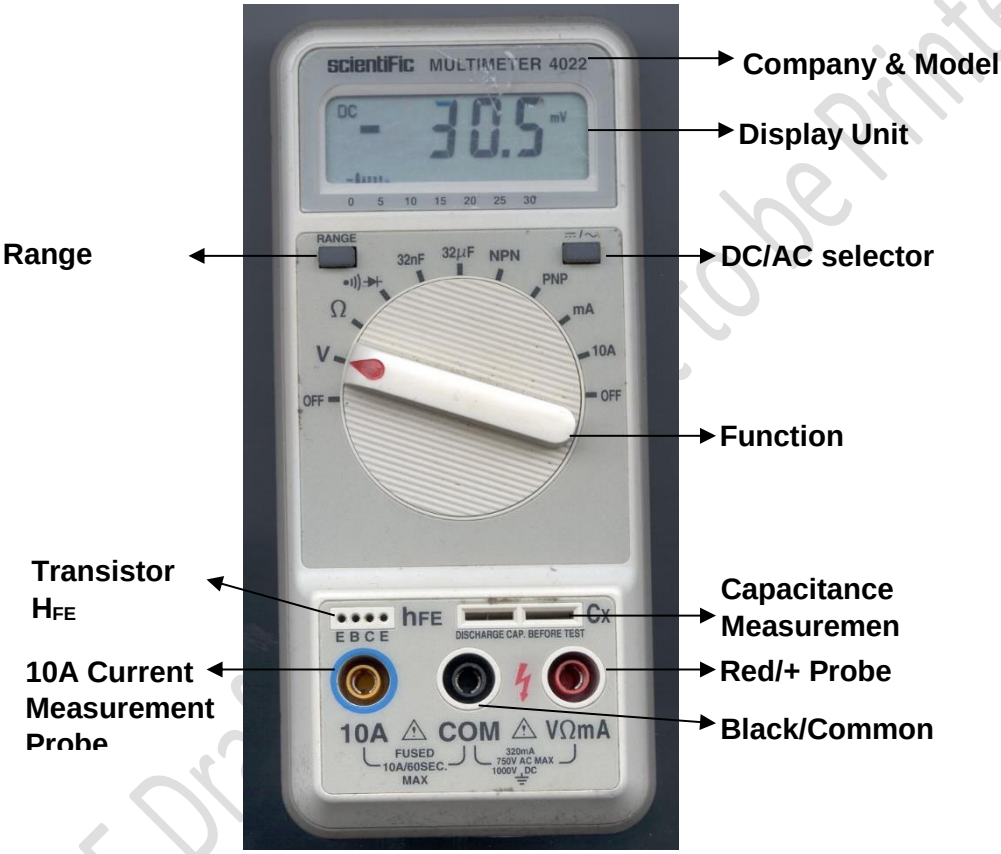
**PRECAUTIONS**

1. Take reading perpendicular to the needle to avoid parallaxes error.
2. Check zero errors of-all instruments before they are used.
3. In DC measurements check polarities.
1. Select higher range for measurement initially and later select required range for accuracy.
2. Select proper rated meter for measurement of electric quantities.

**MULTIMETER:**

The single meter, by which Voltage(V), Current(A), Resistance(R) and other measurement can be measured, is called the Multimeter. With the help of the multimeter, one can localize troubles (such as short circuits, or open circuits) in the electronic circuitry. **Figure** shows the photograph of a commonly used digital multimeter. This instrument is available in a large number of models.

To select the mode of measurement, a "function switch" is provided. By suitably adjusting this switch, the multimeter can be converted into a voltmeter, milli-ammeter, or an ohmmeter. Each position of the switch is labeled accordingly. There is another switch provided, called the

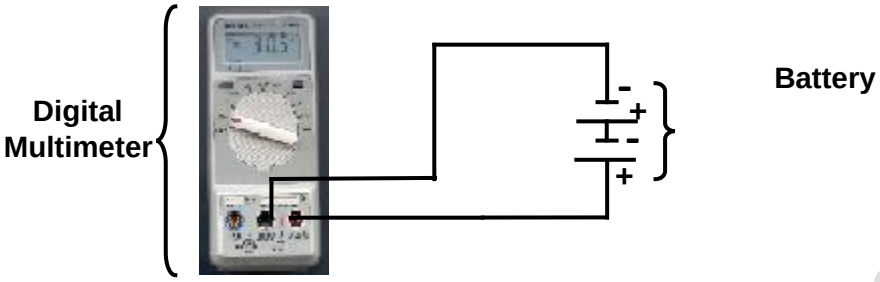



**Digital Multimeter**

"range switch". Each position of this switch is meant to fix a range of measurements. It is useful to start with the highest range and then switch down to lower ones, until the correct range is reached. This way the instrument is saved from damage due to an exceed current flowing through it. There are two types of multimeter basically use for measurement that is – analog and Digital multimeter but now a day the analog multimeter is out dated and digital multimeter is used.

We can measure the following measurement using Scientific 4022 digital multimeter.

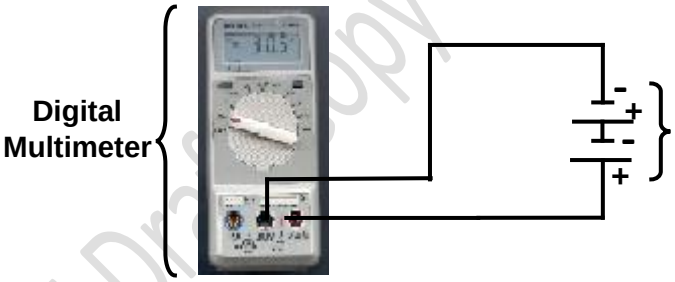
**DC Voltage:** From 320 mV to 1000 V. The battery supply or rectified supply known DC Voltage. DC supply have two wire call Positive (+) and Negative.




**DC Voltage Measurement**

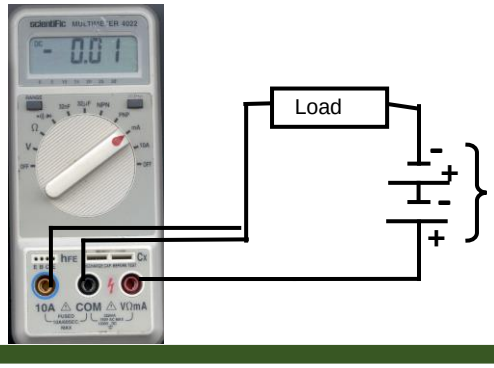
**Procedure of Measurement:** Place black probe on **COM** (Black) socket and Red probe on **VmA** (Red) socket of multimeter. Switch ON the multimeter (default setting on DC Voltage) and place the Red probe(lead) of multimeter on Positive (+) terminal of battery and black probe(lead) of multimeter on Negative(-) terminal of battery (please make connection according the above circuit diagram) and read the voltage of battery on multimeter.

**AC Voltage:** 3.2 V to 750 V (between 40Hz-400Hz). The house or electric supply or Generator supply or without rectified supply known AC Voltage. These supplies have two wire called Phase and Neutral. If we put a tester on phase wire the tester indicates light.




To measure the AC Voltage, make connection according to above circuit diagram and push DC/AC selector button in AC mode.

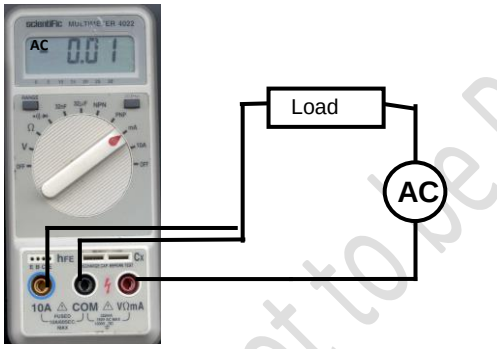
**DC Ampere (DC Current):** From 32 mA to 320 mA and 10A. To measure the DC Ampere, make connection as per following circuit diagram and place the selector switch on **mA** position. The load should not exceed 320mA. When load is greater than 320mA DC and not more than 10A



then selector switch on **10A** position and red probe (lead) of multimeter and place on **10A(Yellow)** socket then measure the DC load.

Circuit Diagram to Measure DC Ampare

**AC Ampere (AC Current):** From 32mA to 320 mA and 10A(between 40Hz to 400Hz). To measure the AC Ampere, make connection as per following circuit diagram, place the selector switch on **mA** position and push DC/AC selector switch on AC mode. The load not more then 320mA. when load is greater than 320mA DC and not more than 10A then selector switch set on **10A** position and red prove(lead) of multimeter place on **10A(Yellow)** socket then measure the AC load.




**Circuit Diagram for AC Current Measurement**

**Resistance:** From 0"Ω" to 32 M"Ω"

**RESISTANCE MEASUREMENTS:**

Set the Function switch to the "Ω" position.

Turn off power to the circuit when under test as external voltage may cause invalid readings.

**Resistance Measurement Diagram**

Connect the red test lead to the '**V□mA**' jack and the black test lead to the "**COM**' jack.

Connect the test lead to the point of measurements and read the value from the display.

**CONTINUITY MEASUREMENTS:**

Set the Function switch to the.**)))** " Position.

Turn off power to the circuit when under test as external voltage may cause invalid readings.

1. To toggle between the continuity/diode modes, press Range Switch.

2. Connect the test leads to the two points at which continuity is to be tested. We can hear a buzz when the resistance is less than approximately 20□

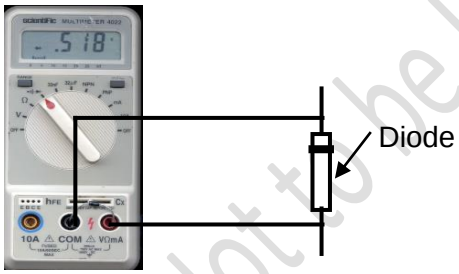
**DIODE TEST:**

1. Set the Function switch to position.
2. Turn off power to the circuit under test. External voltage across the components causes invalid readings.

**Diode Testing Circuit Diagram**

1. To toggle between the continuity/diode modes, press Range Switch.
2. Touch probes to the diode. A forward-voltage drop is about 0.5V or greater
3. Reverse probes. If the diode is good, 'OL' is displayed. If the diode is shorted, a value near 0mV will be displayed.
4. If the diode is open, 'OL' is displayed in both directions.

**CAPACITANCE MEASUREMENTS:**



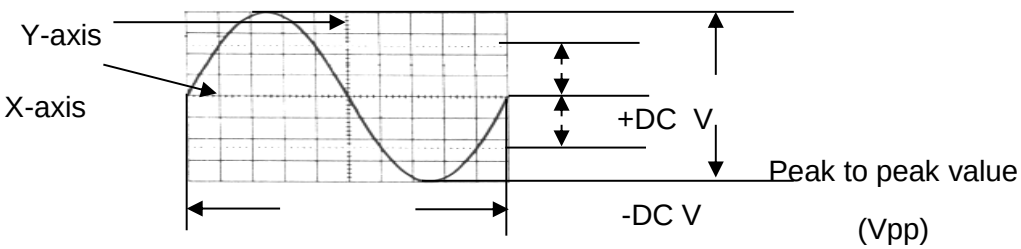

1. Set the Function/Range switch to the 32nF or 32uF range.
2. Never apply an external voltage to the **Cx** sockets as meter could get damaged.
3. Insert the capacitor leads directly into the **Cx** socket.
4. Read the capacitance directly from the display.

**VOLTAGE MEASUREMENT**

A CRO has a large impedance, and hence can be used as a D.C./A.C., voltmeter. The peak dissipation to be measured is connected across the Y-input terminals.

With D.C. the spot (if the time base is off) or line is deflected vertically (if the time base is on).

**AC Voltage Measurement:** With A.C., if Time base off) the spot moves up and down, the line are deflected up and down vertically if time base is




One Cycle

Sine wave

**DC Voltage Measurement:** For DC measurements a single trace line is required. The time base and trigger controls have no effect on the actual measurement. For DC measurements set the respective channel input selector switch to DC. Bring the trace to the reference line of the graticule. When a DC voltage is applied, the trace will move up or down for positive and negative voltages respectively while using ground as reference. The trace displacement can be measured in cm.

**Multimeter**

A meter is a measuring instrument. 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 instrument.

Fig.13 (a) Digital

Fig.13 (b) Analogue

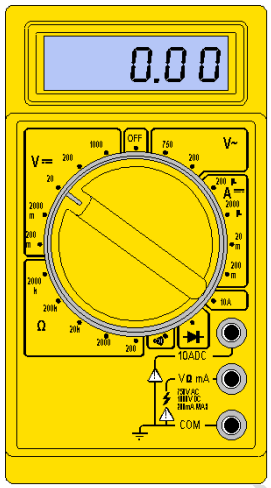
Multimeters are very useful test instruments. By operating a multi-position switch on the meter, they can be quickly and easily set to be a voltmeter, an ammeter or an ohmmeter. They have several settings (called 'ranges') for each type of meter and the choice of AC or DC. Some multimeters have additional features such as transistor testing and ranges for measuring capacitance and frequency.
Multimeters are available in digital and analogue types as shown in Fig.13.

***Digital Multimeter:*** The enlarged view of the digital multimeter is shown in Fig.14. The central knob has lots of positions and is selected for the type of measurement. If the meter is switched to 20 V DC, for example, then 20 V is the maximum voltage which can be measured, this is sometimes called 20 V fsd**,** where fsd is short for full scale deflection**.**
DC means direct current**.** In any circuit which operates from a steady voltage source, such as a battery, current flow is always in the same direction.
AC means alternating current**.** In an electric lamp connected to the domestic mains electricity, current flows first one way, then the other. That is, the current reverses, or alternates, in direction.

***Digital display-***
Values can be read directly from digital displays so they are easy to read accurately.

Digital meters may be connected either way round without damage; they will show a minus sign (-) when connected in reverse. If you exceed the maximum reading most digital meters show an almost blank display with just a 1 on the left-hand side.

All digital meters contain a battery to power the display so they use virtually no power from the circuit under test. For general use digital meters are the best type**.** They are easy to read, they may be connected in reverse and they are unlikely to affect the circuit under test. There are 3 terminals in the multimeter. Two leads are used for measurement. The black lead is always plugged into the common (COM) terminal. The red lead is plugged into either of the terminals depending upon the measurement i.e. voltage (AC or DC), current and resistance.



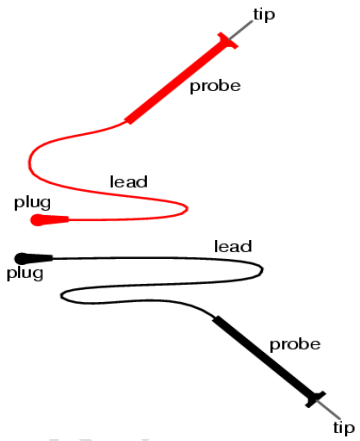




**Fig. 16 Multimeter probes and**

***Analogue Multimeter:*** The enlarged view of the analogue multimeter is shown in Fig.15. Analogue meters take a little power from the circuit under test to operate their pointer. Batteries inside the meter provide power for the resistance ranges, they will last several years but you should avoid leaving the meter set to a resistance range in case the leads touch accidentally and run the battery flat.

***Analogue display***- Analogue displays have a pointer which moves over a graduated scale. They can be difficult to read because of the need to work out the value of the smallest scale division. For example, the scale in the picture has 10 small divisions between 0 and 1 so each small division represents 0.1. The reading is therefore 1.25V (the pointer is estimated to be half way between 1.2 and 1.3).

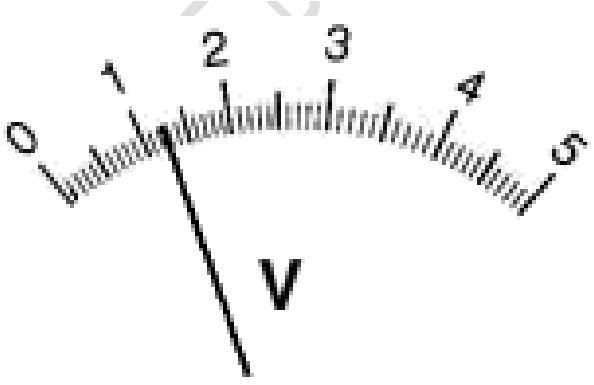




**Fig. 15 Analogue**

The maximum reading of an analogue meter is called full-scale deflection or FSD (it is 5V in the example shown). Like digital multimeter, in the analogue multimeter the black lead is always plugged into the common (COM) terminal. The red lead is plugged into any of the other of the terminals.

***Meter leads:*** Red meter lead is connected to Voltage/Resistance or Amperage port and is considered the positive connection. Black meter lead is always connected to the common port and is considered the negative connection as shown in Fig.16.

***Probes:*** These are the handles used to hold tip on the tested connection

***Tips:*** Are at the end of the probe and provides a connection point

***Common digital multimeter symbols:*** These symbols are often found on multimeter and schematics. They are designed to symbolize components and reference values. These symbols are shown in the table below.

| | | | |
|---|---|---|---|
| ~ | AC Voltage | ⏚ | Ground |
| ⎓ | DC Voltage | ⊣⊢ | Capacitor |
| **Hz** | Hertz | **µF** | Microfarad |
| **+** | Positive | **µ** | Micro |
| **—** | Negative | **M** | Milli |
| **Ω** | Ohms | **M** | Mega |
| ▷\| | Diode | **K** | Kilo |
| **.)))** | Audible Continuity | **OL** | Overload |

***Digital multimeter mode selector:*** As shown in the Fig. , use the mode selector to set the digital multimeter for the type of test to be performed. The meter can be set to the following modes:

1. *Off* – Turns the digital multimeter (DMM) off. Turning the mode selector to any other setting turn the DMM on.
2. *Volts AC*- It is used to measure voltage in alternating current (AC) circuits.
3. *Volts DC*- It is used to measure voltage in direct current (DC) circuits.
4. *Millivolts Dc(mV)DC*- It is used to measure very low voltage in direct current (DC) circuits.

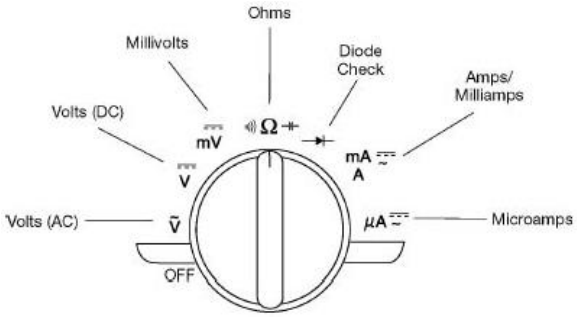



**Fig. DMM mode selector**

5. *Resistance/Continuity (ohms)*- It is used to measure resistance and check continuity.
6. *Diode check*- It is used to check the operation of a diode (DMM sends a small current through the diode).
7. *Amps or Milliamps AC/DC*- It is used to measure current in a circuit.
8. *Microamps (AC/DC)*- It is used to measure very small current in a circuit.

***Measuring voltage with a multimeter:*** Voltage (V) is the unit of electrical pressure. One volt is the potential difference needed to cause one amp of current to pass through one ohm of

resistance. Voltage is AC and DC. Alternating Current (AC) is house voltage (220 V AC) Direct Current (DC) is battery voltage (12V DC).

1. Select a range with a maximum greater than you expect the reading to be.
2. Connect the black (negative -) lead to 0V, normally the negative terminal of the battery or power supply.

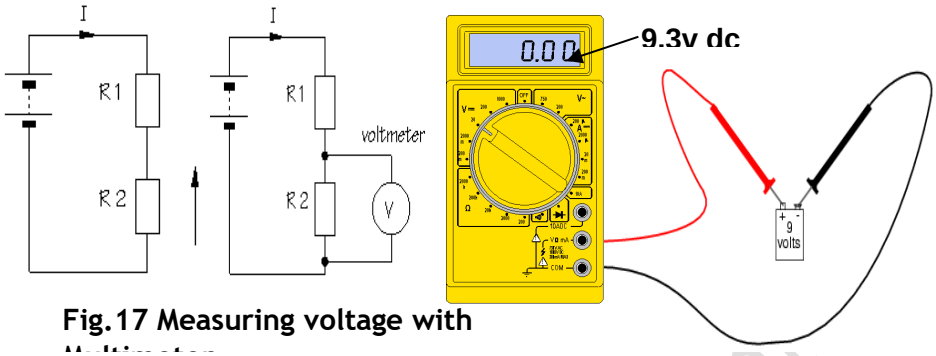



**Fig.17 Measuring voltage with**

3. Connect the red (positive +) lead to the point you where you need to measure the voltage.
4. The black lead can be left permanently connected to 0V while you use the red lead as a probe to measure voltages at various points. Measuring voltage with multimeter is shown in Fig.17.

***Measuring resistance and continuity:*** Resistance (Ω) is the opposition to current and is measured in Ohm's. To measure the resistance of a component it must not be connected in a circuit.

1. Disconnect power source before testing.
2. Remove component or part from system before testing.
3. Set the meter to a resistance range greater than you expect the resistance to be.
4. Touch the meter probes together and check that the meter reads zero. If it doesn't read zero, turn the switch to 'Set Zero' if your meter has this and try again.
5. Put the probes across the component. Avoid touching more than one contact at a time or the resistance will upset the reading. The reading is displayed on the screen of multimeter.
6. Testing for continuity is used to test to verify if a circuit, wire or fuse is complete with no open. The resistance measurement and testing for continuity is shown in Fig. 1

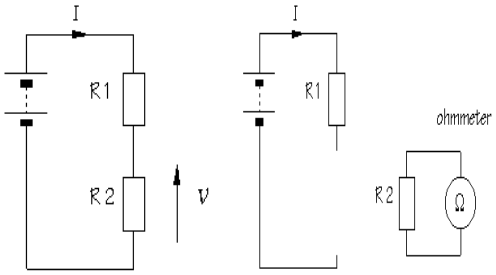
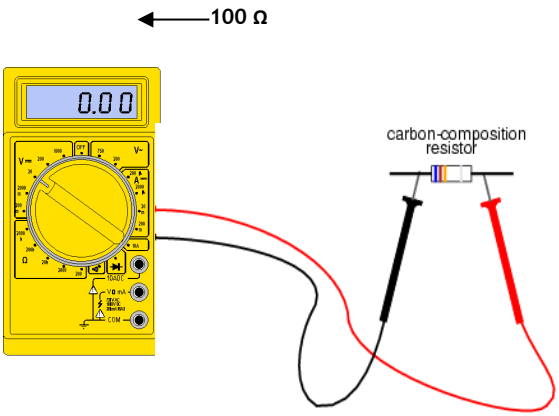



**Fig. 18 Measuring resistance with Multimeter**



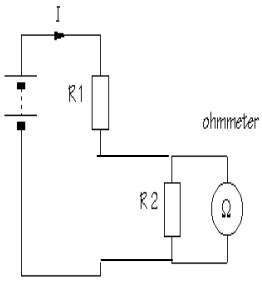
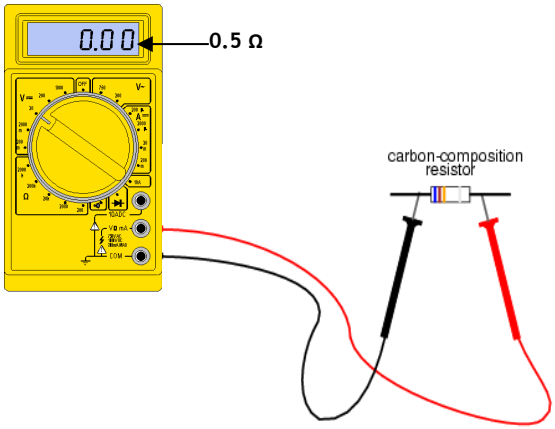




**Fig. 18 Measuring continuity with Multimeter**




***Measuring current:*** Current measurements are made in a different way to voltage and other measurements. Current consists of a flow of electrons around a circuit, and it is necessary to

be able to monitor the overall flow of electrons. A simple circuit is shown in Fig 19 (a); there is a battery, a bulb which can be used as an indicator and a resistor. To change the level of current flowing in the circuit it is possible to change the resistance, and the amount of current flowing can be gauged by the brightness of the bulb. When using a multimeter to measure current, the only way that can be used to detect the level of current flowing, is to break into the circuit so that the current passes through the meter. A typical current measurement can be made as shown in Fig 19(b). From this it can be seen that the circuit in which the current is flowing has to be broken and the multimeter inserted into the circuit.

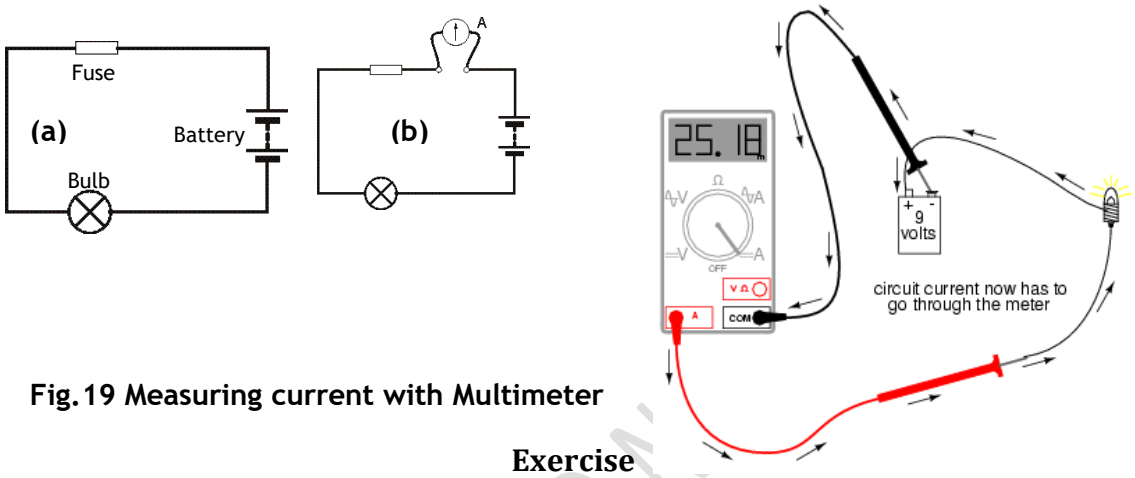



**Fig. 19 Measuring current with Multimeter**

## Exercise

1. Which one of the following is an active component?

   a. resistance
   b. inductor
   c. transistor
   d. Capacitance

2. A milli watt is equal to

   a. 1/10 watt
   b. 1/100 watt
   c. 1/1000 watt
   d. 1000 watt

3. Which one of the following is not an electromechanical component?

   a. Vibrator
   b. Relay
   c. Transformer
   d. Switch

4. In the colour code of resistance is electronic circuits the tolerance is resented by

   a. First band
   b. Second band
   c. Third band

d. Fourth band

5. In the 4-band colour code resistance the number 2 is indicated by colour
   a. 1 red
   b. 2 yellow
   c. 3 black
   d. 4 green

6. The capacitance is measured in

   a. Henry
   b. Ohms
   c. Hertz
   d. Farads

7. The capacitance of a parallel plate capacitor will be more if

   a. Plates have large area and short distance between plates
   b. Plates have small area and large gap between plates
   c. Small area of plates and high applied voltage
   d. Large plate area, large plate distance and dielectric of low value

9. Which Value of AC currents are measured by ammeters?

   a. Peak value
   b. Average value
   c. Instantaneous value
   d. R.M.S. value



## Session 3

## Draw and design basic circuits

### Combination of Resistances

Connecting two resistances to get the required value is known as combination of the resistances. Resistances can be combined in three ways.

1. Series Combination
2. Parallel Combination
3. Series Parallel Combination.

### 1. Series Combination

When one end of a resistance is connected to one end of a second resistance and other end of second resistance is connected to the end of third resistance, then this combination is known as series combination. It is shown in figure. In the series combination, each resistance must be of same watt. In this combination, the total resistance of the combination is the sum total of the resistance

used in it and the total wattage is the wattage of a single resistance. However, if resistances of different watts are used then the total wattage will be the wattage of lowest wattage resistance used. According to the figure.

Total value = 10+20+ 50= 80 Ω

In this way, if in any circuit resistance R1, R2, R3 & R4 are connected in series than total resistance (RT) can be calculated by the given formula.

RT = R1 + R2 + R3 + R4 + … Rn

Where RT = Total resistance

n = No. of resistances used

R1- R4 = Different resistances

**Note:** Total resistance is used to calculate the current in the circuit. In this case, ohm's law will be as follows

$$I = \frac{V_T}{R_T}$$

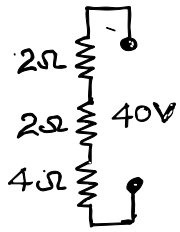
Where $V_T$ = voltage between total resistance

$R_T$ = Total resistance

**For example:** Two resistances, each of 2 Ω and a resistance 4 Ω are connected in series. Calculate the total resistance of the combination. If supply of 40V is given to this circuit, then calculate the total current.

**Solution:**

RT = R1 + R2 + R3 = 2 + 2 + 4 = 8 Ω




The total resistance of the circuit is 8 Ω

Total current. $I = \frac{V_T}{R_T}$

Since $V_T$ = 40V & $R_T$ = 8 Ω

$$I = \frac{40}{8} = 5 \text{ Amp.}$$

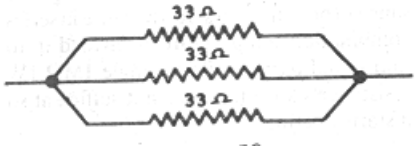
Thus, 5 Amp of current will flow in the circuit on giving supply of 40V. This 5 Amp current will remain same in all the part of the circuit.

**ii. Parallel Combination:**

In parallel combination, two or more resistances are connected across a same voltage source. In this condition, each resistance makes different path for current flow. In this way, voltage across all the resistances is equal to the voltage capacity of voltage source. This is just opposite of the series circuit, where current remains and voltage drops according to the value of resistance. Different wattage resistance can be used in the parallel combination. Hence, total wattage of the combination is equal to the sum total of all the wattage of the resistances and equivalent resistance of the parallel combination can be found by the formula given below.

$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4} + \ldots.(1)$$

Here, RT is the equivalent resistance of all the resistance used in the circuit. According to the figure, the equivalent resistance will be.




$$\frac{1}{RT} = \frac{1}{33} + \frac{1}{33} + \frac{1}{33} = \frac{3}{33} = \frac{1}{11}$$

or RT = 11 Ohm

**Series Circuit**

When resistors are connected as in fig. so that the same current passes through all of them, they are said to be in series.

Here the resisters $R_1$, $R_2$, $R_3$ are connected in series with each other i.e. $R_1$ is connected with $R_2$ and $R_3$ and $R_3$ is connected with $R_1$ through a battery supply. The current flow is in same direction (i.e. one direction)

'I' ampere current flows in all three resisters.

Each register has a voltage drop across it as given by Ohms law. Thus

$$V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$$

The total drop in three registers put together is

$$V = V_1 + V_2 + V_3$$

$$V = I(R_1 + R_2 + R_3)$$

$$\frac{V}{I} = (R_1 + R_2 + R_3)\left[\frac{V}{I} = R\right]$$

Where $R = (R_1 + R_2 + R_3)$

When one or more batteries are connected in series with each other, the potential difference is the sum of the individual ones.

In the above there are four batteries ($V_1, V_2, V_3$ *and* $V_4$) connected in series with each other.

Total potential difference (V) is

$$V = V_1 + V_2 + V_3 + V_4$$

According to Ohm's law

$$I = \frac{V}{R} \text{ and } V = IR$$

Here $V = V_1 + V_2 + V_3 + V_4$

The voltage drop in each resistor is

$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$
$$V_4 = IR_4$$

Where $R_1$, $R_2$, $R_3$ and $R_4$ are the internal resistance of each battery.

Therefor $R = R_1 + R_2 + R_3 + R_4$

**Example**

20 Ω, 40 Ω and 60 Ω resistors are connected in series across a 240 V supply. Find out the total resistance of the circuit and current that flows through the circuit.

$R_1$ = 20 Ω $R_2$ = 40 Ω, $R_3$ = 60 Ω

**Solution**

$R_1$ = 20, $R_2$ = 40, $R_3$ = 60

E = 240 V

R = ?, I = ?

According to Ohm's law

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

Where R $= R_1 + R_2 + R_3$

R = 20 + 40 + 60 = 120 Ω

R = 120 Ω

I = 2 A

**Example**

Three resistors are connected in series. The total resistance of the circuitis 60 Ω. The first two resisters are 25 Ω and 15 Ω. Find out the third one.

**Solution**

In series total resistance (R) is

$$R = R_1 + R_2 + R_3$$

$R_1$ = 25 Ω, $R_r$ = 60 Ω

$R_2$ = 15 Ω

$R_3$ = ?

$R_r$ = $25+15+R_3$

60 = $25+15+R_3$

$R_3$ = 60 – 40

$R_3$ = 20 Ω

**Important rules of a series circuit**

1. In the series circuit, the current flows in one direction
2. Total Resistance
$$R = R_1 + R_2 + R_3 \ldots\ldots\ldots$$
3. In a series circuit, the same current passes through all its resistors.
4. The total drop across the series circuit is the sum of voltage drop across each resistor.
$$V = V_1 + V_2 + V_3 \ldots\ldots\ldots$$
5. The total series circuit will be inactive (there is no current flow) there is a fault in any one of its resistors.
6. This type of connection is used in serial sets (Decorative lamps)

**RESISTANCE IN PARALLEL CIRCUIT**

When resistors are connected across one another so that the same voltage is applied between the end points of each, then they are said to be in parallel. The current in each resistor is different and the current I taken from the supply is divided among the resistors.

In parallel circuit total current (I) is equal to some of the currents $I_1$, $I_2$, $I_3$

$$I = I_1 + I_2 + I_3$$

According to Ohm's law, we can find the total resistance (R) as given below

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

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

But $I = I_1 + I_2 + I_3$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \text{ Where } \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)\frac{1}{R} = \frac{R_3R_2 + R_3R_1 + R_1R_2}{R_1R_2R_3}$$

$$\frac{1}{V} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right), \frac{1}{V} = \frac{1}{R}, \quad R = \frac{R_1R_2R_3}{R_3R_2 + R_3R_1 + R_1R_2}$$

**IMPORTANT RULES OF PARALLEL CIRCUIT**

1. In the parallel circuit current flows through two or more paths at a junction. That is, it gets divided

$$I = I_1 + I_2 + I_3$$

2. The voltage drop is same in all resistors
3. If there are 3 resistors ($R_1$, $R_2$, $R_3$) in circuit

$$R = \frac{R_1R_2R_3}{R_3R_2 + R_3R_1 + R_1R_2}$$

1. If there is a fault in one resistor the other two resistors will work. The current will be divided into two parts and will flow through the two resistors.

**Example**

6 Ω and 4 Ω resistors are connected in parallel through 240v supply. Find out the total resistance and current flows in it.

**Solution**

$R_1$ = 6 Ω, V = 240 v

$R_2$ = 4 Ω

R = ?

In parallel circuit

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 4}{6 + 4} = \frac{24}{10}$$

R = 2.4 Ω

According to Ohm's law

$$I = \frac{V}{R} = \frac{240}{2.4} = 100\ A$$

$I$ = 100 Amp

**Example**

Three resistors 10 Ω, 5 Ωand 2 Ωare connected in parallel.The total current flowing in the circuit is 2A. Find out the total resistance and supply voltage of the circuit.

$R_1$ = 10 Ω

$R_2$ = 5 Ω

$R_3$ = 2Ω

R = ?, I = 2 A, V = ?

$$R = \frac{R_1 R_2 R_3}{R_3 R_2 + R_3 R_1 + R_1 R_2}$$

$$= \frac{10 \times 5 \times 2}{10 \times 5 + 5 \times 2 + 10 \times 2}$$

$$= \frac{100}{10 + 20 + 50} = \frac{100}{80} = 1.25\ \Omega$$

$$R = 1.25\ \Omega$$

$$V = IR$$

$$V = 2 \times 1.25 = 2.5$$

$$V = 2.5\ V$$

**RESISTANCE IN SERIES PARALLEL CIRCUIT**

In this circuit one and more resistors connected in series with one more resistor connected in parallel. It is a combination of series and parallel circuit

In the above series parallel circuit there are five resistors ($R_1$, $R_2$, $R_3$, $R_4$, $R_5$) placed in it among them $R_1$, $R_2$ are connected in series and $R_3$, $R_4$, $R_5$ are connected in parallel. The parallel resistors are connected in series with $R_1$ and $R_2$.

Here the total resistance of the circuit is

$$R = R_1 + R_2 + \frac{R_3 R_4 R_5}{R_3 R_4 + R_3 R_5 + R_4 R_5}$$

**Example**

10 Ω and 8 Ωresistors are connected in parallel with a 4 Ω resistor is series. Find out the total resistance of the series parallel circuit.

Resistance of the parallel circuit

$$R_p = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{10 \times 8}{10 + 8}$$

$$= \frac{80}{18}$$

$$R_p = 4.44\ \Omega$$

Total resistance of the series parallel circuit

$$R = 4.44 + 4$$

$$R = 8.$$

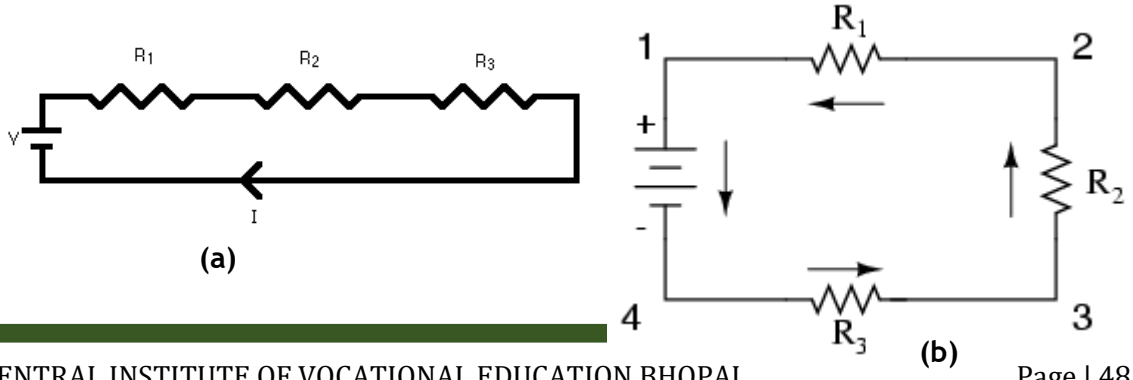



Fig.11 Series Circuits

A series circuit is shown in the Fig. 11(a) the current flows through each resistor in turn. If the values of the three resistors are:

$R_1 = 9\Omega,\ R_2 = 10\Omega$ and $R_3 = 5\Omega,$ The total resistance is $8 + 10 + 5 = 24\Omega$

With a 12 V battery, by V = I R the total current in the circuit is:
I = V / R = 12 / 24 = 0.5 A. The current through each resistor would be 0.5 A.
The defining characteristic of a series circuit is that there is only one path for electrons to flow. In the circuit, Fig.11(b) the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

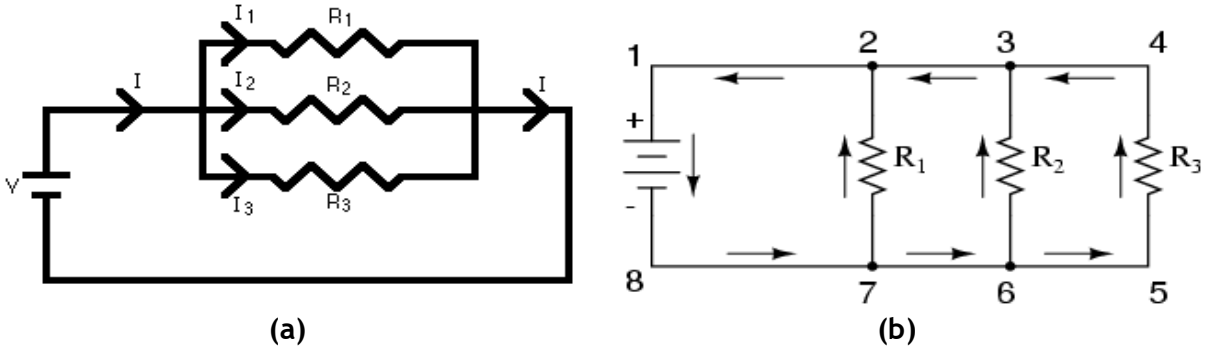
***Parallel Circuit:*** A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same.

The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total:

Equivalent resistance of resistors in parallel:

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

The parallel circuits are shown in Fig.12.




(a) (b)

**Fig.12 Parallel Circuits**

In case of a parallel circuit shown in Fig 12(a) the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance. If the values of the three resistors are:

$R_1 = 4\Omega,\ R_2 = 4\Omega$ and $R_3 = 12\Omega,$ The total resistance is found by

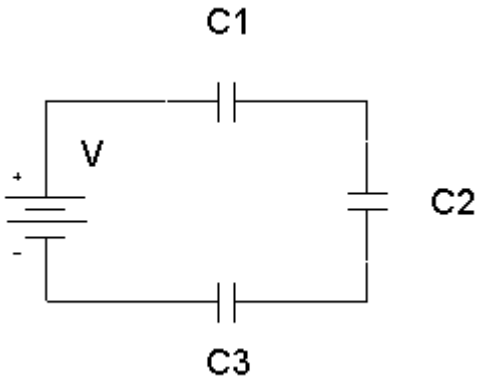
$\frac{1}{R} = \frac{1}{4} + \frac{1}{4} + \frac{1}{12} = \frac{7}{12}$. Therefore $R = 1.71\Omega$

With a 12 V battery, by V = I R the total current in the circuit is: I = V / R = 12/ 1.71 = 7 A.
The individual currents can also be found using I = V / R. The voltage across each resistor is 12 V, so:

$I_1$ = 12 / 4 = 3 A
$I_2$ = 12 / 4 = 3 A
$I_3$ = 12 / 12 = 1 A
The currents add together to 7A, the total current
In Fig.12 (b) there are three resistors, and form more than one continuous path for electrons to flow. First path is from 8 to 7 to 2 to 1 and back to 8 again. Second from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again, and third path from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and back to 8 again. Each individual path (through $R_1$, $R_2$, and $R_3$) is called a branch.

The characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. In the Fig. 12(b) the points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. All resistors as well as the battery are connected between these two sets of points.

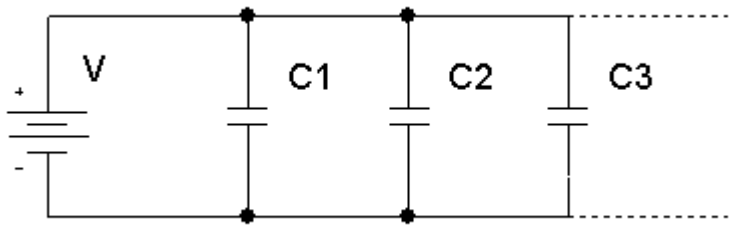
**Capacitors in series**




The total capacitance of capacitors in series, C1, C2, C3, :

$$\frac{1}{C_{Total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

**Capacitors in parallel**




The total capacitance of capacitors in parallel, C1,C2,C3,.. :

$C_{Total} = C_1+C_2+C_3+...$

**Exercise**

1. In serial circuit, current is
   a) Different
   b) Same
   c) Variable
   d) Normal
2. In parallel circuit, voltage is
   a) Different
   b) Same
   c) Variable
   d) Normal
3. The total resistance of two resistors R1 and R2 when connected in parallel is given by…….
4. Four capacitors each of 1 µF are connected in parallel. The equivalent total capacitance will be
   a) 4 µF
   b) 1 µF
   c) 0.25 µF
   d) 2 µF

**Activity**- Connect three bulbs in parallel combination

a. Power is measured in…….
b. When a conductor having 1 V potential between the two end points, one ampere current will be flowing through conductor and the resistance value of conductor is…….

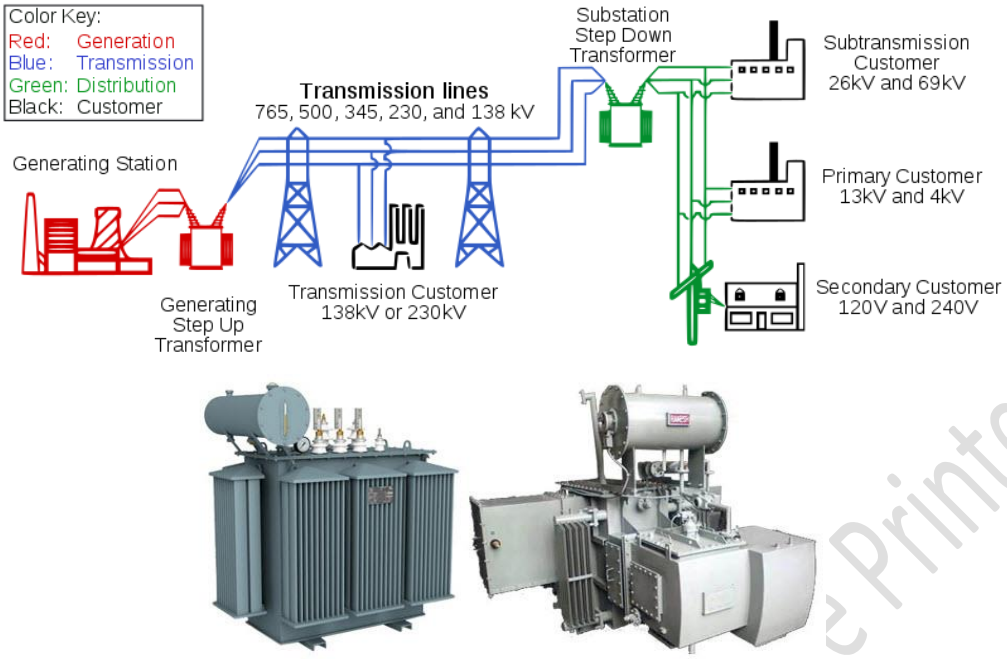
| MODULE 2 | OBSERVE THE OPERATION AND MAINTENANCE OF 11/0.433 KV DISTRIBUTION SUBSTATION |
|---|---|

| Module Overview |
|---|
| This module covers the fundamentals of the power distribution system. It explains the operation and maintenance of 11/0.4 kV distribution substations and transformers. Key components of transformers such as core, winding, conservator, and breather are described. The module highlights tools used in the erection and maintenance of distribution lines. It also focuses on the structure and advantages of the distribution network. |

| Learning Outcomes |
|---|
| After completing this module, you will be able to:<br>1. Explain power distribution system<br>2. Explain operation and maintenance of 11/.4 KV distribution substation<br>3. Explain distribution Transformer maintenance Activity (11KV/0.4 KV)<br>4. Recognise the power distribution system.<br>5. Distinguish the various parts of distribution network.<br>6. Explain the basic function of distribution transformer.<br>7. Explain advantage of distribution transformer.<br>8. Explain various components of transformer e.g. core, winding, conservator, breather etc.<br>9. Explain usage of various tools used for erection and maintenance of lines and distribution substation. |

| Module Structure |
|---|
| Session 1: Power Distribution System<br>Session 2: Operation and Maintenance of 11/.4 KV Distribution Substation<br>Session 3: Distribution Transformer maintenance Activity |

Transformer is at the heart of any power system. Hence, preventive maintenance is always cost effective and time saving. Transformers are used to step down the voltage so that 220/400-volt supply can be given for residential, commercial and industrial purpose. That means supply is directly depend upon the distribution transformer. So it is necessary to maintain distribution transformer in a good condition.






Transformers are very costly equipment so its failure is cost heavily to the discom as well as interruption in power supply also. Distribution transformer maintenance consist of maintenance of transformer, maintenance of 11 KV side and maintenance of LT distribution box. Any failure in one of these can cause failure of transformer.

Power Distribution System is the system that comprises various parts of an electric power system between the sub-transmission system and the consumers' service switches.

The process of distribution system or commonly referred to as distribution lines takes place once the voltage transformation at the distribution substation is completed.

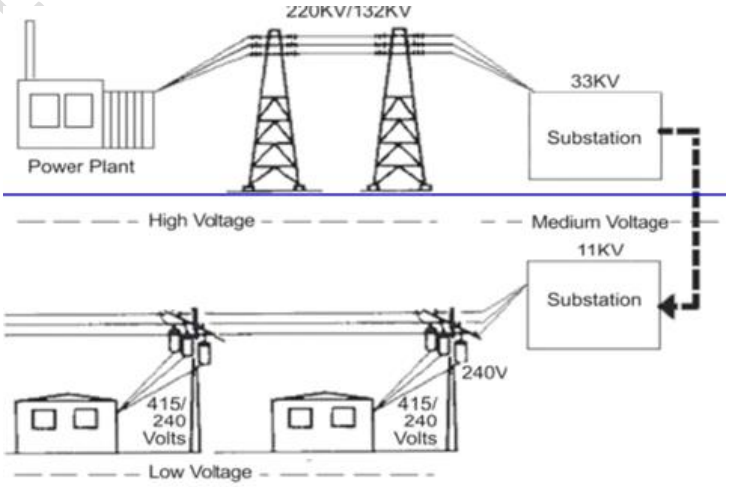



*Fig. 1.1 Distribution System*

The purpose of distribution line is to transmit power through conductors to different parts of the utility's franchise area. These lines typically use medium voltage to circulate power needed by the consumers. Distribution lines is said to be the final stage before satisfying the consumers or end users and when power is delivered to them.

**Types of Distribution System**

The types of distribution system are as follows:

**Radial System**: In this system, separate feeders radiate from a single substation and fee the distributors at one end only and are mainly used in rural area.

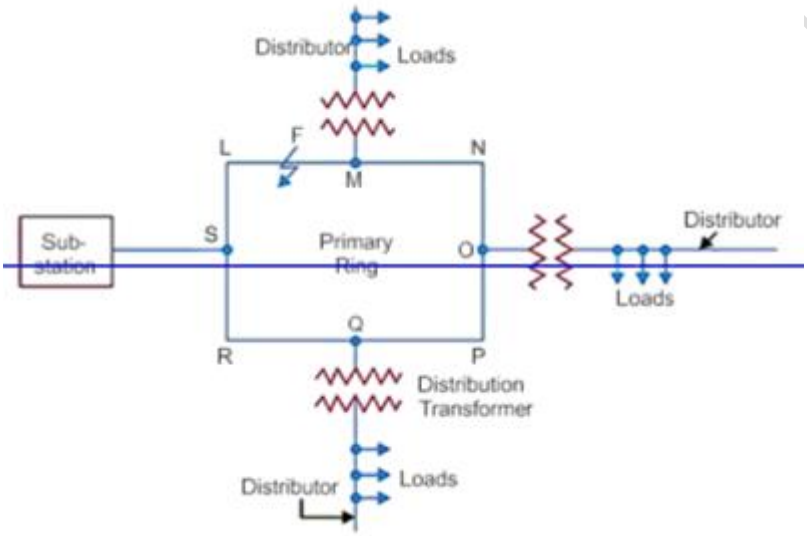



*Fig. 1.2 Interconnected System*

**Distribution Network**

Distribution of electric power is done by distribution networks. The power network, which generally concerns the common man, is the distribution network of 11 kV lines or feeders downstream of the 33-kV substation.

Each 11-kV feeder which emanates from the 33 kV substation branches further into several subsidiary 11 kV feeders to carry power close to the load points (localities, industrial areas, villages, etc.).

At these load points, a transformer further reduces the voltage from 11 kV to 415 V to provide the last-mile connection through 415 V feeders (also called as Low Tension (LT) feeders) to individual customers, either at 240 V (as single-phase supply) or at 415 V (as three-phase supply).

A feeder could be either an overhead line or an underground cable. In urban areas, owing to the density of customers, the length of an 11-kV feeder is generally up to 3 km.

On the other hand, in rural areas, the feeder length is much larger (up to 20 km). A 415 V feeder should normally be restricted to about 0.5-1.0 km. Unduly long feeders lead to low voltage at the consumer end.

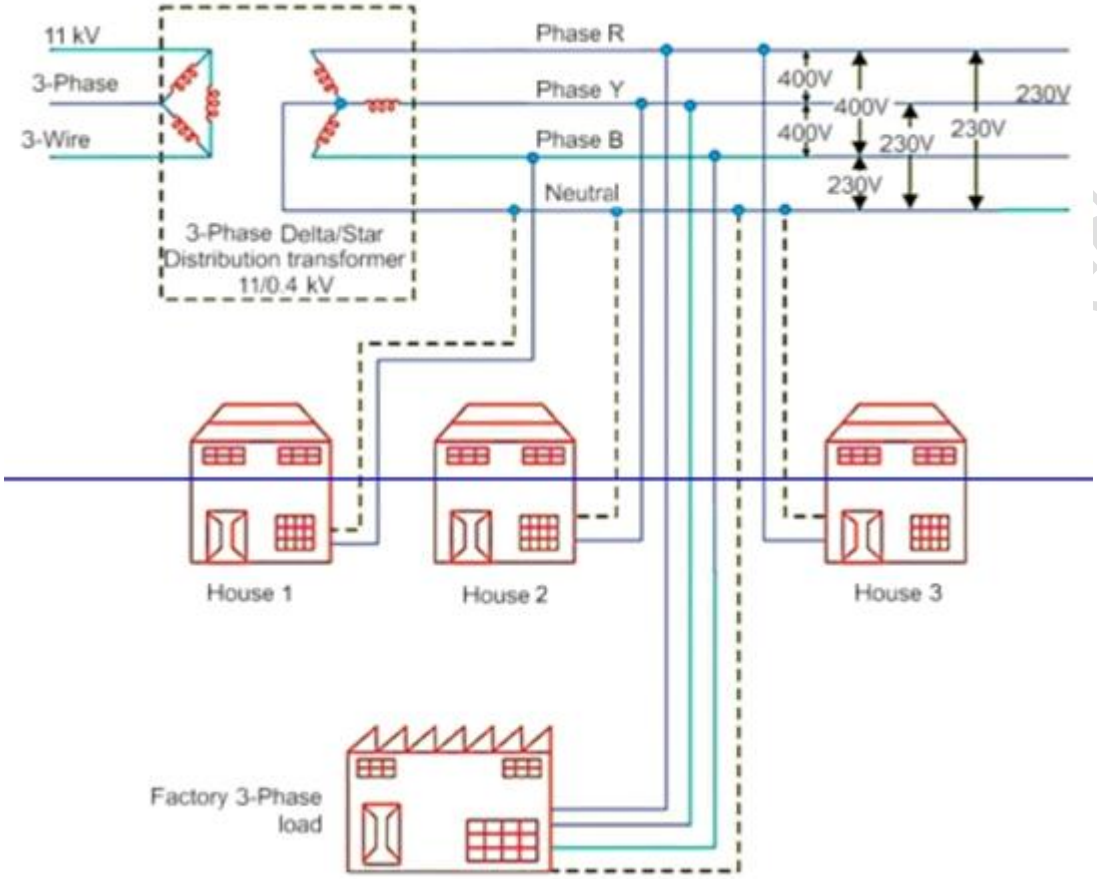



*Fig. 1.3 Distribution Network*



## CHECK YOUR KNOWLEDGE

**A. Fill in the blanks with suitable answers.**

1. Most distribution voltages are between …….. and ……..
2. The amount of current in a circuit depends on the amount of …….. available to motivate the electrons, and also the amount of …….. in the circuit to oppose electron flow.
3. In …… separate feeders radiate from a single substation and feed the distributors at one end only.
4. A …….. could be either an overhead line or an underground cable.
5. …….. and ……. are the two main two types of losses within a network.

**B. Choose the correct answers from the following options.**

1. Functions of Power Distribution Company is:

   (a) Purchase of power (b) Distribution of power

   (c) Accounting of energy (d) All of the above

2. In rural area which type of feeder system is used:

   (a) Radial (b) Interconnected

   (c) Ring main system (d) None of these

3 An electric circuit is formed when a conductive path is created to allow:
   (a) Free electrons to move continuously
   (b) Free protons to move continuously
   (c) Both of the above
   (d) None of the above

**C. Explain the following:**

1. Distinguish the various parts of distribution Network
2. Importance of distribution network



## Session 2
## Operation and Maintenance of 11/.4 KV Distribution Substation

### Various Components of Power System (33/11 kV Substation)

**Components:** Transformer, Isolators, CTs, PTs, Circuit Breaker, various types of panels and substation protection systems.

**Transformer:** An electrical power transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings. It transforms power from one circuit to another without changing its frequency but may be in different voltage levels. There are two types of transformers, namely:

- Power Transformer
- Distribution Transformer

Power transformers are installed at 33/11 KV substation. The standard ratings of a 33/11 kV power transformer are 3.15 MVA, 5MVA, 6.3/8MVA, 10/12.5 MVA, etc.

*Fig. 2.1 Power Transformer*

**Earth Switch:** It is mounted on the frame of an isolator, and used for each incoming or outgoing feeder. It discharges the voltage on the circuit to earth for safety.

*Fig. 2.2 Earth Switch*

**Lightning Arrester:** Over voltages may cause burning of insulation of sub-station equipment, if not well protected. Lightning is one of the most serious causes of over-voltages. Lightning arrestors or surge arrestors are used on electrical power systems to protect the insulation and conductors of the system from the damaging effects of lightning.

Lightening arrester discharges over voltage surges to earth, and protects the equipment insulation from switching and lightening surges.

A lightning arrester is located at three places:

- Near transformer terminals.
- As the first equipment as seen from the incoming overhead line

- Connected between phase and ground.

*Fig. 2.3 Lightning Arrestor*

**Different Parts of Transformer and their function**

The parts of transformer include the main tank, radiators, conservator, explosion vent, lifting lugs, air release plug, oil level indicator, tap changer, wheels, HV/LV bushings, filter valves, oil filling plug, drain plug and cable box.

A transformer is a static device which transforms A.C. electrical power from one voltage to another whilst retaining the same frequency.

The transformer works on the principle of mutual induction.

**Mutual Induction:** When the current passing through a coil or circuit undergoes a change, the magnetic flux linked with a neighbouring coil or circuit will also change. It will effect an e.m.f in the neighbouring coil or circuit. This event is known as Mutual Induction. The coil or circuit in which the current changes is called primary, while the one in which the e.m.f is induced is called secondary.

The distribution transformers are rated as 11/0.433kV. Thus, the voltage is reduced up to 433V to cater to the loads on the secondary side. The distribution transformers have generally ratings of 25kVA, 63kVA, 100kVA, 200kVA, 315kVA, 500kVA and 1000kVA. Transformers up-to 200kVA are generally erected as pole mounting sub-stations and transformers of higher rating are mounted on the plinth and placed on the ground.

The Distribution Transformers have Delta—Star connections. Hence, neutral is available on the secondary side. The loads on the secondary side can be three phased or single phased.

**Advantages of Transformers**

1. Transformer being a stationary machine, do not undergo wear and tear.
2. High voltage insulation can be provided due to stationery windings.
3. They need low maintenance, hence economical.

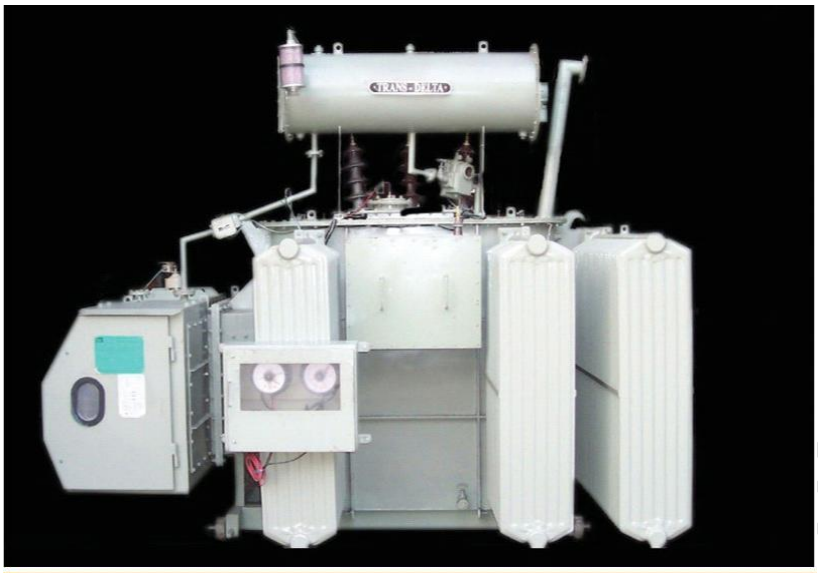


*Fig. 2.4 Distribution Transformer*

Main parts of transformer include:

i. **Main Tank:** It is made of steel sheets by welding them. In the main tank, core, winding and transformer oil is placed.

ii. **Core:** It is a set of 0.35 mm thick high-grade electrical steel sheets. Both sides of these lamination sheets are coated with insulating varnish to insulate them electrically from each other.

iii. **Winding:** Windings of the transformers are assembled on limbs of the core. Assembling the windings on core, first L.V. winding is assembled and then after, H.V. or Secondary winding is assembled over it. Conductors of both the windings are coated with insulation varnish. In addition, they are covered with paper and cotton tapes, which are properly impregnated with insulation, vanish. Both windings are insulated from the core and main tank by providing sufficient electrical insulation. Primary is generally connected in delta, whereas secondary is connected in star. As the resistance of the winding conductor is very low, it cannot be supplied with D.C.

*Fig. 2.4 Pole Mounted Transformer*

Back e.m.f is not created in D.C. This will give way to excessive flow of current, thereby damaging the coil; whereas in case of A.C., due to impedance and back e.m.f, the current does not exceed its limit.

**Accessories of Transformer**

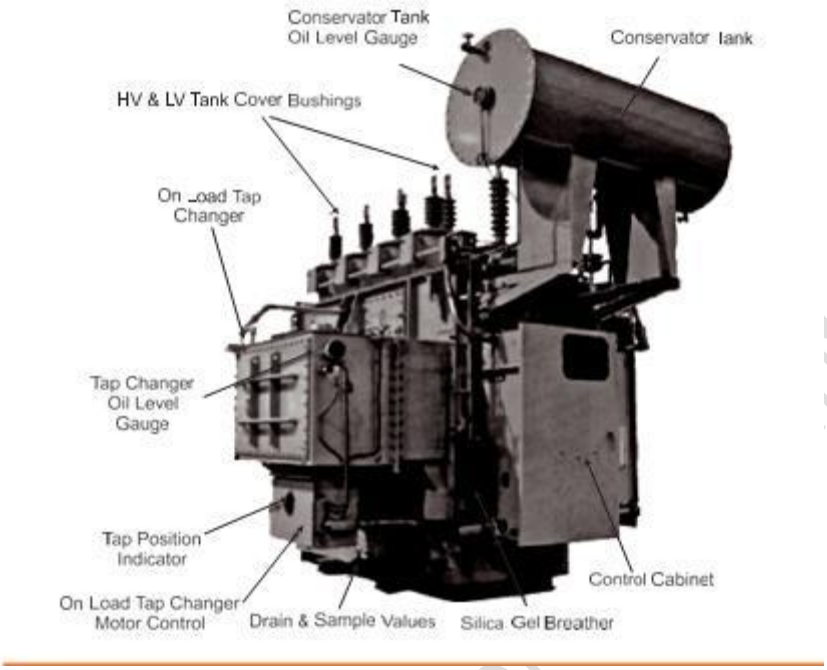



*Fig. 2.5 Parts of Transformer*

**Bushings:** Winding leads are to be removed from the transformer tank for connections. To maintain sufficient safe clearance of these leads from the body, Porcelain Bushings are provided on primary and secondary sides of the transformer. Rain sheds are provided to the bushings to protect them from rainwater.

*Fig. 2.6 Transformer Bushing*

**Explosion Vent:** On the top plate of the transformer tank, a narrow pipe of sufficient diameter with diaphragms on its both ends is fitted. One diaphragm is in between the oil in the tank and the pipe, whereas the upper diaphragm is at the top end of the pipe. Whenever there is severe fault inside the transformer, large quantities of gases are formed in the transformer tank. Due to the pressure of these gases, the lower diaphragm ruptures first. Further, the upper diaphragm ruptures as a result of the upcoming gases and oil, thereby, indicating the faulty conditions inside the transformer. By cause of the offered protection, the oil from transformer

tank is thrown out and chances of bursting of transformer are avoided. Sometimes, the lower diaphragm ruptures without any inside faults simply due to the oil pressure. In such cases, oil is visible in the glass window provided on the explosion vent. If this happens, measures to replace the ruptured diaphragm should be taken immediately.

**Conservator Tank:** Conservator tank, or Expansion Tank, is provided for the expansion and contraction of the oil in the transformer. This tank is connected to the main tank through a pipe with valves. Half of the total volume of the conservator tank is filled with oil. An oil level indicator is provided on the visible side of the conservator tank. Whenever the load on transformer increases, oil inside the transformer tank expands due to heat. Subsequently, the oil level increases. In such a scenario, if sufficient space is not available for the expansion of oil, the top cover of the transformer tank may burst due to excessive pressure. The conservator tank present in the transformer saves the situation by providing space to the expanded oil. The oil goes into the conservator tank, and thus the level of oil in the main tank remains under control. This also prevents the possibility of exposure to windings and damage to the radiators due to partial vacuum.

**Equalizer Pipe:** The pipe connecting the conservator tank and the explosion vent is known as Equaliser Pipe. If small quantities of gases are formed inside transformer tank, these gases will collect in the conservator tank. These gases will maintain equal pressure between the explosion vent and conservator tank with the help of the equaliser pipe.

**Breather:** Due to the variations in load on the transformer, the oil in it expands or contracts. Whenever the oil expands, the air in the conservator tank is to be expelled out, and when the oil contracts, the air gets sucked up by the conservator tank. This process is known as Breathing Action. For this, a breather is connected at the bottom of the conservator tank by way of a pipe projecting inside the conservator tank up to the air borne space. Breather is filled with silica gel crystals and a small cup with holes is provided at the bottom with small quantity of oil filled in it. The silica gel crystals absorb moisture from the air being filled in the conservator tank while the oil in the bottom cup of the breather arrests dust particles getting in the breather. Silica gel crystals let the dry air enter the conservator tank.

*Fig. 2.7 Breather*

Due to the absorption of moisture, the blue colour of silica gel crystals turns to pink. Such pink coloured crystals of silica gel are to be re-activated by application of heat, either by spreading them on a paper in the sun, or by heating them slowly in a metallic vessel. If the crystals turn

white, they are rendered useless, and should be replaced. Oil in the bottom cup of the breather also needs replacement if it becomes dirty.

**Tap Changer:** Many times low voltage complaints are received from the consumers which are away from transformer centres. This happens due to drop of voltage and lengthy of distribution lines. In such cases, tap changers of the transformer should be operated.

To operate the tap changer is not the job of an unskilled helper. Only linemen or senior staffs are authorized for it. Before operating the tap changer, D.O. fuses should be dropped; transformer should be made dead and then only tap changer be operated.

Oil leakages should be attended on priority. New transformer when charged, humming should be checked and if found unsatisfactory; then only load should be taken on it.It is essential to control the voltage in the system for two reasons. They are:

(I) To control the flow of kW & kVAr in the lines connecting generating stations.

(II) To maintain voltage at consumer end as per I.E. rules (+ 6%).


*Fig. 2.8 Tap Changer*

Voltage regulation is done by means of change of number of turns in H.V. winding with the help of tapings and the tap changer switch provided outside the tank. In a three-phase transformer, the arrangement of the switch is made in such a manner that the contacts of all the three windings are changed simultaneously. This tap changing assembly is known as Tap Changer.

There are two types of tap changers for distribution transformers:

- Off Load Tap Changers
- On Load Tap Changers

**Off Load Tap Changer:** Off Load Tap Changer is provided to transformer on H.V. windings by making taps on them. Connection of off load tap changer is brought on the top plate of the tank. It is oil-immersed and is located in main tank. It is designed to carry full load current of the transformer and is dissimilar to Circuit Breaker design i.e. it is not designed to work under loading conditions. Hence if OFF load tap changer is operated while the transformer is "ON";

there can be severe damage to the transformer and so the taps in such type of tap changer are changed by switching the transformer "OFF".

**On Load Tap Changer (O.L.T.C.):** In this type of the tap changers, transformer tap can be changed while the transformer is "ON" and is under loaded conditions. It is not essential to switch off the supply in this type of changer. The operations can be local manually; local electrically and remote electrically as per requirements. As already mentioned above, the ON LOAD Tap Changers are provided only in case of Power Transformers.

**Buchholz Relay:** Buchholz Relays are used for transformers above 500 kVA. It is a gas-operated relay and is used in power transformers. Whenever there is a fault in the transformer due to the decomposition of oil, gases are formed into bubbles. These bubbles pass through the pipe connecting the transformer tank and conservator. In this route, the Buchholz Relay is located. The gas bubbles are trapped in the Buchholz Relay, thereby creating pressure. A Buchholz Relay is made of cast iron consisting of two floats. In the upper hollow float, a mercury switch is located which is connected to the Buchholz Alarm Circuit. The mercury switch located in the lower baffle is connected to the Trip Circuit. On the top of the relay chamber, a pet cock is provided for gas sampling. The gases trapped in Buchholz Relay can be released from this pet cock. The relay chamber is also provided with a glass window through which the quantity and colour of the gas can be seen. There is a provision for operating the trip and alarm mechanism manually. To pump air through the pet cock and operate the relay is one of the simple methods for testing the working of the relay.

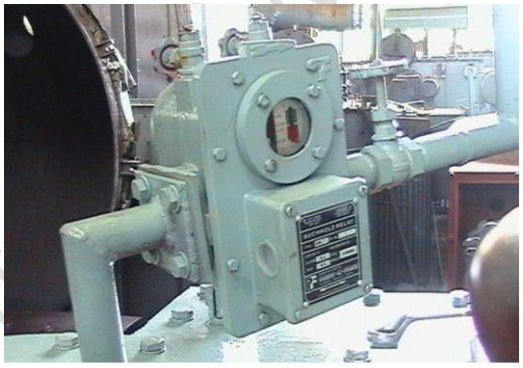


*Fig. 2.9 Buchholz Relay*

**Radiators:** Radiators are used to limit the temperature of the transformers to a safe limit. Fins or radiator tubes are provided to the radiators to radiate the heat of the oil in the atmosphere more effectively. Hot oil circulates through the fins and the heat is radiated to atmosphere according to the principle of conduction and radiation. In the radiator, oil circulates downwards because the hot oil in the main tank goes to the top portion of main tank and to the radiator. After its heat is lost in atmosphere through the radiator, it becomes cool and goes downwards again entering the main tank through bottom valves of the radiators.

*Fig. 2.10 Radiator*

**Lifting Lugs:** These are used to lift the transformer in case of installation, maintenance and relocation. Ropes of suitable strength are tied to these lifting lugs and raised through a crane

**Cable Box:** It is used to connect the underground cable with the transformer on 11kV side with the 11kV bushing through jumpers in case the 11kV system is laid through the underground cable. Similarly, cable box is also used to join underground cable on LT side of the transformer through jumpering of LT Bushings.

**Distribution Substation Installation**

1. REC Construction standard F2 should be followed for Pole mounted distribution substation installation indicating therein details of different items to be installed at Substation along with the necessary clearances thereof.

2. Distribution Substation Earthling Arrangement – REC Construction standard F10 should be followed for pole mounted distribution substation earthing arrangement.

   One of the earth electrodes on either side of DP structure should be connected with:

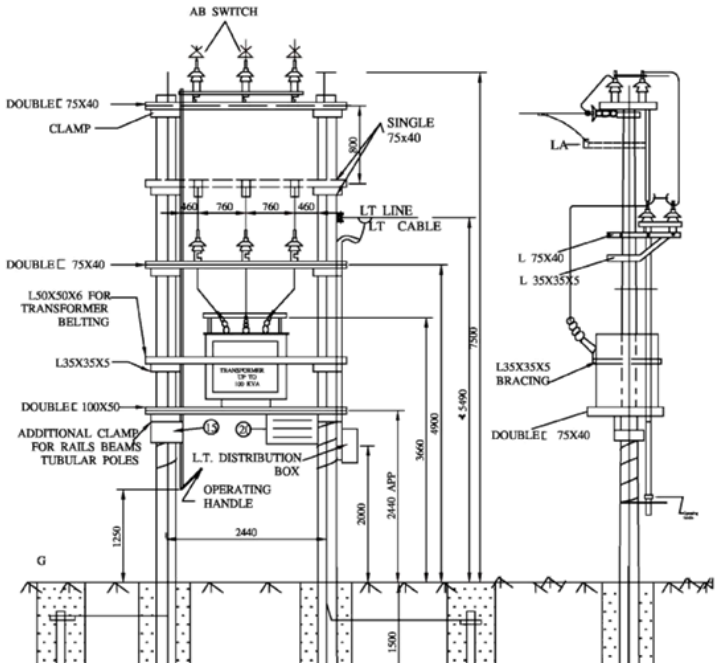
   (a) One direct connection from LT lightening arresters, if provided.
   (b) One direct connection from lightening arrester on HT side (11 KV).

To each of the remaining two earth electrodes, the following should be connected:

(a) One separate connection from the neutral (on medium voltage side of the transformer).
(b) One separate connection from the transformer body and the handle of 11 KV AB/GO Switch.

(c) One separate connection from the earthing terminals of the poles.
(d) Each of the three earth electrode should be at a distance of 6500mm. 4mm/8 SWG/6 SWG G should be used as earth lead. No jointing in earth wire should be done.

Image of Distribution transformer complete erection as per REC drawing




| | | |
|---|---|---|
| SUPPORTS - 9 M | | 2 |
| CHANNELS | 100X50-2800(APPOX.) | 4 |
| CHANNELS | 75X40-2800(APPOX.) | 2+1 |
| CHANNELS | 75X40-X ARM FOR SUPPORTING H.G FUSE & L.A | 2+2 |
| ANGLES | 50X50X6-2800(APPROX.) | 2 |
| ANGLES | 35X35X5- 460(APPROX.) | 2 |
| ANGLES | 35X35X5- BRACING FOR SUPPORTING H.G. FUSE FOR SUPPORTING DISTRIBUTION BOX | 2 |
| DISTRIBUTION TRANSFORMER | | 1 |
| AIR BREAK SWITCH(HORIZONTAL TYPE) | | 1 |
| H.G FUSE UNIT -3 PHASE | | 1 SET |
| 11 KV LIGHTNING ARRESTERS | | 3 |
| DISTRIBUTION BOX | | 1 |
| EARTHING SET | | AS REQD. |
| DANGER BOARD | | 1 |
| CLAMPS,NUTS,BOLTS,BARBED WIRE ETC | | AS REQD. |
| L.T CABLE | | AS REQD. |

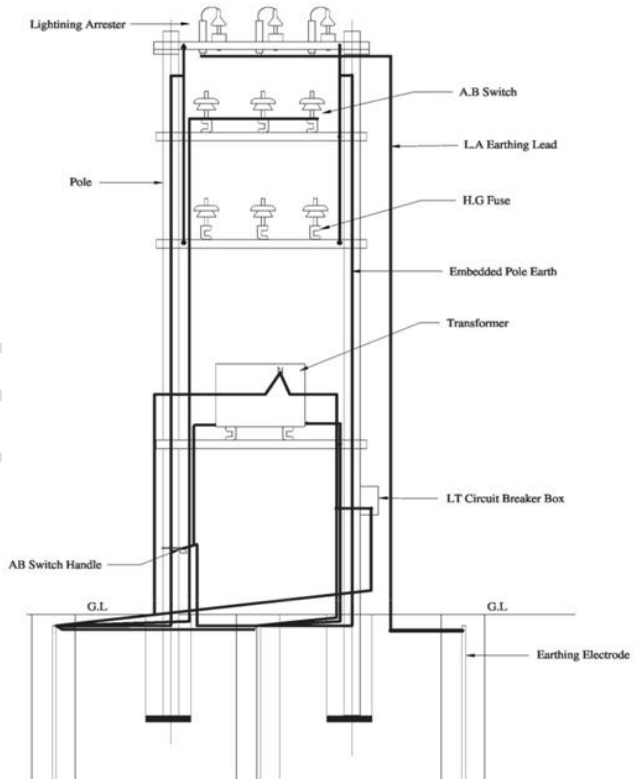



*Fig.2.11 Distribution Substation Earthing Arrangement*

## Distribution Transformer Fuse Ratings

### LT Mains and Cables

| Capacity of Transformer in kVA | Full load Amps 11kV side | Current LT side | Size of Tin copper fuse wire in SWG | | Size of single core PVC A1 cable in sq mm | | Size of LT fuse units to be used | |
|---|---|---|---|---|---|---|---|---|
| | | | 11kv side | LT side | For mains | For feeders | For main (Amps) | For feeder (Amps) |
| 1. Sf 10 | --- | --- | --- | 4 | 25 | --- | --- | --- |
| 2. Sf 15 | --- | --- | --- | 5 | 25 | --- | --- | --- |
| 3. 25 | 1.31 | 33.4 | 38 | 20 | 50 | 1x50 | 3x100 | 3x100 |
| | | | | | | 2x25 | | 2x2x63 |
| 4. 50 | 2.62 | 66.7 | 33 | 2x20 | 70 | 1x70 | 3x200 | 3x100 |
| | | | | | | 1x50+1x25 | | 2x3x63 |
| 5. 63 | 3.31 | 84.0 | 33 | 2x13 | 90 | 1x70 | 3x200 | 3x100 |
| | | | | | | 2x50 | | 2x3x100 |
| 6. 75 | 3.94 | 100.0 | 33 | 2x1(1x14) | 95 | 1x95 | 3x200 | 3x200 |
| | | | | | | 1x70+1x150 | | 2x3x100 |
| 7. 100 | 5.25 | 133.5 | 33 | 2.16 | 150 | 1x150 | 3x300 | 3x300 |
| | | | | | | 1x95+1x75 | | 3x200+ |
| 3x100 | | | | | | | | |
| 8. 150 / 160 | 6.4 | 213.4 | 30 | 2x14 | 2x120 | 2x120 | X300 | 6x300 |
| | | | | | | 1x150+1x95 | | 3x300+ |
| 3x200 | | | | | | | | |
| 9. 200 | 10.5 | 236.7 | 28 | 3x14 | 2x150 | 2x130 | 6x130 | 3x300 |
| | | | | Or 4x16 | | 1x150+1x120 | | |
| 10. 250 | 13.12 | 334.4 | 28 | 4x14 | 3x120 | 1x120 | 9x300 | 9x300 |
| 11. 316 | 16.53 | 420.0 | 20 | --- | --- | --- | --- | --- |

Note: 2x25 means 2 feeders of 25 sq mm Cable

*Table 2.1 Fuse Ratings for Distribution Transformer*

### HT Fuse Ratings

| Capacity of the transformers in kVA | HT voltage rating | Tinned copper fuse size in SWG | Fuse rating in Amps | Horn gap length in MM |
|---|---|---|---|---|
| 500 | 11 kV | 20 | 34 | 205 |
| 250 | 11 kV | 23 | 20 | 205 |
| 100 | 11 kV | 33 | 06 | 205 |

| | | | | |
|---|---|---|---|---|
| 75 | 11 kV | 33 | 06 | 205 |
| 63 | 11 kV | 33 | 06 | 205 |
| 50 | 11 kV | 33 | 06 | 205 |
| 25 | 11 kV | 38 | 03 | 205 |

*Table 2.2 Ratings for HT Fuse*

**CHECK YOUR KNOWLEDGE**

**A. Fill in the blanks with Suitable answers.**

1. .....are used to limit the temperature of the transformers to a safe limit.
2. Small transformers intended to supply low values of current to measuring instruments etc. are called.....

**B. Choose the correct answer from the following options.**

1. **Transformer works on the principle of**

   a. Conduction
   b. Induction
   c. Convection
   d. None of the above

2. **The function of breather in a transformer is**

   a. To reduce the temperature
   b. To act as a cushion for expansion and contraction of oil
   c. To arrest moisture and dust entering into transformer
   d. None of the above

3. **The colour of silica gel in a healthy transformer is**

   a. Pink
   b. Red
   c. Blue
   d. Green

2. **The function of conservator in a transformer is**

   a. To arrest oil leakage
   b. To arrest moisture and dust entering the transformer
   c. To act as a cushion for expansion and contraction of oil
   d. None of the above

**C. Explain the following**

1. Explain the basic function of distribution transformer
2. List various components of Power system
3. List advantages of transformer

**Session 3**

**Distribution Transformer maintenance Activity**

**Distribution Transformer Maintenance Activities (11/0.433 kV)**

Transformer is at the heart of any power system. Hence, preventive maintenance is always cost effective and time saving. Any lapse in the maintenance of transformer can severely affect the whole functioning of the organisation. Transformers give prolonged efficient service if regular inspections and maintenance is done. Maintenance will also require less expenditure, if done regularly.

**Observation of Transformer Oi**

- **Oil Level Checking:** If the oil level is reduced due to leakage or evaporation, the transformer should be topped up with good quality fresh oil. Any leakages to be attended immediately.

- **Oil Temperature:** Transformer temperature rises due to various reasons. Overloading is one of the reasons for rise in the transformer oil and winding temperature. If there is an abnormal rise in winding and oil temperature of the transformer; it should be immediately isolated and inspected for the possible causes. Efficient cooling equipment should be provided to the transformer. If fans are provided for forced air-cooling, they should be kept on till the temperature of the transformer comes to normal.


*Fig. 2.29 Transformer Oil Temperature Indicator*

- Oil BDV and Acidity checking at regular intervals. If acidity is between 0.5 to 1mg KOH, oil should be kept under observation.

- BDV, Color and smell of oil are indicative.

- Sludge, dust, dirt, moisture can be removed by filtration. Oil, when topped up, may lead to sludge formation and acidic contents. Transformer oil is hydrocarbon-based mineral oil. It is free from impurities and moisture. Its physical, chemical and electrical properties

as well as their values are laid down as per IS 335:1989. It should be noted that the dielectric strength of a new transformer oil should be minimum 50 kV for 1 minute.

Visual Inspection observations of transformer oil may be compared with the following:

| Colour | Oil Quality |
|---|---|
| **Yellowish/Transparent/Sparkling** | Very Good |
| **Yellow/Dull** | Good |
| **Brownish** | Bad |
| **Black/Brownish** | Contaminated |
| **Black** | Discard able |

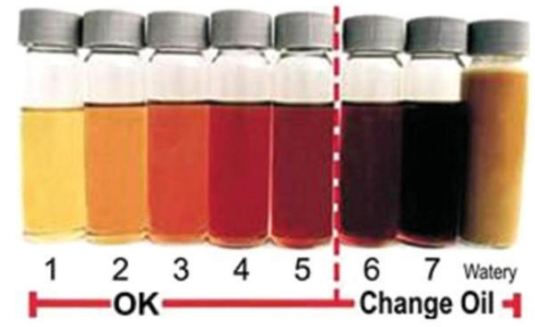



*Fig. 2.30 Transformer Oil Color Change*

*Fig. 2.31 Transformer Oil Testing*

**Reasons for Contamination of Transformer Oil**

**(a) Overloading of Transformer:** When transformer is overloaded, more heat is generated in transformer winding causing overheating and oxidation of transformer oil, thereby reducing its dielectric strength.

**(b) Absorption of Moisture:** Due to load variation, transformer oil expands and contracts, each time the breathing action takes place. If oil is inhaling moist air while breathing, moisture will be absorbed in oil thereby increasing its water content and reducing BDV/resistivity.

**(c) Gases:** When there is inside fault, of incipient nature, such as intermittent sparking, partial discharge, arcing, etc., various gases are generated inside transformer due to decomposition of oil. These gases dissolve in oil thereby reducing its flash point.

**(d) Sludge:** Due to continuous heating of transformer insulation material, such as varnishes, cellulose, paper insulation, etc. get decomposed and dissolved in oil and form a sticky compound called sludge. Sludge formation results into reduction in heat dissipation capacity of oil thereby increasing oil temperature.

**(e) Acids:** Due to the combined effect of heat, dissolution of varnishes and cellulose, inorganic and organic acids are formed in transformer oil thereby increasing its acidity. Acidity when increased, it ultimately results into reduction of resistivity and dielectric strength. It corrodes the winding material as well. Acidic oil is very harmful to transformer.

**Steps**

The step by step precautions to be taken while sampling the oil are as follows:

1. The sampling bottle, preferably a glass or polythene one, should be thoroughly cleaned and dried. It should be rinsed twice with the oil sample itself.
2. Clean the valve externally from which the sample is to be drawn. This would reduce the chances of contamination of the sample due to dust.
3. Draw the sample by PVC tube as rubber may chemically react with oil.
4. Sample should not come in contact with fibrous cloth or body touch.
5. Cock/Stopper of the bottle should be cleaned with the same oil and be replaced immediately after filling the sample bottle. This will avoid insertion of any moisture in the oil sample.
6. Always draw the oil sample from the bottom valves of the transformer or OCB because the impure oil with heavy impurities such as sludge and moisture always settles at the bottom.
7. Do not dip fingers in the oil samples because it reduces BDV of the oil. For example,if the BDV of the oil is 45 kV, and if fingers are dipped in it for few moments, its BDV will be reduced to 20 kV which has been experimentally proved.

8. Always test BDV of oil at ambient temperature because temperature has its effect on BDV as per following table.

| | | | | | | |
|---|---|---|---|---|---|---|
| I. | Temp.: | 30°C | 40° | 50° | 60° | 70° |
| II. | BDV: | 35 | 35 | 36 | 37 | 38 |

Never draw oil samples in rainy or cloudy weather because it will increase moisture in the oil.

A transformer should be isolated from both the sides, and should be grounded well at the bushings before work is commenced on it by the linemen.

**Oil Testing**

Transformer oil samples should be tested regularly. If the dielectric strength of oil goes below 40 kV, it should be filtered till the BDV reaches 50 kV. Oil filtration by regular filter

machines cannot reduce the acidity of the oil unless the filter is provided with special attachment of acidity removal Alumina Column.

Core and windings of the transformer should be checked through the inspection manhole. Oil from the OCB and transformer needs to be tested periodically.

**Method of Oil Testing:** Fill the test cell with the oil sample up to the mark, i.e. 10 mm below top cover of the cell. If the machine is manually operated, raise the voltage (after making the H.T Switch"ON") @ 2kV/Sec. with the help of the variac. If it is motor operated, the stepper motor is set to raise voltage accordingly. Raise the voltage till spark or break down of the oil in between the electrodes takes place. Take 6 readings of the same sample and the average value of these six readings denotes the BDV.

*Fig. 2.32 Transformer Oil BDV Test*

**Oil Testing Kit :** In this instrument, a glass or PVC transparent oil cell with dimensions of 80*55*100 is provided with two numbers of polished and chrome plated electrodes of standard size specified as per I.S. are fitted at a distance of 40 mm from bottom.

The test cell is designed to sustain voltage up to 60 kV. Oil is kept in such test cell for testing with the level adjusted 1mm below the top level of the cell. A single-phase autotransformer is provided in this instrument with 230 V A.C. primary and 0 to 60 kV as secondary output voltage. Voltmeter, which is connected on primary side shows the voltage of the secondary in kV. A switch, an Ammeter and a circuit breaker is provided on primary side. When spark takes places between the electrodes, the C.B. trips on overload thereby isolating the kit from H.T. supply.


*Fig. 2.33 Transformer Oil Management Kit*


*Fig. 2.34 Transformer Oil*

**Maintenance of Distribution Transformer**

1. **Transformer Body:** Check the transformer body and other parts for rusting. If any part is found rusted, it should be painted without further delay. The transformer should be painted periodically.

2. **Core and Winding:** Core and winding should be inspected once in every 5 years. The nuts- bolts should not be tight and sludge should not be allowed to accumulate.

3. **Insulator Bushings:** Clean insulator bushings and make it free of dust, using clean and dry cloth. Check bushings for cracks or chippings. If found, fix it with M-Seal adhesive compound.

4. **Cable Sealing Ends:** Check cable boxes periodically for the sealing. There should not be leakage of the compound. Gasket joints should be tightened, if loose.

5. **External Connections:** All external connections should be checked. Burnt or rusted connectors should be replaced.

6. **Conservator Tank:** Check oil level in conservator tank regularly.

7. **Breather:** Silica gel and oil in the bottom cup of the breather should be checked regularly. Silica gel if turns pink, should either be activated or replaced. Hole at the bottom of breather should be maintained free.

8. **Buchholz Relay:** Inspection of the relay should be regularly carried out and test trials of relay should be conducted after every six months.(in case Power Transformer)

9. **Explosion Vent:** The explosion vent should be investigated. If the diaphragm is found damaged, it should be replaced and the cause of damage should be investigated.

10. **Gaskets:** Nuts and bolts of gasket joints should be tightened periodically and leaking gaskets should be replaced.

11. **Coolers and Cooling Fans:** Radiators should be kept free of dirt and painted, if necessary. Cooling fan bearings in power transformers should be lubricated.

12. **Earthing:** Neutral earthing and soil resistivity should be checked periodically.

13. **Tap Changers:** (a) Diverter switch contacts should be serviced. Oil level in the diverter Tank should be maintained (b) Driving Mechanism: - Notch controller and contact rings should be maintained free of dust. Heaters should be maintained well. Copper contacts should be finely surfaced. If copper contacts are silver amalgamated and if amalgamation is worn, contacts should be replaced. (c) Selector switch contacts should be checked annually.



**Maintenance Schedule of Distribution Transformer**

| | | |
|---|---|---|
| 1. | Cleaning of bushings and external surface of tank | Monthly |
| 2. | Checking of oil levels in the conservator and gauge glass | Monthly |
| 3. | Checking of silica gel in the breather and replacement, if necessary | Monthly |

| | | |
|---|---|---|
| 4. | Checking of oil level in the oil seal of breather and top up, if necessary | Monthly |
| 5. | Checking of HG fuse and LT fuse and renew, if necessary (correct gauge shall be maintained | Monthly |
| 6. | Checking of vent pipe diaphragm | Monthly |
| 7. | Checking of terminal loose connections, if any and tightening the same | Monthly |
| 8. | Checking for any oil leaks and rectification (including replacement of oil seals if required) | Monthly |
| 9 | Taking tong tester readings during peak load hours and remedial action | Quarterly |
| 10. | Noting down neutral currents and load balancing in all the three phases | Quarterly |
| 11. | Testing of oil for BDV, acidity | Half yearly |
| 12. | Measurement of IR values | Half yearly |
| 13. | Checking of lightning arrestors and replacement if required (once before monsoon) | Half yearly |
| 14. | Measurement of earth resistance, checking of earthing system and rectification, if required | Half yearly |
| 15 | Overhaul of transformers | Once in 5 years |

*Table 2.4 Maintenance Schedule followed for Distribution Transformer*

**Responsibilities for Maintenance of Distribution Transformers**

| S.No. | Name of the work to be carried out | Person responsible to do the work | Person ensure that it is done |
|---|---|---|---|
| **1.** | **Monthly maintenance** | | |
| A | Maintaining distribution transformer yard and keeping the earth pits tidy and watering of earth pits | Area LM | Area LI |
| b | Cleaning the transformer including bushings | Area LM | Area LI |

| | | | |
|---|---|---|---|
| c | Checking up of oil level and reporting if it is low | Area LM | Area LI |
| d | Checking for oil leaks and reporting | Area LM | Area LI |
| e | Checking of earth connection | Area LM | Area LI |
| f | Reconditioning breather by reactivating silica gel or replacement and maintaining oil seal | Area LM | Area LI |
| g | Checking the LT fuses and renewing them | Area LM | Area LI |
| h | Topping up oil, where necessary | Area LM | Area LI |
| **2.** | **Quarterly maintenance** | | |
| a | Renewing of H.G. fuses | Area LM | Area LI |
| **3.** | **Annual maintenance** | | |
| a | Lubricating AB switch and checking for proper operation | LM | LI |
| b | Checking line and earth connection at AB switches | LM | LI |
| c | Checking line and earth for lightning arrestor | LM | LI |
| d | Checking connections for HV and LV bushings including LV neutral | LM | LI |
| e | Getting oil samples tested for breakdown and acidity and recording | LI | AE |
| f | Measurement of earth resistance and recording | LI | AE |

*Table 2.5 Responsibilities carried out for Maintenance*



**Causes of Failure of Transformer**

A transformer is a low maintenance device. But if the minimum maintenance and inspection required is not done on time, the transformer fails eventually due to the negligence in maintenance. Failure is because of overload of transformer which results in fire.

*fig. 2.35 Transformer Fire Due to Overload*

1. **Damage of Insulation:** Loosening of core laminations or improper insulation of core, improper or unhealthy insulation in winding or short circuit.

2. **Bushings:** Cracking of bushings or tracking of insulation due to dust.

3. **Switching Surge or Lightning Surge:** Due to improper earthing to LA, failure of LA, or non-availability of LA.
4. **Unbalancing or Overloading:** Unbalancing due to the uneven load/ phase; overloading due to improper size of LT/HT fuses.
5. **Overheating:** Due to lack of proper protection, fuses, loss of oil level, or loose connections

**Maintenance**

The following points/factors should be carefully observed while carrying out maintenance:

1. **Oil Temperature:** Transformer temperature rises abnormally due to overloading. In such case, transformer should be switched off and cooling fans should be made on for cooling.

2. **Oil Leakage:** There can be number of oil leakage sources. After tightening of Nuts & Bolts of the flanges or plates, if the leakage does not stop, gaskets should be replaced. If there is leakage through welding joints; it should be attended by welding.

3. **Bushings should be maintained and kept clean and polished:** Cracks/ Chipping if any found is bushings should be made up with M-seal putty. Joints, connections should be tightened.

4. **Breather:** Silica gel in the breather should be maintained blue as well as hole at the bottom of the breather should be maintained through.

*Fig. 2.36 Maintenance of Transformer on Site*

Discharge rods and hand gloves are the protective shields which will save the life of an employee from all types of accidents due to faulty operations of others or unknown sources.

- HV bushing is one of the transformer components responsible for more than 30% of transformer failures.
- The dielectric withstand strength of the oil part of HV bushing could be very sensitive to contamination of transformer oil with conductive particles due to deposit of carbon on the lower porcelain surface.

**To Identify Neutral Bushing of an Unmarked Old Distribution Transformer**

Make primary connections and charge the transformer without secondary connections. With the help of series test land (i.e. having two bulbs of same wattage in series connection); test two of the four bushings on LT side with test lamp. If the bulbs glow with full brightness, both the bushings are phases and if it glows dim, then one of the bushing is neutral. In this way; neutral can be identified by testing all the bushings.

1. Unbalanced current in neutral is dangerous to transformer and this can be avoided by properly grounding the neutral.
2. Transformer body earthing as well as neutral earthing should be provided with double conductor each with separate earth pits and earth electrodes. [Ref. Fig. 4.17 REC construction standard F-10 (Pg 81)]
3. Some distribution transformers are also provided with explosion vent. In a very loaded areas like Bhivandi; many times, hot oil is expelled out of transformer bushings or explosion vent causing accidents and burning injuries to public. For this, LV side MCB is a must and it should never be by-passed.
4. Many times, due to some reasons, a phase in an AB switch, a fuse in Dist. Box/ or Main switch is made direct. Such practices should never be adopted and if adopted due to utter emergency, clear cut danger board stating the changed status should be displayed. This board or safety warnings will be helpful to avoid accidents.

5. Many times, just due to haste, proper discharging of equipment is not done before starting the works. This practice invites accidents. Discharge rods should have sufficient length such as DO rods. Not using discharge rods just due to idleness habits will invite accidents.

Discharge rods and hand gloves are the protective shields which will save the life of an employee from all types of accidents occurring due to wrong operations done by others or from unknown faults.

1. Failure investigation consists of many steps in accurate sequence to conclude a significant outcome for transformer failure. All the test and maintenance work should be done as per standard manual.

2. Failure investigation starts with failure of transformers. Safety should be maintained when investigation is to be carried. Investigation process consists of following major component:

(a) Preparation/information gathering
(b) Testing
(c) Inspection (externally & internally)

**Distribution Transformer Fuse Ratings**

**LT Mains and Cables**

| Capacity of Transformer in kVA | Full load Amps 11kV side | Current LT side | Size of Tin copper fuse wire in SWG | | Size of single core PVC A1 Cable in sq mm | | Size of LT fuse units to be used | |
|---|---|---|---|---|---|---|---|---|
| | | | side | LT side | mains | For feeders | main (Amps) | feeder (Amps) |
| 1. Sf 10 | --- | - | --- | 4 | 25 | --- | --- | --- |
| 2. Sf 15 | --- | --- | --- | 5 | 25 | --- | --- | --- |
| 3. 25 | 1.31 | 33.4 | 38 | 20 | 50 | 1x50 | 3x100 | 3x100 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 2x25 | | 2x2x63 |
| 4. 50 | 2.62 | 66.7 | 33 | 2x20 | 70 | 1x70 | 3x200 | 3x100 |
| | | | | | | 1x50+1x25 | | 2x3x63 |
| 5. 63 | 3.31 | 84.0 | 33 | 2x13 | 90 | 1x70 | 3x200 | 3x100 |
| | | | | | | 2x50 | | 2x3x100 |
| 6. 75 | 3.94 | 100.0 | 33 | 2x1(1x14) | 95 | 1x95 | 3x200 | 3x200 |
| | | | | | | 1x70+1x150 | | 2x3x100 |
| 7. 100 | 5.25 | 133.5 | 33 | 2.16 | 150 | 1x150 | 3x300 | 3x300 |
| | | | | | | 1x95+1x75 | | 3x200+ |
| 3x100 | | | | | | | | |
| 8. 150 / 160 | 6.4 | 213.4 | 30 | 2x14 | 2x120 | 2x120 | X300 | 6x300 |
| | | | | | | 1x150+1x95 | | 3x300+ |
| 3x200 | | | | | | | | |
| 9. 200 | 10.5 | 236.7 | 28 | 3x14 | 2x150 | 2x130 | 6x130 | 3x300 |
| | | | | Or 4x16 | | 1x150+1x120 | | |
| 10. 250 | 13.12 | 334.4 | 28 | 4x14 | 3x120 | 1x120 | 9x300 | 9x300 |
| 11. 316 | 16.53 | 420.0 | 20 | --- | --- | --- | --- | --- |

Note: 2x25 means 2 feeders of 25 sq mm Cable

*Table 2.6 Fuse Ratings for Distribution Transformer*

**HT Fuse Ratings**

| Capacity of the transformers in kVA | HT voltage rating | Tinned copper fuse size in SWG | Fuse rating in Amps | Horn gap length in MM |
|---|---|---|---|---|
| 500 | 11 kV | 20 | 34 | 205 |
| 250 | 11 kV | 23 | 20 | 205 |
| 100 | 11 kV | 33 | 06 | 205 |

| | | | | |
|---|---|---|---|---|
| 75 | 11 kV | 33 | 06 | 205 |
| 63 | 11 kV | 33 | 06 | 205 |
| 50 | 11 kV | 33 | 06 | 205 |
| 25 | 11 kV | 38 | 03 | 205 |

*Table 2.7 Ratings for HT Fus*

**CHECK YOUR KNOWLEDGE**

1. **Fill in the blanks**
   a. BDV test should be done in .....temperature.
   b. Fuse rating of 500 KVA transformer is .....Amp.
   c. ..... is used as fuse element.
   d. The minimum dielectric strength of transformer oil should be ....KV

2. **Write a note on the following**
   a. Oil testing kit
   b. Transformer oil
   c. HT fuse rating of different capacity of transformer.

3. **True and false**
   a. Silica gel in the breather should be maintained blue (True/false)
   b. All transformer breath. (True/false)
   c. Reasons for Contamination of Transformer Oil is overloading of transformer (True/false)

4. List reasons for contamination of transformer oil

5. Explain causes of failure of Transformer based on parameter given below
   a. Overheating
   b. Damage of insulation
   c. Bushings

# MODULE 3 SAFETY PRECAUTIONS FOR ELECTRICAL WORK

| Module Overview |
| --- |
| This module covers essential safety practices for the workplace. It explains safe working methods and basic first aid procedures. The importance of personal protective equipment (PPE) and safety while working at heights is highlighted. Common safety tools and equipment are listed. The module also compares the functioning of various electrical equipment in relation to safety. |

| Learning Outcomes |
| --- |
| After completing this module, you will be able to:<br>1. Explain safe working practices<br>2. Describe basic First Aid procedures<br>3. Illustrate the importance of safety at workplace.<br>4. List the safety equipment used at heights.<br>5. Compare the working of various electrical equipment.<br>6. Appreciate importance of using PPE. |

| Module Structure |
| --- |
| Session 1: Safe Working Practices<br>Session 2: Basic First Aid Procedures |



Safety precaution is a for most thing to be adopted in a electrical system. Man working on live line as well as dead line should adhere of rules and regulation of safety precaution. Man working on line should have all the safety tools and got tested periodically. Man should know to create the safety zone before starting the allotted work.

## Session 1

## Safe Working Practices

### What is Safety?

Safety means condition or state of a person free from injury, accident, risk or any kind of hazard.


*Fig. 3.1 Safety Comes First*

Some fundamental knowledge that every electrical worker should imbibe:

- Operating instruction
- Line clear approach
- NBFC (No Back Feed Certificate)
- Earthing arrangement
- Deployment of proper tools
- Authorisation to work on power equipment and lines
- Proper approach while withdrawing line clear
- Withdrawal of any tools or equipment lying on the line, while returning line clear should be ensured
- Earth rods are to be withdrawn before returning line clear
- To ensure that effective opening or closing of all AB switch blades as the case may be

**Where to Find Health and Safety Equipment**

Normally all the general health and safety equipment are available with the concerned sub-division in-charge in a construction sub-division. Moreover, all the linemen construction is provided with safety tools and equipment and PPEs for their personal use.

*Fig. 3.2 Safety Tools for Electrical Workers*

**Safety Equipment Used at Heights**

**Portable Ladders**

Portable ladders are normally one of three types:

- Straight
- Extension
- Step-ladders
- Portable ladders are normally constructed on one of the three materials:
- Wood
    - Difficult to maintain
    - Have a limited service life
    - Are used less now
- Aluminium
    - Light-weight and maintenance-free
    - Strong for their weight
    - Bend before they break
- Are good general service ladders unless exposure to heat or electricity is expected
- Fibreglass
    - Strong and durable
    - Relatively stable to heat and electricity
    - Good general service ladders, but are somewhat heavy
- For all their apparent simplicity, two primary hazards are associated with the use of ladders. These hazards are:
- Falls (sudden stop at the bottom!)
- Electrical hazards
    - Electrocution
    - Shocks (often with resulting falls with sudden stops at the bottom!)

The correct way of leaning a ladder is to place it about 1 m out for every 4 m in height i.e. at an angle of 75 degrees. There should be sufficient space behind the rung to provide a proper footing.

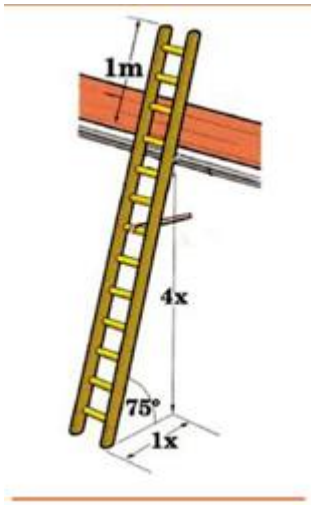



*Fig. 3.3 Correct Way of Leaning a Ladder*

The lineman should understand that portable ladders (of any type) and electricity truly do not mix. Portable ladders are difficult to handle and can easily or sometime accidentally break lighting and other power fixtures. The worst part is, portable ladders used outdoors can contact elevated high-tension supply lines accidentally resulting in electrocution. In many cases, conductive ladders do not have to contact the line – they can merely come sufficiently close to it to cause a short circuit through the ladder to ground.

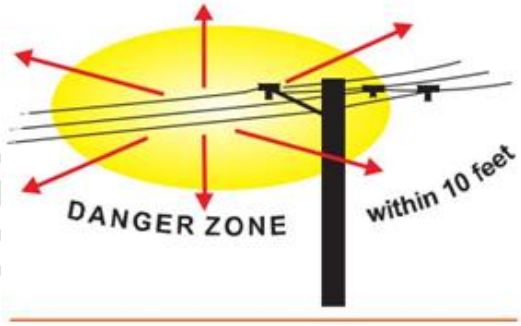



*Fig. 3.4 Danger Zone*

**Tips**

Many workers believe that they have time to regain their balance before they fall. However, this belief is usually untrue. The following table shows how far you can fall in different time spans:

| Time (Seconds) | Distance (Feet) |
|---|---|
| 0.5 | 4 |

| | |
|---|---|
| 1.0 | 16 |
| 1.5 | 36 |
| 2.0 | 64 |
| 2.5 | 100 |
| 3.0 | 144 |
| 4.0 | 256 |

*Table 3.1 Distance Covered in Different Time Span*

If a 70 kg person falls from 64 feet height, he will receive impact of more than 2 ton (force of 2180 kg) more than enough to break a lot of otherwise healthy bones! Makes you appreciate the seriousness of the "sudden stop at the bottom"!

Some safety pointers when working with ladders:

- Do not use metal (or wet) ladders when working near power-lines.
- Keep all ladders at least ten feet away from residential power-lines and much further away from larger power-lines.
- Never hand carry loads up a ladder. If tools or supplies are required, carry them in your pocket, in a tool belt, or lift them from the ground in a line.
- Never stand on the ladder's top three rungs. It is easy to overbalance and fall off.
- Never use a ladder that is damaged or weakened.
- Never "walk" a ladder into position while you are on it. Climb down and re-position the ladder from the ground.
- Use care around electrical fixtures. You can get an electrical shock on any ladder, but dry fibreglass and wood ladders do not normally conduct electricity. Using aluminium ladders around electrical fixtures can result in electrocution.
- Never carry a ladder in the vertical position. Carry a ladder in the horizontal only.
- Never jump from a ladder.
- Be certain you are in good enough physical condition to climb. This includes that person should not be under the influence of alcohol or drugs that make you dizzy, drowsy or subject you to fainting.
- Make sure ladders are kept free of oils, greases or other contaminants that may cause slipping.
- Use ladders only for their intended purpose!
- Ensure the ladder is in good condition and can handle your weight.

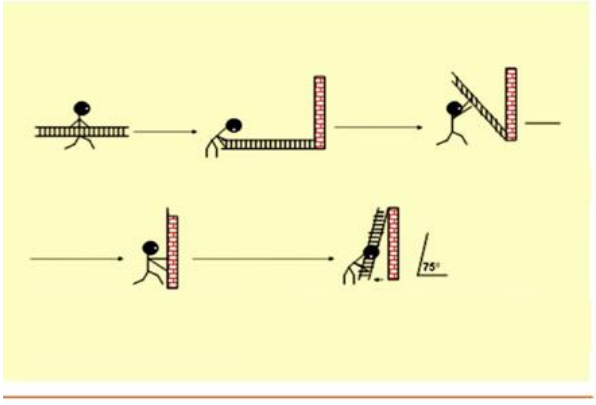



Fig. 3.5 ladder position

**Tips**

Theoretically, a ladder is strongest when it is in the vertical (90°) position relative to the surface it is on. However, vertical ladders are not safe to climb, unless they are secured in some manner. So, a stable angle is used to weight-rate ladders; 75-76° relative to the support surface – a slope of 4/1. Therefore, the most stable angle for a portable ladder is approximately 75° or a 4/1 slope.

**Working with Electrical Equipment**

Work permit system and creation of safety zone:

- Proper and safe operations on the electric system are the qualifications of the people who are responsible for performance of the work.
- It is important that people in charge of jobs be knowledgeable of the hazards and means for providing safe conditions to accomplish the necessary work.
- For this reason, only authorised workers will be permitted to request permits to work on sub-station premises or to perform work on circuits.

How to make safety zone for working in sub-station?

- Check the supply at HT&LT terminals of DT with Neon Tester.
- Test the supply at LT ACBs incoming and outgoing terminals with Neon Tester.
- Discharge it with discharge rods.
- Short the HT/LT bushings of DTs with chain and connect with Earth.
- Short the LT out going feeders with chain to prevent back feed from consumer.

Rules regarding permit and important notices/information:

- Unless line clear permit is issued by the authorised person, worker should not climb on pole or apparatus. No one should go in the vicinity of bare conductor and work.
- Only shift engineer or operation in-charge is authorised to issue permit.
- The line clear permit should only be issued to person duly authorised for said work.
- The only competent authority to authorise a worker is the Executive Engineer of that division or Superintending Engineer. They should issue authorisation order in writing.
- The permit can only be issued or obtained by these authorised persons for the work and jurisdiction as prescribed in the written authorisation order of Competent Authority.

- The written order of the Competent Authority should invariably be displayed on notice board at the concerned sub-station, power house and distribution centres in specific format.
- The consolidated authorisation should be kept at office of the concerned Superintending Engineer.
- The Superintending Engineer or Chief Engineer of Circle/Zone can authorise person other than stated above such as E.E. (Testing) or Testing Staff (or any other person who is competent to work in the views of concerned SE/CE).
- The Area Authority should include the names of such authorised persons in their list. The Area Officer should obtain the list of authorised persons of bulk consumers and area in the vicinity and also handover his list to them.
- Generally, the Line Inspector or persons of equivalent post are authorised for working on H.T. line/installations. However, Division Engineer may authorise the person/persons of below rank, if he is confident about his skills.

Method for issuing/obtaining and returning the permit:

- For obtaining line clear permit, only authorised person should apply. He should apply for line clear permit to the authorised person only and such authority will issue the permit accordingly.
- Where it is not possible to obtain permit in writing then permit can be obtained on telephone. In such case, the permit obtaining authority should confirm by repeating the matter with permit issuing authority on phone. The same should be noted in the permit book by both the persons. The duplicate copy of line clear permit after cancellation shall be sent to each other by post/ in person as early as possible for record. This register should be inspected by Area/Divisional Officer from time to time.
- The permit book is an important record and should be preserved properly. The pages of permit book should be numbered serially. Pages from this book should not be taken out or torn out or used for any other work. In case any page is torn-out or taken-out by some person due to any reason, then the concerned person should sign on the same and make dated entry in the logbook of sub-station/Power House with signature.
- The person, who has taken the permit, should return it. In case where the permit issuing and obtaining authority is same, the self-permit should be taken in his name and cancelled after completion of work. This procedure should be followed strictly.
- In case the permit is taken in person, same can be returned on phone.
- While issuing or returning permit on phone, the code words should be used.

**Precautions to be taken while issuing permit:**

It is the duty of the Shift Engineer or person issuing the line clear permit to ensure that the sub-station/ feeder/equipment for which the permit is being issued, should be made dead, i.e., equipment/ feeder should be discharged and properly earthed. First, he should switch off the

equipment/feeder as per the instructions laid down. Thereafter, he should follow the following instructions regarding grounding and locking of equipment:

- Power T/F should be opened (off position) and locked, at S/stn, respectively.
- Warning boards with following instructions should be tagged on handles of isolators/breakers:

◊ "Do not charge. Workers are working."

◊ "The line/equipment under permit - Don't charge."

◊ "Attention - work in progress - Do not change the line/equipment."

- The same type of warning boards should be tagged on handles of control switchgear. The control circuit fuse of control panel should also be taken out and kept in the custody of permit issuing authority.
- The L.V. side breaker of the T/f should be pulled out from the breaker - panel.
- The H.T. and L.T. Terminals of the T/F should be permanently discharged using discharge rods and earth rods should be kept as it is until cancellation of permit.
- High voltage potential T/f and LAs, if erected on ground level, shall be discharged from outside the fencing and then earthed perfectly.
- Outdoor type circuit breakers should be first discharged from all six terminals and then perfectly earthed. Both sides of the isolator circuit breakers should be locked in off condition and warning board should be tagged to its handle.
- In case of indoor type H.T. panels, P.Ts should be made off, discharged and perfectly earthed before permit is given.
- Outdoor Bus Bar, isolators, etc. and switchgear or complete section of Bus Bar where line clear permit is to be issued, should be first isolated from all equipment and perfectly earthed. The isolated portions or parts should be brought to the notice of person to whom permit is being issued and accordingly noted in the permit. It is possible that some part of isolated switch may remain live; the same shall be brought to the notice of person whom permit is being issued and noted in the permit. While doing maintenance work above the ground level, the live parts or conductors may come in the vicinity of the worker. Such possibilities should be brought to the notice of person whom permit is being issued and in such cases, temporary screening arrangements should be made.
- At some places, the transformers, isolators are associated with the structure. In such cases, the climbing on the fuse structure is not advisable. The ladder should be used for replacement of fuses.
- **Outdoor H.T. (Kiosk):** The O.C.B. must be switched off in case of outdoor H.T. (Kiosk). The incoming and outgoing links of OCB, PT and CT should be removed using operating rod and discharged. The bus isolators are in live condition and this point should be kept in mind.

- **Indoor Cubical Gears:** The OCB should be switched off. Use operating rod to open links and earth. The isolating chamber or incoming cable may be live and such cases should be brought to the notice of person whom permit is being issued.

- **H.T. Overhead Line:** The Circuit/ conductor on which work to be carried out, should be isolated by opening the CB and line links. In case of double feeding circuit, switches of both the ends should be opened and the earth switches of either end closed, if provided or line should be earthed locally before issue of line clear permit. If the feeders are controlled through trunk type metal clad gears, then gear must be separated from each other. Where earthing switch is not provided, conductors should be discharged and earthed perfectly.

- **H.T. Underground Feeders:** The same procedure as H.T. Overhead Lines is also applicable here. Further before taking work in hand it should be discharged and earthed at specific points. The low/medium pressure circuits, apparatus, equipment, control switches should be opened and made electrically dead. If circuit fuses are provided, they should be separated or breaker units should be racked down. The switches should be locked in off position and warning boards should be tagged on it. Where apparatus/or switches are remotely controlled, the control circuit fuses should be removed and kept in the custody of permit issuing authority and handed over to the person of next shift.


*Fig. 3.6 Danger Signboard*

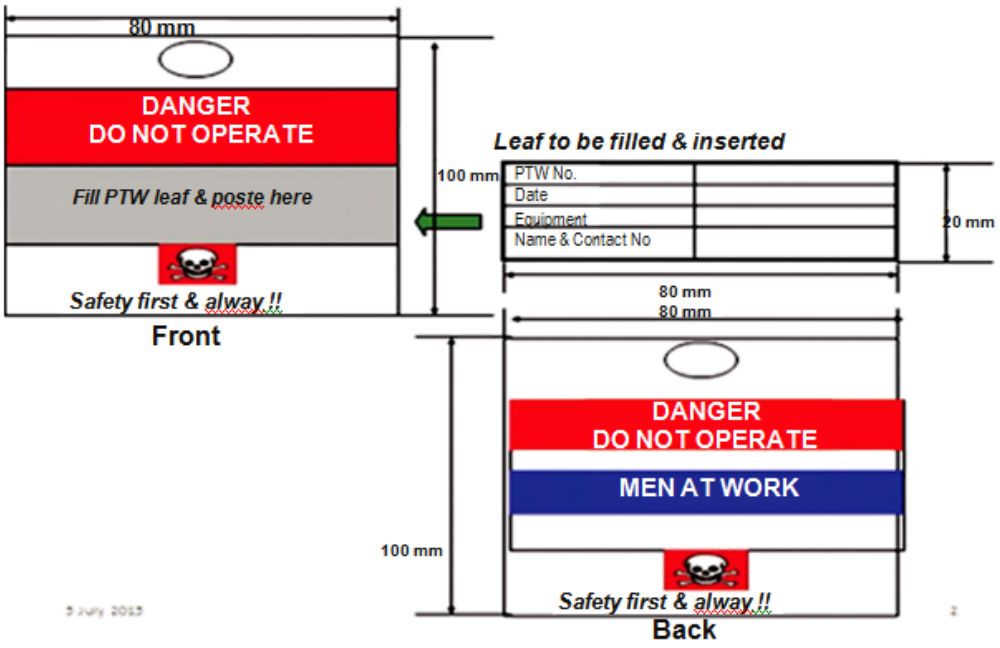



*Fig. 4.46 Tagging Placed on Switchgear Handle after Getting Shut Down and PTW*

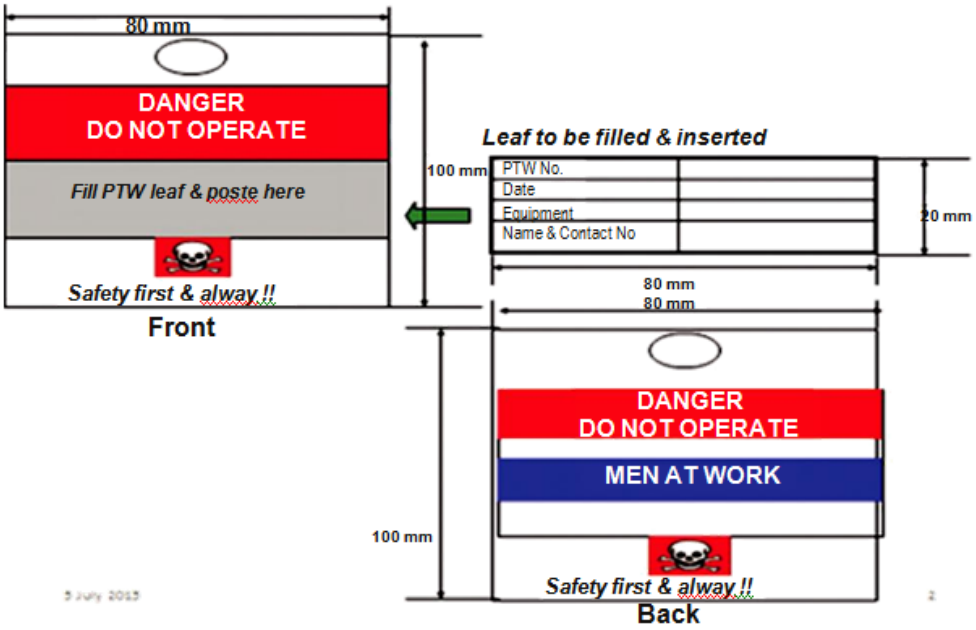



*Fig. 4.46 Tagging Placed on Switchgear Handle after Getting Shut Down and PTW*

**Permit log in, issue and return permit:**

- All the operations carried out should be logged in the substation log book as per the sequence of operations.
- All operations carried out at Down Substation/up substation/other end person should be logged in.

- The last operation regarding issue of/return of permits should be entered in the log-book with red-ink.
- During shift change, the outgoing operator/engineer should give the oral information about pending line permits and logged in the logbook by red ink along with other important information about pending permit.
- The incoming operator/engineer should also note about the balance work and note in the log-book about permit.
- All the sub-station operators concerned should follow the above practice.
- Equipment/line should not be charged unless permit is returned and cancelled.
- The person who has taken the permit should himself return the permit to the person from whom the permit is taken or to the next duty operator if shift changes.

Precautions to be taken during the work by permit holder:

- The permit holder should ensure before taking the work in hand that equipment/lines, switchgear, etc. on which permit is taken, are duly earthed. If it is not earthed properly, then the permit holder should not permit his staff to touch the equipment/switchgear.
- Information regarding specific places where one should not climb, the dead equipment, limit switches and structures, etc. should be brought to the notice of the co-workers/staff.
- The no entry warning boards should be tagged on line portion or on places where climbing is not permitted. The rope or red-flag can also be used at such places.
- When one has to climb on any structure or equipment, which are in the vicinity of live portion, then permit holder himself should be present there and proper guidance be given to the workers.

**Exposure to Toxic Material**

The worker may get exposed to flux or molten lead. Exposure may be due to ingestion, contact with skin, or inhalation. The following preventive and remedial actions should be taken in case of exposure to toxic material like solvents:

- Provide immediate first aid.
- Drink lots of water and vomit to dilute the effect.
- Report exposure to supervisor for medical help.
- Wear mask and get the surrounding ventilated.

## Importance of Using PPE

In this section, you will learn about the importance of Personnel Protective Equipment (PPE) while carrying out any electrical work of switching operation, repair and maintenance. Let us look at some basic PPE for electrical workers.

## Neon (Power) Tester

It is a protective instrument that gives alarm indication of live H.V. and L.V. lines at a distance of 5 meter. It is fitted in a PVC conduit pipe (50 mm) of 2 meter length with extension rod of 3 meter. It has an LED indicator and audio alarm speaker to produce beep sound when its point is brought near the live line. It has three modes – 'ON', 'OFF' and 'Test' mode operated through inside battery backup. No beep sound and no indicator lamp light shows that power supply is dead at that point.

*Fig. 3.7 Neon (Power) Tester*

Precaution and maintenance of Neon (Power) Tester:

- Always ensure battery status by switching in Test mode to confirm the Neon Tester is functioning before checking any line.
- Keep the tester in 'OFF 'mode when not in use and to avoid battery unusual discharge.
- Always keep the tester in its gunny bag to protect from dust and moisture. Handle carefully.

**Discharge Rod**

It is an insulated rod (with extension rod) having Resistance/Corona capsule in its edge connected with earthing lead. The discharge rod shall be used to discharge the static and induction charge of the power line after opening it. The discharge rod is a prime importance safety tool, which can safeguard from unforeseen dangers and even fatal accident. The line should be treated charged until the neutral or earth wire is discharged. There is possibility of charging of line due to static charge, induction or fault current. Hence, first discharge the line by using discharge rod.

*fig. 3.8 Discharge Rod*

- Consumer may start his generator set.
- The line is charged by some mischievous or unknown person not having adequate knowledge.
- The area of T/F under shutdown due to fault, the line is charged from other source.
- Power swing may cause charging line if the guarding is not provided at line crossing.
- Line clear permit is given, but the person forgets to open the line.
- Operator may forget that the line is under permit and he may charge the line for testing, etc.
- The change in status of line feeding is not known to the operator after returning from long leave, etc.
- The use of discharge rod safeguards from the above types of eventualities.

Maintenance of Discharge Rod:

- The rod should not be kept in wet condition.
- Ensure that the continuity of all wires of discharge rod is intact.
- Carbon deposited on hook of the rod should be cleaned regularly.
- The continuity of wires should be tested regularly.

How to work safely with discharge rod:

- Confirm the cleanliness of the wire ends/lugs provided before use. Make firm connection of wires with earth point by nut-bolt. Where use of nut-bolt is not possible then after rubbing the earth wire wrap it firmly to earthing. Confirmation of the continuity and good condition of earthing is a must.
- Hand gloves shall be used while discharging the line by discharge/earth rod.
- While working on L.T. line first discharge the neutral and then phases. Thus, the wire of discharge/ earth rod shall be connected to earthing first and then discharge the phases one by one.
- The line should be discharged at one pole before and one pole after the pole where to attend work.
- The rods shall be kept on line till the work is completed.
- After completion of work and climbing down the pole, discharge rods should be removed one by one using hand gloves invariably. After removing all rods, earthing shall be removed.
- After this, if we notice that some work is still balance or some T&P, etc. is still left on the line, then do not climb on line unless the line is discharged again. The eventuality often occurs within seconds; hence don't take risk or don't be hasty, and work calmly and with concentration, without any disturbances.

*Fig. 4.8 Working with Discharge Rod*

**Chain**

Metallic chains (minimum 5 meters) are placed over the each phase of line and made earth to protect from accidental restoration or back feed of supply while attending break down or planned shutdown.

**Mask**

It is mandatory to place two masks at prominent place (easily accessible) in the substation or generating station to protect from gas and smoke.

**Rope**

It is used to give tools and tackles to the lineman who climbs on pole. One portion of rope is tied on the waist of the lineman.

*Fig. 3.10 Using Safety Gear*

*Fig. 3.11 Lineman Responsibilities*

*Fig. 3.12 Safe Condition*

*Fig. 3.13 Unsafe Condition*

*Fig. 3.14 Lineman Working with Rope*

**Rubber Mat**

For operating any switch gear, it is mandatory to place a rubber mat in front of panel. Nowadays, synthetic rubber mats with very low thickness of 2 to 5 mm and light weight are available.

**Rubber base PVC Sole Shoes**

The worker should use rubber base PVC sole shoes without nails. Proper shoe should be used to work on over head line protection (not sport/tennis shoes) from electric shock.

*Fig. 3.15 Safety Boots*

*Fig. 3.16 Safety Harness*

**Gloves and Helmet**

Rubber insulating gloves are commonly used in L.T. line system to protect from head injury and prevent from electrocution.

*Fig. 3.16 Safety Gloves*

*Fig. 3.17 Safety Helme*

**Safety Requirements Applicable at Work**

The linemen are supposed to brave all weather conditions such as heat, sleet and snow. They are expected to report for duty at odd places and in odd situations. Keeping in view the nature of their job, the linemen are generally physically and mentally trained. However, they are required to follow certain guidelines to avoid any mishap and ensure safety at work. Some important safety tips for the linemen are as follows:

- Wear personal protective equipment.
- Follow a strict discipline, and invariably follow the instruction of the supervisors.
- Identify the hazards.
- Use tools in a proper manner.

**Always follow safety procedures**

- Follow strictly the CEA Regulations 2010 for measures related to safety and electric supply.
- The third safety level is the use of an external disconnect switch, which is essentially a lever that a utility lineman can use to shut down a homeowner's PV system, and physically isolate it from the grid while doing maintenance or repair work.

*Fig. 3.18 Lineman at Work*

**Clean and Safe Environment**

Cleanliness and safety of the workplace is of paramount importance. Workers must comply with the instructions and follow the policies and procedures relating to health and safety at workplace.

Workplaces and facilities should be cleaned on a daily or weekly basis. The cleaning programme of the facilities and equipment should be designed taking into account the work shifts, the work type, the likelihood of contamination and the number of workers using them.

*Fig. 3.19 Working in a Risky Condition*

**Tips**

Lightning Arresters are the most effective means of protecting electrical lines against lightning and switching.

**Work Area Responsibilities**

The tasks to be performed by a lineman, light and power include:

- Erecting and maintaining overhead electric power lines to conduct electricity from the power plant to the place of use.
- Erecting poles and small towers at specified distances with the assistance of other workers.
- Climbing poles and towers, fixing insulators, lightning arresters, cross-brass, etc. and other auxiliary equipment at proper heights.
- Stringing and drawing cables (wires) through insulators fixed on cross bars.
- Exercising great care to leave a proper sag in wires to avoid breakage under changing atmospheric conditions.

- Joining the cable by various methods, fixing joint-boxes at specified places, replacing fuses and faulty components as necessary and testing for electrical continuity.
- Checking overhead lines in the allotted section as necessary and maintaining them for transfer of electricity.
- Maintaining proper repairs of defective electricity lines, poles, towers and auxiliary equipment as per the given instructions.
- Installing and repairing overhead power lines for electric trains, trams or trolley buses.
- Working on high tension or low tension power lines.

*Fig. 3.20 Linemen at Work*

*Fig. 3.21 Lineman Checking the Problem*



**Tips**

"Basic Safety Precaution" is the inherent characteristic that any person should keep in view while working on power equipment. Never should we forget that "Electricity is an obedient servant and dangerous master".

**Exercise**

1. Write any 5 work perform by a lineman?
2. Write a short note on discharge road.
3. Write any 5 personnel protective equipment's?
4. Fill in the blanks
   a. Lineman should fallow ..... for measures related to safety and electric supply.
   b. ..... is used for earthing the line.
   c. ..... should be taken before starting the work on line.
   d. ..... protective instrument that gives alarm indication of live H.V. and L.V. lines

## Session 2

## Basic First Aid Procedures

**LEARNING OUTCOMES**

On completion of this session the student will be able to:

- Arrange basic first aid in case of accidents.
- Provide basic understanding of electrocution.
- Discuss about artificial respiration (cardiopulmonary resuscitation).
- Interpret the types of bleeding which is caused by an injury.

### Basic First Aid

First aid is of prime importance in the event of an accident. Hence, everybody should know the basic methods of first aid:

- Bring the affected person at peaceful and airy place and care should be taken that he should not get suffocated.
- All the parts of body of affected person be kept in straight position and should be laid down on even spot.
- In case of head injury, lay down the affected person in such a way that his head rests in upward position.
- If he is having trouble in proper respiration, then he should be kept in sitting position.
- If he is in the epileptic condition, then lay him down ensuring that his head is below the level of his body.
- If he is having wounds, then take water in one small bucket and add 4 drops of Iodine in it to make it anti-bacterial and wash the wounds neatly and carefully and dry it. Then apply the iodine on wounds and wrap it by medicated/antibacterial cotton.

*Fig. 3.22 Giving Basic First Aid*



**Tips**

When faced with an emergency, try to remain calm and controlled so that you can act effectively. Before assessing the victim's condition and carrying out the appropriate first aid, make sure that you are not putting yourself in danger. You will not be able to help anyone else if you become a victim yourself.

The following medicines/items should be kept in first-aid box:

- Small size dressing cotton/patti
- Medium size dressing patti
- Large size dressing patti
- Yellow patti or dressing pad for burn injuries
- Clean and sterilised cotton pads
- Tincture - iodine
- Potassium permanganate
- Sol-violate spirit (for smelling of unconscious person)
- 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 Dettol or Savlon liquid
- Bottle of spirit
- Scissor, knife, etc.



**Bleeding**

There can be four types of bleeding through injuries:

1. Minor bleeding
2. Bleeding through artery or main blood circulatory system
3. Bluenen or bleeding from vein
4. Internal bleeding

If bleeding is of (1) or (3) type, then first tightly wrap the part of body before and after of wound so as to stop the bleeding. Internal bleeding, such as in stomach, from brain or lungs, etc. cannot be seen. However, it can be seen in the vomiting or spiting of injured person. Internal bleeding is very dangerous rather than external bleeding. In such situations, give the injured person cold water or ice and arrange for immediate medical help. Excessive bleeding after injury may cause death rather than bleeding from wounded spot. Hence, medical help should be arranged without any delay.

**Injuries to Bones**

In the event of accidents, sometimes the bones of the body may break, and the tip of the broken part may come out along with wound. In such cases, first try to stop bleeding without touching the wounded part. Then try to join the broken bones by pushing from both the sides of wound and broken point. Whether it is effective or not always wrap the broken body part resting on wooden plank and take the injured to hospital as early as possible, and if the bones of legs are broken then the injured person should be taken on stretcher.

**Unconsciousness**

If the person loses consciousness, open his airways by tilting his head slightly and monitor his breathing. If breathing becomes difficult for him, call other people to move the victim into recovery position. Put your hands over his ears to keep his head align and working as a team, roll him over gently making sure that you keep the neck and back align at all time making the hands of all team member as stretcher.

*Fig. 3.23 Lying Unconscious*

**Injuries due to Burning**

A burn that affects all the layers of the skin or covers a large area of the body is a severe burn. The aim of first-aid treatment is to cool down the affected area rapidly to minimize damage and loss of body fluids, and therefore reduce the risk of developing shock. Any burn larger than the palm of the victim's hand, whatever the depth, needs hospital treatment.

If the victim's clothing is on fire, force him/her to the ground and use a wool or cotton blanket, rug, or coat to smother the flames. Immerse the burn in cool water, douse it with water, or cover it with cold, wet towels for at least 10 minutes. If the burn injuries are due to acid action then we should first wash and clean the wound using baking soda water. If burn injury is due to carbolic acid, it should be cleaned and washed by spirit,

*Fig. 3.24 Burn Injury*

**Electrocution**

When a worker is electrocuted, the following measure should be taken:

- First disconnect the power supply and if possible send somebody else for disconnecting the supply.
- If the person is under contact of live wires/equipment, do not isolate him by hands or don't try to isolate him away by standing on wooden planks. Because even if we are on wooden plank, the circuit is completed through body of person getting electric shock and there is possibility that you may get electrocuted.
- If a person came into contact with low or medium voltage line/equipment then using rubber gum-boots and hand gloves, the electrocuted person can be isolated from line contacts. However, confirm that the things used for such operations are dry and insulated one. If the shock is through H.T. Line then the safety equipment/items used for separation should be of that much voltage capacity, i.e., H.T. Voltage capacity; otherwise don't try to isolate the person under shock.
- After removing/isolating the electrocuted person from live line/equipment, first loosen his clothes. Then take out the pant, tobacco, betel nuts or artificial teeth from his mouth. If the respiration system has failed, try to give him artificial respiration immediately.
- If the electrocuted person becomes unconscious, do not give him any drink, water, etc.
- Apply Burnol or Soframycin type creams to burnt part of body of electrocuted person and do the bandage. The wound should not come into contact of air.
- Keep the person warm by wrapping blanket or coat. Do such things that his body should remain warm enough. If possible, both his feet should be kept in warm water.

- After the person gains consciousness, do the following things:
- Arrange immediately to call doctor and continue with artificial respiratory system.
- Enough quantity of water mixed with sodium bicarbonate should be given to the electrocuted person.
- Give him table-salt to inhale.
- If his throat is injured or he has pains in throat, no any drink/water be given unless otherwise advised by doctor.
- If the person passes urine, keep the urine sample for pathological tests.
- Don't try to do anything which can cause mental/physical stress till the doctor is available.
- If the person becomes normal then allow him to take rest. Tea can be given.

**Tips**

In case of electrocution:

- Take remedial measures immediately without delay.
- Passing of time may cause into death of the shocked person.
- Though all electric shocks are of fatal tendency, timely aid and remedial measures may save the life of the shocked person. Otherwise delay may cause into certain death.
- The heart muscles remain live up to 1/2 hour time after shock. Hence, the artificial respiration may save the life of the shocked person.
- Start artificial respiration. Continue it till doctor or medical help arrives.

**Artificial Respiration (Cardiopulmonary Resuscitation)**

Artificial respiration is given when a person's respiration fails. There are following types of methods used for artificial respiration:

**Mouth to Mouth Procedure**

In this system, first stand up near the head of electrocuted person or sit on his knee. His head should be kept in down position by one hand and by other hand lift his lower jaw. Inhale the deep breath and keep your opened mouth on the mouth of electrocuted person. Close both nostrils of his nose by one hand and exhale your breath into the lungs of subject person slowly. By doing so, see whether his chest get expanded or not.

*Fig. 3.25 Mouth to Mouth Respiration*

Keep your mouth away and again inhale deep breath in your lungs and repeat the procedure as mentioned above. Try to repeat such artificial respiration about 10 to 12 times in a minute. If there is some difficulty in doing so, try to push the persons head and again pull the lower jaw. If again you find it difficult to give him this treatment, then see whether the lips of the person are open and try to see if the teeth are jammed, if so, then use the nose to mouth method.

**Nose to Mouth System**

If the above procedure is not possible, try to use nose to mouth system. In this process, stand near the head of person or sit on your knees. Push his head fully to down side and pull up the lower jaw of person. Then inhale deep breath and after opening the lips cover the nose of person completely. By other hand close the mouth of the person tightly and exhale the breath from your mouth into the nose of person slowly so that air enters his lungs. See if his chest gets expanded. The same procedure should be repeated 10 to 12 times in a minute.

When the person starts breathing on his own, then give him such breathing in a synchronous way and see if his chest gets expanded. When person comes to comfortable position, allow him full rest. Put him on a stretcher and see that no any difficulty comes in his respiratory system. His body should be wrapped in a blanket and keep him warm. The unconsciousness position due to electric shock may cause damage to his heart. Thus every worker/engineer should know this method and try to get training of such procedures.

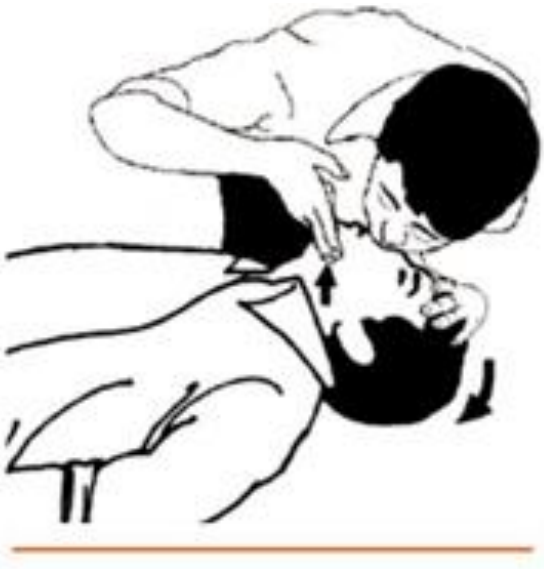


*Fig. 3.26 Mouth to Nose Respiration*

**Tips**

Things to remember:

- If the practice of nose to mouth is required to be done, then the air will go slowly, to the electrocuted person. Hence this system is safer and in case when the nose of the electrocuted person is very narrow then the system of mouth to mouth should be adopted.
- If it is observed that the throat of person is very narrow or closed due to some object, then the same should be cleaned by fingers.
- In case, the teeth of the person are tightly closed, then use the nose to mouth system.
- If possible, keep a thin handkerchief on the mouth of the person for using mouth to mouth procedure.
- For infant or young children, if affected, then use the blow of air from our mouth. Send at least 20 times per minute respiration of which respiration should be done.
- In case, when we have to use this artificial respiration on pole, then first safeguard yourself from the live parts and also from coming into the contact of electrocuted person, if he is still under shock. Stand carefully in such a way on pole by using safety belt so that we place our mouth on the mouth/nose of electrocuted person.
  Sometimes, artificial respiration can be done by way of muscular movement or with help of some equipment. These are described below.

**Holger Nelson System**

In this procedure, first lay down the person in downward position and keep his hands on back in crossed position and on that hand, keep his neck in one-sided position and give pressure lightly. Keep our right-side knee near the head of the person and the feet near the elbow of affected person. Put our palms on the back of affected person in such a way that our thumbs of both hands rest on back-bone of person and the other portion of palms rests on balance portion of back side of person. Then start giving light pressure by both the palms on back of affected person and keeping this position for 2.5 seconds duration and then start releasing pressure slowly from back. Now hold the arms of crossed-hands of person and put his hands in upward position and pull them forward. In this way the procedure should be repeated 10 to 12 times per minute till the person starts breathing on his own.

*Fig. 3.27 Defibrillator in Use*

**Sheffer System**

**Exhale air outside:** In this system also, lay down the person in downward position and keep some pillow/or clothes below his head and put his neck on one side. Now, lay the knees and on the back side of waist, bring the thumb of hands in such a way that both the thumbs are near to each other. Place your fingers of hands on back side of person's fore-arm from both sides. Bow down on person slowly. While doing so, give the constant pressure on back of person.

**Inhaling the breath:** Give a tilt to back side of person in such a way that your hands remain on his back. For exhaling the breath keep your hands on back of person in the same position. Keep doing both the works simultaneously. This simultaneous procedure is to be done with rate of 15 times per minute. The reason behind this is to keep the respiration process of electrocuted person continued through the expansion and contraction of lung muscles. The person doing this function should breathe slowly for exhaling and inhaling action by pushing/pulling the electrocuted person and he can see the effects of this action and amount of pressure will maintain and will result into synchronisations of breathing of affected person. This procedure should keep continued till the person electrocuted starts breathing on his own.

This exercise may take 1/2 hour or more to get proper effect of respiration. The subject system described above is considered as best system. The pressure should be 20 to 25 pound magnitude.

**Silverester's System**

Lay down the electrocuted person in upward position. Loosen the clothes on his chest and stomach. A pillow should be placed below his shoulders in such a way that the neck and head of the affected person will be in somewhat downward position. Then pull his tongue outside. The person giving treatment should sit on his knees near the affected person. Keep the hands of the person below the elbow and pull his hands till it becomes parallel to earth. This treatment should be given for 3 seconds. After that, bring both hands of the person below his chest and press the chest to inside position. This action should be given for 2 seconds. Thus the procedure is repeated 10 to 12 times per minute. In this system since the head of the affected person remains in upward position, the effect or action of artificial respiration can be seen immediately.

**Tips**

For a man, give 20 to 25 pound pressure for 10 to 12 times. In case of women and child, the pressure should be 10 to 15 pounds for 10 to 12 times per minute. For very young child or infant, the pressure should be 15 times per minute. This procedure should be kept continued till the affected person starts taking breath of his own

**Exercise**

1. Write down note on basic first aid?
2. What is Silverester's System?
3. What precaution to be taken during mouth to Nose Respiration?
4. What is Artificial Respiration?



# MODULE 4 WORKPLACE MANAGEMENT, SAFETY AND HEALTH

| Module Overview |
| --- |
| This module focuses on general health and safety rules in the power utility sector. It explains workplace hazards, risks, and accident prevention measures. Fire safety procedures, causes of fire, and fuel classification are covered in detail. The module highlights safety regulations, electrical shock, and the use of fire extinguishers. It also includes documentation, the need for medical facilities, and rules for responding to emergencies. |

| Learning Outcomes |
|---|
| After completing this module, you will be able to:<br>1. Explain general health and safety rules<br>2. Explain workplace hazards and risks<br>3. Demonstrate process of fire Safety<br>4. Recognise general health and safety rules in power utility.<br>5. List basic safety regulations according to CEA gazette notification.<br>6. Evaluate the need for medical facilities in power utility.<br>7. Generate documents specifying health and safety rules.<br>8. Interpret the meaning of hazards and risks<br>9. Analyse the possible causes of accident<br>10. Explain the measures for accident prevention<br>11. Explain electrical shock<br>12. Explain the methods of accident prevention<br>13. Explain the causes of fire at workplace.<br>14. Explain about fuel classification.<br>15. Memorise the working of different fire extinguishers.<br>16. Explain the rules of fighting fires. |

| Module Structure |
|---|
| Session 1: General Health and Safety<br>Session 2: Workplace Hazards and Risks<br>Session 3: Fire Safety |



According to the Safety in the Workplace Fact Sheet:

- Approximately 62 percent of an estimated 32,807 nonfatal electrical injuries, occurring between 1992 and 1998, were classified as electric shock and 38 percent as electric burns.
- Over the last 10 years, more than 46,000 workers were injured from on-the-job electrical hazards.

These figures clearly show how seriously this issue must be tackled, to prevent electrical hazards and the importance of delivering electrical safety training at workplace

Electricity can be very dangerous. Electricity always takes up the shortest path to ground via a conductor. As human body is a conductor, it is very easy and likely for the human body to fall prey to electric shocks. Depending upon the voltage, even a small magnitude of electricity may prove fatal sometimes. Eg: Though 100-200 milliampers appears to be a very small magnitude of electricity, it may even take away a human life.

It is not only the employer who is held responsible for providing safe working conditions. The employees also share an equal responsibility for making the work area a safer one. However, it's the duty of the employer to see that employees be trained to use the equipment correctly, to prevent impending dangers. Proper work management, safety care and health cautions must be taken at site.


**Session 1**

**General Health and Safety**

**General Safety Precautions and Rules**

Self-care as well as the care of the co-workers is the matter of utmost importance while carrying out electrical works to avoid mishap/accident and thereby injuries. The accident will not occur if self-safety is observed. It is important to ensure safety of

- Self and co-workers
- The company's property
- The public

Before starting any work, if the working condition seems to be unsafe or if there is confusion, get the matter clarified and only then take the work

**Tips**

The following safety precautions should be taken before starting work:

- Checkout the working conditions of safety tools and plants like ladder, hand gloves, safety rope / waist-belt, etc. PPE should be carried by the lineman at all times.
- Follow all safety guidelines.
- Learn about correct transportation, handling and storage of materials.
- While working on line avoid cracking of jokes or any foul play. (By order of Supervisor)
- Do not consume liquor while working or before coming to work.

Some general causes of accidents at work place are:

- Working without permission.
- Doing work in an unsafe way, such as throwing tools and equipments (tools and plants)/ line material or doing hasty work.
- Using higher capacity fuse or by-passing the fuse.
- Use of improper tools and equipments example - using pliers instead of screw-driver, using pliers in place of spanner, not using insulated pliers or screw – driver, etc.
- Working on unsafe or dangerous equipment, such as cleaning/greasing or adjusting any of running m/c.
- Diverting the attention of worker from his work or cracking jocks, etc. at work place.
- Non-use of safety equipment and tools and equipments, like - ladder, waist belt /rope, hand gloves, D.O. operating rod, Earthing rod, etc.
- Working in insufficient light.

*Fig. 4.2Accidents while Working on Distribution Lines*

Distribution linemen must keep themselves physically fit and mentally alert and free from any serious ailment. They should observe strict discipline and invariably follow the instruction of their superiors.

*Fig. 4.3 Ensuring Safety at Workplace*

Some specific safety precautions for distribution linemen are:

- Wear clothes and footwear suitable to the job.
- Do not wear loose dhotis, pajamas, neckties, key chains or watch chains near moving machine parts.


- Wear clothes and footwear suitable to the job.
- Do not wear loose dhotis, pajamas, neckties, key chains or watch chains near moving machine parts.


- Do not wear shoes with projecting nails or other types of metal parts liable to slip.
- Those exposed to dangers of falling materials must wear safety hats and shoes.

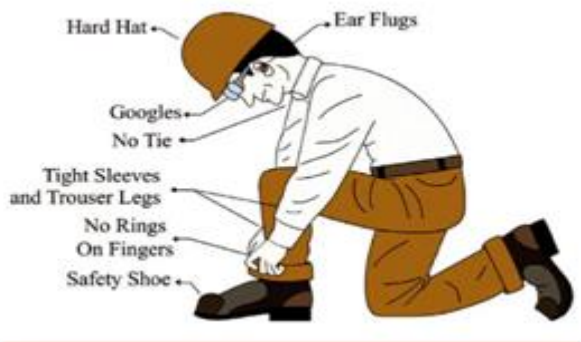



*Fig. 4.4 Distribution Lineman Wearing Safety Equipment*

- Hot stick tool for moving or adjusting live electrical equipment.

- Rubber sleeves protects workers arm from unintentional electrical contact.

### CEA Gazette Notification

Basic Safety Regulations Clauses as per CEA Gazette Notification dated 20-09-2010 are as follows:

### Handling of Electric Supply Lines and Apparatus

Before any conductor or apparatus is handled, adequate precautions shall be taken, by earthing or other suitable means, to discharge electrically such conductor or apparatus, and any adjacent conductor or apparatus if there is danger there from, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon.

*Fig. 4.5 Tools for Distribution Lineman*


*Fig. 4.6Lineman Safety Equipment*

Every person who is working on an electric supply line or apparatus or both shall be provided with tools and devices such as gloves, rubber shoes, safety belts, ladders, earthing devices, helmets, line testers, hand lines and the like for protecting him from mechanical and electrical injury, and such tools and devices shall always be maintained in sound and efficient working condition.

**Provisions Applicable to Protective Equipment**

Fire buckets filled with clean dry sand and ready for immediate use for extinguishing fires, in addition to fire extinguishers suitable for dealing with fires, shall be conspicuously marked and kept in all generating stations, enclosed sub-stations and switching-stations in convenient location.


*Fig. 4.7 Fire Buckets*

The fire extinguishers shall be tested for a satisfactory operation as per relevant Indian Standard at least once a year and record of such tests shall be maintained.


*Fig. 4.8Fire Extinguisher*

First-aid boxes or cupboards conspicuously marked and equipped with such contents as the State Government may specify, shall be provided and maintained in every generating station, enclosed sub-station, enclosed switching station and in vehicles used for maintenance of lines so as to be readily accessible during all working hours and all such boxes and cupboards shall,

except in the case of unattended sub-stations and switching stations, be kept in charge of responsible persons who are trained in first-aid treatment and one of such persons shall be available during working hours.

*Fig. 4.9 First Aid Kit*

Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of 5 MW and above and enclosed sub-station with transformation capacity of 5 MVA and above for use in the event of fire or smoke. The "overhead line" means any electric supply line which is placed above ground and in the open air but excluding live rails of a traction system.

*Fig. 4.10 Gas Mask*

**Clearance above Ground of the Lowest Conductor of Overhead Lines**

*Fig. 4.11 Overhead Distribution Lines*

No conductor of an overhead line, including service lines, erected

across a street shall at any part thereof be at a height of less than:

| | | |
|---|---|---|
| i) For lines of voltage not exceeding 650 Volts | - | 5.8 metres |
| ii) For lines of voltage exceeding 650 Volts but not exceeding 33 kV | - | 6.1 metr |

No conductor of an overhead line, including service lines, erected along any street shall at anypart thereof be at a height less than:

i) for lines of voltage not exceeding 650 Volts - 5.5 metres

ii) for lines of voltage exceeding 650 Volts but not exceeding 33 kV - 5.8 metres

No conductor of an overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than:

i) for lines of voltage up-to and including 11,000 Volts, if bare - 4.6 metres

ii) for lines of voltage up-to and including 11,000 Volts if insulated - 4.0 metres

iii) for lines of voltage exceeding 11,000 Volts - 5.2 metres

For lines of voltage exceeding 33 kV, the clearance above ground shall not be less than 5.2 metres plus 0.3 metre for every 33,000 Volts or part thereof by which the voltage of the line exceeds 33,000 Volts; provided that the minimum clearance along or across any street shall not be less than 6.1 metres.

For High Voltage Direct Current (HVDC) lines, the clearance above ground shall not be less than as follows:

| S. No. | DC Voltage (kV) | Ground Clearance (metres) |
|---|---|---|
| 1 | 100 | 6.1 |
| 2 | 200 | 7.3 |
| 3 | 300 | 8.5 |
| 4 | 400 | 9.4 |
| 5 | 500 | 10.6 |
| 6 | 600 | 11.8 |
| 7 | 800 | 13.9 |

*Table 4.1 Clearances for High Voltage Direct Current*

**Clearance between Conductors and Trolley Wires**

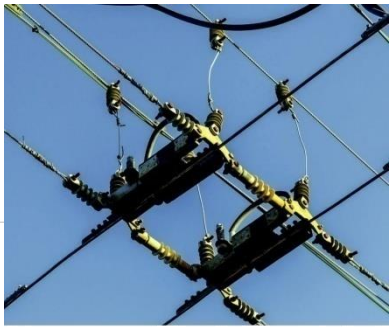


*Fig. 4.12 Trolley Wires*

No conductor of an overhead line crossing a tramway or trolley bus route using trolley wires shall have less than the following clearances above any trolley wire:

i)lines of voltage not exceeding 650 Volts - 1.2 metres

Provided that where an insulated conductor suspended from a bearer wire crosses over a trolley wire, the minimum clearance for such insulated conductor shall be 0.6 metre.

ii) lines of voltage exceeding 11,000 Volts - 2.5 metres but not exceeding 33,000 Volts

iii) lines of voltage exceeding 33 kV - 3.0 metres

**Clearance from Buildings of Lines of Voltage and Service Lines not Exceeding 650 Volts**

**Note:** For the purpose of this regulation, the expression "building", shall be deemed to include any structure, whether permanent or temporary.

*Fig. 4.13 Planning Distribution Lines near Buildings*

1. An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

2. Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed, as follows:

- for any flat roof, open balcony, varandah roof and lean-to-roof:
  - ◊ when the line passes above the building a vertical clearance of 2.5 metres from the highest point, and
  - ◊ when the line passes adjacent to the building a horizontal clearance of 1.2 metres from the nearest point, and
- for pitched roof:
  - ◊ when the line passes above the building a vertical clearance of 2.5 metres immediately under the line, and
  - ◊ when the line passes adjacent to the building a horizontal clearance of 1.2 metres

3. Any conductor so situated as to have a clearance less than that specified above shall be adequately insulated and shall be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg.

4. The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressured.

5. Vertical and horizontal clearances shall be as specified in Schedule-X.

**Clearance from Buildings of Lines of Voltage Exceeding 650 V**

*Fig. 4.14 High Voltage Power Lines*

1. An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

2. Where an overhead line of voltage, exceeding 650 V passes above or adjacent to any building or part of a building, it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than:

i) for lines of voltages exceeding 650 Volts - 3.7 metres up to and including 33,000 Volts

ii) for lines of voltages exceeding 33 kV - 3.7 metres plus 0.30 metre for

every additional 33,000 Volts part thereof

3. The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than:

| | | |
|---|---|---|
| i. | for lines of voltages exceeding 650 V | 1.2 metres up to and including11,000 Volts |
| ii. | for lines of voltages exceeding 11,000 V | 2.0 meters up to and 33000v |
| iii. | For lines of voltages exceeding 33 kV | 2.0 metres plus 0.3 metres for every additional 33 kV or part thereof |

Minimum clearances in metres between lines crossing each other will be as follows:

*Table 4.2 Minimum Clearances in Metres*

| S. No. | Nominal System Voltage | 11-66 kV | 110-132 kV | 220 kV | 400 kV | 800 kV |
|---|---|---|---|---|---|---|
| 1. | Low and medium | 2.44 | 3.05 | 4.58 | 5.49 | 7.94 |
| 2. | 11-66 kV | 2.44 | 3.05 | 4.58 | 5.49 | 7.94 |
| 3. | 110-132 kV | 3.05 | 3.05 | 4.58 | 5.49 | 7.94 |
| 4. | 220 kV | 4.58 | 4.58 | 4.58 | 5.49 | 7.94 |
| 5. | 400 kV | 5.49 | 5.49 | 5.49 | 5.49 | 7.94 |
| 6. | 800 kV | 7.94 | 7.94 | 7.94 | 7.94 | 7.94 |



**Tips**

Some basic fundamentals tips for safety should be kept in mind:

- Co-operation of all co-workers is essential to avoid accident.
- Unsafe worker is burden on the Company, as he may become the cause of accident to self as well as to others.
- Use of incomplete or little knowledge is dangerous and may invite accident.
- Accident is the result of unsafe working condition and unsafe work.

**CHECK YOUR KNOWLEDGE**

1. Fill in the blanks
   a. Clearance above ground for voltage less than 650 V is .....meter.
   b. Do not wear .....and.....during working in line.
   c. The horizontal clearance between the nearest conductor and building should be ..... meter.
2. Write a short note on following
   a. Basic fundamental safety tips
   b. Clearance from building of line voltage exceeding 650 Volts
   c. Safety precaution to be taken before starting the work.
3. Explain general health and safety rules in power utility
4. List safety precautions for distribution lineman
5. List the safety equipment used by Line

**Session 2**

**Workplace Hazards and Risks**

**Meaning of Hazards and Risks**

**Hazard:** Anything that will cause harm of any degree to Man, Machine, Method and Money.

**Risk:** The chances, likeliness, odds of an event occurring.

Safety = Hazard Elimination + Risk Management

*Fig. 4.17 Workplace Hazard Signs*

Hazards occur due to:

- Inadequate wiring
- Exposed electrical parts

- Wires with bad insulation
- Ungrounded electrical systems and tools
- Overloaded circuits
- Damaged power tools and equipment
- Using the wrong PPE and tools
- Overhead power lines

All hazards are made worse in wet conditions. Some unsafe conditions that can lead to hazards are:

- Inadequate guards
- Wearing loose dress like dhoti, kurta, pyjama and chappals
- Lack of earth connection with working on electrical system
- Defective tool, equipment or supplies
- Poor housekeeping
- Hazardous environment (gases, duct, fumes, etc.)
- Excessive noise
- Poor illumination
- Poor ventilation
- Inoperable safety device
- Horseplay, etc.

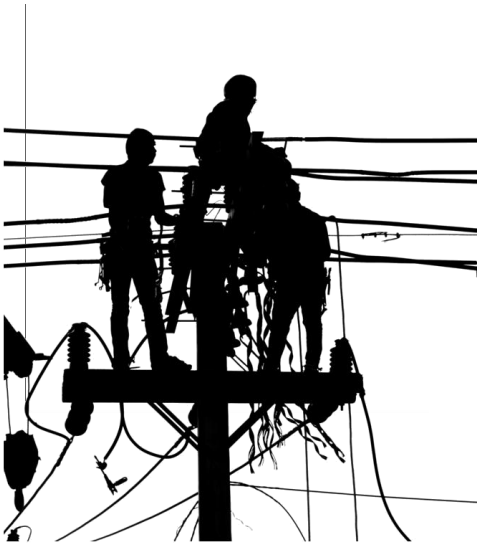


*Fig. 4.18 Workplace Hazards for Distribution Lineman*

Why do people behave unsafe? It may be due to:

- Lack of knowledge
- Job dissatisfaction
- Improper motivation
- Personal problem
- Over confidence

**Hazards Associated with Carrying Out Distribution Line Maintenance**

In order to overcome and minimise the hazards associated with carrying out distribution line maintenance, certain things should be taken care of such as use of PPEs including gloves, helmets, proper shoes, safety belt and eye protection glasses.

*Fig. 4.19 Hazards in Distribution Maintanence*

*Fig. 4.20 Hazards at Distribution Line*

**Suitability of Equipment**

This is of very high importance to ensure that tools and equipment are suitable, well maintained, calibrated and operating effectively so that whenever the need of any equipment arises in any emergency/routine operation they can be used by the lineman and he could get the work done effectively, easily and safely.

*Fig. 4.22 Safety Machines*

**Possible Causes of Accident**

Some possible causes of accident at workplace are:

- Working or operating machinery/equipment without authority
- Doing work in an unsafe way, such as throwing tools and equipments/line material or doing hasty work
- Use of improper tools and equipments. For example, using pliers instead of screw-driver, using pliers in place of spanner, not using insulated pliers or screw- driver, etc.
- Working on unsafe or dangerous equipment. For example, cleaning/greasing or adjusting any machine in operation
- Diverting the attention of a worker from his work, cracking jocks at work place, etc.
- Non-use of safety equipment and tools and equipments, such as ladder, waist belt /rope, hand gloves, D.O. operating rod, earthing rod, etc.
- Not following instructions properly
- Sickness or incapacity (being drunk while working)
- Injuries or contagious illness not treated fully
- Failure to warn co-workers
- Improper loading or placement of equipment or supplies
- Taking an improper working position

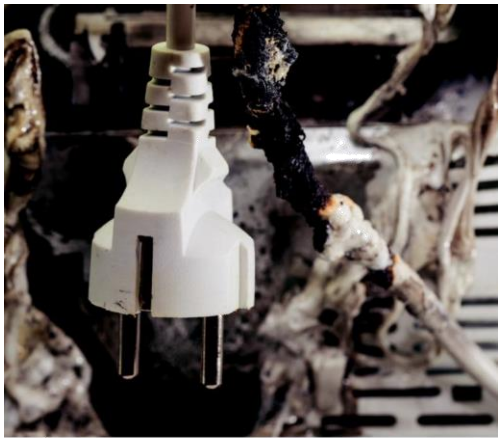


*Fig. 4.23 Accidents at Workplace*

Accidents never occur accidentally but occur due to lack of safe condition or due to unsafe working practices. Accidents may be fatal or non-fatal. Let us discuss why accidents occur under specific working conditions.

**When Working on Distribution Lines**

- Accidents may occur due to falling of poles while stringing of conductor during erection of poles. This is because poles are erected in non-aligned condition.
- Due to non-use of proper earthing, which keeps the line charged, if this charged line falls on a person, accident may occur.
- Due to lack of provision of guarding at road-crossing points and crossing of H.T./ L.T. lines.
- The line coming to AB Switch or D.O. fuse is not connected at proper place and in a proper way.
- Service connection is not provided properly as per standard practice.

Accidents occur when unauthorised or untrained persons work on distribution lines. Accidents may happen when:

- The services of unauthorised persons are used for overhead work or for placing a fuse link.
- Instructions are issued to work on live line to the line helper.
- Fuse links or meter cut-out fuses are replaced by consumers themselves.


*Fig. 4.24 Unauthorised Persons Not Allowed*

Ignoring proper working methods can prove fatal. Some instances of not following proper work methods are:

- Proper precaution is not taken while working on such pole which is fed through both sides, i.e. at multi-feeding points.
- The circuit on which work is to be carried out is not fully and properly made dead, or street light line is not made off.
- Proper precaution/attention is not given when some phase is made direct.
- Proper attention is not given to probable danger while doing crossing work of H.T., L.T. lines or carrying out work at crossing points.
- When permit is taken but line is not made off and person sent for patrolling or climbing on pole.

Risk of accidents increases significantly when:

- Safety rope is not used. The lineman may fall from the pole and injure himself severely.
- Hand gloves or insulated plier, screw driver, etc. are not worn. This increases the risk of electrocution.
- Ladder is not used while doing work of street-light maintenance. This can also lead to fall that may be fatal.
- Discharge rod and earthing rods are not used, which may also lead to electrocution.


*Fig. 4.25 Safety Gear and Kit for Electrical Worker*

Authorised permit needs to be taken when:

- Working on H.T. Line without obtaining proper permit.
- Carrying out work on T/F without opening of D.O. Links.
- Where there is H.T. and L.T. lines on same pole and lineman starts working on L.T. line without taking permit on H.T. Line or not switching off L.T. line.

Regular or necessary maintenance is also required to avoid accidents. Some examples of when proper maintenance is not done include:

- Not giving proper attention to tree-clearances.
- Non-maintenance of broken guarding or earthing.
- Non-replacement of broken kitkats.
- Non-replacement of worn out/cracked service wire.
- Non-maintenance of transformers regularly and properly.

*Fig. 4.26 Maintenance Not Done*

Accidents also occur when the lineman is careless. Some common examples of this are:

- No proper attention is given while erecting the pole or during stringing the line.
- Ignoring to use safety equipment.
- While doing work, the wrist watch or metals/ metallic chain of neck are not removed.
- Working on live line in over-confidence.
- Doing work in unsafe condition or proper safety precaution not taken.

**Tips**

Accidents may lead to "mishap, destruction of property, injury, or even death". Accidents must be prevented through precautions, safety measures and safety management.

**Near Misses**

Near miss is an unplanned event that does not result in injury, illness, and damage or product loss but had the potential to do so. The difference between a near miss and a full blown incident is often a fraction of a second or a fraction of an inch that may not be there the next time. Near misses are warnings of accidents in the making. By accepting these warnings and looking for their causes, we can prevent these situations recurring.

**Short Circuits**

Hazards related to short circuit may result from various factors such as:

- Too many devices plugged into a circuit, leading to heating of wires and possibly a fire.
- Overheating from damaged tools.
- Lack of over current protection.

- Wire insulation melting, which may cause arcing and a fire in the area where the overload exists, even inside a wall.

*Fig. 4.27 Poor and Shabby Meter*

*Fig. 4.28 Too Many Circuits are Open Installation is a Cause o Short Circuit and Fire*

*Fig. 4.29 Burnt Energy Meter Due to Short Circuit*

Electrical protective devices are capable of preventing hazards from short circuit as follows:

- Automatically open circuit if excess current from overload or ground-fault is detected, which leads to shutting off electricity.
- They include GFCIs, fuses, and circuit breakers.

**Fuses and circuit breakers are over current devices. When too much current passes through:**

**OR**

**Fuses melt** **Circuit breakers trip open**

## Electrical Shock

An electrical shock is received when electrical current passes through the body. You will get an electrical shock if a part of your body completes an electrical circuit by:

- Touching a live wire and an electrical ground, or
- Touching a live wire and another wire at a different voltage.

*Fig. 4.30 Risk of Electrical Shock*

Effect of current on human body:

| Current | Effect on Human Body |
|---|---|
| 0 - 5 Milli Amp | Perceptual feeling |
| 5 - 10 Milli Amp | Muscle contraction |
| 10 - 15 Milli Amp | More painful feeling |
| 15 - 20 Milli Amp | Respiratory failure |
| 20 - 30 Milli Amp | Ventricular fibrillation |

*Table 4.3 Various Effects of Current on Human Body*

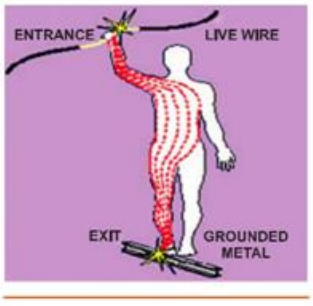



*Fig. 4.31 Effect of Electrical Current on the Body*

Severity of the shock depends on:

- Path of current through the body
- Amount of current flowing through the body (amps)
- Duration of the shocking current through the body.

To protect workers from electrical shock:

- Use barriers and guards to prevent passage through areas of exposed energised equipment.
- Pre-plan work, post hazard warnings and use protective measures.
- Keep working spaces and walkways clear of cords.

- The work area shall be isolated from all possible sources of power supply.
- The equipment like isolators shall be locked in open condition and circuit breaker opened and spring discharged.
- Warning boards shall be exhibited at appropriate places.
- The area of work shall be properly demarcated and cordoned off with easily distinguishable material.
- Each conductor or apparatus shall be checked for absence of voltage.
- Proper inter phase shorting and earthing shall be completed before commencing any work on equipment/line.

**Methods of Accident Prevention**

*Fig. 4.32 Reducing Risk of Accidents*

**General Responsibilities of Supervisory Staff**

Engineers in charge of the various departments/sections works shall have working knowledge of:

- The technique, provisions of the law, and
- All instructions relating to the working of their departments/sections/works.

They shall be responsible for organisation, division and supervision of the work under their charge.

They should ensure that:

- The lineman working under them possesses the requisite ability and experience.
- No man who is either not authorised or not competent is allowed to work on a job.
- A sufficient number of men have been assigned to each job at the time of the allotment of work. These men properly understand:
    - Work to be done,
    - Procedure for doing the work properly and safely, and

- Hazards that may be encountered while working.

- Danger signs or barriers, as may be necessary to warn the public and others of the danger zones and to prevent them from entering that area are put up before taking the work in hand.

- Defective tools, materials and working methods are not employed.
- There is co-operation and co-ordination between the operation and maintenance staff.
- Person in immediate charge of the workmen remains on work site till the work is over and normal conditions are restored.
- Safety drills for staff is organised at least once a month.

- All regular employees of the undertakings other than daily paid in the working party are trained in first aid and use of fire-fighting equipment.

- The persons working under them are periodically subject to tests to ensure that they maintain adequate knowledge of standard working practices.

- The persons working under them are kept informed of the instructions issued by the undertaking/department/section concerned from time to time.

- Various safety devices, first aid kits, fire extinguishing equipment, etc. are maintained in serviceable conditions and the workmen are made aware of their locations.

- Employees working under them are free to share suggestions for improvement of working procedures, safety practices, etc. from time to time.

- Accident reports are properly made. The supervisory staff shall co-operate in investigation relating to accident causes and in evolving procedures for preventing similar accidents in future.

**General Responsibilities of Distribution Lineman**

All linemen shall act in a manner as to provide for:

- Safety to themselves
- Safety to fellow workmen
- Protection to the public
- Protection of property
- Continuity of proper supply to the maximum extent possible
- Safety to installation

All linemen shall ensure that:

- They are familiar with the tools, materials, and methods of work. They shall consult their supervisors in case of doubt at any point.
- They fully understand the instructions (verbal or written) given by their supervisors before commencement of work.
- All tools or equipment are in safe working condition.

**Personal Conduct of Employees**

- Employees shall report to their superior officers any dangerous conditions of the undertaking's properties, equipment or personnel, immediately after it comes to their notice.
- Employees shall be courteous and considerate to the public and towards one another. They shall not engage in flights, practical jokes, scuffling or horse plays while on duty or while in sub-stations.
- Employees shall always remain alert and should not try to indulge in sleeping while on duty. They should refrain from smoking while working in a place where smoking is objectionable and all supervisors shall familiarise themselves with these provisions.
- Use of intoxicants (alcoholic beverages or narcotics) shall not be permitted on duty. Employees under the influence of any intoxicants shall not be permitted to remain on the job or around the premises.

**Work Permit System and Creation of Safety Zone**

Proper and safe operations on the electric system are the qualifications of the people who are responsible for performance of the work. It is important that people in charge of jobs be knowledgeable of the hazards and means for providing safe conditions to accomplish the necessary work. For this reason, only authorised people will be permitted to request permits to work on substation premises or to perform work on circuits.

**Making Safety Zone for Working in Distribution Substation:**

1. Check the supply at HT&LT terminals of DT with Neon tester.
2. Test the supply at LT ACBs incoming and outgoing terminals with Neon Tester.
3. Discharge it with Discharge rods.
4. Short the HT/LT bushings of DTs with chain and connect with earth.
5. Short the LT out going feeders with chain to prevent back feed from consumer and open the Neutral also.

*Fig. 4.35 Lineman Working in Safe Condition*

**Tips**

During the rains, the porcelain insulators may develop hairline cracks, and as water seeps in, the insulators conduct elect

**Tips**

Safety precautions to be taken while working with live line/equipment:

- All electrical circuits or equipment are hazardous. Hence, do not start work unless the following steps are taken:
  - ◊ Circuit is in off condition
  - ◊ Line clear permit is taken on equipment
  - ◊ Equipment/Line is properly earthed
- Every electrical line/equipment should be first made off and take line clear permit before taking the work in hand.
- It is essential to get authorised permit on 11 KV and above voltage line. If the line is under own authority, then take self-permit.
- Make sure that feeder/equipment is made off and properly earthed as noted in line clear permit.
- A.B. Switch should be kept off and locked. If possible, keep somebody there for watch/ward.
- Line should be got discharged and earthed by earth-rod at one pole before and after the work place before starting the work.
- Make sure that all men and material has safely reached/climbed down to ground after completion of work. Further, make sure that no T&P left on the line and earth rods are removed properly.
- While operating A.B. Switch or other line equipment hand gloves should invariably be used.
- Use safety belt and waist belt/rope while working on line.

**CHECK YOUR KNOWLEDGE**

1. Explain the following
   a. Possible cause of accident
   b. Work permit system and making a safety zone
   c. Responsibilities of Distribution Lineman
   d. Interpret the meaning of hazards and risks

2. True and false
   a. Line should not be got discharged before starting the work on line (True/False)
   b. Short the HT/LT bushings of transformer with conductor and connect with earth. (True/False)
   c. Safety zone is not essential during work (True/False)
   d. Accidents occur when authorised or trained persons work on distribution lines. (True/False)

**Session 3**

**Fire Safety**

**What is Fire?**

Fire is the rapid oxidation of a substance often with the evolution of heat and light in varying degrees of intensities. A common misconception is that fire burns the actual chair or piece of wood. However, it is the gases given off by an object that burns. Heat causes objects to give off these flammable gases. When the gases reach their ignition temperature, the light given off during the oxidation is known as fire. Fire itself generates more heat to the object and thus an endless cycle begins until all of the gases have been exhausted from an object. Then the remaining particles or ash are what is left.

*Fig. 4.65 Fire at Workplace*

Take a look at the flame on the candle. You can see the wick is burning. But again, it is not really the wick burning. Notice that there is no flame in the immediate area surrounding the wick. A cross-sectional view would show this better. The gases around the wick are in too much concentration to allow them to ignite. In other words, there is not enough oxygen to support combustion. As the gases spread away from the wick they ignite due to the already present heat being generated by the fire.

Fire can be extinguished by eliminating any of these four things:

- **Boiling range:** The range of temperature from lowest to highest during which all fractions of different gravity and boiling points are converted to vapour.
- **Flash point:** The lowest temperature at which a substance will give off vapours sufficient to form a flammable mixture with air that will flash across the surface when ignition source is applied. Lower the flash point of a substance, greater is the fire hazard.
- **Ignition temperature:** Lowest temperature of a sufficient volume of heat required to ignite the vapour or finely divided particles of specific substance when these are in a correct mixture with air.
- **Explosive range:** All concentration of a mixture of flammable vapour or gas in air (usually expressed in per cent by volume of vapour to air) in which a flash will occur or a flame will travel if the mixture is ignited. The lowest and highest percentage of vapour air mixture of substance indicates the limit of its explosiveness. Vapour concentration less than the lowest limit in air is too lean to burn as also the vapour concentration more than the highest limit in air is too rich to burn.

**Causes of Fire**

Some common causes of fire when working with power lines are:

- Careless smoking
- Bad housekeeping
- Welding/cutting without fire precautions
- Improper storage of flammable liquids and gases
- Unattended/misuse of heating equipment
- Static electricity
- Oil/chemical leakage or spillage
- Self-ignition of oily wastes

**Fuel Classification**

Fires are classified according to the type of fuel that is burning. If you use the wrong type of fire extinguisher on the wrong class of fire, you might make matters worse. Hence, it is very important to understand the four different fire (fuel) classifications:

- **Class A:** Wood, paper, cloth, trash, plastics — solids that are not metals.
- **Class B:** Flammable liquids—gasoline, oil, grease, acetone (Includes flammable gases).
- **Class C:** Flammable gas and Live Electrical Equipment— LPG, Natural Gas, Methane, etc. and Fire on Electrical Equipment.
- **Class D:** Metals—potassium, sodium, aluminium, magnesium.

  Most fire extinguishers will have a pictograph label telling you which type of fire the extinguisher is designed to fight.

**Steps: How to Use a Fire Extinguisher**

The following are the steps to use a fire extinguisher in a proper manner:


**STEP 1:** P – Pull the pin.

**STEP 2:** A – Aim at the base of the fire.


**STEP 3:** S – Squeeze the top handles.


**STEP 4:** S – Sweep from side to side.

- Pull the pin – This will allow you to discharge the extinguisher.
- Aim at the base of the fire – Hit the fuel. If you aim at the flames, the extinguishing agent will fly right through and do no good.
- Squeeze the top handles – This depresses a button that releases the pressurised extinguishing agent until the fire is completely out.
- Sweep the extinguisher from side to side – This will help the extinguishing process.

**Tips**

Start using the extinguisher from a safe distance away, and then slowly move forward. Once the fire is out, keep an eye on the area in case it re-ignites. In case the extinguisher malfunctions, or something unexpected happens, you need to be able to get out quickly. You don't want to get trapped in the fire.

**Rules for Fighting Fires**

Fires can be very dangerous and you should always be certain that you will not endanger yourself or others when attempting to put out a fire. For this reason, when a fire is discovered:

- Assist any person in immediate danger to safety, if it can be accomplished without risk to you.
- Call 100/101. The fire alarm will notify the fire department and other building occupants and shut off the air handling system to prevent the spread of smoke.
- If the fire is small (and only after having done these 2 things), you may attempt to use an extinguisher to put it out.

However, before deciding to fight the fire, keep these things in mind:

- Know what is burning. If you don't know what's burning, you won't know what kind of extinguisher to use.
- Even if you have an ABC fire extinguisher, there may be something in the fire that is going to explode or produce toxic fumes.
- Chances are you will know what's burning, or at least have a pretty good idea. But if you don't, let the fire department handle it.
- Is the fire spreading rapidly beyond the point where it started? The time to use an extinguisher is at the beginning stages of the fire.
- If the fire is already spreading quickly, it is best to simply evacuate the building.
- As you evacuate a building, close doors and windows behind you as you leave. This will help to slow the spread of smoke and fire.

**Tips**

Remember, even after all training, sometimes it is difficult to handle fire on your own. Do not fight the fire if:

- You don't have adequate or appropriate equipment. If you don't have the correct type of large enough extinguisher, it is best not to try fighting the fire.
- You might inhale toxic smoke. When synthetic materials such as the nylon in carpeting or foam padding in a sofa burn, they can produce hydrogen cyanide, acrolein, and ammonia in addition to carbon monoxide. These gases can be fatal in very small amounts.
- Your instincts tell you not to. If you are uncomfortable with the situation for any reason, just let the fire department do their job.
- The final rule is to always position yourself with an exit or means of escape at
- your back before you attempt to use an extinguisher to put out a fire.

**CHECK YOUR KNOWLEDGE**

1. Write a short note on the following
   a. Fire
   b. Fuel classification
   c. Flash point.
   d. Handling of Fire Extinguisher
2. Explain the causes of fire at workplaces
3. List the rules of fire fighting