UG S2 02 (SEC 2)

FOUR YEAR UNDERGRADUATE PROGRAMME

(CBCS and Accordance with NEP 2020)

ELECTRICITY AND ELECTRICAL WIRING

Second Semester

Skill Enhancement Course

GPD School of Interdisciplinary and Vocational Studies

KRISHNA KANTA HANDIQUI STATE OPEN UNIVERSITY

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COURSE INTRODUCTION

This course has been designed as Skill Enhancement Course (SEC) for undergraduate level learners of the second semester. It is a multidisciplinary course of 3 credits. The total duration of the course is six months. The objective of the course is to provide the basic concepts of various forms of energy and their sources. This Course will familiarize the learners with the basic principle of electricity and magnetism. It will also help to learn about wires, cable, house wiring, materials required for house wiring and earthing. This Course will also focus on electrical safety precaution and the Indian Electricity Rule. After the completion of this course, the learner will be able to acquire knowledge and skill about electricity and the electrical wiring procedures

There are eleven units in the course.

The **first unit** covers the forms of energy, Sources of Electricity, Atomic structure, Static and dynamic electricity; Basic terms used in electricity and their definitions, Ohm's Law; Resistance and Specific Resistance, Conductor and Insulator.

The **second unit** includes the common components and their connections, advantages and disadvantages of series and parallel circuit, voltage and current divider rule and Kirchhoff's Laws.

The **third unit** consists of magnet and types of magnet, permeability and type of magnetic materials on the basis of permeability, magnetic property of materials, magnetic effect of electric current, electromagnetic induction, Faraday's Laws of Electromagnetic Induction and some common devices.

The **fourth unit** covers the Direct Current (DC) and Alternating Current (AC), Electro Motive Force equation, Ac Circuit and Power factor.

The **fifth unit** focuses on the multimeter, Tong Tester, Measuring Instrument, Measurement Meters, Voltmeter and Ammeter, Current Transformer and Potential Transformer Earth resistance meter.

The **sixth unit** covers the Types of wires and cables, Types of joints and termination, Safety consideration and regulations.

The **seven unit** includes method of house wiring, Types of surface wiring and concealed wiring, wiring accessories and their specifications, wiring diagram, Types of connections of lamps including staircase connection and testing of house wiring.

The **eighth unit** comprises of the Importance of earthing, Ground connection and size of GI wire

for ground connection, various types of earthing and measurement of earth resistance.

The **ninth unit** covers the hazards of electricity, safety precautions and electrical safety sign, Shock treatment, Firefighting equipment for fire involving electrical equipment, Indian Electricity Rules and Indian Electricity Act.

The **tenth unit** includes about the semiconductor; PN junction diode, zener diode; Transistor; Field effect transistor; power transistor; LDR.

The **eleventh unit** includes the Electrician trade, responsibilities of electrician and wiremen and training of electrician.

While going through a unit, you will notice some boxes, containing such information as would help you to understand some of the difficult, unfamiliar terms. You will find an item called "ACTIVITY' where you will apply your knowledge and thoughts in some questions pertaining to the relevant topic. Again, we have included some relevant concepts in "LET US KNOW" along with the text. And, at the end of each seection, you will get "CHECK YOUR PROGRESS" questions. These have been designed to self-check your progress of study. It will be better if you solve the problems put in these boxes immediately after you go through the sections of the units and then match your answers with "ANSWERS TO CHECK YOUR PROGRESS" given at the end of each unit.

UNIT 1 : FUNDAMENTALS OF ELECTRICITY

UNIT STRUCTURE

1.1 Learning Objectives

1.2 Introduction

1.3 Forms of Energy

1.3.1 Advantages of Electrical Energy

1.4 Sources of Electricity

1.4.1 Conventional

1.4.2 Non-Conventional

1.5 Atomic Structure

1.6 Static and Dynamic Electricity

1.7 Basic Terms Used in Electricity

1.8 Ohm's Law

1.9 Resistance and Specific Resistance

1.10 Conductor and Insulator

1.11 Let Us Sum Up

1.12 Further Readings

1.13 Answers to Check Your Progress

1.14 Model Questions

1.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- get an idea about various forms of energy
- explain the sources of electricity
- discuss the atomic structure
- describe the static and dynamic electricity
- illustrate the basic terms used in electricity
- state the Ohm's law
- explain the resistance and specific resistance
- discuss the conductor and insulators.

1.2 INTRODUCTION

In this unit, we will introduce you to the basic concept of electricity. Various forms of energy, types and advantages of electrical energy will also discuss in this unit. In this unit, we shall also highlight the sources of electricity, static and dynamic electricity and the terms used in electricity. An attempt is made to explain the Ohm's law, resistance and specific resistance and their effect on temperature in this unit.We shall also focus the conductor and insulator and their properties and applications at the end of this unit.

1.3 FORMS OF ENERGY

Energy can be defined as the capacity of doing work. Energy is available in various forms. It is not possible to create or destroy energy. Energy can be converted from one form to another form. This principle is known as conservation of energy. Energy can be converted from one form to another form. A motor converts electrical energy into mechanical energy. Energy can be converted from one form to another in various ways.In hydel power station, potential energy of water is converted into electrical energy. Similarly, other forms of energy is converted into mechanical or electrical energy by many kinds of devices, including fuel-burning heat engines, generators, batteries, fuel cells etc.There are different types of sources of energy. These, all types of sources can be converted to other forms which can be used by humans. Many types of energy conversion devices were developed by humans for their benefit over the centuries. People started to use wind energy for propelling boats along the river Nile as early as 5000 BC. People used windmills hundreds of years ago. The early windmills converted the kinetic energy of wind into mechanical energy for pumping water and grinding grain.

Thus we get that energy is available in various forms such as

i) Heat energy ii) Nuclear energy iii) Electrical energy
iv) Light energy v) Sound energy vi) Chemical energy
vii) Mechanical energy

1.3.1 Advantages of Electrical Energy

Energy is available in different forms. One form of energy can be converted into other form of energy. Electrical energy can be converted into other forms of energy like mechanical, thermal etc. easily. Electric energy is unrivalled for many uses such aslighting, computer operation, traction and entertainment applications. It is also used for many industrial heating applications, cooking, space heating, and railway traction.The use of electrical energy is pollution free. Electrical energy is considered more advantageous than other forms of energy. The main advantages of electrical energy are:

a) The conversion of electrical energy into other form of energy is easy.

b) It can be transmitted from one place to other place easily.

c) The transmission efficiency is high.

d) The operation and control of electrical machine are simple and easy.

e) Electrical energy is cheaper than other forms of energy.

f) It is neat and clean and free from smoke and fumes or poisonous gases.



CHECK YOUR PROGRESS

Q 1: Is it possible to convert electrical energy into heat energy? Write one name of such household appliance.

.....

.....

Q 2: What are the advantages of electrical energy?

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1.4 SOURCES OF ELECTRICITY

There are different sources of energy. Coal, oil and natural gas are sources of energy known as fossil fuel. Fossil fuel can be converted into energy. There are many other sources of energy like solar, geothermal, tidal, wind etc. All these sources are available in the nature.

Fossil fuels and other renewable sources are the sources of energy provided by nature. All over the world, energy converter is used for the production of electricity, mainly from fossil fuel, converting thermal energy of fossil fuel into electrical energy through different stages. Nuclear fuel is also used for production of electricity. In nuclear power station, nuclear energy of radioactive material is converted into electrical energy. The potential energy of water at high head is converted into electrical energy in hydel project.

There are many sources of electricity. These sources are of two types. These are

a) Conventional or non-renewable sources

b) Non-conventional or renewable sources

1.4.1 Conventional Sources

Fossil fuel sources are known as conventional sources of energy. B Potential energy of water in case of big hydel projects, nuclear energy of radioactive material are also conventional types of energy sources. Fossil fuels take millions of years to form. At the time of burning of fossil fuels to produce energy, produces green house gases such as carbon dioxide. Conventional sources of energy are

i) Natural gases

ii) Coal

iii) Oil

iv) Nuclear

v) Water (big hydel project)

1.4.2 Non-Conventional or renewable Sources

Sources like solar, geothermal, tidal, wind etc are known as non-conventional or renewable sources of energy. Renewable energy is derived from natural sources. Replenishment rate of renewable sources is higher than they are consumed. These sources do not produce green house gases. Example of few renewable sources of energy are given below.

i) Wind
ii) Biomass
iii) Solar
iv) Geothermal
v) Tidal
vi) Water (mini or micro-hydel project)



CHECK YOUR PROGRESS

Q 3: What are the conventional sources of electricity available in Assam?

.....

.....

1.5 ATOMIC STRUCTURE

The study of atomic structure is important to understand theelectron theory. The electron theory clarifies the phenomenon of electricity and electric charge. Before explaining the atomic structure, we must know the following things.

- Matter
- Molecule
- Atom

Matter

Things that has some mass and occupies some space, they are known as Matter. Matter can be classified as following–

- Solid
- Liquid
- Gas

Molecule

If you go on breaking any matter to smaller and smaller parts, a stage will come when it becomes unbreakable. This the smallest size that a matter can occupy, where all the properties of the matter are preserved. If you try to break it further, it will lose all its properties. This smallest size that occupies the complete set of properties of a matter is known as molecule. Every matter (both living & non-living) is made from the combination of such molecules.

Atom

If molecules are further divided, smaller parts become available which are known as atom. But the atoms cannot exist independently; the only exception to it is that when a molecule is made up of only one atom. The properties of an individual atom are totally different to that of the matter.

According to the Electron Theory all matters are made of such atoms and these atoms consist of three fundamental elements, viz.–

- Proton
- Neutron
- Electron

The central part of an atom is known as nucleus. It almost contains all the mass of the whole atom. The nucleus consists of neutron and proton. Protons are positively ***charge***d and electrons are negatively charged. Neutrons are neutral i.e. they possess no charge. So in this way the nucleus is positively charged. The electrons move around the nucleus in some ***orbit***s. The positive charge of a proton is equivalent to the negative charge of an electron. So, in an atom the number of proton and electrons are same. The number of electron and proton depends on the matter and is different for different matter. Fig. 1.1 shows the structure of a Hydrogen atom–

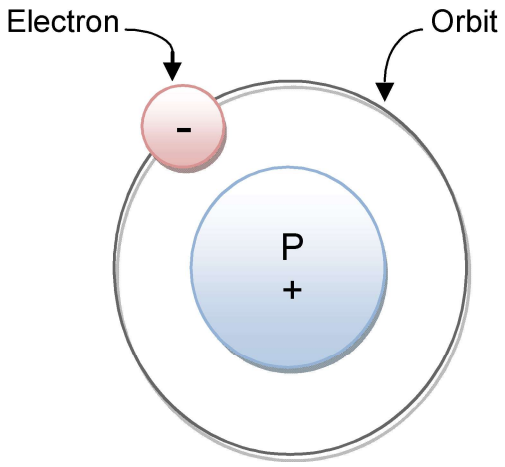


Fig. 1.1: Structure of a simplest atom (Hydrogen atom)

In hydrogen, it contains one electron and one proton. Whereas in case of a carbon atom it contains six protons in its nucleus and six electrons move around it in two orbits-two electrons in the inner orbit and four in the outer orbit. The maximum number of electrons that the orbits can have follows the following mathematical formula-

$$e = 2\ n^2$$

where, n = count of the orbit (orbits are counted from the inner side)

e = maximum number of electrons that the orbit can have

It means that for the first orbit, n=1 so e=2, so it cannot have more than two electrons. Similarly, the second orbit can have a maximum number of eight electrons; the third one can have 18 and so on. When the number of electrons and protons are same then they neutralise each other's charge so as a whole the atom is neutral. If the case is such that the outermost orbit of the atom contains more electrons than the fixed value, then the atom is called negatively charged and if the number of electron is less in the outer most orbits than the maximum value then the atom is called positively charged.



CHECK YOUR PROGRESS

Q 4: Fill in the blanks:

i. Matter can be categorised as _____, _____ and _____.

ii. An atom consists of _____, _____ and _____.

iii. The number of electrons and protons in an atom are _____.

iv. Neutrons have _____ charge.

v. The maximum number of electrons that an orbit can have follows the mathematical formula _____.

1.6 STATIC AND DYNAMIC ELECTRICITY

When certain materials, such as leather and glass, are rubbed for a period, they exhibit the ability to attract small pieces of paper and other lightweight objects. Likewise, when a comb is rubbed with wool or passed through dry hair, it also develops this attractive property. The acquisition of this property signifies that the material has acquired an electric charge, and this phenomenon is referred to as electricity.

Electricity appears in two forms – one positive and the other negative. The fundamental concept of charge, however, comes from the description of the atom. As we already discussed in the previous section that atom is constituted by protons and electrons. Electron is electro-negative while proton is electro-positive.In the normal state, the electrical characteristics of the atom is in the balanced state as the electric charge distribution of electrons and protons cancel out each other. If an electron is taken away or if there is an excess electron in the atom, the balance is disturbed. If there is excess electrons it is called negatively charges and if there is a deficiency of an electron it is called positively charged.

The phenomenon of attraction is due to the reaction between two opposite charges. In this process electrons never flow freely, it just changes its position once, so it is known as static electricity. Static electricity cannot do any work, but ***dynamic electricity*** does a lot of work. All electrical

appliances around us run due to this dynamic electricity. Whenever electricity is produced due to free moving electrons it is called dynamic electricity.

When a difference of electric state or potential exists between two points, charge will from the higher potential to the lower potential. This difference in state or potential has forced a displacement of the particle from one position to another. This is defined as **potential difference** or **electromotive force** (emf).

When electricity is stored between the two plates of a capacitor (figure 2.1) it cannot flow till a conductor is connected to a capacitor. In that situation a static electricity develops. The charges are held between the plates of the capacitor which continues to hold it till a conductor connected to it provides a path of flow.

Electrons that move from one atom to another are called **free electrons** and such random motion can continue indefinitely. However, if an electric pressure, potential difference or voltage is applied across any material there is a tendency for electrons to move in a particular direction. This movement of free electrons, known as **drift**, constitutes an electric current flow. Thus current is the rate of movement of charge. The movement of electric charges constitutes dynamic electricity.

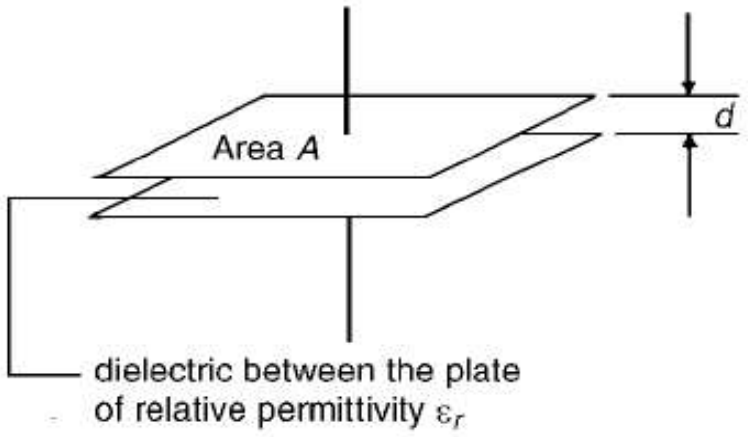


Fig. 1.2: Parallel plate capacitor that can hold static electricity



CHECK YOUR PROGRESS

Q 5: Define the static and dynamic electricity.

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1.7 BASIC TERMS USED IN ELECTRICITY

In an atom, the attraction of nucleus to the outermost orbit is poor, the electrons in the outermost orbit are also known as valance electron. Sometimes they get detached from the atom. These electrons are now free to move from one end to another. This flow of free electrons is termed as electricity and by the increasing movement of these free electrons produces electricity flow or current. The number of free electrons in a conductor is more and it is very less in case of an insulator. If a conductor is connected to the battery terminals, then the free electrons in the conductor flows towards the positive (+) terminal and current flows from positive (+) terminal towards the negative (-) terminal. Figure 1.2 shows the direction of electron flow and current flow in a conductor.

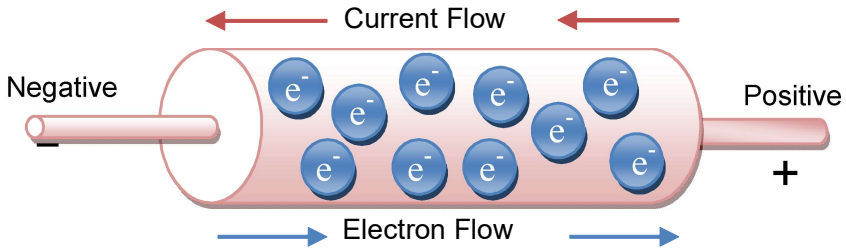


Fig 1.2: Current flow direction and electron flow direction

Current is measured as the rate of flow of free electrons or charge per unit time. Mathematically–

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

where, Q represents the charge and is measured in coulomb; t represents time and is measured is second. It means coulomb per second is the current and is termed as Ampere. So the unit of current is ampere.

Electrical Potential:

Whenever a body is to be charged, work is to be done for charging

it and this work done is stored in the body in the form of Potential Energy. Now, the charged body is capable of doing some work in the form of moving another charged body by attraction or repulsion. This capacity to do work of a charge body is known as electric potential. The electric potential can be defined as the work done for charging a body to a unit charge. Mathematically Electric Potential can be written as,

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

Where, W is the amount of work done, and is measured in Joules and Q is the charge, measured in coulomb. So the unit of electric potential is joules/coulomb and it is termed as Volt.

Potential Difference:

Voltage, also termed as Potential Difference or E.M.F (Electro Motive Force). This can be defined as the difference in electric potentials of two charged bodies.

If two charged bodies have different potentials, then they are said to have a potential difference. For example, let us take two charged bodies A and B having different potentials and the potential of B is higher than A. So, as shown in the Figure 1.3, if these two bodies are connected together free electrons from A will flow to B. This occurs as because, B is at a higher potential and, as the definition of electric potential shows charge is inversely proportional to potential, so this signifies that B is it at higher potential; so its charge is less, so naturally charge i.e. the free electrons from A will rush towards B.

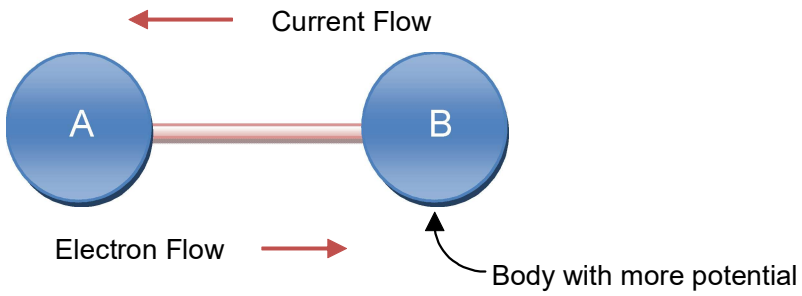


Fig. 1.3: Current Flow and Electron Flow direction for two charged bodies having different potential.

It means that a current flow will occur between these two bodies and whose direction is opposite to that of the electron flow. This current will retain till the potential of these two bodies become equivalent. So, whenever there is a difference in potential at two ends of a conductor, the current flow will occur in the conductor. As the unit of potential is Volt, so the unit of potential difference or voltage will also be same i.e. volt.

Electrical Power:

Generally, the rate at which ***work*** is done is known as power. Power can also be defined as the work done per unit time. As the unit of work done is Joule so unit of power is Joule/sec and this unit is known as Watt. In case of electrical system whenever voltage is applied across a conductor current flow starts because of the movement of electrons. During this process of movement, the electrons collide with the atoms of the conductor and in this process of collision heat is produced. This heat produced totally depends on both the applied voltage and the current and it is produced as work has to be done to overcome the friction due to the electron movement. This work done per unit time is power and it is always equal to the product of current and the voltage for a particular circuit. So for electrical system mathematically, we can express power as–

$$\text{Power (P)} = \text{Voltage (V)} \times \text{Current (I)}$$

Hence, in a conductor or an electrical circuit power is said to be 1 Watt when for an applied voltage of 1 Volt, 1 A current flow.

Energy:

Energy can be defined as the capacity to do work. Whenever work is done by a body, the work done is stored in the form of energy. To best understand this, consider the case of electrical conductor. Whenever power is applied to the conductor heat is produced and this heat is one form of energy. Energy is equivalent to the amount of work done so the unit of energy is same to that of the work, i.e. Joule. One joule is the energy required to do one joule of work.



CHECK YOUR PROGRESS

Q.6. Fill in the blanks:

i. The rate at which _____ is done is known as power.

ii. In conductor, heat is produced due to _____.

iii. Power can be expressed in terms of voltage and current as:
Power = _____ × _____.

iv. Energy can be defined as the _____ to do _____

v. The amount of work done is equivalent to _____.

vi. The unit of Energy is _____.

1.8 OHM'S LAW

The basic law of electrical circuit is based on the Ohms Law. The Ohm's law gives the relationship between voltage, current and resistance in a dc circuit. According to Ohm's law the current (I) flowing through a ***conductor*** at constant temperature is directly proportional to the potential difference (V) across its ends.

i.e. $V \propto I$

$V = IR$

The constant R is known as the resistance of the conductor. The graph between V and I is a straight line means that the resistance of the conductor is constant irrespective of the applied voltage.

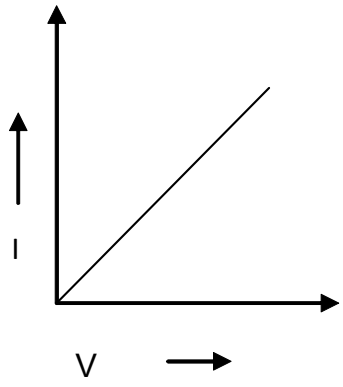


Fig. 1.4: Graph of Ohm's law



CHECK YOUR PROGRESS

Q 7: State true or false

a) The Ohm's Law gives the relation between voltage, current and resistance.

b) According to Ohm's law the current flowing through a conductorat constant pressure is directly proportional to the potential difference across its ends.

c) The graph between V and I is a straight line.

1.9 RESISTANCE AND SPECIFIC RESISTANCE

Electric current in any electrical circuit is the flow of free electrons. When an opposition applied to the flow of electric current, it is called resistance. In other words, a resistance is a measure of opposition applied by a substance to the flow of free electrons. The resistance is represented as R. The unit of resistance is ohm and is represented by the symbol Ω .A substance is said to have a resistance of 1 ohm if a potential difference of 1 volt across its ends causes 1 ampere of current to flow through it.

Resistance of a substance is depending upon various factors. They are length, area and type of the substance. It also depends on the changes in temperature. So, resistance can be expressed as,

$$R \propto L/A$$

Where, L is the length and A is the area of cross section of the substance.

We can also have written as, $R = \rho$ **L/A**

Where, ñ is a constant and is known as resistivity or specific resistance of the substance. The value of specific resistance depends upon the type of the substance.

If, $L = 1m, A = 1m^2$, then $R = \rho$

Thus, specific resistance is defined as the resistance applied by a substance of 1 m length having an area of cross section of $1m^2$. In SI unit, specific resistance is expressed as ohm-m.

1.10 CONDUCTOR AND INSULATOR

All materials are classified into three categories depending on their electrical conduction properties. They are conductor, insulator and semiconductor.

The electrical conduction properties of these materials can be explained in terms of ***energy bands***.

Conductor:

The material through which electric current can easily flow easily is called a conductor. Common examples of conductors are copper (Cu), aluminium (Al), iron (Fe) etc. In conductor, plenty of free electronsare available for conduction. They have very low resistivity. It is in the range of 10^{-8} to $10^{-6}\,\Omega$ m. In terms of energy band, they have overlapping valence and conduction bands. The valence band (VB) is the range of energies occupied by the valance electrons. The conduction band (CB) is the range of energies that occupied by the electrons which have left the valence band. These free electrons in the conduction band are responsible for the conduction of current through the material. Hence, they are called conduction electrons.

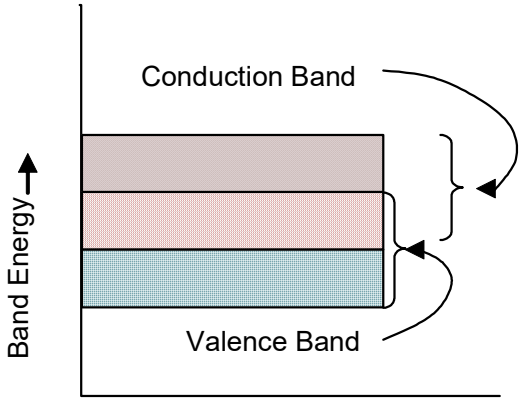


Fig. 1.5 Energy band diagram of Conductor

Insulator:

Insulators are those materials which do not allow to flow electric current through them. Common examples of insulators are glass, plastic, wood, ceramic etc. The valence electrons of insulators are very strongly bounded to their parents atoms. Hence, it requires large fields to remove

them from the bonds of their nucleus. In terms of energy band, insulators have a full valence band (VB) and an empty conduction band (CB). The energy gap between the two bands, called the forbidden gap, is very large (15ev). The resi-stivity of insulator is very high in the range of 10^7 to 10^{18} Ω m.

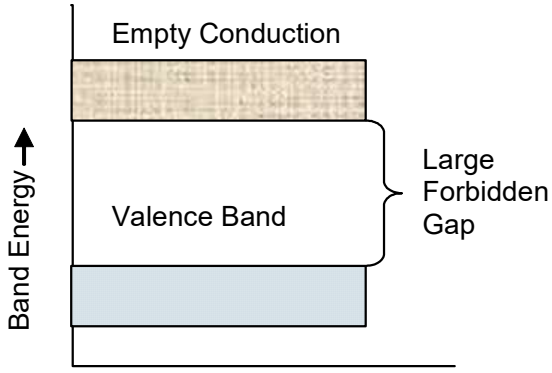


Fig. 1.6 Energy band diagram of Insulator.



1.11 LET US SUM UP

- Matters have molecule, molecule have atom and atoms have electrons, protons and neutrons.
- Electricity is of two types-Static and Dynamic.
- Free electrons are the main cause of current.
- The direction of current flow is always opposite to the direction of electron flow.
- The work done for charging a body to a unit chargeis known as electric potential.
- For electrical system mathematically we can express power as– Power (P) = Voltage (V) × Current (I).
- Energy can be defined as the capacity to do work
- Ohm's law gives the relationship between voltage, current and resistance in an electric circuit.
- Specific resistance is defined as the resistance applied by a substance of 1 m length having an area of cross section of $1m^2$.

- All materials are classified into three categories namely conductor, insulator and semiconductor depending on their electrical conduction properties.



1.12 FURTHER READINGS

1) **Basic Electronics** –*B. L. Theraja (S. Chand Publication).*
2) **Principles of Electronics** –*V. K. Mehta &Rohit Mehta (S. Chand Publication).*
3) **Basic Electronics and Linear Circuits** –*N. N. Bhargava & S. C. Gupta (TATA McGraw-Hill Publication)*.
4) **Electronic Devices and Circuits** –*J. B. Gupta (S. K. Kataria and Sons).*



1.13 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1:

Ans to Q No 2:

Ans to Q No 3:

Ans to Q No 4:

i. Solid, liquid and gas
ii. Proton, electron and neutron.
iii. same
iv. positive
v. $e = 2\ n^2$

Ans to Q No 5: The phenomenon of attraction due to the reaction between two opposite charges where electrons never flow freely, it just changes its position once, is known as static electricity. Static electricity cannot do any work.

When electricity is produce due to free moving electrons it is called

dynamic electricity.

Ans to Q No 6: i. Work ii. Collusion of electrons
iii. Voltage (V) × Current (I) iv. Capacity, work
v. Energy vi.Joule

Ans to Q No 7: a) True b) False c) True



1.14 MODEL QUESTIONS

Q 1: Describe briefly the constituents of molecule and atom.

Q 2: Describe in short about the origin of electricity and electric charge.

Q 3: What are free electrons and how these are related to electric current.

Q 4: Write a note on static and dynamic electricity.

*** ***** ***

UNIT 2 : FUNDAMENTALS OF ELECTRICAL CIRCUITS

UNIT STRUCTURE

2.1 Learning Objectives
2.2 Introduction
2.3 Familiarization of Common Components
2.4 Interconnection of Passive Components
2.5 Advantages and Disadvantages of Series and Parallel Circuit
2.6 Voltage and Current Divider Rule
2.7 Kirchhoff's Laws
2.8 Let Us Sum Up
2.9 Further Readings
2.10 Answers to Check Your Progress
2.11 Model Questions

2.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- identify the common components used in electrical circuit
- explain the interconnection of passive components in the circuit
- enlighten the series and parallel connections
- describe the voltage and current division rule
- discuss the Kirchhoff's Laws of any electric circuit.

2.2 INTRODUCTION

In the previous unit you have learnt the basic concept of electricity. In this unit, we will provide you the various types of components that can be used in any electrical circuit. This unit describes the interconnection of basic components in electrical circuit. We will also focus on the series and parallel connections of a circuit. This unit also provides a description of the voltage and current division rule applicable when components are interconnected in various ways. Finally, this unit will focus on the Kirchhoff's laws used to determine currents and voltages

2.3 FAMILIARIZATION OF COMMON COMPONENTS

An Electronics Laboratory contains a variety of components, equipment and related set-ups. Among the components some are called active while some are called passive components. **Active Components**: These components are capable of ***amplifying*** or ***processing*** an electrical signal on their own. Examples are vacuum tubes, diodes, transistors, silicon controlled rectifier (SCR)s etc.

Passive Components: Passive components cannot amplify or process signals on their own. These are however have very important role to play as the active devices can work only with the aid of passive devices. Examples of passive devices are: resistors, capacitors, inductors etc.

Resistor:

A resistor is a two-terminal electronic component that resists or opposes the flow of current through it. When current flows through the resistor, it comes across an opposing force called the resistance. The resistance is defined as the ability to resists the flow of electricity through any material. It is measured in ohms (W).

When an electric current of one ampere passes through a component across which a potential difference (voltage) of one volt exists, then the resistance of that component is one ohm. In resistors, current is directly proportional to the applied voltage.

Resistors Types:

Resistors are mainly of two types– fixed and variable.

The schematic symbol for fixed and variable resistors are shown in Figure 2.1



Fixed Variable

Fig. 2.1(a): Schematic symbols for fixed and variable resistor.

Variable resistors:

Variable Resistors are those whose resistance can be changed

between zero and a certain maximum value. They have three leads, two fixed and one movable. There are two kinds of variable resistors- rheostats and potentiometer. They can be wire-wound or carbon type.

When two leads of the resistor (stationary lead and moving lead) are joined, the variable resistor may be used as a rheostat. Rheostats are usually used to control current flowing in the circuit. They are generally used for high energy device. The symbol for a rheostat is given in Figure 2.1(b)

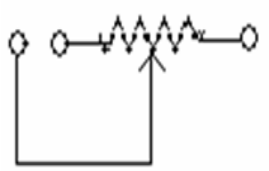


Fig: 2.1(b) Symbols for Rheostat

The potentiometer or “pot” is a three terminal variable resistor with an adjustable sliding contact that determines the resistance value in the circuit. It has smaller variable resistances than rheostat and is more efficient. The rheostat works as potentiometer if all the three terminals are used.

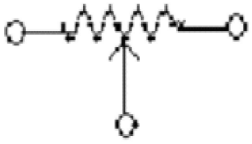


Fig. 2.1(c): Symbol for potentiometer

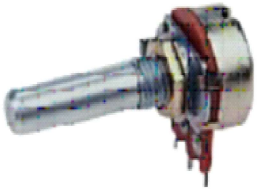


Fig. 2.1(d): A Potentiometer

Colour Coding and Standard Resistance Values:

Some resistors are too small in size to print the value of their resistance on their body. Hence they are colour-coded to indicate their resistance in ohms. For the fixed carbon-composition resistors, four colour bands are printed at one end around the body. Each colour stands for a digit and it can be translated into a number by using the standard colour code given in the following table.

Table 2.1: Colour Coding

Colour	Digit	Multiplier	Tolerance %
Black	0	100 = 1	20
Brown	1	101 = 10	1
Red	2	102	2

Orange	3	103	3
Yellow	4	104	4
Green	5	105	5
Blue	6	106	6
Violet	7	107	7
Gray	8	108	8
White	9	109	9
Gold	-	10-1= 0.1	±5
Silver	-	10-2= 0.01	±10
No Colour	-	-	±20

The colour bands are always read left to right from the end that has the bands closet to it. The first band represents the first figure and the second band the second figure and the third band is decimal multiplier i.e. the number of zeros to add the first two figures to get the total resistance. The limit of accuracy also called tolerance is indicated by the colour of the fourth band.

The resistance having a colour band sequence yellow, violet, red and gold. By using the colour coding table you can find that yellow and violet colour has the digit of 47. The third colour (red) value is 2; hence 100 have to be added with 47. The total resistance value is as follows:

Yellow	Violet	Red	Gold
4	7	102	±5%

Resistance Value = 4700 Ω or 4.7 KΩ

Now 5% of 4.7 KΩ = 4.7 ×5/100 = 0.235 KΩ

Therefore, the resistance should be within the range 4.7KΩ ± 0.235 KΩ or between 4.465 KΩ to 4.935 KΩ.

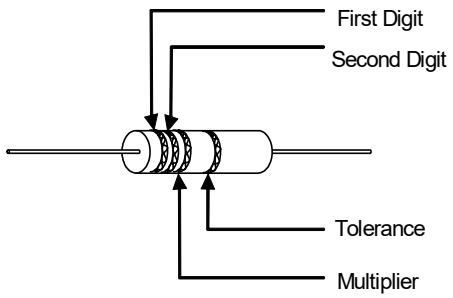


Fig. 2.2 Colour bands of fixed resistor

Capacitor:

A capacitor is an electronic component which is capable of storing electric charge when a voltage exists across it. The voltage applied across a capacitor generates an electric field which stores the electrical energy within it. It can reduce voltage fluctuations in the circuit and blocks dc signal but easily passes ac signal through it.

A capacitor consists of two conducting plates separated by an insulating material known as dielectric. The dielectric may be air, mica, ceramic, paper, polyester, oil etc. When a voltage is applied to these plates, a current flows through it, charging up the plates with electrons giving one plate a positive charge and the other plate an equal and opposite negative charge. This flow of electrons to the plates is known as the **Charging Current** and continues to flow until the voltage across the plates (and hence the capacitor) is equal to the applied voltage VC. At this point the capacitor is said to be fully charged.

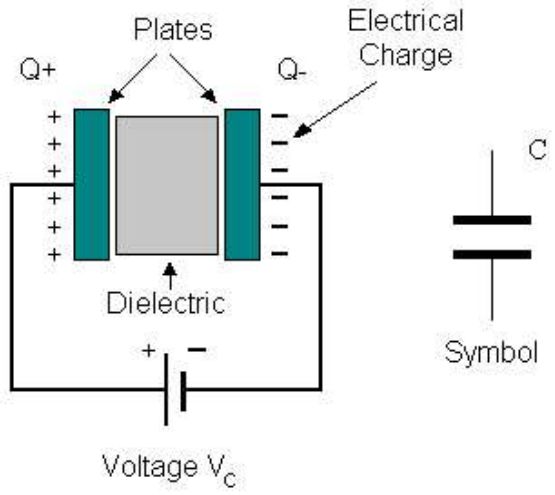


Fig. 2.3(a) Structure of capacitor

(Source- wikipedia.org)

Capacitance:

The Capacitors ability to store the electrical charge between its plates is known as the capacitance C. Capacitance C is always positive. The unit of capacitance is the farad (F). The Farad is a very large unit so micro-farads, nano-farads and pico-farads are generally used.

For example:

Microfarad (μF) 1 μF = 1/1,000,000 = 0.000001 = 10^{-6} F

Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F

Picofarad (pF) 1pF =1/1,000,000,000,000=0.000000000001=10^{-12} F

The capacitance depends upon the area of plates, distance between the plates and the nature of insulating material (or dielectric).

The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the **dielectric constant** of the substance separating the plates.

When a voltage V is applied to a capacitor and if it stores Q coulomb charge then the capacitance C of the capacitor is the ratio of the charge Q to the voltage V. It is given as: C = Q/V or Q = C x V.

Capacitors Types:

Like resistors, all capacitors are also classified into two classes–

- Fixed capacitor
- Variable capacitor.

Fixed capacitors are further classified into–

- Electrolytic and
- Non-electrolytic capacitors.

The schematic symbols for capacitors are shown in figure below.

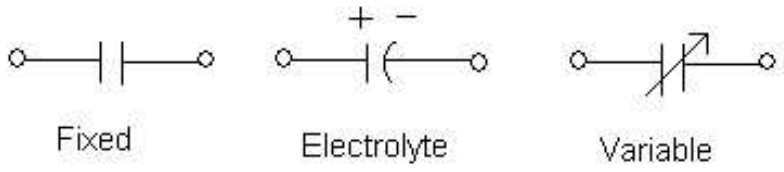


Fig. 2.3 (b) Schematic symbols for capacitors.

Non-Electrolytic Capacitors:

Small value capacitors are non-electrolytic or unpolarised and may be connected either way round in the circuit. Non-electrolytic capacitors are divided into following types-

- Mica capacitors
- Paper capacitors and
- Ceramic capacitors.

Mica Capacitors:

It consists of a mass of alternate parallel layers of mica and metal (Cu or Al) sheets. Alternate sheets are connected together and leads attached for outside connections. The whole structure is enclosed in a plastic or bakelite case. These capacitors have small capacitance values and generally use in radio circuits.

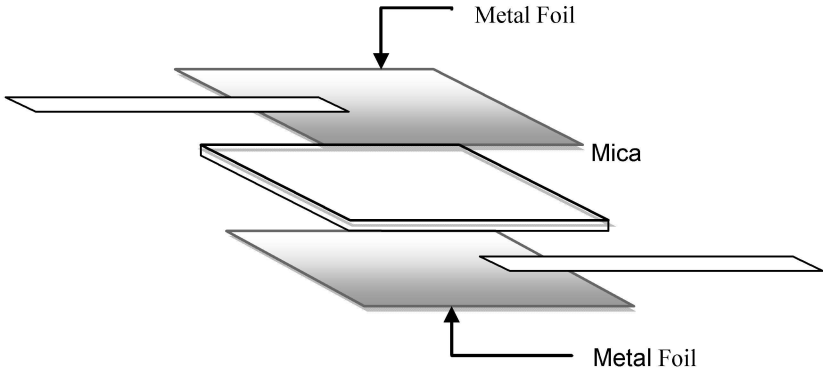


Fig. 2.3(c) Mica Capacitor

Paper Capacitor:

It consists of two metal sheets separated by thin layer of paper, plastic or polyester. The metal foil and paper is then rolled into a cylindrical shape and enclosed in a plastic case. Two leads are internally attached to the metal foil at each end of the capacitor. They have large size and can be used for both dc and ac circuits.

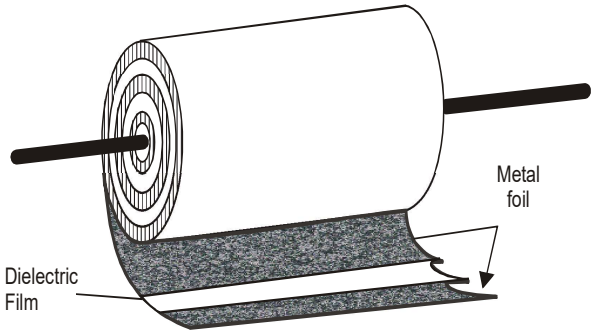


Fig. 2.3(d) Tubular paper capacitor.

(Source- wikipidia.org)

Ceramic Capacitor:

It consists of a ceramic layer as dielectric material which is surrounded by two thin metal film that acts as capacitor plates. Leads are

connected to each plate and the whole unit is enclosed in a moisture-proof coating. They are very small in size, have large capacitance value compare to mica and paper capacitor, and can be used in both ac and dc circuits.



Fig. 2.3(e) A Ceramic Capacitor

(Source – bikudo.com)

Electrolytic Capacitor:

The electrolytic capacitors are polarized and must be connected the correct way round in the circuit. They are not damaged by heat when soldering. There are two designs of electrolytic capacitors. They are axial and radial. In axial, the leads are attached to each end and in radial, both the leads are at the same end.

The electrolytic capacitors contain an aluminum foil which is coated with a thin insulating film of aluminum oxide (Al2O3) on one side. The aluminum plate acts as the positive plate and the oxide layer is acts as the dielectric of the capacitor. The oxide is covered with a layer of paper or gauze saturated in electrolyte of borax. The electrolyte forms the negative plate of the capacitor. Another layer of metal is coated over the electrolyte to provide contact between one of the terminals and the electrolyte. Electrolytic capacitors has a large capacitance value and used in the circuits where only dc voltages are applied across the capacitors.

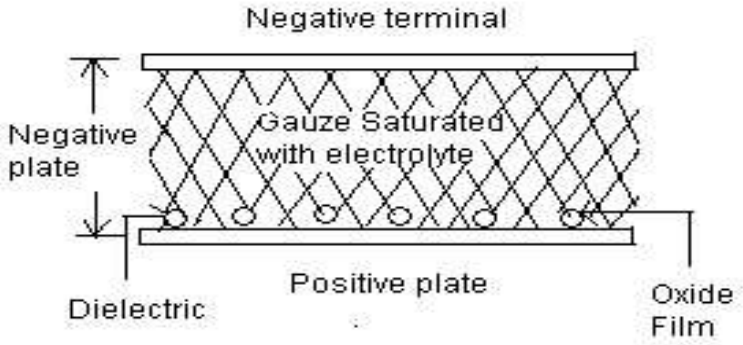


Fig. 2.4(f) construction of Electrolytic Capacitor.

Inductor:

An inductor is a component that can opposes a sudden change in current in a circuit. It is shaped as a coil. When electric current flows through the coil, it generates a magnetic field. This magnetic field acts to oppose any change in the current and trying to keep the current flowing at a steady rate. This opposing force it develops is called induced emf (electromotive force).

The inductance is the ability of an inductor to produce induced emf when the current varies in it. The unit of inductance is henry (H). An inductor with an inductance of 1 henry produces an emf of 1 volt when the current through the inductor changes at the rate of 1 ampere per second.

An inductor offers high **impedance** to ac and very low impedance to dc i.e. it blocks ac signal but passes dc signal.

The schematic symbol of inductor is–

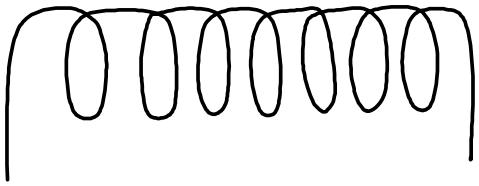


Fig. 2.5(a) Schematic symbol of inductor

Inductors Type:

Like the resistors and capacitors, all inductors may be divided into two categories:

- Fixed and
- Variable.

They can also be classified on the basis of their core material. They are:

- Iron core
- Air-core inductors.

The symbols for air core and iron core are given below.

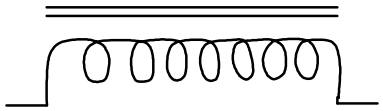


Fig. 2.5(b) Iron core

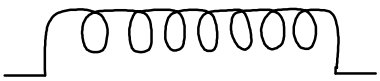


Fig. 2.5(c) Air-core

The inductors can also be classified into–

- Filter chokes
- Audio-frequency chokes
- Radio-frequency chokes

Filter choke has many turns of wire wound on an iron core and is used in smoothing the pulsating current produced by converting ac into dc. Generally, power supplies use filter chokes having inductance ranging from 1 H to 50 H, capable of carrying current up to 0.5A.

Audio-frequency choke (AFC) is used to provide high impedance to audio frequencies (50 Hz to 5 KHz). These are smaller in size and have lower inductance in comparison to filter choke.

Radio-frequency choke (RFC) is used to tune the radio frequencies. (Above 10 KHz). They are smaller than AFCs even and have very small value of inductance (about 2mH).

Variable Inductance

In some applications variable inductors are used. Circuits like tuning circuit, phase shifting circuit and switching of bands in amplifiers, variable inductors are required. Two variable inductors are shown in the figure. In Fig. 2.16(c) inductance can be varied by switching from one tap on the coil to another. In figure 2.16(d) a movable core is shown.

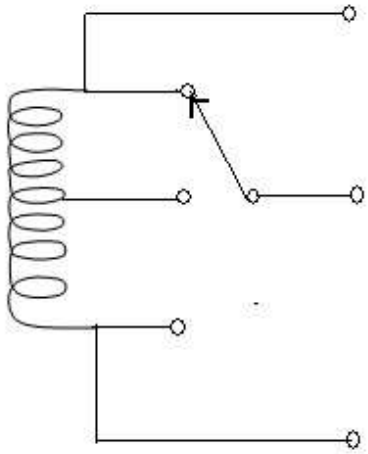


Fig. 2.5(d) Tap Switching

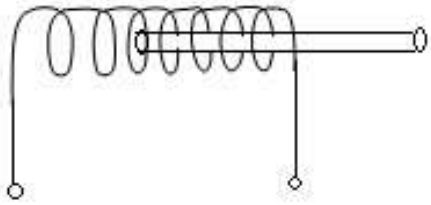


Fig. 2.5(e) Movable Core Type



CHECK YOUR PROGRESS

Q 1: Define passive and active components

.....

.....

Q 2: Fill in the blanks:

a) Inductor is a/an _____ Component.

b) As separation between the two plates of a capacitor is increased, its capacitance is _____.

c) Ceramic capacitors are preferable for use at _____ frequency.

d) Electrolytic capacitors are called _____ capacitors.

e) In a capacitor the charge is stored in the _____.

2.4 INTERCONNECTION OF PASSIVE COMPONENTS

Passive components like resistor, capacitor and inductor can be interconnected to form combination to design devices as required. Three components can be connected in series and in parallel with separate effects. Also, the components can be used in unique combinations to create resistive and reactive effects.

Interconnection of Resistance

In some electric circuits resistances are interconnected into two orders- Series and Parallel. For this reason there is a change in total value

of resistance group.

Series Combination: When all the resistances of a circuit are connected continuously so that the same current flows through them is called the series combination. The total resistance is the sum of all the individual resistances. An example is shown in the following figure.

Here, total resistance $R = R_1 + R_2 + R_3$

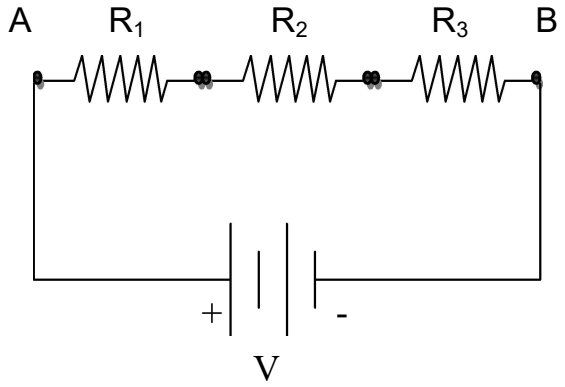


Fig. 2.6 (a) Series connection of resistors.

Parallel Combination: When one end of each resistance in a circuit is combined to a common point and the other end of each resistance is combined to another common point so that there are many paths to flow current, it is called a parallel combi-nation. Thus when a number of resistances are connected in parallel, the reciprocal of total resistance is equal to the sum of reciprocals of individual resistances. An example is given in the figure. Here, total resi-stance is–

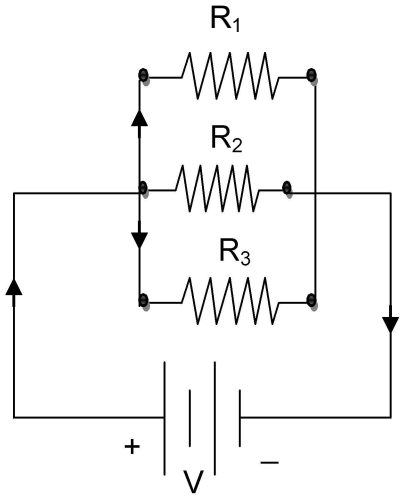


Fig. 2.6(b) Parallel connections of resistors

Interconnection of Capacitors:

Like resistors, capacitors are interconnected in the circuits in two ways. Series and parallel. Hence total capacitance value in the circuit is different for different combinations.

Series Combination: When capacitors are connectedin series there is a increase in the thickness of the dielectric medium. Hence the total capacitance is less than the smallest individual capacitance values. The charge on each capacitor is the same independent of their capacitance. The potential difference across each capacitor isinversely proportional to its capacitance. Consider the following circuit of series connection. The total capacitance is given by,

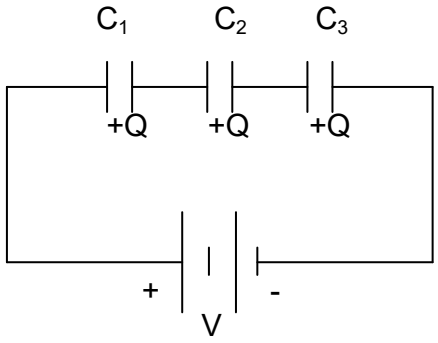


Fig. 2.6(c) Series combination of capacitors

Parallel Combination: When capacitors are connected in parallel their plate areas are increases. Hence, the total capacitance is equal to the sum of individual capacitances. The charge across each capacitor is directly proportional to its capacitance (Q=CV). The potential difference across each capacitor is equal to the applied voltage (V). An example of parallel combination is given in the figure. The total capacitance is given by,

$C = C_1 + C_2 + C_3$

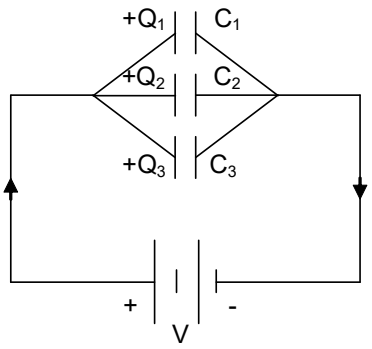


Fig. 2.6(d) Parallel combinations of Capacitors

Interconnection of Inductors:

Inductors are also connected in two different combinations. Series and parallel. The total equivalent inductance is different depending on their connections.

Series Connection: Inductors in a series connection each have the same current, but the voltage across them is different. The sum of the voltage across each inductor is equal to the total voltage. The total inductance is given by, $L_{eq} = L_1 + L_2 + L_3$

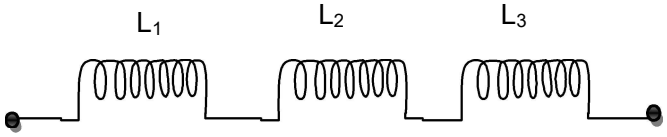


Fig. 2.7(e) Series Combination of Inductors

Parallel connection: In this connection all inductors have same potential difference. The total equivalent inductance of parallel connection is given by,

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

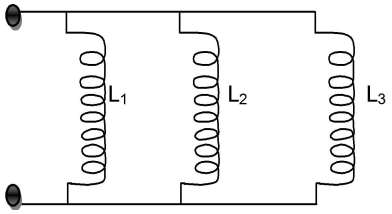


Fig. 2.7(f) Parallel Combination of Inductance



CHECK YOUR PROGRESS

Q 3: Answer True or False.

a) For increasing capacitance, the given capacitors should be connected in parallel.

b) When connected in series combination, all capacitors have the same charge but different voltages.

c) Connecting capacitors in parallel is equivalent to increasing the voltage rating of the combination.

d) Capacitors of values 3F, 4F and 6F are connected in series combination. The total capacitance value is 5F.

2.5 ADVANTAGES AND DISADVANTAGES OF SERIES AND PARALLEL CONNECTIONS

The advantage of Resistance connected in series circuit are listed below:

i) Same current flows through all resistances.

ii) Supply voltage is equal to the summation of voltage drops across each resistor.

iii) The voltage drop across any resistor is proportional to the resistance of that resistor.

iv) The powers dissipated are additive.

The disadvantage of Resistance connected in series circuit are listed below:

i) No current will flow through any resistance or load if the circuit is open.

ii) Resistances are additive.

Advantages of Resistance connected in parallel circuit:

i) The voltage across all parallel resistances is same.

ii) Resistances are not additive.

iii) The current will not flow through that branch which is open. But current will flow through other branches.

Disadvantages of Resistance connected in parallel circuit:

i) Total current flowing through the circuit is more than individual current flowing each individual resistor.

ii) Same current will not flow through each resistors having different resistance.

2.6 VOLTAGE AND CURRENT DIVISION RULE

The voltage division refers to the partitioning of a voltage among the components of the circuit. The voltage division rule is applicable when all resistors in a circuit carry the same current i.e. they are in series connection. The principle of voltage division is that the voltage drop across the nth resistor (RN) is equal to the ratio of RN to the total equivalent resistance Req times the total voltage across all N series resistors.

Let us consider the following circuit,

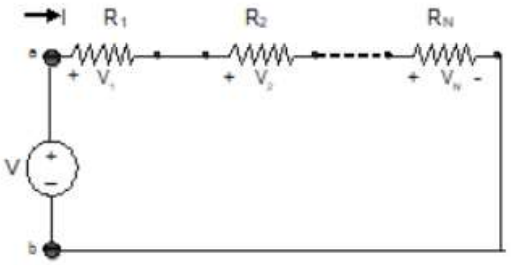


Fig 2.8 (a)

$V_N = (R_N / R_1 + R_2 + \text{————}+R_N).\ V$

$= R_N / R_{eq} .V$

The current division rule is applicable when the same voltage appears across all the resistors in a circuit. The total current is shared by the resistors in inverse proportion to their resistances. The principle of current division rule is that the current through the n^{th} resistor (R_N) is equal to the inverse ratio of R_N to the total equivalent resistance Req times the total current through N parallel resistors.

Let us consider the following circuit.

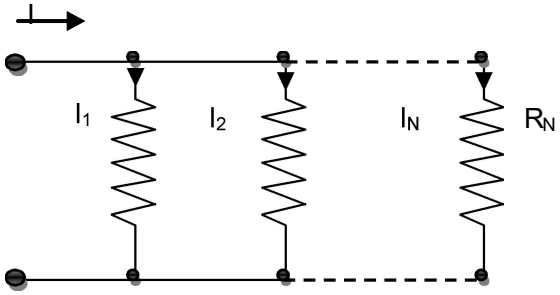


Fig 2.8(b)

$$I_N = (\frac{1/R_N}{1/R_1 + 1/R_2 + ... + 1/R_N})I$$

$$I_N = (\frac{1/R_N}{R_{eq}})I$$

2.7 KIRCHHOFF'S LAW

For the steady current flowing through a network of conductors, two laws known as Kirchhoff's law are used.

First law: The algebraic sum of current meeting at any junction in the circuit is zero. This law is also known as Kirchhoff's Current Law.

In the figure consider four conductors carrying currents I_1, I_2, I_3 and I_4. All are meeting at a point O. Taking the currents flowing towards the point O as positive and those flowing away from the point as negative. Thus applying Kirchhoff's law to the point O is given as–

$$I_1 - I_2 + I_3 - I_4 = 0$$

Or $I_1 + I_3 = I_2 + I_4$

i.e. Incoming currents = Outgoing currents.

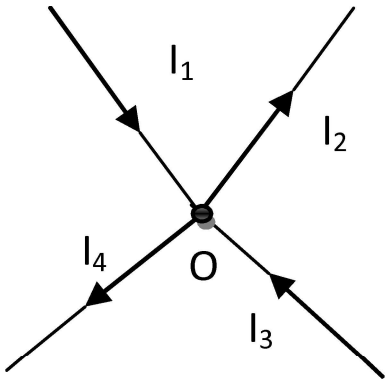


Fig. 2.24(a) Circuit shows Kirchhoff's Current law

Second Law: It states that in a closed electric circuit, the algebraic sum of the products of the currents and resistances of various branches is equal to the total electromotive forces (e.m.f) of the circuit. This law may be called Kirchhoff's Voltage Law (KVL).

Consider the following electrical circuit to analysis the KVL. The currents and resistances in various branches are shown in the diagram.

Applying KVL in the loop ABCFA,

$$E_1 = I_1R_1 + (I_1 + I_2) R_3$$

Or, $E_1 - = I_1R_1 + I_1R_3 + I_2 R_3$

$$E_1 = I_1(R_1 + R_3) + I_2 R_3.$$

Applying KVL in the loop CDEFC,

$$E_2 = I_2R_2 + (I_1 + I_2) R_3$$

Or, $E_2 = I_1R_3 + I_2 (R_2 + R_3)$.

Again applying KVL in the loop ABCDEFA,

$$E_1 - E_2 = I_1 R_1 - I_2 R_3.$$

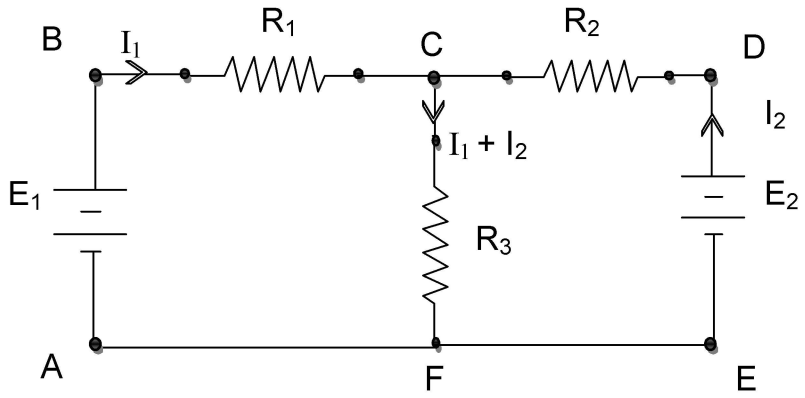


Fig. 2.24(a) Circuit shows Kirchhoff's Voltage law



CHECK YOUR PROGRESS

Q 4: State Kirchhoff's First and Second laws.

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2.8 LET US SUM UP

- All electronic components are classified into two categories- Passive and Active Components.
- Passive Components are resistor, capacitor and inductor that can dissipate the power.
- Active components are vacuum tubes, diode, transistor etc. that can generate as well as dissipate the power.
- A resistor can be fixed or variable one.
- There are two types of variable resistors- Rheostat and Potentiometer.
- A capacitor isacomponent that can store charge, opposes any change of voltage in the circuit and blocks the passes of DC through it.
- Inductor is a component that opposes a sudden change in current in a circuit.
- All passive components can be interconnected into two order- Series and Parallel.



2.9 FURTHER READINGS

1) **Basic Electronics** –*B. L. Theraja (S. Chand Publication).*

2) **Principles of Electronics** –*V. K. Mehta &Rohit Mehta (S. Chand Publication).*

3) **Basic Electronics and Linear Circuits** –*N. N. Bhargava & S. C. Gupta (TATA McGraw-Hill Publication)*.

4) **Electronic Devices and Circuits** –*J. B. Gupta (S. K. Kataria and Sons).*



2.10 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: Active components are capable of amplifying or processing an electrical signal on their own. Examples are vacuum tubes, diodes, transistors, silicon controlled rectifier (SCR)s etc.

Passive components cannot amplify or process signals on their own. These are however have very important role to play as the active devices can work only with the aid of passive devices. Examples of passive devices are: resistors, capacitors, inductors etc.

Ans to Q No 2: a) Passive b) Decreased c) Higher

d) Polarized

e) Dielectric

Ans to Q No 3: a.True b.True c.False d. False

Ans to Q No 4: Kirchhoff's First Law:The algebraic sum of current meeting at any junction in the circuit is zero. This law is also known as Kirchhoff's Current Law.

Kirchhoff's Second Law:It states that in a closed electric circuit, the algebraic sum of the products of the currents and resistances of various branches is equal to the total electromotive forces (e.m.f) of the circuit. This law may be called Kirchhoff's Voltage Law (KVL).



2.11 MODEL QUESTIONS

Q 1: Give some important applications of capacitors and inductors.

Q 2: Name a few active components (devices) used in electronic circuit.

Q 3: Explain the Kirchhoff's law.

Q 4: Describe the Voltage and Current division rule.

*** ***** ***

UNIT 3 : INTRODUCTION TO MAGNETISM

UNIT STRUCTURE

3.1 Learning Objectives

3.2 Introduction

3.3 Magnet and Type of Magnet

3.4 Permeability

3.5 Magnetic Property of Materials

3.6 Magnetic Effect of Electric Current

3.7 Electromagnetic Induction

3.7.1 Faraday's Law

3.8 Familiarization with Some Common Devices

3.9 Let Us Sum Up

3.10 Further Readings

3.11 Answers to Check Your Progress

3.12 Model Questions

3.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- explain the magnet and type of magnets
- discuss the permeability
- describe the magnetic property of materials
- illustrate the magnetic effect of electric current
- explain the electromagnetic induction
- familiarise with some common devices.

3.2 INTRODUCTION

In the previous unit we have introduced you to the fundamentals of electrical circuits. In this unit, we will focus on the basic concept of magnetism.In this unit, we shall highlight the magnet and type of magnets. Permeability and type of magnetic materials on the basis of permeability will also discuss in this unit. This unit will also provide you the magnetic

property of materials, the magnetic effect of electric current and the electromagnetic induction.In this unit we shall familiarise with some common devices.

3.2 MAGNET AND TYPE OF MAGNET

A magnet is a special kind of material that has the property of attracting small pieces of iron. It was first discovered in natural form as an iron ore known as magnetite. The naturally occurring magnets always retain the magnetic properties; hence they are known as Permanent Magnet. A current carrying coil or conductor also produces magnetic effects in its surrounding area, but it loses its magnetic property as soon as current flow is stopped. These types of magnets are known as Electromagnet.

Properties of a Magnet:

A magnet has two special properties; first it can attract iron, nickel, cobalt etc. The materials which are attracted by a magnet are known as magnetic material. Second, another special property of a magnet is that if a piece of magnet is suspended freely in air its two end always point towards the geographical north-south of the earth. The end which is always directed towards the geographical north of the freely suspended magnet is known as the north pole of the magnet and the other end which points towards the south is known as South Pole of the magnet. attract each other and repel the poles of same nature. This is similar to the case of electric charge, like charges always repel each other and opposite charges attract.

Types of Magnet:

Magnet can be classified into three categories. They are-

- Permanent magnet
- Temporary magnet and
- Electromagnet

The permanent magnets are commonly used magnets whose magnetic property retainsfor a long period of time once they are magnetised. Examples of permanent magnets are iron, nickel, cobalt etc. Permanent magnets are again classified as Ceramic or ferrite, Alnico, Samarium Cobalt and Neodymium Iron Boron. Alnico is an alloy of aluminium, nickel and

cobalt. The magnetic property of permanent magnet can be destroyed by exposing the magnet to extreme temperatures, by hammering the magnet and stroking one magnet with another magnet.

Temporary magnets are the magnets that can be magnetised in presence of a magnetic field. They are called temporary magnets because they are losing their magnetic property when the magnetic field is removed. Examples of temporary magnet are iron nails, paper clips, safety pins etc.

Electromagnet is a temporary magnet which consists a coil surrounding it. It gets magnetised when electric current flows through the coil. Due to the flow of current a magnetic field is produced around the magnet and the strength of the magnetic field is controlled by the electric current.

Electromagnet is used in many household devices like electric fan, induction cooker, speaker, motors, transformer etc.



CHECK YOUR PROGRESS

Q 1: What are the types of a magnet?

.....

.....

Q 2: What is the difference between a permanent and temporary magnet?

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.....

3.4 PERMEABILITY

When different magnetic materials are placed in magnetic field they allow the magnetic field lines to penetrate through them to different level. To express the level or degree of penetration of the field lines through a magnetic material a physical quantity called permeability is introduced. Magnetic permeability is defined as the ratio of magnetic induction (B) and magnetic intensity (H) in a magnetic field. Thus permeability is given by,

$$\mu = \frac{B}{H}$$

In other words, permeability of a material specifies its conductivity for magnetic flux. The greater value of the permeability of a material means the greater is its conductivity for magnetic flux and vice versa. There are two types of permeability. One is absolute permeability and the other is the relative permeability.

Air and vacuum is the poorest conductor of magnetic flux. The absolute permeability (μ_0) of air or vacuum is $4\pi \times 10^{-7}$ H/m. The absolute permeability of a magnetic material is symbolised as μ. The absolute permeability μ of magnetic materials is much greater than μ_0.

Now, the ratio of absolute permeability (μ) of a magnetic material to the absolute permeability (μ_0) of air or vacuum is called relative permeability (μ_r).

i.e, $\mu_r = \mu / \mu_0$

The SI unit of μ_0 and μ is Henry-metre^{-1} or Newton-amp^{-2} or Weber-apm^{-1}metre^{-1} and μ_r is a dimensionless quantity. The value of relative permeability μ_r of all non-magnetic materials is 1 whereas the relative permeability of magnetic materials is very high. Pure iron has a relative permeability of 8000.



CHECK YOUR PROGRESS

Q.3. State true or false.

a) Permeability of a material specifies its conductivity for magnetic flux.

b) There are three types of permeability.

c) The relative permeability of air or vacuum is $4\pi \times 10^{-7}$ H/m.

d) The relative permeability of a material is expressed as $\mu_r = \mu/\mu_0$.

3.5 MAGNETIC PROPERTY OF MATERIALS

As discussed in the earlier unit, all materials are made up of atoms. According to electron theory, an atom is constituted by the ultimate particles electron, proton and neutron. An electron carries negative charge of

magnitude e=1.6X10^{-19} Coulomb and a proton carries positive charge of equal magnitude where as a neutron is a neutral particle. The simplest Hydrogen atom consists of an electron revolving round the nucleus constituted by a proton. In all other atoms electrons revolve round the central nucleus formed by the proton and neutron packed together.

The obvious relation between electricity and magnetism basically originates from the intrinsic spin and orbital motion of the electrons round the nucleus. A current carrying loop or closed conductor behaves like a magnetic dipole of dipole moment.A magnetic dipole is a magnetic north pole and a magnetic south pole that separated by a small distance. The magnetic dipole moment is expressed as the product of the current and the area of the loop.

$$\mu_m = iA$$

Where μ_m is the magnetic dipole moment, i is the current flowing through the loop and A is the area of the loop. The orbital motion of an electron round the nucleus is equivalent to a current loop giving rise to orbital magnetic moment. In case of the atoms having more than one electron, the resultant magnetic moment of all the electrons is important. The intrinsic spin related to an electron also contributes spin magnetic moment. In an atom, protons and the neutral neutrons have very small non-zero magnetic moments.

The magnetic properties of the materials are mostly determined by the resultant of the orbital and spin magnetic moment of the electrons of the atoms constituting them. The effective contribution from nuclear magnetic moments can be taken to be zero. When magnetic materials are placed in an external magnetic field they exhibit different behaviour depending upon the magnetic moments of their constituting atoms.

3.6 MAGNETIC EFFECT OF ELECTRIC CURRENT

In the study of magnetic circuit, we generally come across the following important terms.

Magnetic Field

The influence of a magnet can be felt only to a certain area

surrounding it. The area or space within which magnetic influence can be felt is known as Magnetic Field. The strength of Magnetic Field is not same throughout the field. It is stronger near the poles of the magnets. The magnetic field around a magnet is represented by some imaginary lines; these imaginary lines are known as magnetic lines of force. The lines of force have a unique direction and conventionally these lines of force start at the north pole of the magnet and ends at the South pole. The lines of force of a magnet can be easily traced out with the help of a compass needle. Figure 3.1 shows the nature and direction of these magnetic lines of force.

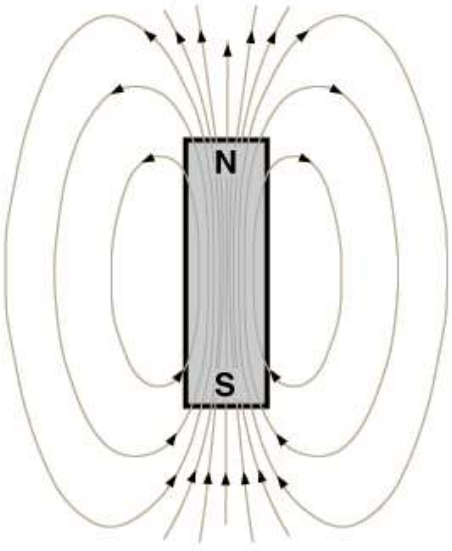


Fig. 3.1: Fig 1.6: Magnetic Lines of Force

(Source: hyperphysics.phy-astr.gsu.edu)

Magnetic Flux

Magnetic Flux is the measure of the strength of the magnetic field. The amount of magnetic field produced due to a magnetic source is known as magnetic flux. In other words, it can be said that the magnetic flux is the measure of the number of lines of force produced by a magnet. Magnetic flux is denoted by the Greek letter 'Φ' (pronounced as phi).

Magnetic Induction

It is already mentioned that a current carrying coil or conductor produces magnetic field around it. There is also a reverse phenomenon. If a coil is exposed to a changing magnetic field, in other words, if a coil is

placed in such an environment or condition where the amount of magnetic lines of

When electric current flows through a conductor, magnetic field is produced along the length of the conductor and the path of the magnetic lines of force are in the form of concentric circles around the conductor. The direction of lines of force depends upon the direction of current which can be determined by method called Right-hand rule.

Right-hand rule: In this rule, hold the conductor with right hand with the thumb pointing in the direction of current then the fingers will point in the direction of magnetic field around the conductor. The thumb hold parallel to the axis of the conductor will always point towards the north pole of the conductor.

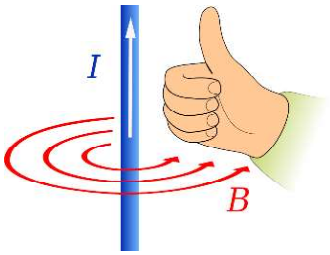


Fig. 3.1:https://en.wikipedia.org/wiki/Right-hand rule



CHECK YOUR PROGRESS

Q.4. What is magnetic field?

.....

.....

Q. 5. Define the term magnetic flux.

.....

.....

3.7 ELECTROMAGNETIC INDUCTION

In 1831, a famous English scientist named Michael Faraday explained that a magnetic field can create an electric field in a conductor. This phenomenon of producing electricity from magnetism is called electromagnetism. When the magnetic flux linking with a conductor changes,

an Electro Motive Force (e.m.f.) is generated in the conductor. This phenomenon is known as electromagnetic induction. In other words, the generation of electromotive force (e.m.f.) in a conductor due to the change in magnetic flux linked with the conductor is known as electromagnetic Induction. The e.m.f. developed in this process is the induced e.m.f. and the corresponding current through the conductor is called the induced current.

Depending on different experiment Faraday established two laws of electromagnetic induction. To understand these laws, the term magnetic flux needs to be clear which we have discussed in the previous section. The number of magnetic lines of force passing normally through a surface is called Magnetic Flux. It is a scalar quantity denoted by ø.

If **B** is the strength of the magnetic field that passes through a surface of area vector **S**, the flux through the surface will be

Ø = **B. S**= BScosŸ where Ÿ is the angle between **B and S.**

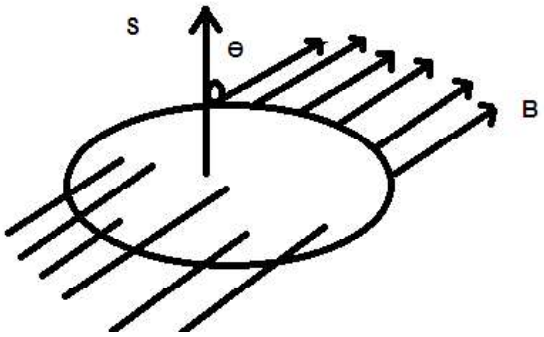


Figure.1 An oval surface area **S** at an angle Θ with the magnetic field **B**

Faraday's 1st law: Whenever magnetic flux linked with a closed circuit changes, an emf is induced in the coil and the induced current flows through the coil as long as the change in magnetic flux continues.

Faraday's 2nd law: The magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux linked with the coil.

Let Ø be the magnetic flux linked with a coil at any instant t, then the emf induced in the coil is

$$e \propto \frac{d\emptyset}{dt} \quad \text{.....(1)}$$

If N be the number of turns in the coil, then

$e = N \frac{d\varnothing}{dt}$ .....(2)

If the flux changes from $\varnothing_1$ to $\varnothing_2$ in time t_1 to t_2 then

$e = N(\frac{\varnothing_2 - \varnothing_1}{t_2 - t_1})$ .....(3)



CHECK YOUR PROGRESS

Q 6: State the Faraday's first and second laws of electromagnetic induction.

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3.8 FAMILIARIZATION WITH SOME COMMON DEVICES

There are many devices which are needed in laboratory or workshop for the testing, fault finding and repairing of electronic goods. Some of the widely used such devices are briefly described below–

Power Supply

Power supply is one of the most important devices for all pieces of electronic equipment. All electronic equipment run on electrical energy, but all electronic devices require different voltage and current. So to supply the specific power to the electronic equipment a power supply device is required for them. Generally, all electronic devices run on DC, so the first function of the power supply is to supply DC current. Again, depending on their feathers they are of the following types–

- Battery Power Supply
- Linear Power Supply
- Switched Mode Power Supply
- Programmable Power Supply
- Uninterruptible Power Supply

Battery Power Supply: This is one of the simplest, portable and reliable power supplies. The sources of the supply are electrochemical cells. Here electrical energy is produced due to some chemical reaction.

Linear Power Supply: In these power supplies the AC available on our mains is converted to DC through rectifier and then to the proper voltage

and current level through some filters and regulators. All these are discussed in detail in Unit 3.

Switched Mode Power Supply: A switched mode power supply or commonly known as SMPS is slightly different from the other power supply types. It does not use any transformer before rectification, the AC coming from mains is directly converted to DC and this DC is sliced in many small pieces using very high speed electronic switch. The sizes of the slices are in accordance with the output requirement; slice size goes bigger with the increasing power requirement.

Programmable Power Supply: Programmable power supplies are more advanced and sophisticated. As the name suggest the main advantage of the type of power supply is that they can be programmed that means the output voltage, current and frequency can be controlled through some programming circuits and digital control through computer interface.

Uninterruptible Power Supply: Uninterruptible Power Supply or UPS is essential for running equipment like computer. The main advantage of a UPS is that, when there is a power failure in the mains it gives back up from its battery for some time so that the device gets ample of time for a proper shut down. When the main power is available, it simultaneously supplies power to devices that are attached to it and charges the battery. When power supply is off the UPS draws power from the battery. The time up to which it can supply power from battery backup depends on the charging capacity of the battery.

Regulator

A regulator is a device that helps to maintain the constant characteristics of any process. In case of electricity a regulator is a device that maintains a power supply which is free from fluctuation. A common (electrical) regulator is a voltage regulator which provides regulated voltage supply to electrical equipment. It is essential for safety of the device. AC mains supply always has fluctuations. As a result, the equipment may get damaged. A regulator prevents fluctuations and supplies constant power. A voltage regulator is an electronics device which is associated with low power applications and DC. Most of the electric devices or electrical circuits need a constant voltage level, below which it will not work or if the level is above

it the device or the circuit may be damaged or blown. The regulator may be of electromechanical type; it may consist of active and passive components. Now-a-days, they are available in the form of IC. More about these IC and most popular regulator IC are discussed in subsequent units.

Stabilizer

Stabilizers are mainly voltage stabilizers. As the name suggests it is a device meant for stabilizing voltage. In our AC mains line, the voltage is never stable. It sometimes goes much higher or lower than the rated voltage level for electrical equipment, and this happens much frequently. This condition may cause the device either not to work or damage. So, here comes the need of voltage stabilizer. Voltage stabilizer maintains a constant voltage level at its output, irrespective of the voltage level at its input. It uses some electronic circuitry for its operation. It helps not only to keep a constant voltage level without fluctuation but also helps to filter the unwanted noise coming with the incoming power.



CHECK YOUR PROGRESS

Q 7: What are the different types of power supply?

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3.9 LET US SUM UP

- Magnets have the special property of attracting magnetic material.
- The area or space within which magnetic influence can be known as Magnetic Field.
- Magnetic Flux is the measure of the strength of the magnetic field.
- To supply the specific power to the electronic equipment a power supply device is required for them.
- A regulator in general terms is a device that helps to maintain the constant characteristics of any process.
- Voltage stabilizers are a device meant for stabilizing voltage



3.10 FURTHER READINGS

1) **Electricity and Magnetism with Electronics** –*K.K.Tiwari (S Chand Publication)*



3.11 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: There are three types of magnet. They are permanent magnet, temporary magnet and electromagnet.

Ans to Q No 2: Permanent magnets are the magnet that retains the magnetic property once they are magnetised. But temporary magnet loses the magnetic property when they are removed from the magnetic field.

Ans to Q No 3: a) True b) False c) False d) True

Ans to Q No 4: Magnetic field is the area within which magnetic influence can be felt.

Ans to Q No 5: The amount of magnetic field produced due to a magnetic source is known as magnetic flux.

Ans to Q No 6: Faraday's 1st law: Whenever magnetic flux linked with a closed circuit changes, an e.m.f. is induced in the coil and the induced current flows through the coil as long as the change in magnetic flux continues.

Faraday's 2nd law: The magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux linked with the coil.

Ans to Q No 7: Different types of power supply areBattery Power Supply, Linear Power Supply, Switched Mode Power Supply, Programmable Power Supply and Uninterruptible Power Supply.



3.12 MODEL QUESTIONS

Q.1: Discuss in short about the properties of a magnet.

Q.2: Briefly describe the need of a power supply and its various types.

Q.3: Write a note on regulator and stabilizer.

Q.4: Describe the magnetic effect of electric current.

*** ***** ***

UNIT 4 : FUNDAMENTALS OF ALTERNATING CURRENT

UNIT STRUCTURE

4.1 Learning Objectives

4.2 Introduction

4.3 Direct Current and Alternating Current

4.4 Electro Motive Force Equation

4.5 Alternating Circuit

4.6 Let Us Sum Up

4.7 Further Readings

4.8 Answers to Check Your Progress

4.9 Model Questions

4.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- explain the direct current and alternating current
- discuss the electro motive force equation
- describe the alternating circuit.

4.2 INTRODUCTION

In the previous unit,we have focused on the basic concept of magnetism. This unit will deal with the fundamentals of alternating current. In this unit, we will provide you the concept of direct and alternating current. We will also explain the electro motive force equation.Alternating circuits and itsadvantages will also be highlighted at the end of this unit.

4.3 DIRECT CURRENT AND ALTERNATING CURRENT

Whenever a circuit having a conductor and a load is connected to a voltage source the current flow starts through the conductor. If the voltage source is a battery having a positive and negative pole, then a current will

flow in a single direction as shown in the Figure 4.1 until and unless a potential difference exists between the two battery terminals.

This type of unidirectional current flow is known as Direct Current or shortly written as DC.

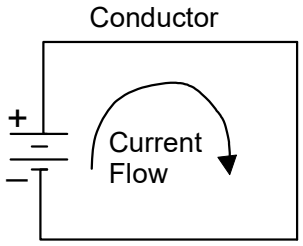


Fig. 4.1: DC Source

Direct Current or DCis obtained from battery. It has no variation in magnitude if the voltage or the potential difference remains same despite variation in the time despite variation in time. This movement of electrons takes place in a properly directed manner such that the flow is from a higher potential state to a lower potential state. These potential states may be referred to as positive and negative polarities. It means that conventionally current flows from positive to negative sides (Figure 4.2 a). But in the true sense, electron moves in the opposite direction i.e. from negative to the positive side as negatively charged electrons are attracted towards the positive polarity (Figure 4.2 b).

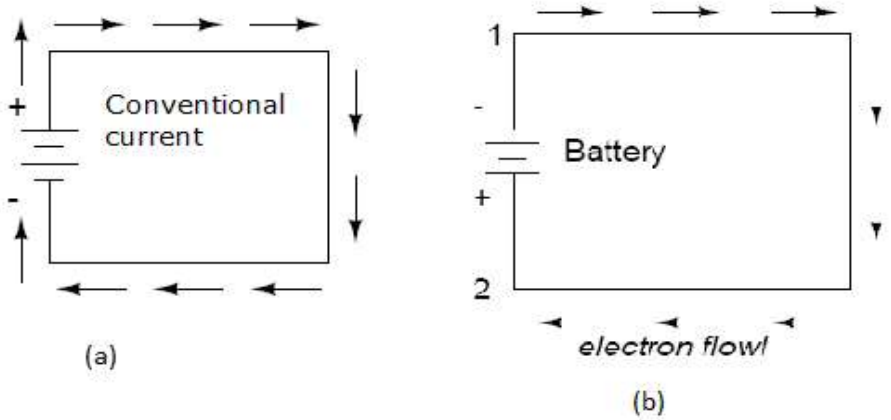


Fig.4.2: Setting up of conventional and electron current

Again if the voltage source is alternating, i.e. the polarity of the voltage source keeps changing in regular interval than the current flow through at any instant depends on the polarity of the voltage source at that instant.

This type of current flow whose direction of flow changes at regular interval is commonly known as Alternating Current or shortly written as AC.

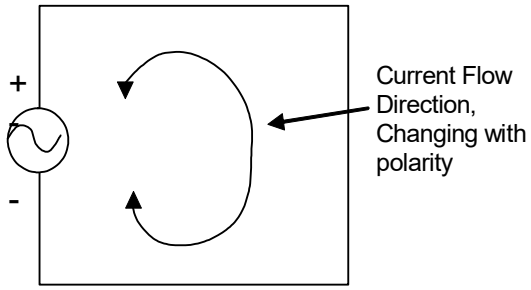


Fig. 4.3 (a) AC Source

AC or Alternating Current are special wave forms that have their waveforms continually varying in direction (i.e. alternately positive and negative) with respect to time. The sources that generate AC produce voltages alternating in polarity, reversing positive and negative over time. An AC waveform is similar to a sine wave.

A simple approach to generate AC is depicted below (Figure 4.3 b):

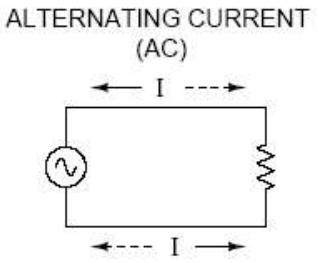


Fig. 4.3 (b): Arrangement with AC source

Let a single turn coil be free to rotate at constant angular velocity symmetrically between the poles of a magnet system as shown in Figure 2.4.

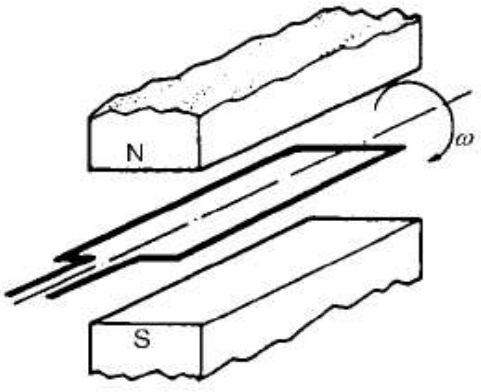


Fig. 4.4: Arrangement to generate AC

An e.m.f. is generated in the coil (from ***Faraday's Law***s) which varies in magnitude and reverses its direction at regular intervals. The waveform generated due to the movement of the magnet between the coil is a sinusoid and is depicted in Figure 4.5.

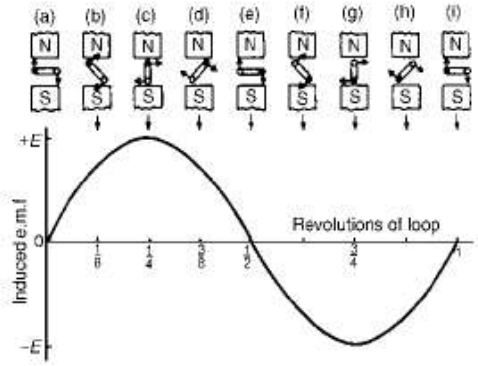


Fig. 4.5: Sinusoidal wave generated by different pole positions of a magnet

A waveform thus created can be represented as

$$x(n) = A\cos(\omega n + \theta)$$

where angular frequency

$$\omega = 2\pi f \Rightarrow x(n) = A\cos(2\pi n f + \theta)$$

The time taken for an alternating quantity to complete one cycle is called the **period** or the **periodic time**, ***T***, of the waveform. The number of cycles completed in one second is called the **frequency**, ***f***, and is measured in **hertz**, **Hz**. In India, the standard value of AC supply is 50 Hertz.

$$T = \frac{1}{f} \text{ or } f = \frac{1}{T}$$

Electricity is produced by generators at power stations and then distributed by a vast network of transmission lines to industry and for domestic use. It is easier and cheaper to generate alternating current (a.c.) than direct current (d.c.) and a.c. is more conveniently distributed than d.c. since its voltage can be readily altered using transformers.

The main advantages of AC over DC is its direction changing property which makes the transformer action possible and this makes easier for power transmitting to long distances.



CHECK YOUR PROGRESS

Q 1: What is the difference between direct current and alternating current?

.....

.....

4.4 ELECTRO MOTIVE FORCE EQUATION

The electromotive force (EMF) is defined as the potential difference between two electrodes of cells when no current flows. In other words, EMF is defined as the maximum potential difference that is delivered by the battery when there is no flow of current. The EMF is usually denoted by the symbol ε. The equation for electromotive force can be stated as:

$$\varepsilon = V_+ + V_-$$

where V_+ is the voltage at the positive terminal of the cell (a battery or a generator) and V_- is the voltage at the negative terminal. The unit of electromotive force is Volt.EMF dimension is given as $M^1L^2T^{-3}I^{-1}$.The electromotive force of a cell is remain constant.

4.5 ALTERNATING CIRCUIT

Electricity is produced by generators at power stations and then distributed by a vast network of transmission lines to industry and for domestic use. It is easier and cheaper to generate AC than DC.AC is more conveniently distributed than DC since its voltage can be readily altered using transformers.

In applications where electricity is used to dissipateenergy, the polarity or direction of current is irrelevant, so long as there isenough voltage and current to the load to produce the desired power dissipation. However,with AC it is possible to build electric generators, motors and power

distribution systems that arefar more efficient than DC. For high power applications AC systems are required.

Another advantage is the ease of design of ad motors compared to dc motors and the efficiency that the former provide.

The greatest advantage of the AC over DC is with regards to distribution of power. This is possible due to the use of transformer for which AC is required. The transformer's ability to step AC voltage up or down with ease gives AC an advantage which the DC cannot in the realm of power distribution.

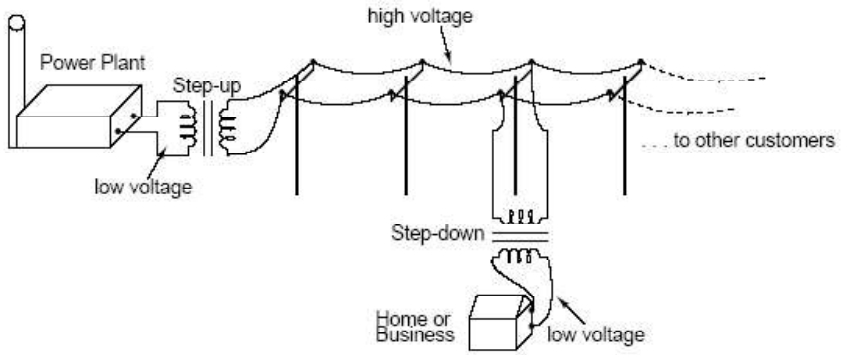


Figure 4.6: Power distribution

Without theability to efficiently step voltage up and down, it would be cost-prohibitive to construct powersystems for long range distribution. In such a situation power distribution would be possible only in close-range (within a few miles at most) use.Because the phenomenon ofmutual inductance relies on changing magnetic fields, and DC can only produce steady magnetic fields, transformers simply will not work with direct current.

The following terms are essential for the understanding of the working of appliances using AC.

Instantaneous values are the values of the alternating quantities at any instant of time. The largest value reached in a half cycle is called the peak value or the maximum value or the crest value or the amplitude of the waveform.Peak amplitude is the height of an AC waveform as measured from the zero mark to the highestpositive or lowest negative point on a graph.The largest value reached in a half cycle is called the peak value or the maximum value or the crest value or the amplitude of the waveform.

Peak-to-peak amplitude is the total height of an AC waveform as measured from maximumpositive to maximum negative peaks on a graph.

The amplitude of an AC waveform is its height as depicted on a graph over time. An amplitudemeasurement can take the form of peak, peak-to-peak, average, or RMS quantity.

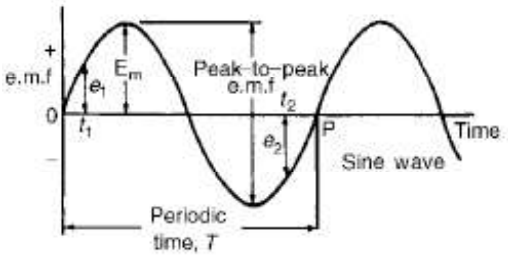


Figure 4.7: AC waveform and its values

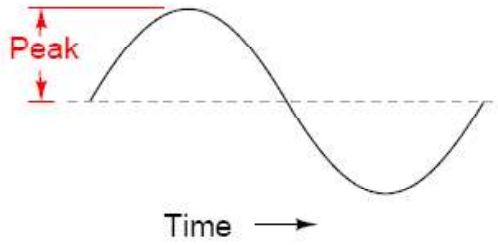


Figure 4.8: Peak value of a AC

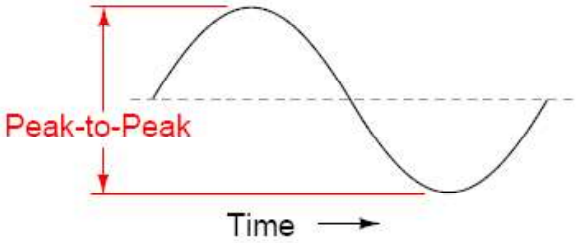


Figure 4.9: Peak to peak value of an AC wave

The average or mean value of a symmetrical alternating quantity,(such as a sine wave), is the average value measured over a half cycle. This is because over a complete cycle the average value of a sine wave is zero.

$$\text{Average or mean value} = \frac{\text{area under the curve}}{\text{length of base}}$$

Average amplitude is the mathematical mean of all a waveform's points over the period of one cycle. T. For a sine wave, average value = 0.637 × maximum value.

"RMS" stands for Root Mean Square, and is a way of expressing an AC quantity of voltage orcurrent in terms functionally equivalent to DC.The effective value of an alternating current is that current which will produce the same heating effect as an equivalent direct current. This effective value is called the root mean square (rms) value. Whenever an alternating quantity is given, it is assumed to be the rms value.

For a sine wave, rms value = 0.707× maximum value(i.e. $\frac{1}{\sqrt{2}} \times \text{maximum value}$).

Reactance and Impedance:

The impedance is a measure of the total opposition of a circuit to current.It is similar to resistance but it also takes into account the effects of capacitance and inductance. Impedance is measured in ohms and denoted as Z. Impedance is more complex than resistance because the properties of capacitance and inductance vary with the frequency of the current passing through the circuit and this means impedance varies with frequency. But the resistance is independent of frequency.

Impedance $Z = R = V / I$.

Where V = Voltage in volts (V)

I = Current in amperes (A)

R = Resistance in ohms (Ω).

The impedance can be divided into two parts:

- Resistance R and
- Reactance X.

Reactance is a measure of the opposition of capacitance and inductance to electric current. It is varies with the frequency of the electrical signal. Reactance is also measured in ohms and denoted as X.

There are two types of reactance.

- Capacitive reactance (X_C)
- Inductive reactance (X_L)

The total reactance is the difference between the two:

$$X = X_L - X_C$$

Capacitive reactance, X_C

$$X_C = 1 / 2\pi fC$$

Where f = frequency in hertz (Hz)

C = capacitance in farad (F)

Capacitive reactance is large at low frequencies and small at high frequencies. For direct current which is zero frequency, XC is infinite. Hence the capacitors pass AC but block DC.

Inductive reactance, X_L

$$X_L = 2\pi fC$$

Where f = frequency in hertz (Hz)

L = inductance in henry (H)

Inductive reactance is small at low frequencies and large at high frequencies. For DC which has zero frequency, X_L is zero. Hence the inductors pass DC but block high frequency AC.



CHECK YOUR PROGRESS

Q 3: Fill in the blanks:

1. Impedance is divided into _____ and _____.
2. Capacitors can _____ AC but _____ DC.
3. Impedance of a circuit is varies with _____.
4. Capacitive reactance is _____ at low frequencies.
5. Inductive reactance is _____ proportional to the frequency.



4.6 LET US SUM UP

- The difference between AC and DC lies in the direction in which the electrons flow.
- The time taken for an alternating quantity to complete one cycle is called the period or the periodic time, *T*, of the waveform.

- AC is more conveniently distributed than DC since its voltage can be readily altered using transformers.
- Peak amplitude is the height of an AC waveform as measured from the zero mark to the highest positive or lowest negative point on a graph.
- Impedance is divided into two parts- resistance and reactance.



4.7 FURTHER READINGS

1) Electrical Technology- B.L. Thareja, Khanna Publishing,
2) Electrical Technology- Edward Hughes and Ian McKenzie Smith, ELBS.



4.8 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: The difference between AC and DC lies in the direction in which the electrons flow. In direct current, electrons flow steadily in a single direction, while in alternating current electrons keep switching directions, going forward and then backward.

Ans to Q No 2: 1. resistance, reactance 2. pass, block
3. frequency 4. large 5. Directly.



4.9 MODEL QUESTIONS

Q 1: What are the advantages to AC over DC?

Q 2: What are peak, peak-to-peak, average and RMS values of an AC signal?

Q 3: Define the terms Amplitude, time period, Frequency and RMS value. What are the respective units?

*** ***** ***

UNIT 5 : ELECTRICAL MEASUREMENT INSTRUMENTS

UNIT STRUCTURE

5.1 Learning Objectives

5.2 Introduction

5.3 Multimeter

- 5.3.1 Analog Multi-meter
- 5.3.2 Digital Multi-meter

5.4 Tester

- 5.4.1 Tong Tester
- 5.4.2 Energy-meter
- 5.4.3 Megger
- 5.4.4 Earth resistance meter

5.5 Extension of range of measurement instruments

- 5.5.1 Voltmeter
- 5.5.2 Ammeter
- 5.5.3 Loading effect of voltmeter
- 5.5.4 Voltage drop effect of an ammeter

5.6 High Voltage Testing and Measurements

5.7 Calibration

5.8 Let us sum up

5.9 Further Readings

5.10 Answer to check your progress

5.11 Model Questions

5.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- describe the working principle of the multimeter
- discuss the principles behind the working of different testers
- classify the different processes of extension of range of electrical instruments

- explain high voltage testing and measurements
- get an idea of calibration process of measurement equipment.

5.2 INTRODUCTION

In the previous unit, we have focused on the fundamentals of alternating current. In this unit, you will learn the basic concepts of electrical measurement instruments. It is essential to monitor conditions of different electrical quantities and some of the instruments are vital in testing and servicing of appliances. Moreover, domestic electricity supply is also regulated and monitored using these instruments. The most commonly used electrical instrument is the multimeter which can be useful for measurements of dc and ac voltages as well as currents. In this unit we shall highlight the use of multimeter and different types of testers. There are certain techniques through which the range of measurements of electrical instruments can be extended. This unit will also provide you the fundamental principles related to the high voltage testing and measurements and the calibration process for comparing the performance of instruments.

5.3 MULTIMETER

As the name suggest, a multi-meter is a versatile instrument that combines several functions into one unit. It can be used to measure current, voltage, resistance, capacitance etc. Multi-meters are hand-held devices useful for a range of fault finding applications. These are also useful for servicing and trouble-shooting of electrical problems in a wide array of industrial and household devices. These can provide measurementswith a high degree of accuracy. Thevolt-ohm-milli-ammeter (VOM) is the most commonly used multi-meter. The typical VOM has a meter movement with a full scale current of 50 μA, or a sensitivity of 20 KW/V, when used as a DC voltmeter. A single meter movement is used to measure current, AC and DC voltage, and resistance. Range switches are usually provided for scale selection (e.g., 0-1V, 0-10V, etc). There are two broad categories of multi-meters: analog and digital.



Multi-meter is a versatile instrument that combines several functions into one unit.

5.3.1 Analog Multi-meter

Analog multi-meters are commonly used electrical instruments implemented using a galvanometer. Analog multi-meters have limited accuracy. These are however suitable for determining the rate of change of a reading. This is due to the fact that a needle moves over a scale and with better sensitivity detects small variation in the electrical quantity.

In a analog multimeter, the current to deflect the coil and pointer is drawn from the circuit being measured; it is usually an advantage to minimize the current drawn from the circuit.

The sensitivity of an analog multi-meter is given in units of ohms per volt. For example, an inexpensive multi-meter would have a sensitivity of 1000 ohms per volt and would draw 1 milli-ampere from a circuit at the full scale measured voltage. To avoid the loading of the measured circuit by the current drawn by the meter movement, some analog multi-meters use an amplifier inserted between the measured circuit and the meter movement. Multi-meters can be used as voltmeters, ammeters and ohmmeters. While measuring voltage, a multi-meter is connected in parallel while during current measurement it is placed in series.

Resolution of analog multi-meters is limited by a number of factors. These are the scale pointer width, vibration of the pointer, the accuracy of scale-printing, calibration, number of ranges, errors in observation, eyesight and errors due mechanical display.



Figure 5.1: Analog multi-meter

5.3.2 Digital Multimeter

The digital multimeter or DMM is a versatile device that can be used to measure both ac and dc voltage and current from say micro to a few tens or hundreds ranges. The DMM is essential equipment in the laboratory. Without it, making measurements of current and voltage values will be very tedious and time consuming. The DMM can also be sued to find component values and determine terminals of semiconductor devices like diodes and transistors. A basic DMM used frequently in the laboratory is as in Figure 3.2.



Figure 5.2: DMM used frequently in laboratory

The DMM is an instrument which can be used to do the following:

a) Measurement of d.c and a.c voltages and currents,
b) Measurement of resistance values,
c) Measurement of capacitance values,
d) Obtain forward current gains of transistors, thereby providing a terminal identification of transistors.
e) Provide diode check to identify terminals of a diode.

Signals are input to the DMM through two leads (red for positive, and black for negative), and then the value measured is displayed.

While measuring voltage using a DMM it must be connected in parallel to a resistance (Figure 3.3).

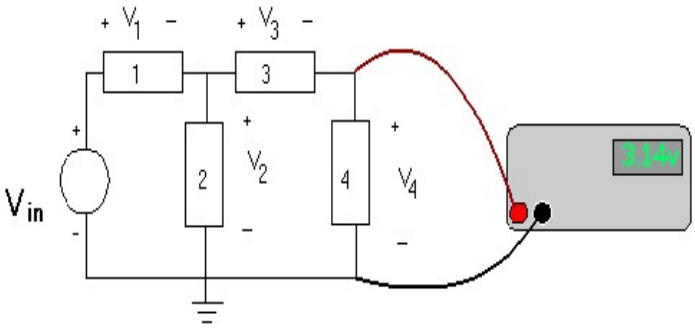


Figure 5.3: Measuring voltage across a resistance

But while measuring current the DMM must be connected in series (Figure 3.4).

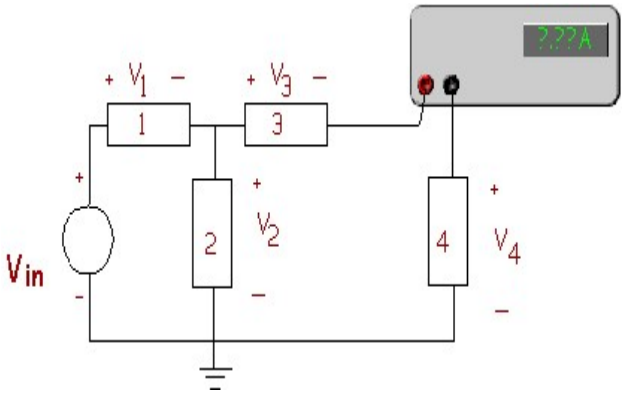


Figure 5.4: Measuring current using a DMM

While measuring resistance the DMM works as an ohmmeter. An ohmmeter sends out a current and measures the voltage produced across the DUT. Because the ohmmeter is ultimately measuring a voltage, it should be connected in parallel with the DUT. When measuring a resistance, one end of the resistor should be disconnected from the circuit so that all of the current from the DMM's current source is passing through the resistor to be measured. The precision of the DMM is an important criterion while making measurements. The precision of a DMM is dependent on the number of bits used by the internal ADC (Analog to Digital Converter) while converting an analog readout to digital form.



CHECK YOUR PROGRESS

Q 1: Find True or False.

a) A multi-meter is a versatile instrument that combines several functions into one unit.

b) Multi-meters are useful for servicing and trouble-shooting of electrical problems.

c) Analog multi-meters are implemented using a galvanometer.

d) Resolution of analog multi-meters is limited by a factor.

e) The precision of a DMM is dependent on the number of bits used by the internal ADC.

5.4 TESTER

Testing is part of installation of any electrical instrument. It also is essential before making any electrical appliance operational. Even after servicing, testing is required to determine if the device can be used or not. Troubleshooting of defects requires a series of testing as well. Some of the commonly used electrical testing equipment are tong - tester, energy-meter, megger, earth resistance meter, power factor meter etc.

5.4.1. Tong Tester

Tong tester is a special purpose current probe which allows measurement of current without having to disconnect the conductor from the circuit. When an ammeter or a voltmeter cannot be connected to a conductor to measure the current or voltage, the tong tester is used. In short, current or voltage of cable or insulated conductor is measured by Tong Tester. It has two jaws which open to allow clamping around an electrical conductorand find the value without any break in the existing arrangement of the conductor or device. A few types of tong testers even induce current in an electrical appliance to find out the amount of current flowing. Tong testers find out root mean square (RMS) values of current flowing through

electrical appliances without any consideration to waveforms. These are applicable even for high voltage applications as well. Tong testers can also be used to measure temperature, resistance, frequency, check transistors, diodes etc.



Figure 5.5: Tong tester

5.4.2 Energy Meter

Energy meters can be used to amount of electrical energy consumed by consumers, industries etc. while using electrical appliances. The read-outs provided by energy meters is in billing units, the most common one being the kilowatt hour. The read-outs of electric meters providebilling cycles and energy consumed during a cycle.Electricity meters operate by continuously measuring the instantaneous voltage and current and providing the product of these to give instantaneous electrical power in watts. It is next related to time which provides the energy spent in joule or in kilo-watt hour. The most common energy meter is the electro-mechanical induction watt-hour meter.

The electromechanical induction meter operates by counting the revolutions of an aluminum disc which is made to rotate at a speed proportional to the power. The disc rotates over a scale which is properly printed to provide the read-out. The number of revolutions is thus proportional to the energy usage. It consumes a small amount

of power, typically around 2 watts.



Figure 5.6: Energy meter

5.4.3 Megger

The megger is used to measure insulation resistance. It is a portable instrument and is formed by a hand-driven DC generator and a direct reading ohm meter.

The primary function of a Megger is to assess the quality of insulation in electrical systems. It works by applying a high voltage to the insulation under test and measuring the resulting current. The instrument then calculates the resistance by Ohm's Law (Resistance = Voltage / Current).

This measurement helps determine whether the insulation is in good condition or if there is a risk of leakage or breakdown.



Figure 5.7: Megger

Megger instruments are commonly used in maintenance and troubleshooting of electrical systems to prevent electrical failures and ensure the safety and reliability of electrical installations. It is frequently used for measurement of insulation value of lines, transformers, breakers etc.

5.4.4 Earth Resistance Meter

Earth resistances become vital in such situations where an electrical appliance should be provided with a connection that has a flow continuity with ground. The continuity check between the electrical appliance and ground is measured using earth resistance meters.

Ground resistance testers can be used to take different measurements like grounding system resistance, insulation resistance, earth continuity, current leakage, ground bond, grounding system resistance and insulation resistance. Such a device is important for maintaining the safety of instruments that come into contact with people. These tests are performed to confirm the electrical integrity of an instrument.

Most ground resistance testers have an analog or digital display, or an LED indicator. There are 3 terminals of an Earth Tester meter. The first two terminals of the meter are connected to earth as far as cables can. Two rods are fixed into the soil with the help of a small hammer and then connect two knobs of the meter with these rods. The third terminal of the meter is connected to the earth pit, of which the earth resistance is to be measured. The meter reading will indicate the resistance of the earth pit.The best resistance of an earth pit must be less than one.

A earth resistance meter also can work as a ground detector.

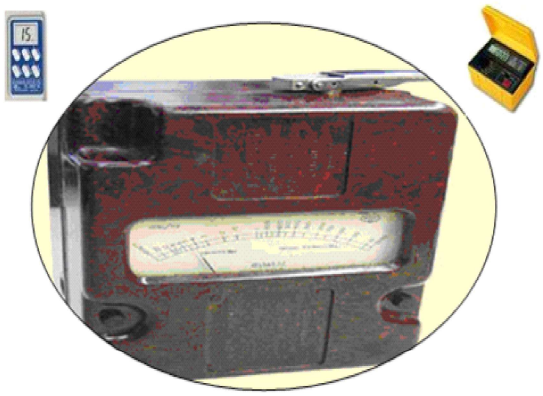


Figure 5.8: Earth Resistance Meter



CHECK YOUR PROGRESS

Q 2: Find True or False.

a) Tong testers find out root mean square (RMS) values of current without any consideration to waveforms.

b) Power factor is related to the phase differences between voltages and currents flowing through a circuit.

The continuity check between the electrical appliance and ground is measured using earth resistance meters.

5.5 EXTENSION OF RANGE OF MEASUREMENT INSTRUMENTS

The basic electrical measurement instrument is the milli-ammeter. It can be used for measurement of both voltage and current. This device can be suitably modified to measure both voltage and current of higher magnitudes. Such modifications provide range extension of the device. The following sections provide some of the fundamental principles related to the modifications usually carried out for these applications.

5.5.1 Range Extension of a Voltmeter

The milli-ammeter is converted into a voltmeter by connecting a highvalue resistance (called a multiplier) in series with it as shown inFigure 10.

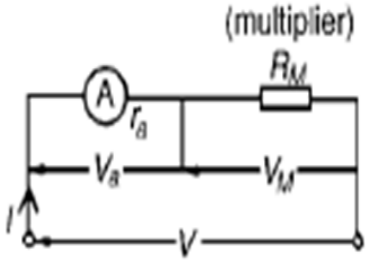


Figure 5.10: Conversion of an ammeter into voltmeter

From the diagram,

$V = V_a + V_M = Ir_a + IR_M$.

$$R_M = \frac{V - Ir_a}{I}$$

Thus the value of the multiplier,

The range of this instrument can be extended further to enable it measure higher voltage levels.

For measuring voltages of higher ranges, a resistance of higher value is connected in series with the instrument to limit the current in the coil to a safe value. This value of current should never exceed the current required to produce the full- scale deflection. The high resistance connected in series with the instrument is called a multiplier. A multiplier is made of magnanin or other suitable alloy having a negligible coefficient of resistance. It therefore also serves as swamping resistor for the instrument coil.

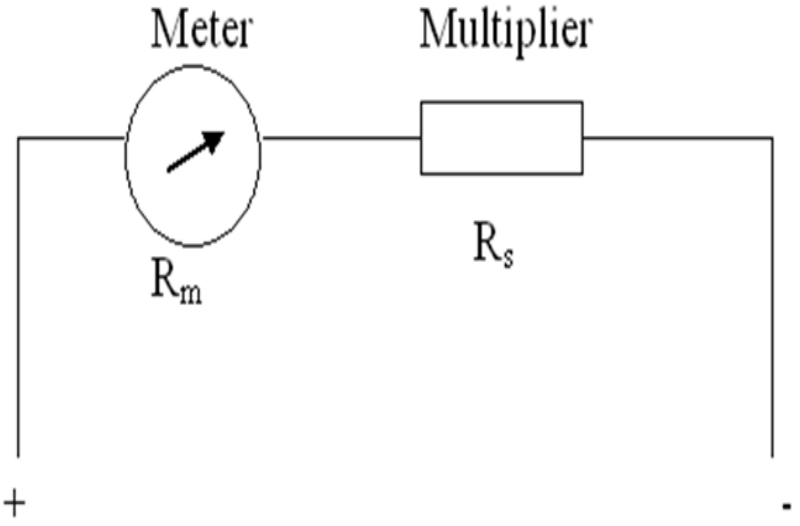


Figure 5.11: Extension of range of a voltmeter

The value of the multiplier resistance maybe calculated as below:

Let V = voltage to be measured, V

I = circuit current to give full scale deflection, A

I_m = meter current, A

R_m = meter resistance, Ω

R_s= resistance of multiplier, Ω

Since the same current flow through the instrument and multiplier

$I = I_m$

By Ohm's law,

Total circuit voltage = total circuit current X total circuit resistance

$$V= I_m (R_m + R_s)$$

For extension of voltage ranges, an arrangement for practical purposes maybe shown as in Figure 3.12.

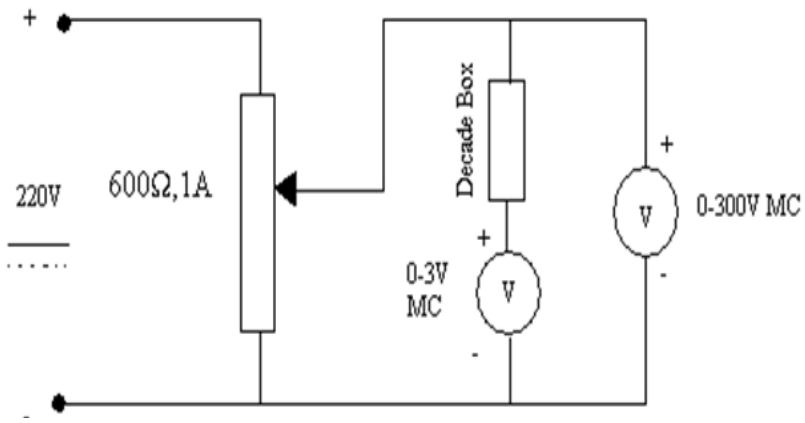


Figure 5.12: Arrangement for extension of range of a voltmeter

5.5.2 Extension of Range of an Ammeter

An ammeter can be suitably modified to measure currents of larger values. For such purposes the ammeter is connected in parallel with a low - value resistance so as to divert a portion of the current. Such a diverting resistoris called a shunt.

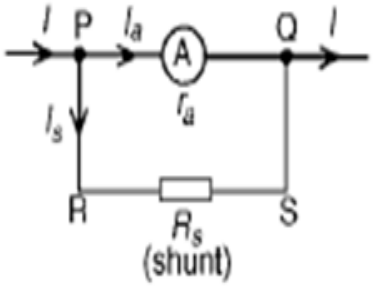


Figure 3.13: Extending the range of an ammeter

From Figure 3.13, VPQ= VRS. Hence Iara= ISRS. The value of the shunt resistance can thus, be given as

$$R_s = \frac{I_a r_a}{I_s}$$

To calculate the value of shunt resistance the following points should be noted:

1. The meter current Im should never exceed the current required to produce full scale deflection.
2. Since the arrangement shown in figure is simply a parallel circuit, current to be measured = instrument current + shunt current ie. $I = I_a + I_s$.

For practical purposes, the arrangement shown in Figure 3.14 maybe used.

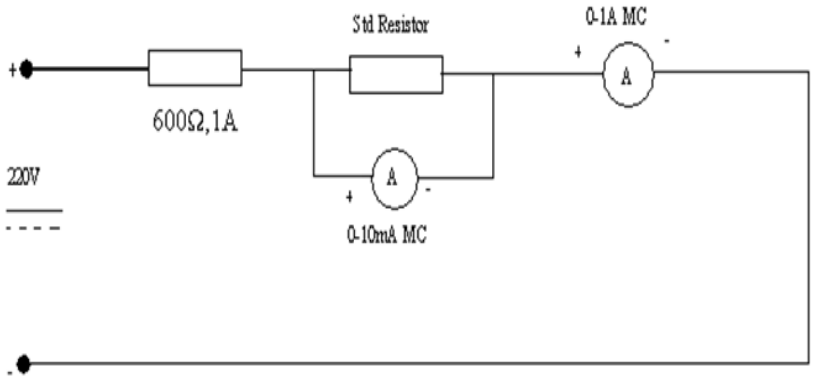


Figure 5.14: Arrangement for extension of range of an ammeter

5.5.3 Loading Effect of Voltmeter

While making measurements with a voltmeter it is important

to know the sensitivity rating of the instrument. The rating, generally printed on the meter dial, specifies the resistance of the meter for one volt range. The sensitivity of a voltmeter is defined as $S_v = \frac{1}{I_{fp}} = \frac{1}{I_m}$ where I_{fp} is the current required for full scale deflection.

The sensitivity of a voltmeter is an important factor when selecting a meter for a certain voltage measurement. A low resistance voltmeter may give correct readings while measuring voltages in low resistance circuits but is certain to produce unreliable readings in high resistance circuits. A voltmeter, when connected across two points in a very resistive, circuit acts as a shunt for that portion of the circuit. The meter will then give a lower voltage drop than existed before the meter was connected. This effect is called the loading effect of a voltmeter and results primarily due to low sensitivity of the instrument.

5.5.4 Voltage drop effect of an ammeter

The ammeter is connected in series in a network to measure a current. The arrangement maybe shown as below (Figure 3.15):

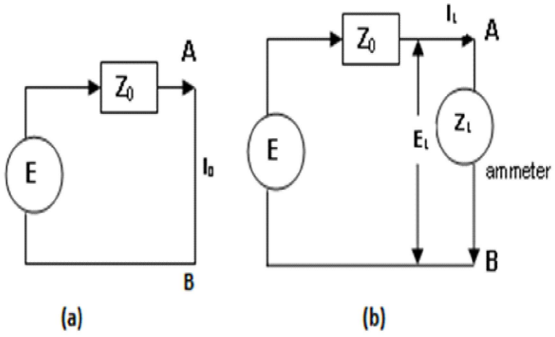


Figure 5.15: Arrangement to show voltage drop effect of ammeter

The network shown in (a) has a voltage E while has an impedance of Z_0. When points A and B are shorted current flows in the network. The current is given as $I_0 = \frac{E}{Z_0} \quad \Rightarrow E = I_0 Z_0$

But when an ammeter is inserted between A and B as shown in (b), the impedance of the circuit increases and modifies the value

of the current flowing. The measured current then becomes $I_L = \frac{E}{Z_0 + Z_L}$. This can be called the measured current.

In order that the measured current be equal to the actual value of the current, $Z_0 >> Z_L$. This means that the impedance of the ammeter should be very small as compared to the output impedance of the source else the ammeter will be a source of voltage drop. This is a loading effect shown by the ammeter.



CHECK YOUR PROGRESS

Q 3: Find True or False.

a. The basic electrical measurement instrument is the milli-ammeter

b. The milli-ammeter is converted into a voltmeter by connecting a low value resistance.

c. An ammeter can be suitably modified to measure currents of larger values by using a shunt resistor.

d. Sensitivity of a voltmeter is printed on the instrument.

5.6 HIGH VOLTAGE TESTING AND MEASUREMENTS

High voltage applications are common due to the over - reliance of the present life-style on electricity. Right from the stage of generation of electricity to its distribution to the consumer, high voltage applications are critical for consumer and industrial applications. Hence, high voltage measurements and testing forms an essential component of any installation. High voltage testing and measurementequipment can be classified into two categories:

1. Methods for measurement of RMS values and
2. Methods for measurement of peak values of voltage.

Among the RMS measurement methods three are three primary methods:

a. Electro-static voltmeters- Among these methods the attracted disc voltmeter is a complex device and is not preferred. A large disc space is necessary to avoid flashover and corona. With appropriate

modifications, this instrument in a form called absolute high voltage attracted disc voltmeter, is used with a voltage difference of 300 KV and a disc spacing of just 3 cm. But these devices become unstable at times and requires care while handling voltages beyond a certain range.

Another sub-type called attracted sphere voltmeter designed using electro-static force between two spheres can handle forces between 4.2 to 7.5 N with gaps of 100 mm and 500 mm while measuring voltages even upto 1 MV.

The other sub-class in this category called the oscillating ellipsoid voltmeter uses two electrodes and produces high degree of accuracy.

b. Transformer ratio method- This method the primary voltage of a high voltage testing transformer is measured with a low voltage voltmeter and the secondary voltage obtained is given as Vs=nVp where n is the turns ratio, Vs is the voltage across the secondary and Vp is the voltage across the primary. This is a simple method but is not accurate. It is, however, convenient for use and continuous measurement only after proper calibration.

c. Potential divider method- In this method, a potential divider is connected across the secondary winding (high voltage winding) of a high voltage testing transformer. A definite fraction of the secondary voltage is measured using a low voltage electrostatic voltmeter. Two types of potential divider arrangements can be formed- one resistance potential divider and the other capacitance potential divider. This method is suitable only under appropriately arranged set-ups.



CHECK YOUR PROGRESS

Q 4: Find True or False

a. Measurement of RMS values is a class of high voltage testing.

b. Electro-static voltmeters are used for measurement of RMS values of high voltages.

c. Attracted sphere voltmeter can be used for measurement upto 1 MV.

5.7 CALIBRATION

Calibration is the process through which performance of instruments can be gauged and compared against known standards. It helps to identify errors and accuracy. Calibration of an instrument involves comparison of the instruments performance and capacity with a primary standard, a secondary standard that has a higher accuracy or an instrument which has a known accuracy and a verified capacity.

5.7.1 Necessity of Calibration

All instruments must be calibrated against some known standards before use. The behaviour of an instrument can be predicted only after doing appropriate calibration. The reading given by a particular instrument is acceptable only after the instrument has been calibrated using a primary standard, a secondary standard of higher accuracy or an instrument which has a know accuracy and a verified capacity. Instruments not calibrated can cause errors and be a source of inaccurate measurements.

5.7.2 Types of Calibration

Calibration can be of two types: static and dynamic. This classification is based on the division of instrument and measurement systems that exist due to the individual operations procedure. Static calibration is done with instruments that measure quantities which vary slowly or remain constant. Under these circumstances, the characteristics derived can be used to provide a meaningful description of the measured quantity and use a standard instrument to calibrate the meter used for measurement. The accuracy ot the reading shown by the meter shall depend upon the effectiveness of the calibration.

The other type of calibration is done in case of quantities that show rapid variations. A dynamic relation exists between input and output in such cases. The instrument used for measurement of

such quantities must be calibrated against a known standard or an instrument during the run- time or operations time which captures the varying nature of the quantity and the considers the dynamic nature of the operation.



CHECK YOUR PROGRESS

Q 5: Find True or False.

a) Calibration is the process through which performance of instruments can be gauged and compared against known standards.

b) All instruments must be calibrated against some unknown standards before use.

c) Calibration can be of two types: static and dynamic.



5.8 LET US SUM UP

- As the name suggest, a multi-meter is a versatile instrument that combines several functions into one unit.
- Analog multi-meters are commonly used electrical instruments implemented using a galvanometer.
- The digital multi-meter or DMM is a versatile device that can be used to measure both ac and dc voltage and current from say micro to a few tens or hundred ranges.
- Tong tester is a special purpose current probe which allows measurement of current without having to disconnect the conductor from the circuit.
- Energy meters can be used to amount of electrical energy consumed by consumers, industries etc while using electrical appliances.
- The megger is used to measure insulation resistance.
- Earth resistances become vital in such situations where an electrical appliance should be provided with a connection that has a flow continuity with ground.
- The basic electrical measurement instrument is the milli-ammeter. It

can be used for measurement of both voltage and current.

- High voltage testing and measurementequipments can be classified into two categories: Methods for measurement of RMS values and Methods for measurement of peak values of voltage.



5.9 FURTHER READINGS

1) Electrical Technology- B.L.Thareja, Khanna Publications.
2) Electrical and Electronics Measurement and Instrumentation- A. K. Sawhney, Dhanpat Rai & Co (Pvt) Ltd.
3) Electrical Technology- B.L. Thareja, Khanna Publishing,
4) Electrical Technology- Edward Hughes and Ian McKenzie Smith, ELBS



5.10 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) True b) True c) True d) False e) True.

Ans to Q No 2: a) True` b) True c) True

Ans to Q No 3: a) True b) Truec) True d) False

Ans to Q No 4: a) True b) Truec) True

Ans to Q No 5: a) True b) False c) True



5.11 MODEL QUESTIONS

Q 1: Why a multi-meter is a versatile instrument?

Q 2: What are the two broad classes of high voltage electrical measurement instruments?

Q 3: Describe the methods which can be used to extend the range of a voltmeter and an ammeter.

Q 4: Describe the working of a megger.

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UNIT 6 : WIRES AND ACCESSORIES

UNIT STRUCTURE

6.1 Learning Objectives

6.2 Introduction

6.3 Wires and Cables

6.4 Terminations and Joints

6.5 Wiring Accessories

6.6 Safety Considerations and Regulations

6.7 Let us Sum up

6.8 Further Readings

6.9 Answer to Check Your Progress

6.10 Model Questions

6.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- explain the types and characteristics of wire and cable
- describe the importance of joints and terminations
- discuss the accessories required for wiring
- familiarize with the electrical safety regulations and recommendations.

6.2 INTRODUCTION

In the previous unit you have learnt the electrical measurement instrument. In this unit, you will learn the basic principles behind electrical wires. You will also lean about wiring diagrams, types and characteristics of wire and cable. The unit shall also inform you regarding the importance of joints and terminations. You will also get an idea about wiring accessories, safety rules and regulations.

6.3 WIRES AND CABLES

Any metallic conductor with a symmetrical cylindrical shape that

facilitates conduction of electric charges and is shielded be a non-conducting cover is an electrical wire. Electrical wires have markings stamped or printed on the outside sheath of the cable which indicate the type and size of wire available for applications. The colour of the wires inside of the sheath, like in type indicates that different colour wires are intended for different purposes.

Black Wires - Black wires are always used for hot wires. These wires may feed a switch or outlet and are often used as switch legs. Black wire is not used for a neutral or ground connection.

Red Wires - Red wires are also used for hot wires, switch legs etc. Another useful application is the interconnect wire between two appliances.

Blue and Yellow Wires - Blue and yellow wires are used as main conductors and are pulled through conduits and casings. The blue wires are used as switch legs to things like lights and fans. Yellow wires are generally used for switch legs and control things like light, fans, and switched outlets.

Green and Bare Copper Wires - Green wires and bare copper wires are used only for grounding. These wires will ground devices and shall be bonded to junction boxes and appliance connections for safety.

Wire Color Exceptions - In certain instances, wire colors may be used for connections that don't follow these general rules. For instance, a white wire in a two-conductor cable may be used for the second hot wire on a 240-volt appliance or outlet connection.

A cable is formed by two or more wires running side by side and bonded, twisted or braided together to form a single assembly. Cables are used to carry special purpose electric signals. Cables have a protective jacket that works as insulation also. When a conductor carries current it radiates an electromagnetic field. It is true with a cable also. Similarly, a conductor or cables can also pick-up energy from any existing electro-magnetic field around. These effects are undesirable as it leads to unwanted transmission of energy which is loss making and unwanted pickup of noise which may degrade the desired signal being carried by the cable. It can also corrupt electric voltages being carried by a cable to such an extent as

to cause equipment malfunction.

There are particular cable designs that minimize electromagnetic pickup and transmission. These are shielding, coaxial and twisted-pair geometry used in cables.

Shielding encases the cable for its entire length in foil or wire mesh. All wires running inside this shielding layer is isolated from external electric fields, particularly if the shield is connected to a point of constant voltage, such as earth.

Coaxial design helps to further reduce magnetic transmission and pickup. In this design the foil or mesh shield is perfectly tubular - i.e. with a circular cross section - and the inner conductor is situated exactly at its center. This causes the voltages induced by a magnetic field between the shield and the core conductor to consist of two nearly equal magnitudes which cancel each other.

The twisted pair is a result of two wires twisted around each other, forming a pair of intertwined helices. This can be achieved by putting one end of the pair in a hand drill and turning while maintaining moderate tension on the line. Field cancellation between successive twists of the pair considerably reduces electromagnetic pickup and transmission.

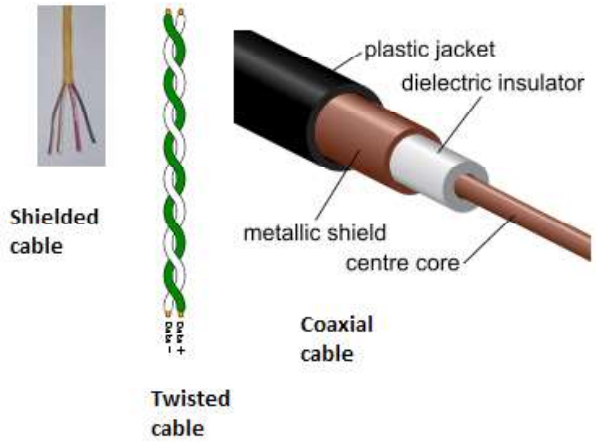


Figure 6.1: Shielded, twisted and coaxial cable.

Wires gauge and application:

Electric wires shielded with one medium of conduction are called a **single strand** wire. Single strand wires are generally used as hook-up wires. These are mostly used with jumper circuits, laboratory experiments and

certain low-voltage applications.

In contrast to single strand, **multi-strand** wires have several layers of conductors or more than one wires are packed so that they acquire greater current conduction capability. Multi-strand wires have several advantages compared to single strand wires. A few of them are:

- Greater flexibility
- Easy of bending in any direction
- Rugged
- Higher current carrying capacity, hence suitable for higher power applications Better compatibility with high frequency applications due to low frequency-induced losses
- Cancellation of nearby magnetic effects.

Certain considerations are taken into account while constituting stranded wires. Stranded wires will always have certain voltage ratings which must not be crossed for hazard free application. The wire has certain diameter specifications including the thickness of the jacket and a operation temperature limit which must not be exceeded to make it suitable for intended applications. The jacket around the wire is formed by an insulation layer which has strong resistance to prevent current flow through it. Some common insulation materials that are used as jackets across single and multi-strand wires are:

- Ethylene propylene diene elastomer (EPDM)- a chemically cross-linked elastomer with excellent flexibility at both high and low temperatures (- 55° C to 150° C).
- Polyethylene (PE) - a thermoplastic material with excellent electrical properties and a stable dielectric constant over all frequencies. It is stiff to very hard and provides excellent moisture resistance.
- Polyvinyl chloride (PVC) - a general-purpose thermoplastic used for wire and cable insulation. PVC offers high flexibility and is often used in nonplenum wire insulation and cable jackets. Modified PVC may be found in the jacketing of some plenum-rated cables.
- Teflon is used widely in wire and cable jacketing. It is inert to most chemicals and extremely slippery.

The material used as conductor of the wires also play an important role in determining its ability to conduct electricity. Some of the common choices are

- Aluminum- a metal characterized by high resistance to corrosion, proper electrical and thermal conductivity, and can be used as a power conductor, or for wire and cable shielding. Some wires have a steel core to which an outer shell of aluminum is fused.
- Copper and copper alloys offer high corrosion resistance, thermal conductivity, and ease of fabricating, joining and forming. Copper is the most widely used electrical conductor in wires and cables.

Conducting properties of wires are also dependent on the dimension of the conductor. American wire gauge (AWG) is a standard for wires made of non-ferrous conductor like copper and aluminum. The term “gauge” refers to the wire’s diameter. The higher the gauge number, the smaller the diameter and the thinner the wire. Typical household wiring is AWG 12 or 14. Telephone wire is usually AWG 22, 24, or 26. International practices may also indicate wire thickness in terms of square millimeters (mm^2).

Selecting the appropriate wire gauge is critical while ensuring safe functioning of appliances. The table below summaries the wire size in terms of gauge and the intended application.

Table 6.1: Wire conductor thickness and application

SlNum	Application	Ampere rating	Wire Gauge
1	Low-voltage Lighting and Lamp Cords	10 Amps	18 Gauge
2	Extension Cords	13 Amps	16 Gauge
3	Light Fixtures, Lamps, Lighting Runs	15 Amps	14 Gauge
4	Receptacles, 110-volt Air Conditioners, Sump Pumps, Kitchen Appliances	20 Amps	12 Gauge
5	Electric Clothes Dryers, 220-volt Window Air Conditioners, Built-in Ovens, Electric Water Heaters	30 Amps	10 Gauge
6	Cook Tops	45 Amps	8 Gauge
7	Electric Furnaces, Large Electric Heaters	60 Amps	6 Gauge
8	Electric Furnaces, Large Electric Water Heaters, Sub Panels	80 Amps	4 Gauge
9	Service Panels, Sub Panels	100 Amps	2 Gauge
10	Service Entrance	150 Amps	1/0 Gauge
11	Service Entrance	200 Amps	2/0 Gauge



CHECK YOUR PROGRESS

Q 1: Find True or False.

a) Black wires are always used for hot wires.

b) Green wires and bare copper wires are used only for supplying power.

c) Coaxial cables help to further reduce magnetic transmission and pickup.

6.4 TERMINATIONS AND JOINTS

In electrical installation and wiring appropriate termination is important to ensure safe operations of the appliances. Terminations ensure that the electric supply reaches the intended end and carries out the required work. An electric termination can be an appliance or a point from which another connection can be made. Without appropriate termination, an electrical connection may not only be dangerous but also prove to be loss making. An electrical termination is a connecting wire or cable or a special terminal or a terminal connector. Terminations are required to establish appropriate electrical connections. All terminations therefore should fulfill the following conditions:

- Physical firmness,
- Appropriate electrical conductivity and zero resistance and
- Prevention of contact with other metallic part, conductors etc near to it.

If terminations are loose following may occur:

a) Electrical arching leading to heating of wires and terminals with probability of burn out and fire;

b) Increase in electrical resistance leading to unwanted voltage drop;

c) Slipping of live wires from connections leading to electrical shock, short circuits, accidental fire and similar hazardous situations.

Therefore, extra-care must be taken while installing termination. Regular inspection is required to ensure that the terminations are firm and strong enough to withstand physical strain. It can be tested by pulling a

terminated wire either by hand or by using a tool. Also close scrutiny is required to prevent any terminating wire from touching some metallic contact that may exist in the vicinity even when the set-up is moved or shaken as part of some application.

There are three types of terminations:

1. Screw type termination
2. Crimp type termination and
3. Solder type termination.

1. Screw type termination- In this type of termination, a wire is skinned a bit at its end and wounded round a screw to which a nut is bolted and fixed. Over – tightening of the screw should be avoided as it can lead to cutting of the terminating wire. Special purpose nuts- bolts are available with appropriate teeth like arrangement to hold terminating wires firm. This type of connection is suitable for domestic low voltage (< 230 V) applications.



Figure 6.2: Screw type termination

2. Crimp type termination- This is stronger and a bit better then the screw type due to the fact that it establishes appropriate physical contact between a wire and a termination point. In this type of connection, conductors of a wire is inserted or placed in a crimping fitting or tied around crimp eyelets and reshaped into an arrangement using a crimping tool such that the joint with the termination point becomes securely fastened. It is a one-stroke process. A loosely crimped connection cannot be re-worked but shall require a fresh crimping. To ensure appropriate crimping the exact tool and arrangement is essential.



Figure 6.3: Crimp type termination

3. Soldering type termination- It is the best way to do a termination. A soldering instrument, material and flux is used to permanently fix a wire with a terminating point. The soldering iron when heated up using electric power burns the soldering material and fixes the joint.



Figure 6.4: Soldering type termination

Joints are required during wiring. Since there are corners and bend in the structures of houses, rooms and similar places where wiring is to be done, a host of joints are available to meet the requirements. A few of them are as below:

1. Straight joint.
2. Tee joint.
3. Right- angled joint.
4. Corner joint.
5. Tee-bridge joint.
6. Cross- bridge joint.

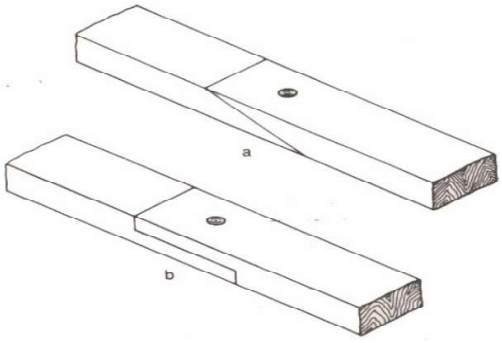


Figure 6.5: Straight joint

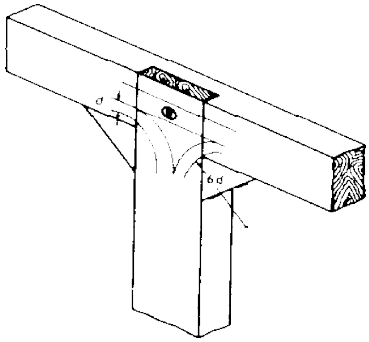


Figure 6.6: Tee- joint

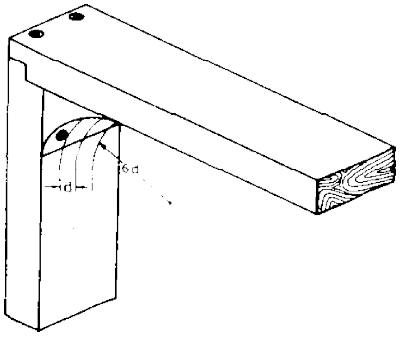


Figure 6.7: Right angled- joint

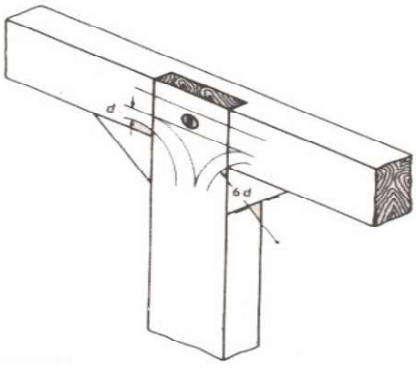


Figure 6.8: Tee- bridge joint

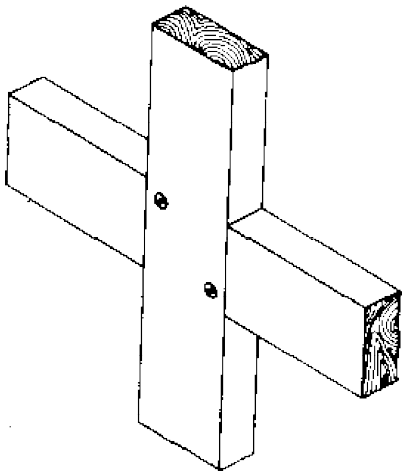


Figure 6.9: Cross bridge- joint



CHECK YOUR PROGRESS

Q 2: Find True or False.

a) An electrical termination is a connecting wire or cable or a special terminal or a terminal connector.

b) A termination should have appropriate electrical conductivity and zero resistance.

c) Regular inspection is required to ensure that the terminations are firm and strong enough to withstand physical strain.

d) In screw type of termination, a wire is skinned a bit at its end and wounded round a screw to which a nut is bolted and fixed.

e) Joints are required during inspection.

f) A loosely crimped connection can be re-worked.

6.5 WIRING ACCESSORIES

Electric accessories are essential components of the wiring process. Without them, the wiring remains incomplete. Junction box is an important wiring accessory. It is made of either metal, wood or PVC. It has certain dimension and is regularly used to hold wires joined for diversion and extension of connection. Sometimes junction boxes play the roles of termination points or electrical taps.

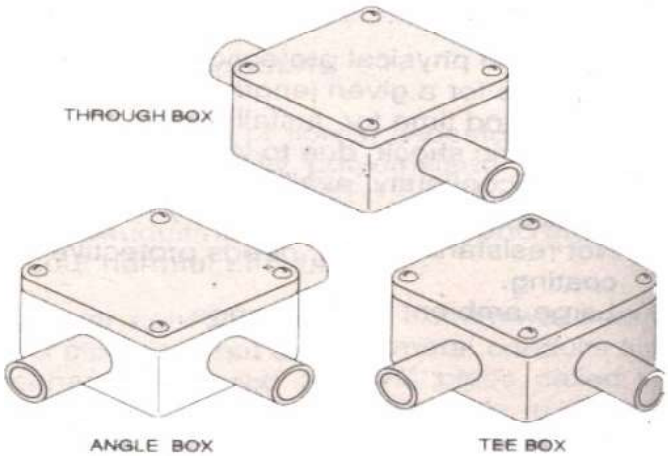


Figure 6.10: Junction box

Some other wiring accessories include the following:

1. Couplers
2. Elbow
3. Bends
4. Circular boxes
5. Rectangular boxes.

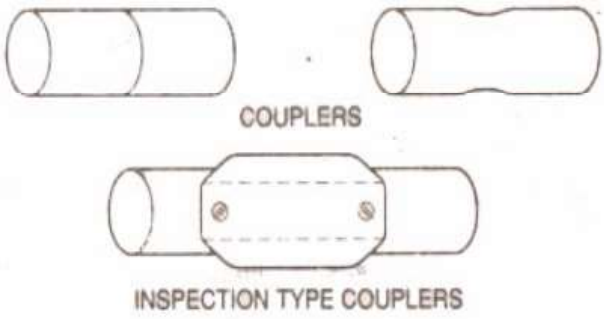


Figure 6.11: Couplers

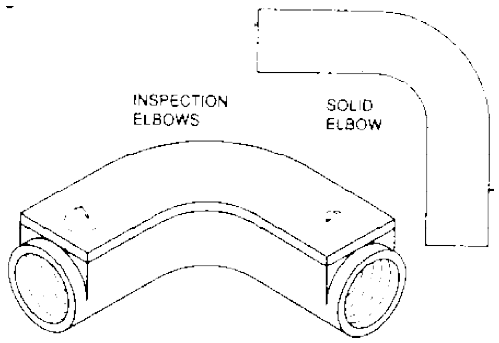


Figure 6.12: Elbows

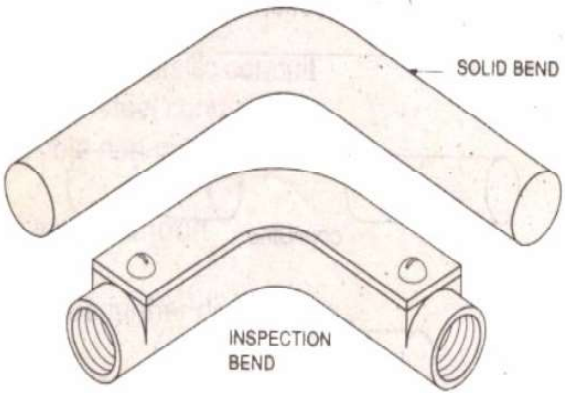


Figure 6.13: Bends

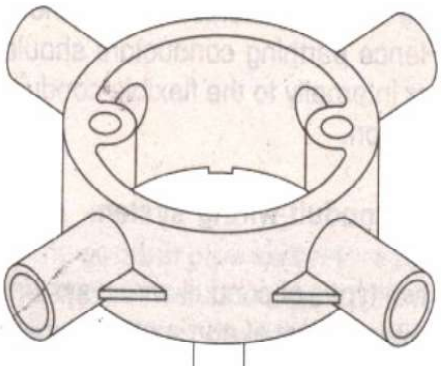


Figure 6.14: Circular box

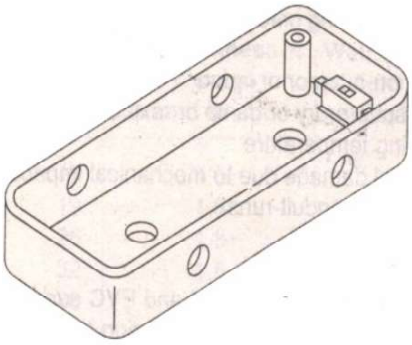


Figure 6.15: Rectangular box

Connectors- These are required to connect a switching arrangement for supply of electricity to common domestic appliances. Sometimes the connection can be with the phase line, at times to the neural and in certain cases to the earth connector. These are metallic and in most cases made up of brass. These connectors require screws to fix the links which come in appropriate sizes. Screws are available in brass as well as steel material.



Figure 6.16: Different types of connectors

Switch-

Single pole double through switches are common in domestic connections. These are used to connect the phase line to the appliances. Polycarbonate used in the switch to make them user friendly nearly safe. These prevent sudden spark and when in proper state they prevent fire, spark etc. Sizes of switches vary as per applications with 5A rates ones being the most common. Along with switches, sockets are also available. Like switches, sockets also vary as per applications. They can have a three or two wire connection.

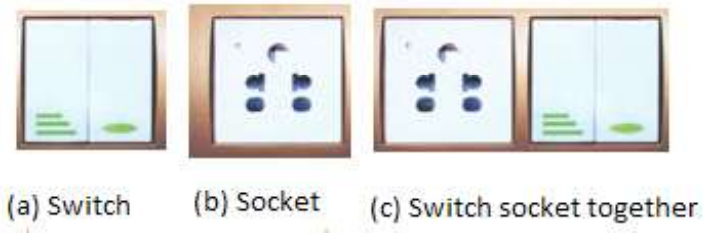


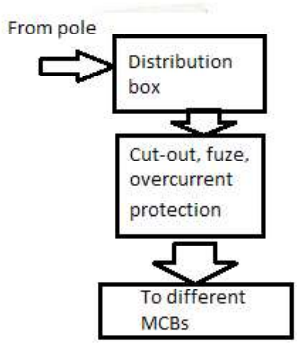
Figure 6.17: Switch and socket.

DB Box-

A distribution board (or panelboard) is part of an electricity supply system used to subdivide the incoming electrical power into subsidiary segments. The distribution board holds protective fuse which acts as a circuit breaker, a main switch and a few isolators in a common enclosure. Fuse Boxes usually use cartridge or rewirable fuses with no other protective device In certain cases these may even have Residual Current Breakers with Overcurrent protection (RCBO) for greater safety and higher voltage appliances.



(a) Distribution board



(b) From pole through DB to MCBs

Figure 6.18: Distribution board.

MCB Box

MCB stands for miniature circuit breaker. It is an arrangement through which a number of switch boards can be connected to the distribution box. The switch boards are used by the consumer to run an electrical appliance.

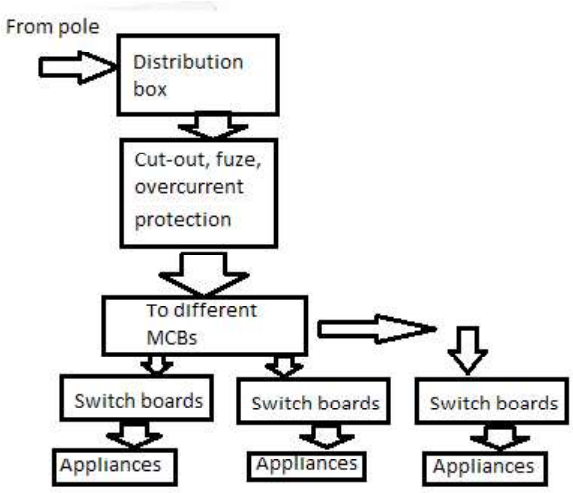


Figure 6.19: From pole to the appliance through the MCB.

The MCB is formed by a number of isolators, two-way single pole switches etc. which ensure safe connection and supply of electric power. The MCB has slots for input, output and earth connection. Special metallic enclosures are available for holding the MCB arrangement. The MCB shown in Figure 2.20 is a single pole with neutral, busbar, incoming contact, din channel and has a transparent acrylic window.



Figure 6.20: MCB with enclosure



CHECK YOUR PROGRESS

Q 3: Find True or False.

a) Junction box is made of either metal, wood or PVC.

b) Junction box is used to hold wires joined for diversion and extension of connection.

c) MCB stands for Miniature Circuit Beaker

6.6 SAFETY CONSIDERATIONS AND REGUALTIONS

Some electrical safety considerations should always be flowed for safe operation of appliances and installation. A few of the safety considerations are listed below:

- Don’t put a lot of connections into one electrical or extension cord. It could damage the electrical system in the premises or even cause a fire.
- Always ask the technician to put safety caps on all unused electrical outlets. It will provide safety
- Don’t pull an electrical cord from the wall. It can damage an appliance, the plug or the outlet.
- Always ensure that all electric cords are installed with casing or concealment neatly and tidy. Else pets might chew on electrical cords, and people might trip and fall.
- Always have a line tester to test a supply line before doing any

maintenance work. Don't touch a live wire, it can be dangerous.

- While working with electrical appliances using a ladder always ensure that there is no open connection or live conductor around which is carrying current. It can give electric shock on touching.
- Always keep electrical items away from water and fire.
- Do not touch or tamper with any electrical gear or conductor unless it is not conducting electricity and earthed.
- Do not open or close switch or fuse slowly or hesitatingly. Do it quickly and positively.
- Do not use wires with poor insulation.Do not touch any electrical circuit when your hands are wet or bleeding from a cut or an abrasion

In India, electricity considerations are governed by the provisions of the Indian Electricity Rules, 1956. It contains details of nearly all provisions of electricity generation, distribution, use, safety etc. Also the Electricity Act, 2003 provides a set of laws governing generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff etc.



CHECK YOUR PROGRESS

Q 4: Find True or False.

a) Some electrical safety considerations should always be flowed for safe operation of appliances and installation.

b) Also the Electricity Act, 2003 provides a set of laws governing generation, transmission, distribution etc.



6.7 LET US SUM UP

- Electrical wiring is a system through which electricity is distributed from a source to appliances.

- Cleat wiring is a cheap wiring method and is most suitable for temporary wiring.
- Batten wiring is suitable on wooden battens.
- Casing capping wiring is suitable for low voltage installation.
- A conduit is a type of a tube or channel. Tubular conduit is the most commonly used material in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.
- An electrical wiring diagram is an installation plan required to set-up an electrical system which can be used for domestic, commercial and industrial purposes as per requirements.
- Electrical wires have markings stamped or printed on the outside sheath of the cable which indicate the type and size of wire available for applications.
- An electrical termination is a connecting wire or cable or a special terminal or a terminal connector. Terminations are required to establish appropriate electrical connections.
- Electric accessories are essential components of the wiring process. Without them wiring remains incomplete.
- Some electrical safety considerations should always be flowed for safe operation of appliances and installation.



6.8 FURTHER READINGS

1) Process Control and Instrumentation Technology- Johnson, Pearson Education, 1st Ed., New Delhi, 2003.
2) Electrical and Electronics Measurement and Instrumentation- A. K. Sawhney, Dhanpat Rai & Co., Eleventh Ed., New Delhi, 1997.
3) Indian Electricity Rules, 1956.
4) Electrical Technology- B.L. Thareja, Khanna Publishing,
5) Electrical Technology- Edward Hughes and Ian McKenzie Smith, ELBS.

6.9 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) True b) False c) True

Ans to Q No 2: a) True b) True c) True d) True
e) False f) False

Ans to Q No 3: a) True b) True c) False

Ans to Q No 4: a) True b) True

6.10 MODEL QUESTIONS

Q 1: What is electrical wiring? Why is it necessary? What are its different types?

Q 2: What is conduit wiring? Describe briefly.

Q 3: Write a brief note regarding the importance of wiring diagram.

Q 4: Write short notes on the following:

a. Electrical accessories

b. Electrical terminations

c. Electrical Safety Norms

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UNIT 7 : ELECTRICAL HOUSE WIRING

UNIT STRUCTURE

7.1 Learning Objectives

7.2 Introduction

7.3 Methods of House Wiring

7.4 Wiring and its Types

7.5 Wiring Diagrams

7.6 ToolsUsed in Wiring

7.7 Let us Sum Up

7.8 Further Readings

7.9 Answer to Check Your Progress

7.10 Model Questions

7.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- explain the methods ofhouse wiring
- describe the types of wiring
- discuss the wiring diagrams
- describe the importance of wiring tools and accessories.

7.2 INTRODUCTION

In the previous unit you have learnt the use of wires and accessories.In this unit, you will learn the methods of house wiring. This unit will also provide you the various types of wiring. You will also lean about wiring diagrams and characteristics.The technician requires a ranges of tools to make proper of the electrical instruments. The commonly used screw driver, hacksaw, hammer etc. are required by the technician to fix an electrical problem. Similarly, there are tools for cutting wood, metal etc. This unit provides a brief introduction about these tools as well.

7.3 METHODS OF HOUSE WIRING

Out of the above mentioned tasks of an electrician, House Wiring is most common task. So let us discuss it in some detail. House wiring refers to the ofproviding electrical connection to a house, building or premises. Proper House wiring is necessary to cause and facilitate controlled and safe flow of the electrical power from the electrical power distribution system to electrical loads in a house, building or premises. Electrical connection to a house or building is given from the nearby electrical power carrying conductors of electrical power distribution system of supplier like the electricity board. This connection is called service connection. Rating and type of service connection depends on the electrical load. One has to apply and complete certain formalities for obtaining a service connection. House wiring starts from the entry of the service connection. At the beginning is the energy meter and main switch or circuit breaker with safety switches and devices. Then there may be panel and switchboards. Laying of conductors, cables, switch boards and the fitting of accessories for light, fan and other devices form the common house wiring tasks. Now a day installation of voltmeters, ammeters both analog and digital and indicators at various points are frequently done to display the instantaneous values. Necessary rating, specifications and quality of materials, fittings and items are to be decided considering the requirements, related factors and the possibility of future expansion. Some important steps in house wiring are

1. Making a plan
2. Drawing a layout diagram
3. Selecting location for Energy meter and Mains switch
4. Load calculation
5. Selection of wires, cables and fitting accessories.
6. Deciding on points/location for light, fan
7. Location for switch boards
8. Earthing
9. Testing

Depending on the load house wiring is classified as Domestic house

wiring and Industrial house wiring. Domestic house wiring is for residential houses and buildings with normal household electric loads like light, fan etc and without heavy machineries like high capacity motors. Industrial house wiring is for factories and industrial units with heavy machineries. Industrial house wiring supplies electric powers to heavy loads like high capacity electric motors, heaters, furnace, etc.and requires special safety and control devices which are also costly.

7.4 WIRING AND ITS TYPES

Electrical wiring is a system through which electricity is distributed from a source to appliances. Electrical wirings maybe different with the field of application. Normally electricity is used for domestic, commercial and industrial purposes. Wiring considerations also vary according to these requirements. The wiring requirements for domestic appliances are very much different to that of industrial applications. Similar differences exist between the requirements of commercial and domestic applications.

The electricity reaches to a household through the distribution system (Figure 1.1 a). Generally, the power stations step up three phase 11KV supply to 132KV and distribute it through transmission grids till it reaches a substation where it is stepped down to 11KV and send for domestic consumption. Next, from such a supply, a connection for domestic consumption is terminated at an electric pole. From this termination pole two insulated copper wires come to the household connection from where the electricity is distributed among the appliances. A high potential of 220 V at 50 Hz is given to one of these wires. It is called **live wire** and is denoted by L. A wire having red-coloured insulation is used as a live wire for domestic connection. The other wire is held at ground potential of zero volt and is known as the **neutral wire**. It is represented by N. Any wire except with red and green colour maybe used as neutral wire. The domestic appliancesare connected in parallel to these two wires from which they draw electric power. An arrangement for a typical household circuit is shown in Figure 1.1b.

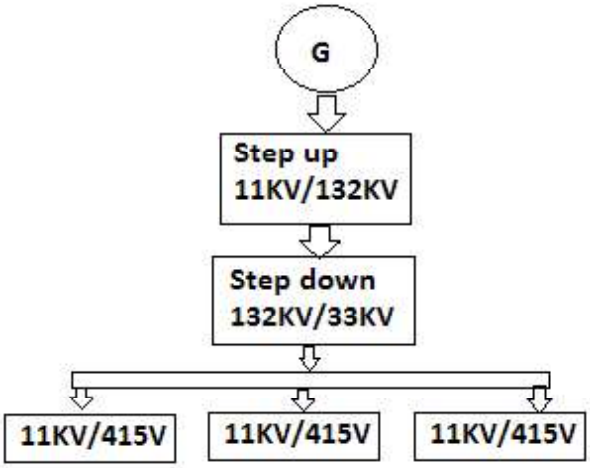


Figure 7.1 a: Electricity from generator to home

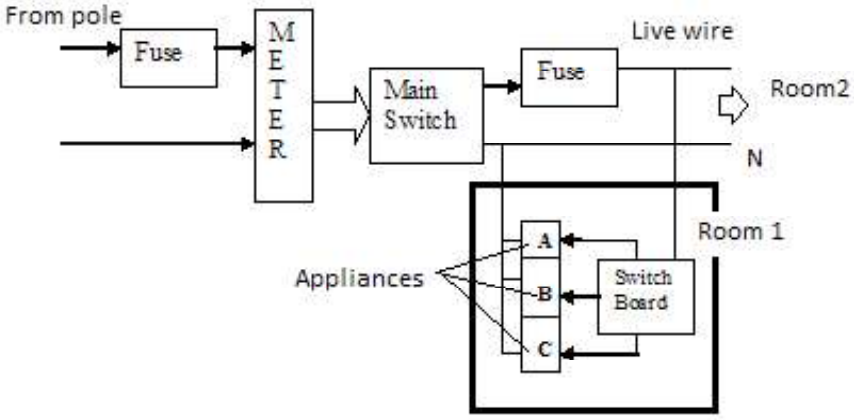


Figure 7.1b: Domestic connection from pole

For domestic consumption electricity is available in two pin or three pin outlets.

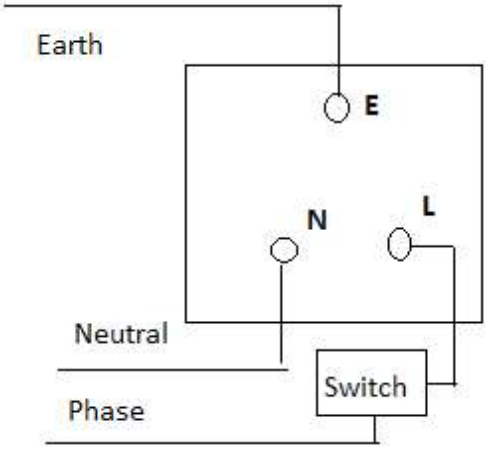


Figure 7.1 c: Phase neutrality in a 3-pin outlet.

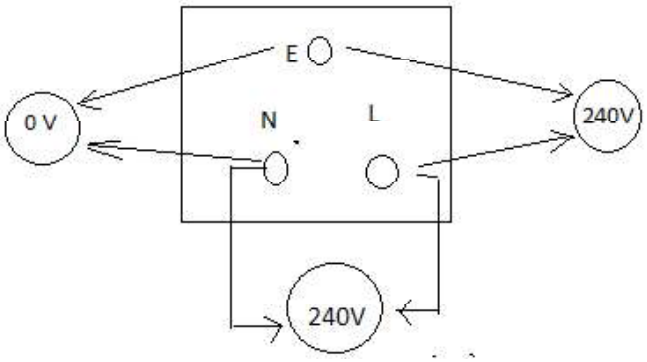


Figure 7.1d: Voltage distribution in a 3-pin outlet.

The phase line should be connected through a single pole on/off switch. Phase should always be to the right side of the socket and should be connected through a switch. The voltage distribution as shown in Figure 7.1d should be ensured for safe working of the electrical appliances.

The types of wiring to be adopted is dependent on various factors, viz, durability, safety, appearance, cost, consumer's budget etc. Generally following are the types of wiring observed in terms of wiring – practice to fulfill domestic, commercial and industrial applications:

- Cleat Wiring
- Batten Wiring
- Casing capping wiring
- Conduit Wiring

Cleat Wiring:

Cleat wiring is a cheapwiring method and is most suitable for tempo

rary wiring. This wiring can be quickly installed, easily inspected and altered. When not required, this wiring could be dismantled without damage to the cables, cleats and accessories.

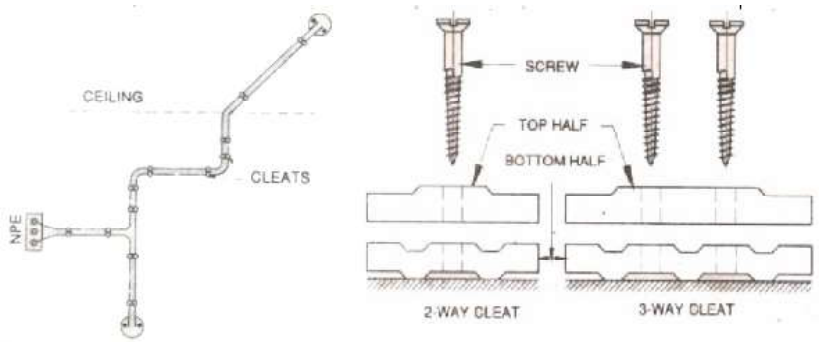


Figure 1.2: Cleat wiring

This wiring is not employed for wiring on damp walls or ceilings unless precautions are adopted for effectively preventing dampness and thus the deterioration of the insulation of the conductors.Vulcanized rubber insulted cables, PVC and polythene insulted cables, braided or unbraided insulted cables are used withfurther safety and protection considerations.

Where cleat wiring is laid along an iron made structure, porcelain cleats are inserted either with varnished wood fillets or varnished wood clamps securely fixed so as to prevent the conductors from coming in contact with the metal along witch they are passing.

No cleat wiring is to be left unprotected up to 1.5 m above the floor level. When brought through the floor it is enclosed in a conduit.

Batten Wiring:

This type of wiring is suitable on wooden battens. Tough rubber-Sheathed (T.R.S.) or PVC- Sheathed cables are suitable for batten wiring. Varnishing of teak wood batten is done before wiring. There are proper methods for securing the battens. The wiring must consider how the conductors are passed through the walls and cables are securely held. Special link clips are used to tie up conductors used in batten wiring. Link clips are made of tin or brass- coated tin or aluminium.

Casing Capping Wiring:

This system of wiring is suitable for low voltage installation. Cables surrounded by vulcanized rubber, insulated cables or plastic insulated cables are use in this type of wiring. These wires are carried within the casing enclosures. Casing maybe made of wood or PVC. The wood casing wiring is not used in damp places and in ill-ventilated places, unless suitable precautions are taken. Wood casing used should have special consideration. All casing should be made of first class, seasoned teak wood or any other approved hardwood free from knots, shakes, saps or other defects, with all the sides with a smooth finish, and all sides well varnished, both inside and outside. The casing should have a grooved body with a beaded or plain-moulded cover.

The size of casing and capping to be used for various sizes of 250 volts grade insulated cables in a groove must be in accordance with

recommendations.



Figure 7.3: Wooden casing wiring

Nowadays PVC casing is also used. Domestic PVC casings come in 1-inch, ¾ - inch and ½ - inch sizes through which wires pass. The casings are securely fixed on walls.

Conduit Wiring:

A conduit is a type of a tube or channel. Tubular conduit is the most commonly used material in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

There are four types of conduits used for wiring.

1. Rigid steel conduit
2. Rigid non-metallic conduit
3. Flexible steel conduit
4. Flexible nonmetallic conduit.



CHECK YOUR PROGRESS

Q. No. 1. Find True or False.

a) Cleat wiring is a cheapwiring method and is most suitable for permanent wiring.

b) Special link clips are used to tie up conductors used in batten wiring.

c) Casing capping system of wiring is suitable for low voltage installation.

d) When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

7.5 WIRING DIAGRAMS

An electrical wiring diagram is an installation plan required to set-up an electrical system which can be used for domestic, commercial and industrial purposes as per requirements. The diagram consists of details of different connections relative distances, wires to be used, number of sockets and switches to be used, distribution box location, electrical taps etc. It also contains details of wire characteristics and types, types of wiring to be used etc. A wiring diagram is different from a schematic diagram. Wiring diagrams use more symbolic notation to emphasize interconnections over physical appearance.A pictorial diagram shows more details of the physical appearance unlike a wiring diagram. Wiring diagrams are full of electrical symbols of sockets, switches, fans, panel boards etc. The electrical symbols not only show where something is to be installed, but also what type of device is being installed.A set of wiring diagrams may be required by the electrical inspection authority to approve connection for domestic, commercial or industrial purposes taken from a public electrical supply system.A wiring diagram is an important aid for trouble shooting can help in locating where a fault can be.

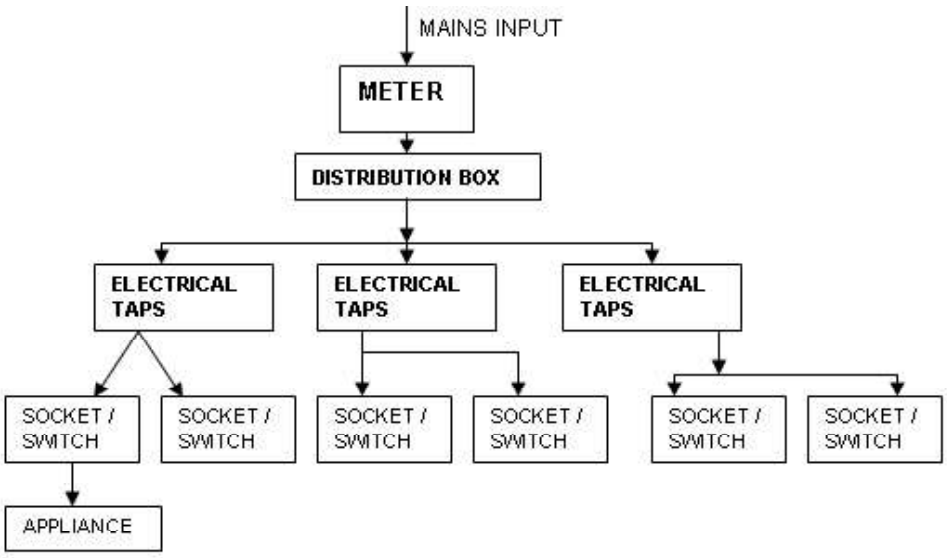


Figure 7.4: Schematic diagram

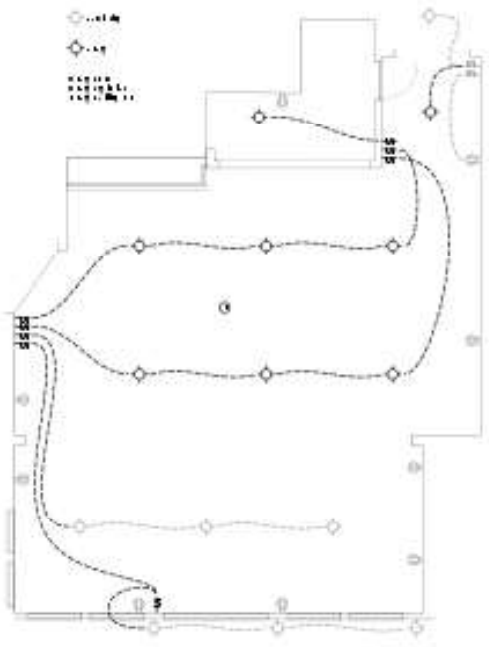


Figure 7.5: Wiring diagram



CHECK YOUR PROGRESS

Q 2: Find True or False.

a) An electrical wiring diagram is an installation plan required to set-up an electrical system.

b) A wiring diagram is different from a schematic diagram.

c) Wiring diagrams are full of electrical symbols of sockets, switches, fans, panel boards etc.

7.6 TOOLS USED IN WIRING

Electrical tools are the aids with which the technician can make the electrical appliances operational. Without the help of the tools the user cannot make the electrical instrument ready to do some useful work. Tools are required even during testing and maintenance of electrical appliances. The technician always carries a set of tools commonly required to make an electrical appliance operational. Even the user should possess a selective set of such tools to carry-out some initial work before or after installation of an electrical appliance. Some of the commonly required tools are described below:

Screw driver

Screw driver is a tool used to tighten screws and electrical machines. Screw drivers come in different shapes and sizes as per the requirement and types of screws. Screw drivers used for electrical applications are insulated to prevent accidental shock. The appearance of a screwdriver is constituted by a head or tip. The tip comes in contact with a screw. The screw driver also has a facility to apply force by rotation of the tip. It also has some way to fix the position with the screw and support the screwdriver with a cylindrical handle approximately similar in size and shape to be held by a human hand. An axial shaft is fixed to the handle. The handle ends in a tip which is shaped to fit a particular type of screw. The combination of the handle and shaft allow the screwdriver to be positioned and supported. These two also allow force to be applied when rotated.

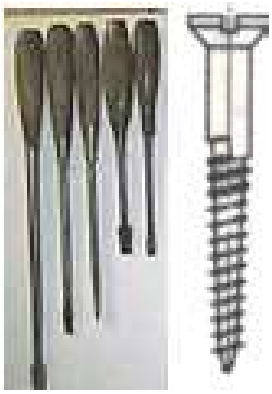


Figure 7.6: Screw drivers of different shapes

Files:

File is a tool used to cut a fine piece of metal from a bigger metal block. A file can have an all metal handle, a sharp ridge called tooth. The tooth maybe sharp and is used to cut metal. The tooth may come in different shapes and sizes as per the requirement.

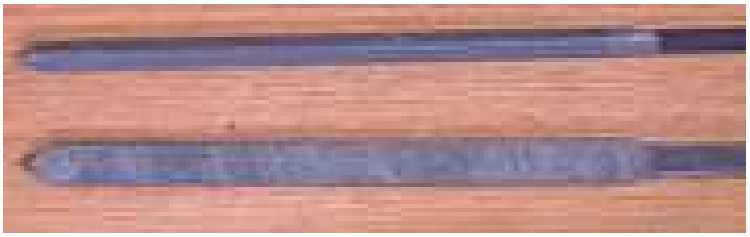


Figure 7.7: Set of two files

Chisel:

A chisel is a tool used to cut wood. It is formed by a handle that has a sharp cutting edge or a blade at one of its end. The other end of the handle is formed by a head which maybe metallic or wooden. The sharp edge or blade is placed over wood and manual force applied using a mallet or hammer. Some chisel maybe used to cut metal as well.

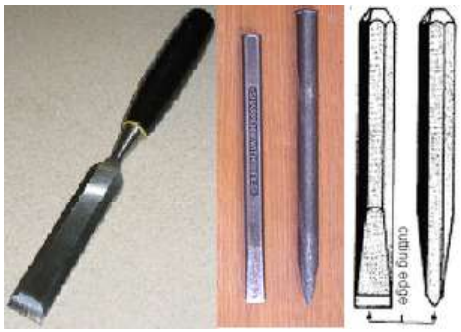


Figure 7.8: Set of chisels

Marking punch:

Marking punches can beused as a center punch or to permanently mark parts or equipment using number or letter punches. Such marks are required for identification purposes. Also, punching is done to identify a location where a drilling is to be done. It may also be done to position dividers and make dimensional changes in a container. Punchers are made of hardened steel with a narrow tip on one end.



Figure 7.9: Marking punch

Calipers

A caliper is used to find the distance between two ends of an object such that the measurement can indicate very finer differences. The tips of the caliper can be moved flexibly so to hold the points across which the measurements are to be made. The caliper has one ruler which contains a scale to record the distance between the points.

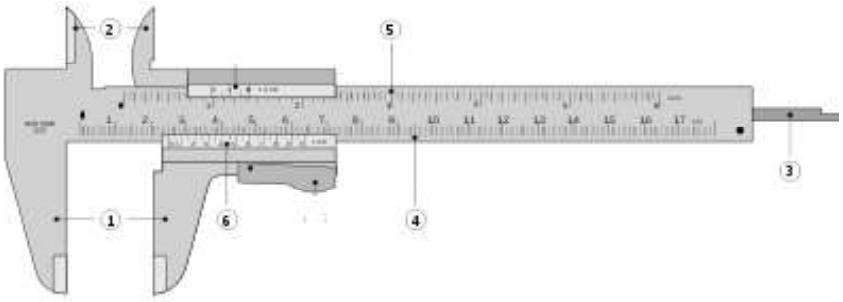


Figure 7.10: Caliper

Parts of a vernier caliper:

1. *Outside jaws* find external diameter or width of an object.
2. *Inside jaws* are used to measure internal diameter of an object
3. *Depth probe* determines the depths of an object or a hole
4. *Main scale* is used to mark the measurement in inches and fractions
5. *Vernier* gives values scaled to 1/10 mm or better
6. *Retainer* blocks the movable part to permit recording of a measurement

Gauge:

In electrical measurement gauge is related to the wire. The diameter of an electrical wire is fixed by the American Wire Gauge (AWG) standard which with different numbers means varying diameters of wires. Varying diameters of wires represent varying current carrying capacity. As gauge numbers increase from 0 to 36, the diameter and circular area decreases. Higher wire gauge indicates thinner wire sizes. The circular are doubles for every three gauge sizes. For example, No. 7 gauge wire has approximately twice the area of No. 10 wire gauge.

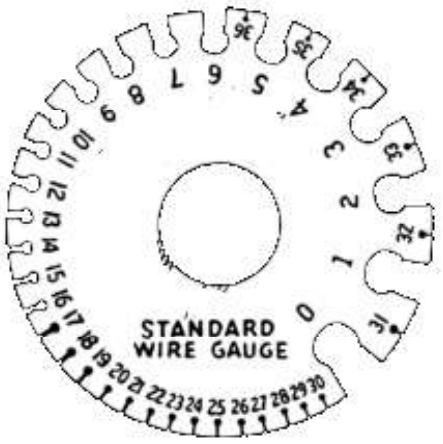


Figure 7.11: Wire Gauge

Hacksaw

A hacksaw is tool used for cutting metal etc. Domestic hacksaws are found in hand-held forms with a frame holding a specially designed blade under tension. The handle ends in a grip which is suitably designed for holding by the hand to enable application of manual force.

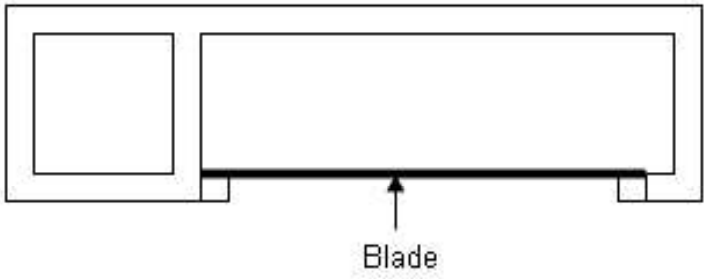


Figure 7.12: Hacksaw

Bench vice

A viceis metallic apparatus that uses a screw to hold a piece of wood, metal etc to enable cutting or reshaping work to be done using saws, planes, screwdrivers etc.The vice is formed by one fixed jaw and the other a movable. Both of them are parallel. The position of the movable one is altered using a screw. Though common vices are hand-held or can be mounted over benches, there are large mechanical vices as well which can be used for special applications.

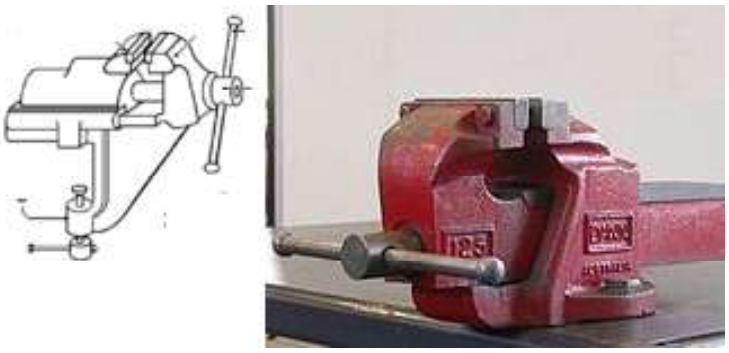


Figure 7.13: Bench Vice

Hammer:

A hammer is a tool used most commonly to force bails inside wood. It is a tool required to apply an impact on an object to change position or alter shape. Other applications of hammer include fitting parts, forging metal etc. Hammers come in different shapes and sizes as per the requirement.

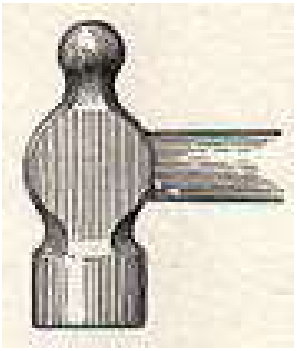


Figure 7.14: Hammer

Taps:

Taps are used in different ways in electrical applications. They are commonly used to split household circuits to allow multiple devices to use the same electrical outlet. Three- and six-outlet adapters that plug into wall sockets are sometimes referred to as triple-taps and six-taps. Taps are points from where electric connection is established. Tap most commonly refers to a terminal from which certain amount of current can be drawn.

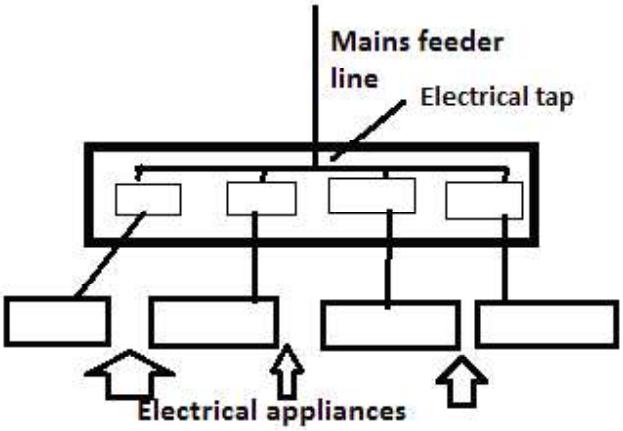


Figure 7.15: Electrical tap

Wrench:

A wrench or spanner is used to provide mechanical force to turn objects in rotary forms to fasten nuts and bolts so as to prevent them from turning. Wrenches are made of special quality allows made from chromium – vanadium and are chrome plated. Some wrenches are made for specific nut while adjustable wrenches can be used with any type of nuts.



Figure 7.16: Wrench

Crimping tool:

Crimping is the process of joining two pieces of metal or other malleable material by changing the shape of one or both of them to hold each other together. The tool used to carry out this process is called a crimping tool.



Figure 7.17: Crimping tool

Drilling machine

At times holes or gapes maybe required to be created over plastic, wood, concrete walls and metals. For such processes, drilling can be carried out. A hand – held drilling machine is a handy tool which can be used for such purposes.There are power drilling machines as well but these are costly and a bit complicated. The hand held manual drilling machine safer and quieter than a power drill, and costs much less. The drilling machine has a head on which needles of different sizes and shapes maybe mounted. A hand operated paddle is used to apply force on the surface on which a hole is to created. As the paddle is moved in a direction, the needle moves inwards and pierces through the surface upto the required depth.



Figure 7.18: Hand held drilling machine



CHECK YOUR PROGRESS

Q 3: Find True or False.

a) Screw driver is a tool used to tighten screws and electrical machines.

b) File is a tool not used to cut a fine piece of metal from a bigger metal block.

c) A chisel is a tool used to cut wood.

d) Punching is done to identify a location where a drilling is to be done.

e) A caliper is used to find the distance between two ends of a object such that the measurement can indicate very finer differences.

f) As gauge numbers increase from 0 to 36, the diameter and circular area increases.

g) Domestic hacksaws are found in hand-held forms with a frame holding a specially designed blade under tension.



7.7 LET US SUM UP

- Electrical wiring is a system through which electricity is distributed from a source to appliances.
- Cleat wiring is a cheapwiring method and is most suitable for temporary

wiring.

- Batten wiring is suitable on wooden battens.
- Casing capping wiring is suitable for low voltage installation.
- A conduit is a type of a tube or channel. Tubular conduit is the most commonly used material in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.
- An electrical wiring diagram is an installation plan required to set-up an electrical system which can be used for domestic, commercial and industrial purposes as per requirements.
- Electrical tools are the aids with which the technician can make the electrical appliances operational.
- Screw driver is a tool used to tighten screws and electrical machines.
- File is a tool used to cut a fine piece of metal from a bigger metal block.
- A chisel is a tool used to cut wood.
- Punching is done to identify a location where a drilling is to be done.
- A caliper is used to find the distance between two ends of a object such that the measurement can indicate very finer differences.
- As gauge numbers increase from 0 to 36, the diameter and circular area decreases.
- Domestic hacksaws are found in hand-held forms with a frame holding a specially designed blade under tension.
- A **vice** is metallic apparatus that uses a screw to hold a piece of wood, metal etc to enable cutting or reshaping work to be done using saws, planes, screwdrivers etc.
- Hammer is a tool required to apply an impact on an object to change position or alter shape.
- Tap most commonly refers to a terminal from which certain amount of current can be drawn.
- Wrenches are made of special quality allows made from chromium – vanadium and are chrome plated. Some wrenches are made for specific nut while adjustable wrenches can be used with any type of

nuts.

- **Crimping** is the process of joining two pieces of metal or other malleable material by changing the shape of one or both of them to hold each other together.
- At times holes or gapes maybe required to be created over plastic, wood, concrete walls and metals. For such processes, drilling can be carried out.



7.8 FURTHER READINGS

1) Process Control and Instrumentation Technology- Johnson, Pearson Education, 1st Ed., New Delhi, 2003.

2) Electrical and Electronics Measurement and Instrumentation- A. K. Sawhney, Dhanpat Rai & Co., Eleventh Ed., New Delhi, 1997.

3) Indian Electricity Rules, 1956.



7.9 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) False b) True c) True d) True

Ans to Q No 2: a) True b) True c) True

Ans to Q No 3: a) True b) False c) True d) True
e) True f) False g) True



7.10 MODEL QUESTIONS

Q 1: What is electrical wiring? Why is it necessary? What are its different types?

Q 2: What is conduit wiring? Describe briefly.

Q 3: Write a brief note regarding the importance of wiring diagram.

Q 4: Write a brief note regarding the importance of tools to a technician.

Q 5: Write short notes on the following:

a. Screw drive

b. File

c. Wrenches

d. Calipers

e. Crimping

f. Vice

g. Hacksaws.

*** ***** ***

UNIT 8 : EARTHING

UNIT STRUCTURE

8.1 Learning Objectives

8.2 Introduction

8.3 Importance of Earthing

8.4 Basic Considerations of Earthing

8.4.1 Measurement of Soil Resistivity

8.5 Types of Ground Connections

8.5.1 Pipe Earthing and

8.5.2 Plate Earthing

8.6 Ground Testing

8.7 Let us Sum up

8.8 Answer to Check Your Progress

8.9 Further Readings

8.10 Model Questions

8.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- discuss the importance of earthing
- explain the types of ground connections for earthing
- describe the process of ground testing.

8.2 INTRODUCTION

In the previous unit we have discussed the basic concept of electrical wiring. In this unit, we will focus on the basic principles behind earthing and its importance. You will also lean about the basic considerations which are taken into account while doing earthing and the accessories that are required to do ground connections for earthing. The unit shall also inform you regarding the types of earthing, methods in which these are implemented and the testing associated in the earthing process.

8.3 IMPORTANCE OF EARTHING

A grounding system is an essential component of an electrical system. It allows the excess charges to flow through without causing damage to the system. Without an effective grounding system, the user is exposed to the risk of electricshock. An electrical system without an effective ground is always hazardous. An earthing is a conductingconnection, whether intentional or accidental between an electrical circuitor equipment and the earth, or to some conducting body that permits excess electric current to flow to or sink into the earth.

Earthgrounding is an intentional connection from a circuit conductor usuallythe neutral to a ground electrode placed in the earth. Equipment groundingis to ensure that operating equipment within a structure is properlygrounded. These two grounding systems are required to be kept separateexcept for a connection between the two systems to prevent differencesin potential from a possible flashover from a lightning strike.

By putting proper grounding in an electrical, system, safety is ensured and it becomes less risky for operation and use. Grounding connections provide a safe path for the dissipation of fault or excess currents, lightning strikes, static discharges etc.

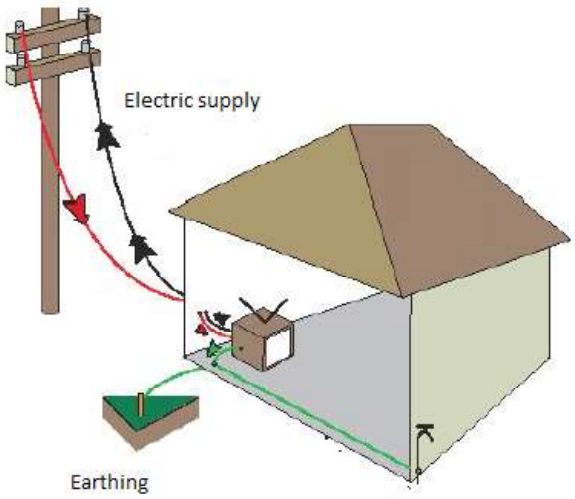


Figure 8.1: Shielded, twisted and coaxial cable.

All earthing conductors should be of high conductivity G.I./ Aluminum /copper and is protected against mechanical injury or corrosion.

Main earthing conductors are taken from the earthconnections at the main switchboards to an earth electrode withwhich the connection is to be made. Sub-earthing conductors runs from the main switchboard to the sub-distributionboards. Final distribution boards earthing conductorsshall run from sub-distribution boards.

Earthing conductors, outside the building, should be laid 600 mmbelow the finished ground level.

Neutral conductor, sprinkler pipes or pipes conveying gas, wateror flammable liquid, structural steel work, metallic enclosures forcables and conductors, metallic conduits and lightningprotection stem conductors must not be used as a means ofearthing an installation or even as a link in an earthing system.The electrical resistance of metallic enclosures for cables andconductors measured between earth connections at the mainswitchboard shall be low enough to permit the passage ofcurrent necessary to operate fuse or circuit breakers and shallnot exceed one ohm. When there is evidence that the soil is aggressive to copper, buried earthing conductors should be protected by suitable serving andsheathing so that the earthing conductor is not damaged by corrosion.



CHECK YOUR PROGRESS

Q 1: Find True or False.

a) A grounding system allows the excess charges to flow through without causing damage to the system.

b) Earthing conductors, outside the building, should be laid 600 mm below the finished ground level.

c) By removing proper grounding in an electrical, system, safety is ensured and it becomes less risky for operation and use.

8.4 BASIC CONSIDERATIONS OF EARTHING

To prevent damage and insure proper operation of electrical equipment, dissipation of lightning energy and return paths forground fault currents is a necessity. This equipmentincludescomputers, other electrical and electronic equipmentlike Magnetic Imaging equipment, Telecom

Installations and MicrowaveTowers, CNC Machines and other Sophisticated Electronic equipment used in differentIndustries Offices and Electric Power Substations.Proper grounding has other benefits, such as Enhanced Personnel Safety, Reduction inSystem Noise and Protection from Unwanted Voltages, Currents and Power Surges andProtection from Lightning. Without a proper “Low-Impedance Ground”, standardprotection devices such as breakers - or transient voltage surge and lightning protectionsystems - are rendered ineffective. When grounding systems are installed they are required to meet certain resistancecriteria, such as 10, 5, 3 or 1 ohm. Unfortunately, most grounding systems are notproperly maintained and tested after installation.

There are confusions regarding proper groundand the appropriate ground resistance value that needs to be selected. Ideally a ground should be of zero ohms resistance. A singleelectrode consisting of a rod, pipe,or plate which does not have aresistance to ground of 25 ohms orless should be augmented by oneadditional electrode. This does not mean thatthe value of the ground now has tobe 25 ohms or less. The groundresistance values objectives varyfrom industry to industry.Telecommunications industry hasoften used 5 ohms or less as theirvalue for grounding and bonding.The goal in ground resistance valuesis to achieve the lowest groundresistance value possible that makessense economically and physically. Grounding is done with the help of electrodes.

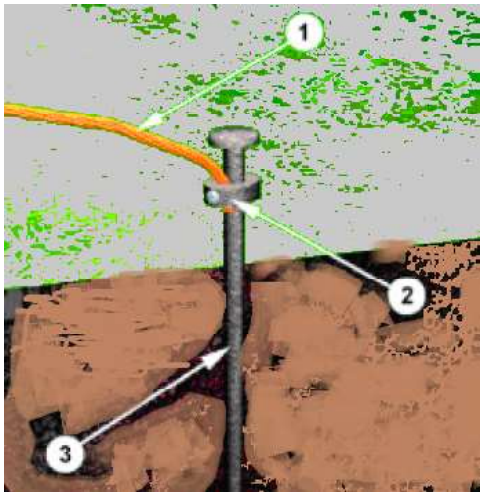


Figure 8.2: Ground electrode components

The essential components of a ground electrode are as below:

1. Ground conductor
2. Connection/bonding of the conductorto the ground electrode and
3. Ground electrode.

The resistance of a ground electrode has three basic components:

A) The resistance of the groundelectrode itself and the connectionsto the electrode.The resistance of the ground electrode andits connection is generally very low. Groundrods are generally made of highly conductive/low resistance material such as steelor copper

B) The contact resistance of thesurrounding earth to the electrode. This resistance is found to bealmost negligible provided that the groundelectrode is free of paint, grease, etc. andthat the ground electrode is in firm contactwith the earth.

C) The resistance of the surroundingbody of earth around the groundelectrode.The ground electrode is surrounded by earth which is made up of concentricshells all having the same thickness.Those shells closest to the ground electrodehave the smallest amount of area resultingin the greatest degree of resistance. Eachsubsequent shell incorporates a greater arearesulting in lower resistance. This finallyreaches a point where the additional shellsoffer little resistance to the ground surroundingthe ground electrode.

8.4.1 Measurement of soil resistivity

Resistance offered by soil while inserting a ground connection is an issue which plays a significant role in determining the quality of the earthing. The soil surrounding the ground electrode generates a resistance which must me know in order to make the design of the earthing proper. The reason for measuring soilresistivity when selecting a locationfor installing a ground connection with an electrical appliance must have the lowestpossible resistance value. This ensures smooth passage of the excess charges to ground. Once a site has been selected, measuring the soilresistivity will give the information necessary to design and build aground field that will

meet the groundresistance requirements. These are primarily important for cases where there are high power applications involved.

There are a number of factors affecting soil resistivity. The first one is the soilcomposition. Soilis rarely homogenous and theresistivity of the soil will varygeographically and at different depths.

The second factor affecting soil resistivityis moisture or the amount ofwater in the ground. Moisture contentchanges seasonally, varies accordingto the nature of the sub layers of earth. Since soil resistivity is so closelyrelated to moisture and moisture ispresent in the soil we can logicallyassume that as moisture increasesresistivity will decrease and vice versa.

The third factor related is temperature.

Soil resistivity will varythroughout the year whenever seasonal changes bring about a change in themoisture and temperature content of the soil. For agrounding system to be effective it should be designed towithstand the worst possible conditions.Since soil and water are generally more stable at deeperstrata, the ground rods be placedas deep as possible into the earth, the water table ifpossible. Ground rods should also be installed wherethere is a stable temperature.

The ground resistivity offered by different types of soil at varying depths is shown in Table 8.1 below:

Table 8.1: Ground resistivity variation with soil types and depth

Type of Soil	**Soil resistivity** R_E	**Earthing resistance (**W)					
		Earthing rod m depth			Earthing strip m		
	Ohm m	3	6	10	5	10	20
Moist humus soil, moor soil, swamp	30	10	5	3	12	6	3
Farming soil loamy and clay soils	100	33	17	10	40	20	10

Sandy clay soil	150	50	25	15	60	30	15
Moisty sandy soil	300	66	33	20	80	40	20
Dry sand soil	1000	330	165	100	400	200	100
Concrete 1: 5	400	-	-	-	160	80	40
Moist gravel	500	160	80	48	200	100	50
Dry gravel	1000	330	165	100	400	200	100
Stoney soil	30,000	1000	500	300	1200	600	300
Rock	10^7	-	-	-	-	-	-

The formula used for calculating soil resistivity is given as:

$\rho = 2 \pi A R$

Where: ρ = the average soil resistivity to depth A in ohm - cm

π = is the constant 3.1416

A = the distance between the electrodes in cm

R = the measured resistance value in ohms from the test instrument



CHECK YOUR PROGRESS

Q 2: State True or False.

a) Ideally a ground should be of zero ohms resistance.

b) A singleelectrode consisting of a rod, pipe,or plate which does not have aresistance to ground of 25 ohms orless shouldnot be augmented by oneadditional electrode.

c) The resistance of the ground electrode andits connection is generally very high.

d) There are a number of factors affecting soil resistivity. The first one is the soilcomposition.

8.5 TYPES OF GROUND CONNECTIONS

In the most rudimentary form, two types of groundingsystems are observed. These are simple and complex. Simple grounds consist of a single earthing electrodedriven into the ground. The use of asingle ground electrode is the mostcommon form of grounding. It is commonly used with

houses, residential complexes and is easy to install. Complex groundingsystems are required to provide effective earthing connection where the electrical power involvement is larger. Complex grounding systems consist of multiple groundrods connected, mesh or gridnetworks, ground plates and groundloops. These systems are typicallyinstalled at power generating substations, central offices, mobile network towers and similar installations.

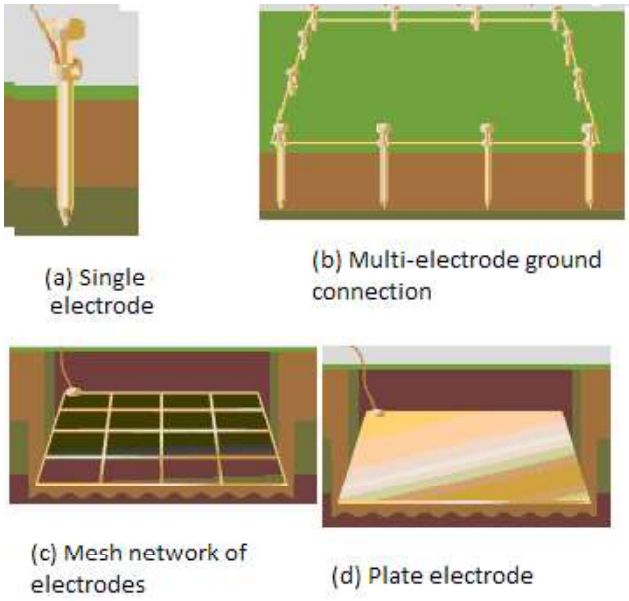


Figure 8.3: Types of ground connectors

8.5.1 Pipe Electrode Earthing

Earthing electrode consist of a metallic pipe (of Aluminum or Copper). It should have a diameter of 40 mm or above and should be not less than 3 meters long. The pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm diameter drilled at 75 mm interval upto 2.5 meters length from bottom. The electrode is buried vertically in the ground as far as practicablebelow permanent moisture level. The depth of burial should not be, in any case, less than 3 meters below ground level. The electrode should be in one piece with no joints in the structure. Earth electrode must not be located close to a metal fence. It should be kept clear of the building foundations and in no case; it should be nearer than 2 meters

from the outer face of the wall.

The pipe earth electrode should be kept vertically and surrounded with150 mm thick layer of charcoal dust and salt mixture upto a height of 2.5 meters from the bottom. At the top of the electrode a metallic threadedcap is provided for watering the earth. The main earthconductors are connected to the electrode just below the metallic cap, with proper terminal lugs and check nuts. The metallic cap over the pipe and earth connection should kept in a chamber, approximately 300 mm length x 300 mm wide and 300 mm deep. Thechamber shall be provided with a cast iron inspection coverresting over a strong metallic frame.

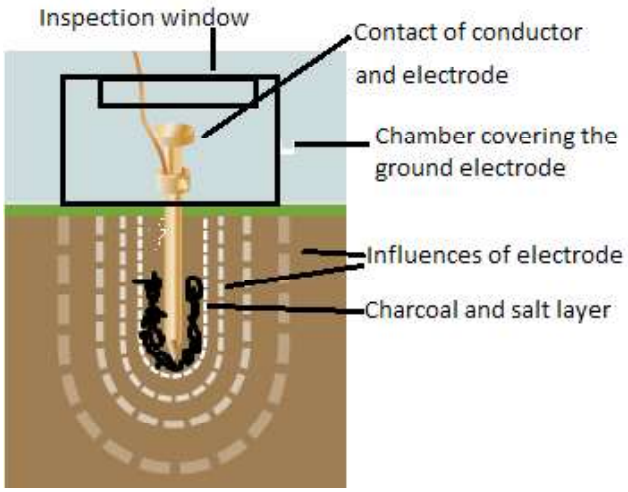


Figure 8.4: Single electrode ground connection

8.5.2 Plate Electrode Earthing

Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mmx 12 mm thick. The plate electrode is buried belowland that permanently has moisture. The depth, in any case, must not less than 3 meters below ground level. The earthplate is placed vertically and surrounded with 150 mm thick layer of charcoal dust and salt mixture. A 20 mm metallic pipe is connected from the topedge of the plate to the ground level. The top of the pipe is provided with a metal threaded cap for watering the earth through apipe.

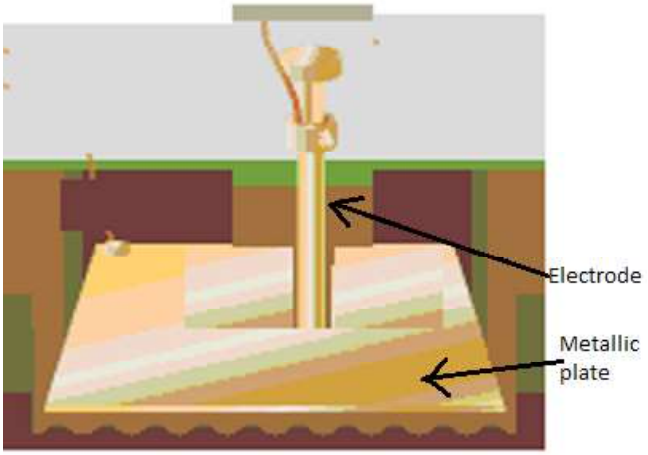


Figure 8.5a: Plate and electrode connected ground connection

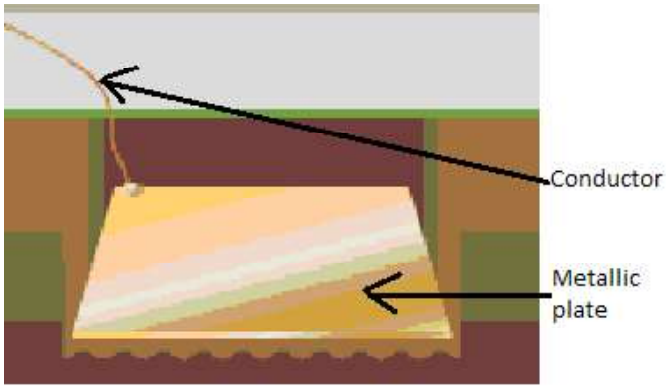


Figure 8.5b: Plate ground connection



CHECK YOUR PROGRESS

Q 3: State True or False.

a) In the most rudimentary form, two types of groundingsystems are observed. These are simple and complex.

b) The use of a single ground electrode is the most common form of grounding.

c) Earthing electrode consist of a metalic pipe (of Aluminum or Copper). It should have a diameter of 40 mm or above and should be not les than 3 meters long.

d) Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mmx 12 mm thick.

8.6 GROUND TESTING

Soil resistivity is most necessary when determining the design of the grounding system for new installations. There are four types of earth ground testing methods available:

- Soil Resistivity (using stakes)
- Fall-of-Potential (using stakes)
- Selective (using 1 clamp and stakes)
- Stakeless (using 2 clamps only)

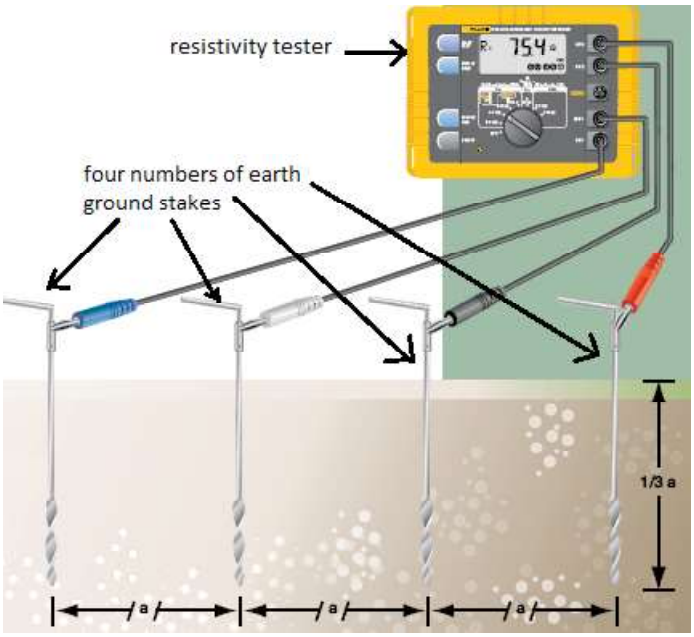


Figure 8.6: Ground resistivity testing using stakes

Four earth ground stakes are positioned in the soil in a straight line, equidistant from one another. The distance between earth ground stakes should be at least three times greater than the stake depth. So if the depth of each ground stake is one foot (.30 meters), the distance between stakesis greater than three feet (.91 meters). The resistivity tester generates a known current through thetwo outer ground stakes and the drop in voltage potential is measured between the two innerground stakes. The resistivity tester automatically calculates the soilresistance.

Stakeless measurement only measures individual ground rod resistances in parallel toearth grounding systems.



CHECK YOUR PROGRESS

Q 4: Find True or False.

a) Soil resistivity is most necessary when determining the design of the grounding system fornew installations.

b) Stakeless measurement only measures individual ground rod resistances in parallel to earth grounding systems.

c) In the ground testing method with stakes, four earth ground stakes are positioned in the soil in a straight line, equidistant from one another.



8.7 LET US SUM UP

- A grounding system is an essential component of an electrical system. It allows the excess charges to flow through without causing damage to the system.
- Main earthing conductors are taken from the earth connections at the main switchboards to an earth electrode with which the connection is to be made.
- Earthing conductors, outside the building, should be laid 600 mmbelow the finished ground level.
- When there is evidence that the soil is aggressive to copper, buried earthing conductors should be protected by suitable serving and sheathing so that the earthing conductor is not damaged by corrosion.
- When grounding systems are installed they are required to meet certain resistance criteria, such as 10, 5, 3 or 1 ohm.
- The goal in ground resistance valuesis to achieve the lowest ground resistance value possible that makes sense economically and physically.
- Resistance offered by soil while inserting a ground connection is an issue which plays a significant role in determining the quality of the

earthing.

- There are a number of factors affecting soil resistivity. The first one is the soilcomposition.The second factor affecting soil resistivityis moisture or the amount ofwater in the ground.The third factor related is temperature.
- The two types of groundingsystems are simple and complex. Simple grounds consist of a single earthing electrodedriven into the ground.
- Earthing electrode consist of a metalic pipe (of Aluminum or Copper) having a diameter of 40 mm or above and should be not less than 3 meters long.
- Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mmx 12 mm thick. The plate electrode is buried belowland that permanently has moisture.
- There are four types of earth ground testing methods available. These are- Soil Resistivity (using stakes), Fall-of-Potential (using stakes), Selective (using 1 clamp and stakes) and Stakeless (using 2 clamps only)



8.8 FURTHER READINGS

1) Process Control and Instrumentation Technology- Johnson, Pearson Education, 1st Ed., New Delhi, 2003.
2) Electrical and Electronics Measurement and Instrumentation- A. K. Sawhney, Dhanpat Rai & Co., Eleventh Ed., New Delhi, 1997.
3) Indian Electricity Rules, 1956.
4) Electrical Technology- B.L. Thareja, Khanna Publishing,
5) Electrical Technology- Edward Hughes and Ian McKenzie Smith, ELBS



8.9 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) True b) True c) False

Ans to Q No 2: a) True b) False c) False d) True

Ans to Q No 3: a) True b) True c) True

Ans to Q No 4: a) True b) True c) True



8.10 MODEL QUESTIONS

Q 1: Why is earthing so essential? Mention a few points to justify your answer.

Q 2: What are the basic considerations that are followed while doing an earthing connection?

Q 3: What are the different methods of installing an earthing?

Q 4: Write short notes on ground testing.

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UNIT 9 : SAFETY REQUIREMENTS

UNIT STRUCTURE

9.1 Learning Objectives

9.2 Introduction

9.3 Hazards of Electricity

- 9.3.1 Fire Hazard
- 9.3.2 Electric Shock

9.4 Safety Precautions and Electrical Safety Sign

9.5 First Aid

9.6 Indian Electricity Rules and Indian Electricity Act

9.7 Let Us Sum Up

9.8 Further Readings

9.9 Answers to Check Your Progress

9.10 Model Questions

9.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- explain the hazards of electricity
- discuss the safety precautions and electrical safety signs
- describe the first aid treatments
- explain the Indian Electricity Rules and Indian Electricity Act .

9.2 INTRODUCTION

In the previous unit, we have focused on the basic concept of earthing. This unit will provide you the hazards of electricity. In this unit, we will also provide you the safety precautions and electrical safety signs. We will also explain the first aid treatments required in common emergencies. Indian Electricity Rules and Indian Electricity Act will also discuss at the end of this unit.

9.3 HAZARDS OF ELECTRICITY

Electricity can be dangerous if proper adequate precautions are not taken. A large number of accidents and fire resulting from hazards of electricity causing death of persons and loss of property are reported every year. Hazards associated with electricity are electric shock, electric burn, electric fire etc.

9.3.1 Fire Hazard

Fire is combustion of a substance with generation of heat and light. Basically it is a chemical process in which oxygen chemically combines with the burning substance producing heat, light and byproducts like ash. When a substance gets heated, the temperature gradually increases. Above certain temperature oxidation of the hot substance begins and fire starts producing heat and light. Heat, fuel and oxygen are essential for a fire to continue and a fire ceases to exist when any one or more of them are absent. Firefighting strategy consists of removing any one of the essential elements of fire namely fuel, heat or oxygen. Ordinary fire resulting from burning of wood, paper, cotton cloth, etc. can be extinguished by throwing water on the fire. By its cooling effect water removes heat necessary to sustain such fire and fire ceases to exist. Fire resulting from burning of petroleum products like petrol, kerosene or chemical substances which reacts with water cannot be extinguished by water and special fire extinguishing substances and techniques are required. Old or faulty wiring or equipment, overloading of circuits, loose connection, sparking etc can cause electrical fire. Overloading heats the wires, insulating material melts because of heat and fire starts. Water is a conductor of electricity and gets converted to vapor when comes into heated wires or insulating material. Throwing of water on electrical fire can hence be dangerous and involves risk of electric shock. One must not throw water on electrical fire. In case of electrical fire the electrical

supply should immediately be disconnected. Throwing of dry sand is helpful and fire extinguisher is necessary to extinguish the electrical fire.

9.3.2 Electric Shock

A person gets an electric shock when he comes in direct contact with live wire or voltage source and current passes through him. Severity of shock depends on the amount of current, path of current through the body, duration of contact and area of contact. The current again depends on the voltage and body resistance. Body resistance varies from person to person and depends on the condition of skin. With dry skin electrical resistance of the human body is of the order of mega ohms and with wet skin it may be as low as kilo ohms. The electrical resistance of internal human body is smaller than kilo ohm. The minimum current for electric shock is about 1 milli ampere (mA) which gives a mild electric shock that result in tingling sensation. Severe electric shock involving more current may results in muscular contraction, electric burn, respiratory paralysis and even death. The victim may become unconscious and breathing may slow or stop. Immediate attention and care is necessary to save the victim. The victim may remain stuck to the source of electricity. The most important thing is to immediately turn off and disconnect the power supply. While dealing with a victim of electric shock one should be very careful and the following points are particularly important.

1. Do not touch the person without being sure that he is not in contact with live conductor or apparatus or source of electricity. In case the victim of electrical shock is still in contact with live apparatus or conductor, anyone touching him will also get electrical shock.
2. Immediately Switch off the Mains switch and disconnect electrical supply.
3. Separate the victim. Do not touch with bare hands. Use non

conducting materials like dry wood, insulated hand gloves etc.

4. Once the victim has been separated, check if he is breathing. If breathing has stopped or is slow, administer artificial respiration to restore or assist breathing. Continuous direct mouth to mouth artificial respiration is necessary till the breathing condition improves.
5. If the victim has burns, do not break blisters. Rinse the burn with cool running water and cover the burn with a dressing.
6. Get emergency medical help as soon as possible.

9.4 SAFETY PRECAUTIONS AND ELECTRICAL SAFETY SIGN

Safety is a primary concern for all of us. Whether at home or in workplace safety is a must. Electricity is very useful and is essential in our everyday life. But electricity can be dangerous if proper safety precautions are not taken and can even kill. Awareness and continuous effort of all concerned are required to ensure safety. Lack of safety or breach of safety norms may lead to undesirable event like accident, fire etc. which can lead to damage or harmful impact on life and property.There are always certain most suitable steps and procedures to perform and complete a job satisfactorily and safely. Haphazard way of doing a job is unsafe and can lead to undesirable events.

Safety procedure is a set of steps that are to be followed to ensure safety. It may consist of a lists of DOs and DO NOTs. There are certain general steps that are always relevant.

General steps to ensure safety

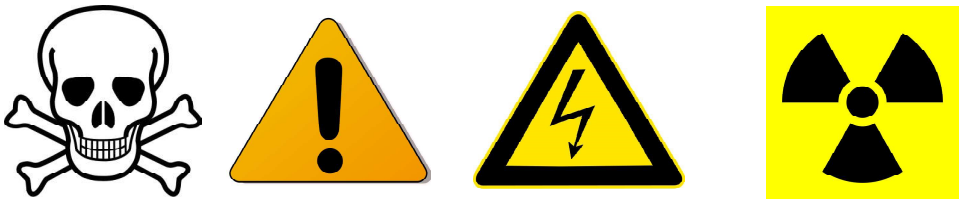
Some General steps relevant in ensuring safety are:

1. Always be careful. A careless person is a potential danger to himself, his fellow workmen and to the environment.
2. Never work with tools, equipment or electricity when you are not feeling well, sick or dizzy.
3. Working with barefoot should be avoided. Wear shoes with good insulating sole.

4. Know the locations of Mains of electrical supply and switches, fire extinguisher and emergency exit if any. One should also have an idea about the most valuable things to be removed first in case of emergency.
5. Before starting the work collect information necessary to complete the work. At times it is important to ensure that you are authorized to do the work.
6. Know the possible hazards associated with the work and steps to be initiated in case of emergency.
7. You should not tamper anything unnecessarily and without any purpose. You must not play with tools, accessories, equipment etc.
8. Do not put sharp edged tools, accessories or spare in pocket.
9. Avoid using tools like knife, screw driver, hand saw etc that are without handle. Be careful in handing over such tools to someone to avoid injury.
10. Battery charging room should be well ventilated and should have sufficient light.

Safety Sign

Safety signs are standard symbols, pictures or signs. They are displayed to inform about status of some items or locations. The basic purpose is to prominently display what to DO and what NOT TO DO. Safety signs are very important items in ensuring electrical safety. There are many Safety Signs used in electrical installations and works. It is very important for an electrician to get acquainted with safety signs. Some common safety signs are given below.



Danger Sign Caution Sign High Voltage Sign Radiation Sign

Fig. 9.1: Electrical Safety Sign

One can easily get the set of commonly used safety signs in poster form from various sources.

Electrical Safety

Some general rules pertaining to electrical safety are

1. The electrical power supply connection also called the service connection to the premises should be properly installed by licensed persons. Wiring should be done using good quality wires of necessary rating. One should always use items and equipment of reputed manufacturer.
2. Wire joints demands special care. Improper wire joints and loose connections are potential hazards and may lead to unnecessary heating of wires and cables, sparking and ultimately to fire. Hence wire joints should be avoided as far as possible. When it is necessary the wire should be joined preferably using lugs and should be securely tightened using screw and nut and should be insulated and taped properly. One has to be more careful in joining wires of different metals e.g. joint of copper wire and aluminum wire as joints of dissimilar metals are more problematic.
3. It is mandatory and essential to install good electrical earthing in every premise. Earthing should be properly installed and should be tested by licensed persons.
4. The main switch fuse used should be of appropriate rating. All adult persons in the premises should know how to switch off the main switch in the event of emergency.
5. The electrical system should be periodically inspected thoroughly at least once in every year.
6. Sparks or flashes, abnormal sound, odor of insulation burning, frequently blown fuse or circuit breaker that trips frequently, warm or hot wires, or faceplate of outlets etc are danger signals and are indication of some defects. The defects should be rectified immediately.
7. Outlets and plugs that are old or worn out or has loose pins or are partially damaged or burnt or gets discolored because of heat etc should be replaced immediately. Loose and bad quality outlet and plugs can be dangerous.
8. Never disconnect a plug by pulling flexible cable particularly when the

switch is on.

9. Always use electrically insulated tools. It is essential that you use good quality proper tools for a particular job.
10. Sudden change and frequent on off can result in power surges that can damage equipment particularly sensitive electronic devices like computer etc. and should be avoided.

Extension Cord

Extension cords are very useful. It takes electrical power to places where outlets are not available. However certain precautions are essential in using extension cords. Accidents and injuries may occur from misuse of extension cord.

1. Extended cords are for temporary use. Frequent use for the same job in the same location should be avoided and in such case a power outlet should be installed.
2. Overloading of extension cords can be dangerous. Overloading heats the cord, the insulation melts because of heat and short circuit, electric shock may result.
3. Only three wire type (live, neutral and ground) extension cords should be used. Two wire extension cords without ground wire connection should be avoided.
4. Common defects in extension cords are loose parts, deformed and missing pins, damaged insulation, improper taping of joints, pinched or crushed outer jacket etc. Before using an extension cord, one should thoroughly examine the same and should rectify the defects if any.
5. Joints in extension cords should be avoided and must be properly taped by insulation tape in case unavoidable.
6. Extension cords should not be run through places where it may get damaged. On should be careful while running extension cord through walls, doors, windows, sharp corners etc.
7. Wires and cords of portable equipment must not be used to lift or to lower or to drag the equipment.
8. Avoid using electrical extension cords in wet or damp place. Electrical extension cord must not be used in locations where there is water.

Rules and Regulations

There are laws, regulations, rules, norms and guidelines for carrying out the tasks involving electricity. These are specified by government and non-government agencies and organizations of local, state level, national level and international level. Examples are Indian Electricity Act, Indian Electricity Rules, Regulations and Manuals of supply authority like Assam State Electricity Board (ASEB), Bureau of Indian Standards (BIS) regulations pertaining to electrical installations, National Electric Code (NEC) of America, British Standards (BS) of Institute of Electrical Engineers (IEE) of Great Britain now known as Institute of Engineering and Technology (IET). These are documents available in book form.

Indian Electricity Act governs the relations between the consumer and supplier of electrical energy. Permissions for the generation, distribution and supply of electrical energy, are given as per this Act. The Act defines powers and obligations of such agencies and also the obligations of consumers.

The Indian Electricity Rules are framed as per provisions of Indian Electricity Act. These rules regulate the supply, transmission, generation and use of electricity. These rules specify how the tasks related to electricity are to be performed and cover aspects like construction, installation, maintenance, transmission, distribution, generation, safety and use of electricity. Everyone has to obey these rules.

An important reference document is British Standard BS 7671 of IEE which contains wiring regulations and defines how works relating to electrical installations are to be carried out providing safety and proper functioning for intended use.

It is essential and mandatory that the house wiring tasks are performed as per the relevant rules and norms.



CHECK YOUR PROGRESS

Q 1: Fill in the blanks-

a) One should not use tools like knife, screw driver, hand saw etc. that are without _____.

b) Safety signs are very important items in ensuring _____.

c) Extension cords without _____ connection should be avoided

d) BIS stands for _____.

9.5 FIRST AID

Whether it is home or workplace, there must be First Aid kits so that immediate actions can be taken in response to accidents and emergencies that may occur. First Aid kits are a must at workplace. In the event of an accident, injury or emergency First aid is to be administered so that the situation does not worsen till proper medical care is reached.First aid is the provision of initial care for an illness or injury. It is usually performed by a lay person to a sick or injured casualty until definitive medical treatment can be accessed. Certain self-limiting illnesses or minor injuries may not require further medical care past the first aid intervention. It generally consists of a series of simple and, in some cases, potentially life-saving techniques that an individual can be trained to perform with minimal equipment. The key aims of first aid can be summarised in three key points :

- Preserve life - the overriding aim of all medical care, including first aid, is to save lives.
- Prevent further harm - also sometimes called prevent the condition from worsening, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.
- Promote recovery - first aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

First aid training also involves the prevention of initial injury and responder safety, and the treatment phases. “

First Aid Kit:

A basic minimum First Aid Kit should contain the following items

- Adhesive strips and tape for dressing
- Sterilized Cotton, gauge pad and roll, cotton swab for cleaning wounds
- Bandage materials, band aid, triangular bandage
- Antiseptic solution
- Antibiotic ointment
- Petroleum jelly
- Eye pads for emergency eye cover
- Thermometer
- Sterile / saline water for cleaning wounds and for eye wash
- Scissors, tweezers, needles and safety pins
- Soap and sanitizer for washing and cleaning.
- Syringe, medicine cup and spoon
- Torch light with extra batteries, candle and match
- Emergency Phone numbers of doctors, emergency services, ambulance etc.
- A First Aid Manual and poster display.

The First Aid Kit should be checked regularly and all items should be kept in good ready to use condition. Location of the First kit should be easily accessible and everyone should be familiar. There may be suitable poster display near the First Aid kit. Large organizations have separate room for administering First Aid, more additional facilities and responsible persons trained in First Aid Techniques.

First Aid in Common emergencies:

The very common and possible injuries and illness that may occur at workplace are burn, bleeding and cut, eye injury, fall, electric shock, unconsciousness, breathing problem etc. and First Aid for these emergencies should be available.

A minor burn should immediately be cooled by applying cold running water or by immersing in cold water. Use of ice is not recommended as it may cause frostbite and can damage skin. Never break blisters as broken blisters easily catches infection. The burn should be covered by a sterile bandage. In case of severe burn, removal of burnt clothing and use of cold water to cool the burn are not recommended. For severe burn, immediate

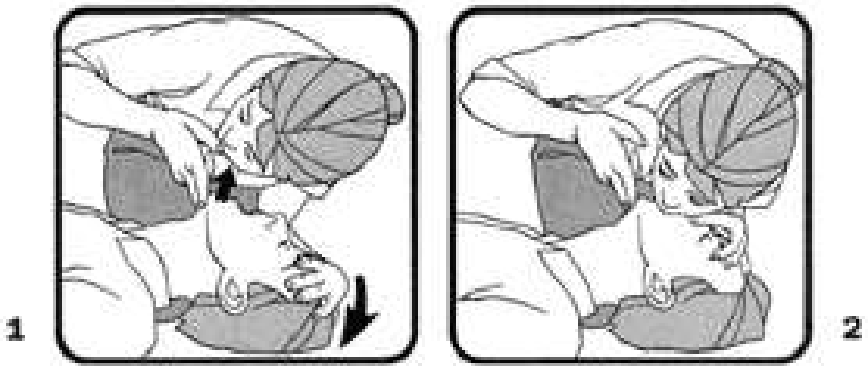
proper medical care is essential and the area of burn may be covered by sterile loose cool bandage or cotton cloth till proper medical care is reached.

In case of a cut or bleeding injury the bleeding is to be stopped first by applying pressure and then by using a bandage or clean cloth. Once bleeding stops, the wound should be cleaned by clean sterile water and an antibiotic cream or ointment should be applied at the wound. The wound should be covered by bandage and further treatment with consultation of doctors should be taken. It is always better to take anti titanus injection.

Eyes are delicate and immediate medical treatment should be taken in case of eye injury. There is a tendency to rub the eye in case of an injury. Never rub the eye as rubbing can cause further damage. In case of eye irritation or minor injury resulting from dust, foreign particle in the eye or from chemical burns or fume etc rinse the eye with clean water.

To administer First Aid to victims who have become unconscious because of fall, electric shock or other injury, the most important point is to ensure breathing. Oxygen is essential for survival, without air or oxygen permanent damage or even death may result. Suffocating condition may be dangerous and hence it is to be ensured so that the victim gets open air for breathing. In case the victim is not breathing or breathing slowly, the victim is to be assisted by artificial respiration. Mouth to mouth direct artificial respiration is an effective method in such situations and the procedure (taken from safety manual of Bangalore Electricity Supply Company Limited with website www.bescom.org)is given below.

Direct Artificial Respiration (Mouth to mouth method)



‘Fig 9.2: Direct artificial respiration

(a) Place the victim on back immediately

(b) Clear throat of water, mucous, toys, coins or food.

(c) Tilt head back as far as possible

(d) Lift jaw to keep tongue out of air passage

(e) Pinch nostrils to prevent air leakage when you blow.

(f) Blow until you see the chest rise

(g) Listen for snoring and gurgling signs of throat obstruction

(h) Repeat blowing 10-20 times a minute

In case of infant or small children tilt the head fully back, surround the mouth and nose completely with your mouth. Blow with enough force to produce a visible rise in the victim's chest and no more. Repeat every 3 seconds.

Continue direct artificial respiration until victim breathes for himself or until expert help is obtained.



CHECK YOUR PROGRESS

Q 2: Fill in the blanks:

1. The burn should be covered by a _____ bandage.
2. Use of _____ is not recommended to cool severe burn.
3. The key aims of first aid can be summarised _____, _____, and _____.
4. Rubbing of injured eye is_____.
5. A victim not breathing is to be assisted by _____.

9.6 INDIAN ELECTRICITY RULES AND INDIAN ELECTRICITY ACT

THE INDIAN ELECTRICITY ACT governs the matter relating to the supply and use of electrical energy. In our country all aspects like generation, distribution, transmission and supply, licensing, utilization, safety, offences etc. relating to the supply and use of electricity are as per this Act. Indian Electricity Rules are framed under the guidelines of Indian Electricity Act. For application of the principles of the IE act in the real life, IE rules are

needed.

The Act is passed by the Government and the rule is made to implement and follow the Act. Few points about the rules are noted below-

- The main purpose of these rules is to ensure the safety of human beings, animals and property. Other purposes of these rules are smooth, safe and efficient utilization of electrical energy. The responsibilities of an electrician & others including the supplying authority and the consumer include conforming of the norms and rules as specified by Indian Electricity rules as per Indian Electricity act.
- As per Indian electricity rules all electric supply lines and apparatus shall be of sufficient ratings for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty which they may be required to perform under the environmental conditions of installation, and shall be constructed, installed, protected.
- The relevant code of practice of the Bureau of Indian Standards including National Electrical Code should be followed.
- The material and apparatus used shall conform to the relevant specifications of the Bureau of Indian Standards.
- As per Indian electricity rules it is the responsibility of the supplier that he ensures all electric supply lines, wires, fittings andapparatus belonging to him or under his control, which are on a consumer'spremises, are in a safe condition and in all respects fit for supplying energy andthe supplier shall take due precautions to avoid danger arising on such premisesfrom such supply lines, wires, fittings and apparatus.
- The consumer shall, as far as circumstances permit, take precautions forthe safe custody of the equipment on his premises belonging to the supplier. It is one of the responsibilities of wiremen/electrician to create awareness.
- The supplier shall provide a suitable cut-out in each conductor of everyservice-line other than an earthed or earthed neutral conductor or the earthedexternal conductor of a concentric cable within a consumer's premises, in anaccessible position. Such cut-out shall be

contained within an adequatelyenclosed fireproof receptacle.

- An indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected there to enable such conductor to be distinguished from any live conductor.
- The supplier shall provide and maintain on the consumer's premises for theconsumer's use a suitable earthed terminal in an accessible position at or near the point of commencement of supply as defined under rule.
- The consumer shall take all reasonable precautions to prevent mechanicaldamage to the earthed terminal and its lead belonging to the supplier.
- Where bare conductors are used in a building, the owner of such conductors shall–
  a) Ensure that they are inaccessible;Danger Notices- The owner of every medium, high and extra-high voltageinstallation shall affix permanently in a conspicuous position a danger notice inHindi or English and the local language of the district, with a sign of skull andbones onevery motor, generator, transformer and other electrical plant andequipment together with apparatus used for controlling or regulating the same;
  b) Use all supports of high and extra-high voltage overhead lines which can beeasily climbed-upon without the aid of a ladder or special appliances; such asrails, tubular poles, wooden supports, reinforced cement concretepoles without steps, I-sections and channels, that shall be deemed as supports which cannot be easily climbed upon for the purposes of this clause.
  c) Use luminous tube sign requiring high voltage supply, X-ray and similar high frequencyinstallations.



CHECK YOUR PROGRESS

Q 3: What is Indian Electricity Act?

.....

.....



9.7 LET US SUM UP

- Safety is a primary concern for all of us. Whether at home or in workplace safety is a must.
- Electricity is very useful and is essential in our everyday life. But electricity can be dangerous even life threatening if proper safety precautions are not taken.
- Safety signs are standard symbols, pictures or signs. They are displayed to inform about the status of some items or locations.
- Accidents and injuries may occur from the misuse of the extension cord.
- There are laws, regulations, rules, norms and guidelines for carrying out the tasks involving electricity. These are specified by the government and non-government agencies and local, state level, national level and international level organisations.
- Indian Electricity Act governs the relations between the consumer and the supplier of electrical energy.
- Electricity can be dangerous if proper adequate precautions are not taken.
- Throwing of water on electrical fire can be dangerous and involves risk of electric shock.
- A person gets an electric shock when he comes in direct contact with live wire or voltage source and current passes through him.
- First Aid kits are a must at workplace. In the event of an accident, injury or emergency First aid is to be administered so that the situation does not worsen till proper medical care is reached.

- THE INDIAN ELECTRICITY ACT governs matter relating to the supply and use of electrical energy.



9.8 FURTHER READINGS

1) Bhatnagar J.P., Electricity Manual, Orient Law House.
2) Bangalore Electricity Supply Co. Ltd, Safety Manual, http:// www.besom.org.
3) Emergency Handbook, Red Cross.



9.9 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) handle, b) electrical safety, c) ground wire, d) Bureau of Indian Standards.

Ans to Q No 2: 1. Sterile 2. Ice 3. Preserve life, prevent further harm, Promote recovery. 4.harmful 5.artificial respiration.

Ans to Q No 3: The Indian Electricity Act governs matter relating to the supply and use of electrical energy.



9.10 MODEL QUESTIONS

Q 1: What are the advantages to AC over DC?

Q 2: What are peak, peak-to-peak, average and RMS values of an AC signal?

Q 3: Define the terms Amplitude, time period, Frequency and RMS value. What are the respective units?

*** ***** ***

UNIT 10 : SEMICONDUCTOR DIVICES

UNIT STRUCTURE

10.1 Learning Objectives

10.2 Introduction

10.3 Semiconductor and its Types

10.4 PN Junction Diode

10.5 Zener Diode

10.6 Transistor

10.7 Let Us Sum Up

10.8 Further Readings

10.9 Answers to Check Your Progress

10.10 Model Questions

10.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- describe the semiconductor and it types
- explain the PN junction diode and zener diode
- familiarise with the transistor and its working principle.

10.2 INTRODUCTION

In the previous unit you have learnt the safety requirements. In this unit, we will provide you the various types of semiconductor. This unit will also describe the PN junction diode and zener diode. We will also focus on the working principles of transistor.

10.3 SEMICONDUCTOR AND ITS TYPES

A semiconductor is a material whose electrical properties lie in between the conductor and insulator. Two usually used semi-conductors are Silicon (Si) and Germanium (Ge). They require very small energy to release an electron from their valance band. For Ge, it is 0.7 ev and for Si 1.1 ev. The resistivity of semiconductor is in the range of 0.4 to 2500 ?m. In

terms of energy band, they have partially filled valence band and nearly empty conduction band. The forbidden gap is very small (1ev) that is why smaller electric field is required to push an electron from the valence band to the conduction band.

At 0 K,the valence band is completely filled and the conduction band is totally empty. So at absolute zero temperature, a semiconductor behaves like an insulator. When the temperature increases, the forbidden gap is decreased so that few electrons can be injected into the conduction band. This means, the conductivity of semiconductors increases with temperature. That is why they have negative temperature coefficient of resistance. At 300 K the semiconductor acts like a conductor.

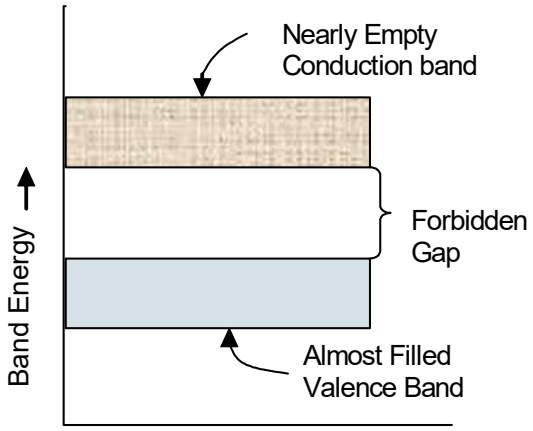


Fig. 10.1 Energy band diagram of Semiconductor

Types of Semiconductors: Semiconductors are classified into two types. They are–

- Intrinsic or Pure semiconductors.
- Extrinsic or Doped Semiconductor.

The extrinsic semiconductors are also two types.

- N-type and
- P-type.

Intrinsic Semiconductors: The semiconductor material in its pure form is called intrinsic semiconductor. Pure Silicon and Germanium are the intrinsic semiconductors. Each atom of the semiconductor has only four electrons in its outermost orbit. They require four more electrons in the valence shell to become a stable structure. Hence each of the four valence

electrons forms a ***covalent bond*** with another four valance electrons, one from each of the four neighbouring atoms. The two electrons of the covalent bond are shared by the two atoms.

At absolute zero temperature, all valence electrons are strongly bounded to the parent atoms; hence no free electrons are available for conduction. The intrinsic semiconductor acts like a perfect insulator at absolute zero temperature.

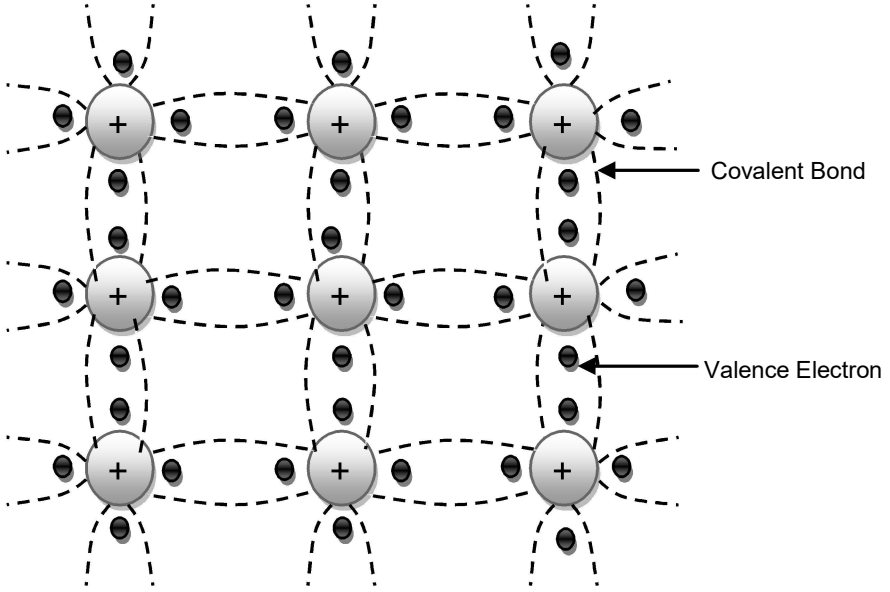


Fig. 10.2 Structure of intrinsic semiconductor at absolute zero temperature

At room temperature(300K) some of the covalent bonds of the semiconductor breaks due to thermal energy and valence electrons of the atom moves away from the nucleus. They become free to move in the ***crystal.*** When the electron moves away by breaking a covalent bond, a vacancy is created in that covalent bond which is called a hole. For every free electron, a hole is generated. Hence in intrinsic semiconductors the number of free electrons is equal to the number of holes. A hole is a positively charged particle.

Since, an electron is a negatively charged and a hole is positively charged, when a potential difference is applied in an intrinsic semiconductor, electrons will move towards the positive terminal and the holes will flow towards the negative terminal of the battery. Therefore, the total current in

the intrinsic semiconductor is the sum of currents due to free electrons and holes.

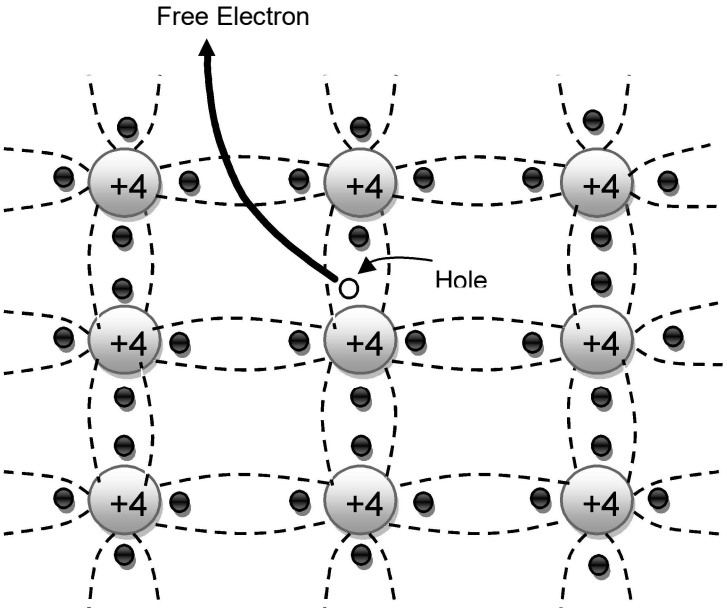


Fig. 10.3 Generation of electron-hole pair in an intrinsic semiconductor

Extrinsic Semiconductors: The conductivityof intrinsic semi-conductor can be increased by adding some suitable impurity atoms to the semiconductor. When a small amount of impurity atom is added to the intrinsic semiconductor, it is called extrinsic or impurity semi-conductor and the process of adding impurities to the semiconductor is known as doping. The conductivity of semiconductor increases means either the number of free electrons or holes increases in the semiconductor crystal. When a ***trivalent*** impurity atom is added to the semiconductor, a large number of holes are produced in the semiconductor. On the other hand, addition of ***pentavalent*** impurity atoms creates a large number of electrons in the semiconductor crystal.

Depending upon the type of impurity added, extrinsic semiconductors are classified into two types. They are –

- P–type and
- N-type.

P-type Semiconductor: When a trivalent impurity atom is added to an intrinsic semiconductor, it is called P-type semiconductor. Some typical examples of trivalent impurities are Boron, Aluminum, Gallium and

Indium.They are known as acceptor impurities because the holes created can accept the electrons.

Let us consider that a Boron impurity is added to pure Silicon atom. Since the boron atom has three valence electrons, three covalent bonds will be formed with the three neighbouring Silicon atoms. The fourth covalent bond is incomplete as Boron has no valence electron to share with Silicon atom to form the covalent bond. This missing electron is called a hole. Therefore, for each Boron atom added, one hole is created. To fill this vacancy, electrons from adjacent covalent bond can jump due to thermal energy by creating another hole in the adjacent bond. This hole is positively charged and the Boron atom has a negative ionas it accepts the electron. Thus, a P-type semiconductor has holes in majority and free electrons in minority in addition, negative ions.

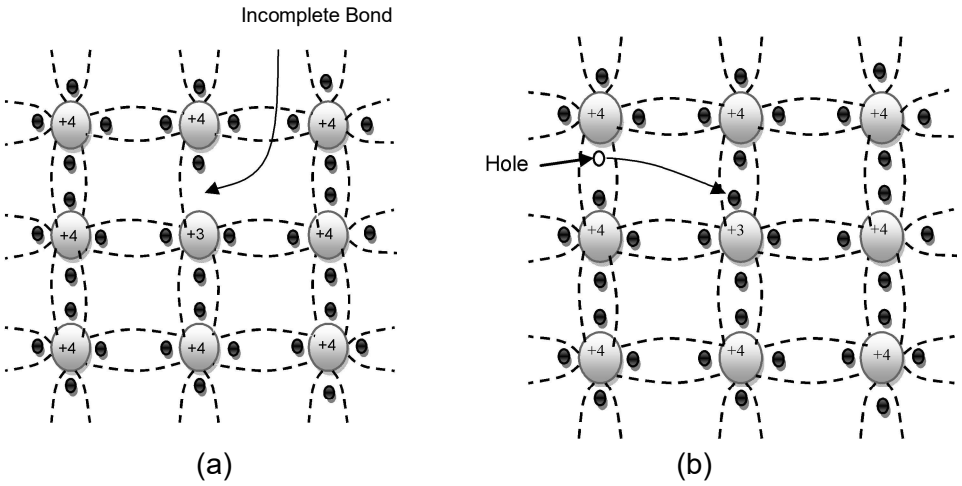


Fig. 10.4 P-type Semiconductor

a) Boron added to Silicon, b) Creation of a hole.

N-type Semiconductor: When a pentavalent impurity atom is added to an intrinsic semiconductor, it is called N-type semiconductor. Examples of pentavalent atoms are phosphorus, arsenic and antimony. They are called donor impurities because they donate one valence electron to the semiconductor crystal.

We consider a phosphorous impurity atom is added to a silicon atom. The phosphorousatom has five valence electrons, four of these form covalent bonds with four neighbouring silicon atoms. The fifth electron is excessive

and loosely bound to the nucleus. Hence it is easily energized from the valence band to the conduction band by increase in the thermal energy. Thus, at room temperature each impurity atom donates one electron to the conduction band and achieved a positive ion. Due to the thermal energy, there will also some electron-hole pair generated because of the breaking of the covalent bonds. The number of free electrons generated by the pentavalent impurity is very large than the number of holes. Hence, an N-type semiconductor has electrons as majority carriers and holes as minority carriers, in addition positive ions.

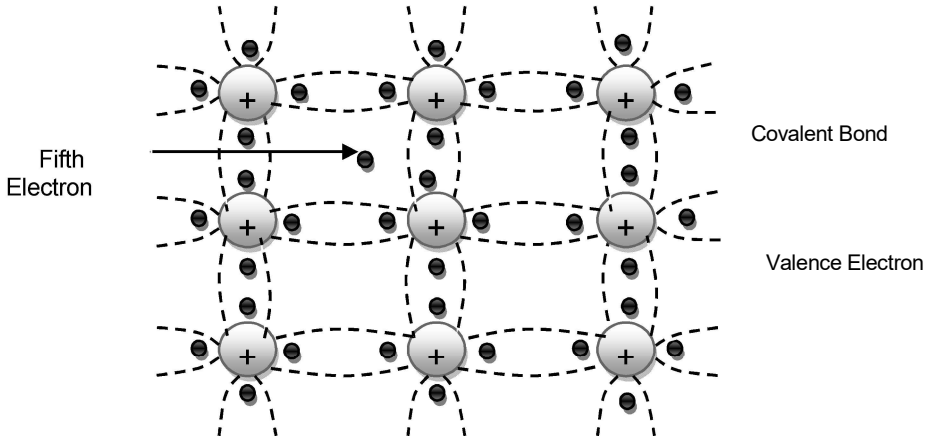


Fig. 10.5 N-type semiconductor



CHECK YOUR PROGRESS

Q. No. 1. Choose the correct answer.

a) A semiconductor has generally _____ valence electrons.

i) 2 ii) 3 iii) 6 iv) 4.

b) A semiconductor is formed by _____ Bonds.

i) covalent ii) electrovalent

iii) co-ordinate iv) none of the above.

c) Insulators have a _____ valence band.

i) empty ii) full

iii) nearly filled iv) none of the above.

d) Conductors have _____ valence band and condu-ction band.

i) overlapping ii) filled

iii) empty iv) none of the above.

e) A semiconductor has _____ temperature coefficient of resistance.

i) positive ii) negative

iii) zero iv) none of these.

Q. No. 2. Find True or False:

a) A hole in the semiconductor is positively charge.

b) Phosphorus is a trivalent impurity atom.

c) An intrinsic semiconductor at the absolute zero temperature behaves like a conductor.

d) The conduction band is also called the forbidden gap.

e) A P-type semiconductor is negatively charged.

f) Addition of pentavalent impurity to a semiconductor creates many free electrons.

g) Electrons are the majority carriers of N-type semiconductor.

10.4 PN JUNCTION DIODE

P-N junction diodeisa semiconductor device that hasthe ability to conduct current in one direction and control the flow in the opposite direction. This device is small in size, cheaper, tough, has higher operating efficiency. It contains one p-n junction. The circuit symbol is shown in fig. 10.6. Before discussing the diode in detail, let us first try to know what p-n junction is.

P-N Junction

When a P-type semiconductor is connected to an N-type semi-conductor, the contact surface is called p-n junction. As we know from the previous section that the P-type semiconductor contains holes and negatively charged impurity ions and the N-type contains free electrons and positively charged impurity ions. When the P-N junction is formed, the holes from the P-side move into the N-side and combine with the free electrons.Similarly, the free electrons from the N-side diffuse into the P-side and combine with the holes. ***Diffusion*** takes place because they move randomly due to thermal

energy and difference in their concentration. After few recombination of holes and electrons in the junction, a preventive force is set up automatically. This force is called barrier that stopped further diffusion. Due to the recombination process, the negative acceptor ion in the P-side and positive donor ion in the N-side remain unaccounted near the junction. The additional holes and electrons trying to diffuse are repelled by these fixed or immobile ions and further recombination cannot occur.

The region containing the acceptor and donor ions but no free electrons and holes is called depletion region. An electric potential is set up across the junction that opposes the further flow of carriers across the junction which is known as junction or barrier potential (VB). At room temperature of 300 K, VB is about 0.3 V for Ge and 0.7 V for Si P-N junction.

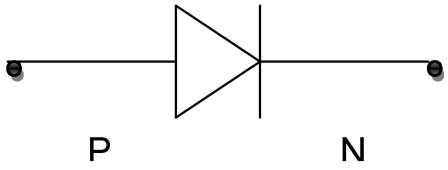


Fig. 10.6 Symbol of Diode

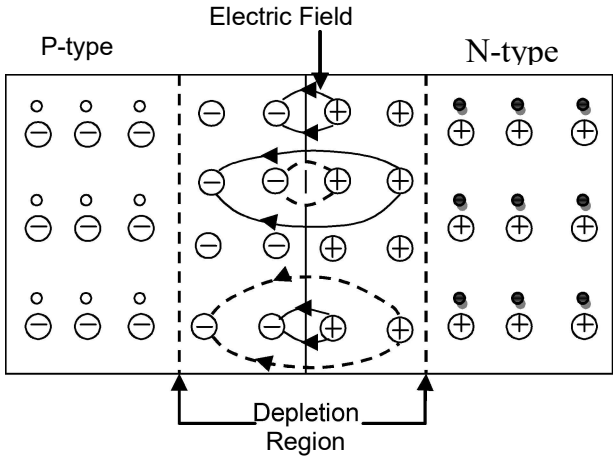


Fig. 10.7 Formation of depletion region of the P-N junction

There are two ***bias*** conditions available to a P-N junction. They are–

- Forward bias and
- Reverse bias.

Forward Biased P-N Junction

When the positive terminal of a battery is connected to the P-side of

a semiconductor and the negative terminal to the N-side, the P-N Junction is said to be in forward biased state.

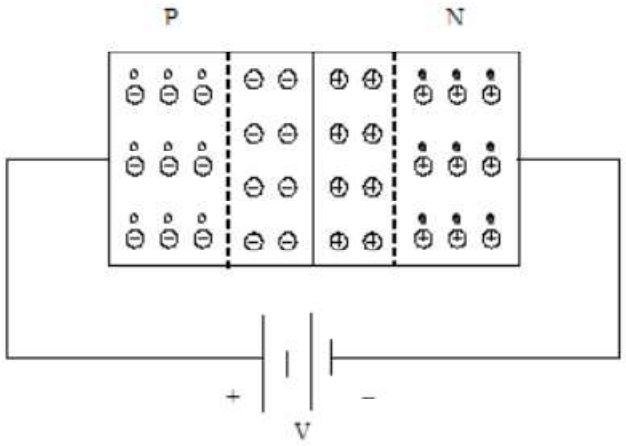


Fig. 10.8 Forward Biased P-N Junction

When the P-N junction is forward biased, the positively charged holes are repelled from the positive terminal of the battery and are forced to move towards the junction. The electrons are repelled from the negative terminal of the battery and flow towards the junction. Because of the application of forward voltage, an electric field is set up which acts against the field due to potential barrier. Therefore, the resultant field is weakened and the potential barrier as well as the thickness of the depletion region is reduced. As a result, more majority carrier crosses the junction where they recombine and movement of electrons and holes continues a large current flow through the semiconductor which is called forward current. Thus the junction offers low resistance in the forward bias.

There is also present a small amount of current I0 due to minority carriers on the either side that depends on the temperature but is almost independent of applied voltage.

Reverse Biased p-N Junction

When the negative terminal of the battery is connected to the P-side and the positive terminal to the N-side, the P-N junction is said to be in reverse biased. The holes in the P-side and the electrons in the N-side are attracted to the negative and positive terminals of the battery respectively. Thus the majority carriers are move away from the junction, causing the thickness of the depletion region to increase. This increases the potential

barrier and offers a high resistance to the flow of charge carriers. Thus it allows minimum electric current to cross the p-n junction. However, a very small amount of current flows in the circuit due to the minority carriers. This current is called reverse saturation current which is very small and depends on the temperature. In Silicon, it is of the order of nA and in Ge it is μA.

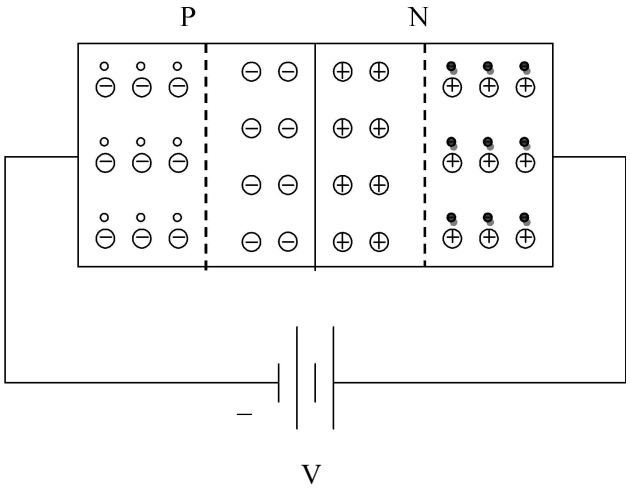


Fig. 10.9 Reverse Biased P-N Junction

V-I Characteristics

The graph between the voltage applied across the two terminals i.e. anode and cathode and the current that flows through the P-N junction is known as the V-I characteristics of a P-N junction diode. The voltage is taken along X-axis and current along Y-axis. In the given figure, the dc battery V is connected to the diode through the potentiometer P. It helps in varying the voltage applied to the diode. The milliammeter (mA) measures the current in the circuit and the voltmeter measures the voltage across the diode.

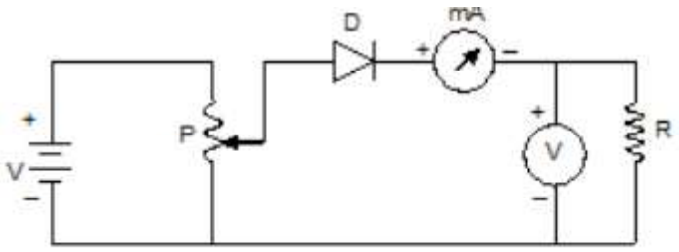


Fig.10.10 (a) The circuit do determine V-I characteristic curve of P-N juction diode

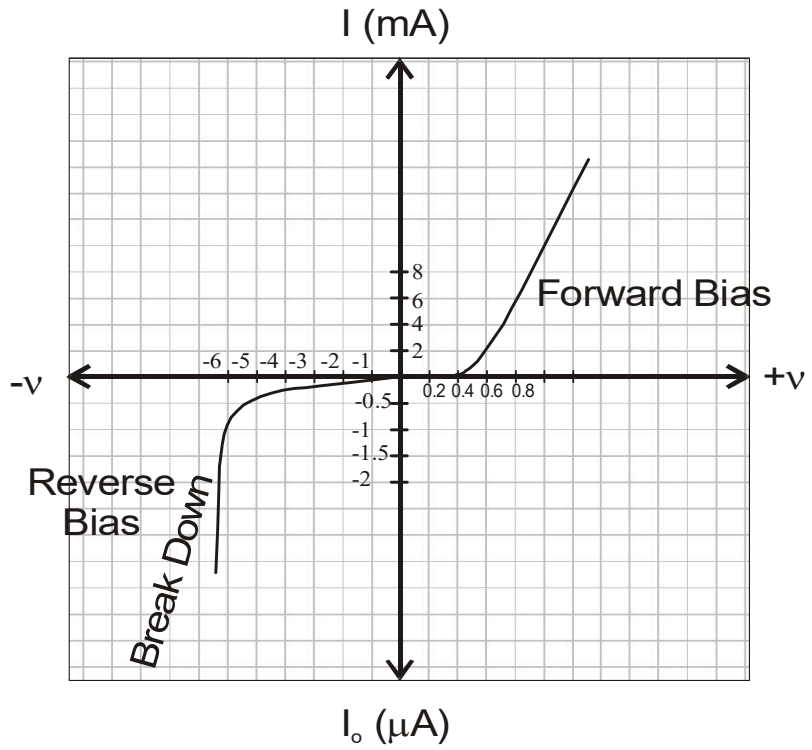


Fig.10.10 (b) V-I Characteristic Curve

The characteristics can be considered under three heads, namely; zero external voltage, forward bias and reverse bias.

Zero external voltage: When no external voltage is applied, the potential barrier at the junction does not allow current flow. Therefore, the circuit current is zero as indicated by point o.

Forward bias: When forward bias is applied, the potential barrier is reduced. The current increases very slowly when applied voltage is less than the potential barrier. At some forward voltage, the potential barrier is eliminated and current starts flowing in the circuit. It increases with increase in the forward voltage and the curve is almost linear.

Reverse bias: When reverse bias is applied,the potential barrier is increased. As a result the junction resistance is very high and practically no current flows through the circuit. A very small amount of current called reverse ***saturation*** current due to minority carriers flow in reverse bias. If reverse voltage is increased con-tinuously, break-down of the junction occurs, causing a sudden rise of reverse current and a rapidfall of the barrier resistance.

Application of P-N Junction Diode

There are many applications of semiconductor diode depending on there variations in dopants, semiconductor materials, and manufacturing techniques. The main applications are as below:

1. As rectifier diodes. They can convert ac current into dc current or dc power supplies used in electronic circuits.
2. As single diodes for modulation and demodulation purposes in communication systems.
3. As Zener diodes in voltage stabilizing circuits.
4. As Varactor diodes – for use in voltage controlled tuning circuits as found in radio and TV receivers.
5. In logic circuits used in computers.



CHECK YOUR PROGRESS

Q 3: Answer True or False :

a) A diode has two P-N junctions.

b) The resistance of forward biased diode is low.

c) When reverse bias is applied to a junction diode, it Increases the potential barrier.

d) The depletion region in a junction diode contains fixed donor and acceptor ions.

e) Rectification is a process of converting of d.c. to a.c.

Q 4: Fill in the Blanks:

a) In reverse bias the junction resistance is very _____.

b) When the P-N junction is forward biased, the positively charged holes are _____ from the positive terminal of the battery.

10.5 ZENER DIODE

A Zener Diode is a special kind of diode. It allows current to flow in the forward direction as usual, but will also allow it to flow in the reverse direction when the reverse voltage above a certain value is applied. This reverse voltage is called the breakdown voltage. It is also known as the Zener

voltage. The breakdown is the voltage at which the current is suddenly increases to a large value. When a diode breaks down, two mechanisms take place, Zener breakdown and Avalanche breakdown.

In Zener breakdown, the covalent bonds of the semiconductor atoms breaks down by strong electric field set up in the depletion region by the reverse voltage. It generates a large number of electrons and holes that constitute the reverse saturation current also called Zener current (IZ). It is independent of applied voltage and is limited by the external resistance in the circuit. This process is reversible and takes place with highly doped P-N junction.

In Avalanche breakdown, the electrons acquire enough energy to collide with other carriers. This collision breaks covalent bond and more electron-hole pairs are generated which gives rise to high reverse current. This process is irreversible and damages the diode permanently. It occurs with lightly doped P-N junction.

In the junction diode, when breakdown occurs below 5V, it is caused by zener effect and when the breakdown voltage is above 5V, it is caused by avalanche effect.

The zener diode is used in reverse bias mode. In a Zener diode, when the supply across the diode is exceeds the breakdown voltage, it acts like a constant voltage source. The circuit symbol and the V-I characteristic curve of the diode is shown in the figure below.

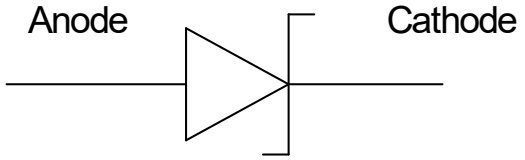


Fig. 10.11(a) Symbol of Zener Diode

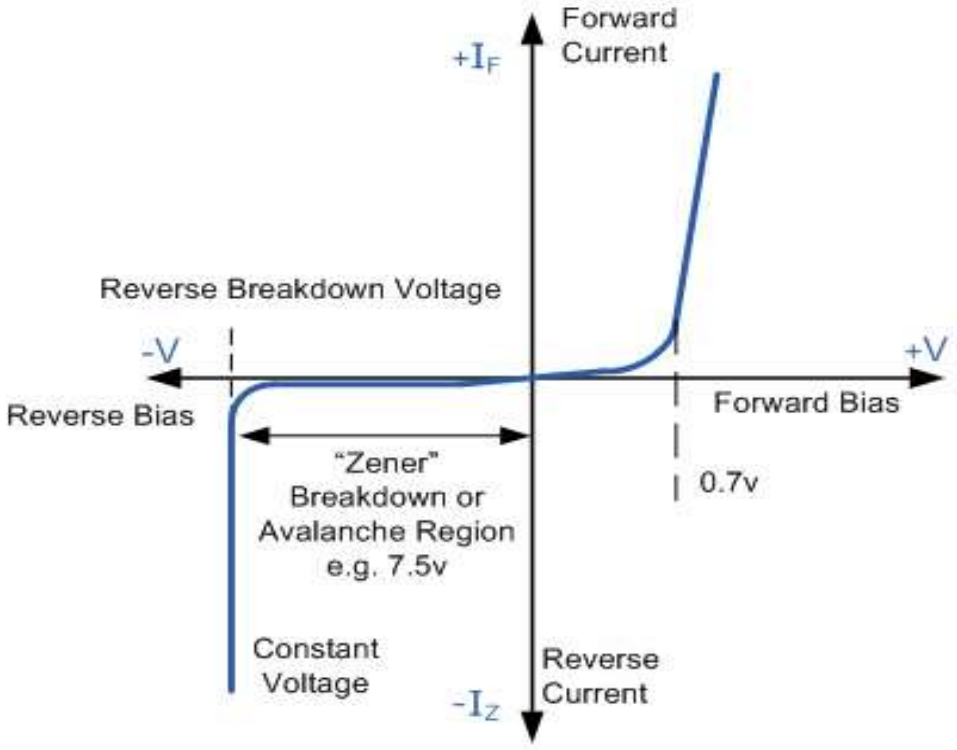


Fig. 10.11 (b) V-I Characteristic of Zener Diode



CHECK YOUR PROGRESS

Q 5: Fill in the blanks :

1. A semiconductor diode designed to operate in the breakdown region is called _____ diode.
2. A Zener diode is used in _____ biased mode.
3. When the reverse voltage exceeds the breakdown voltage, a Zener diode acts like a _____.

10.6 TRANSISTOR

A transistor is a semiconductor device generally used to amplify or switch electric signals. A transistor is made of a single piece of a semiconductor crystal containing two P-N junctions formed by sandwiching one type of semiconductor material between two layers of other type. A transistor has three regions, namely; emitter, base and collector.

Emitter: It is the left most region of transistor and is more heavily doped than the other regions because it is mainly used to release electrons

or holes to the next region i.e. base.

Base: The middle region is called the base. It is very lightly doped and is very thin because it passes most of the emitter injected carriers to the next region i.e. collector.

Collector: It is the right most region of the transistor. The main function is to collect the majority carriers through base. It is moderately doped and large in size because it is required to dissipate more heat.

The junction between the emitter and base is called the emitter-base junction which is in forward biased and has low resistance. The other junction between the base and collector is called the collector- base junction which is in reverse biased and has high resistance. The Transistor has the capability of transferring a signal from low resistance circuit to high resistance circuit. Hence the name transistor is joining the two terms “transfer” and “resistor”.

Types of transistor

Transistor is also known as Bipolar Junction Transistor (BJT) because both the carriers i.e. electrons and holes are takes place in current conduction. The BJTs are divided into two types.

- P-N-P Transistor and
- N-P-N Transistor.

P-N-P Transistor: A P-N-P transistor is composed of two P-type semiconductors separated by a thin layer of N-type semiconductor. In this transistor the conduction is by holes.

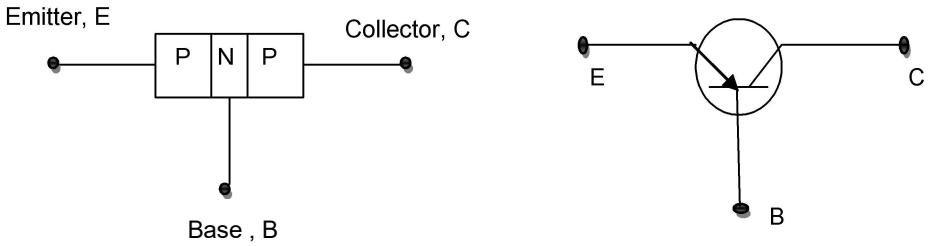


Fig. 11.12 (a) Structure of P-N-P Transistor; (b) Circuit Symbol of PNP transistor

N-P-N Transistor: An N-P-N transistor is made of two N type material sandwiched between a P type materials.

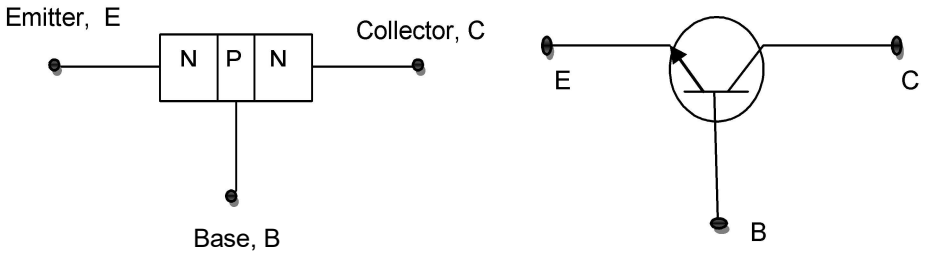


Fig. 10.13 : (a) Structure of N-P-N Transistor; (b) Circuit Symbol

Transistor Configuration

Generally, there are three types of circuit arrangements for operating a transistor.

They are–

- Common Base (CB)
- Common Emitter (CE)
- Common Collector (CC).

Common Base: In this configuration the base terminal is common to both the input and output circuit. The input signal is applied between the emitter and base and the output is taken out from the collector and the base terminal.

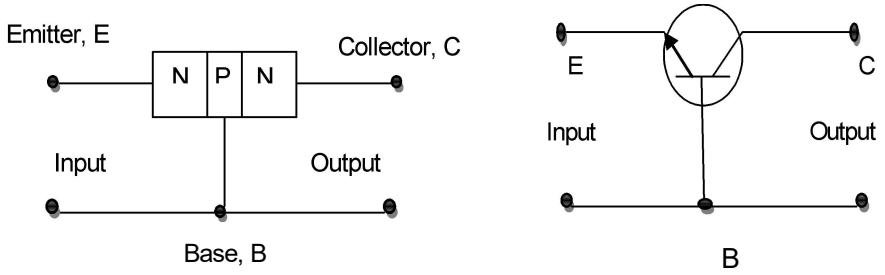


Fig. 10.14 : Common base configuration of NPN transistor

Common Emitter: Here the emitter terminal is common to both the input and output circuit. The input signal is applied between the base and emitter terminal and the output is taken out from the collector and emitter terminal.

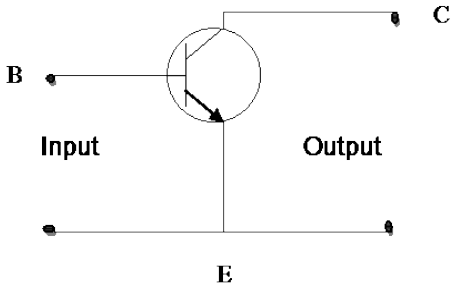


Fig. 10.15 Common emitter configuration of NPN transistor

Common Collector: In this configuration the collector terminal is common to both input and output circuit. Here the input signal is applied between the base and collector terminal and the output is obtained from the emitter and collector terminal.

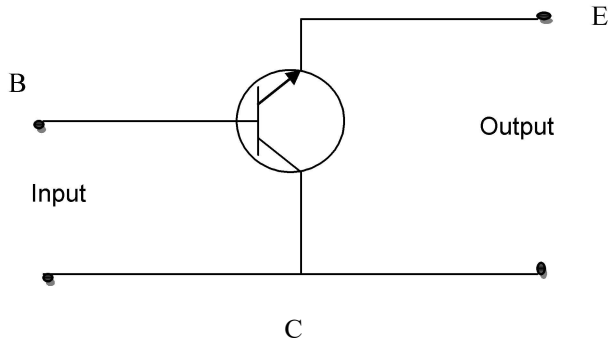


Fig. 10.16 Common Collector Configuration of NPN transistor

Operation Modes

Transistor can be operated in three different modes. They are discussed below.

Active Mode: In this mode, the emitter-base junction of the BJT is forward biased and the collector-base junction is reversed biased. This mode of the transistor is used for amplification.

Saturation mode: In this mode, the emitter-base junction and collector-base junction are forward biased and the transistor has very large value of current. This mode is suitable when the BJT is operated as a switch.

Cut-off mode: In this mode both the emitter-base and the collector-base junctions are reversed biased. In this case, the current in the transistor is practically zero, because emitter provides no current. The BJT operates as an open switch when in this mode for switching application of transistor; saturation and cut-off mode are used alternately.

The three operating modes are shown in figure 10.17.

Operating mode	EBJ	CBJ
Cut-off	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

For p-n-p transistor the polarities of the batteries will be just reversed.

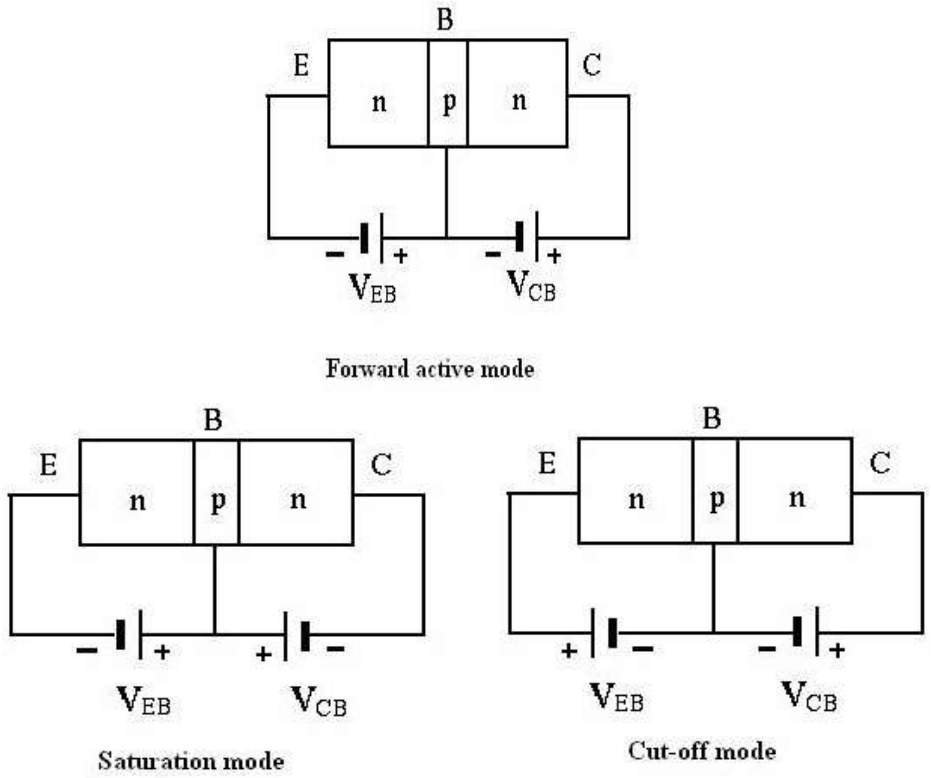


Fig. 10.17 Modes of BJT Operation

Working of Transistor

When there is no battery connection between the different terminals of a transistor, the transistor is said to be in an unbiased state. The process of applying DC voltages across the different terminals of a transistor is called biasing. In normal operation the EB junction is forward bias and the CB junction is in reverse biased. The forward bias reduces the barrier potential and narrows the depletion region whereas the reverse biased produces a wide depletion region.

Let us discuss the working of a PNP transistor which is shown in Figure 3.20.The EB junction of a PNP transistor is forward biased by the battery VEB and the CB junction is reverse biased by a bigger battery VCB. The forward bias causes the holes in the P-region cross over to the N-region or the base region. As the base is comparatively thin and is lightly doped, a majority of holes are cross into the collector region. A small number of holes are lost in the base region due to recombination with electrons. The holes that enter the collector region are attached by the negative terminal

of the battery VCB. Each hole is neutralizedby the electrons from thenegative terminal of the battery.

As each hole is lost by combination with an electron in the base and the collector region, an electron is free by the breaking down of a covalent bond near the emitter and the electrons so enlightened by the positive terminal of the battery VEB. Hole is produced by the breaking of covalent bond that moves towards the emitter –base junction and this process goes continuously.

It is noted that condu-ction within the PNP transistor is by holes and the conduction in external circuit is by the electrons.

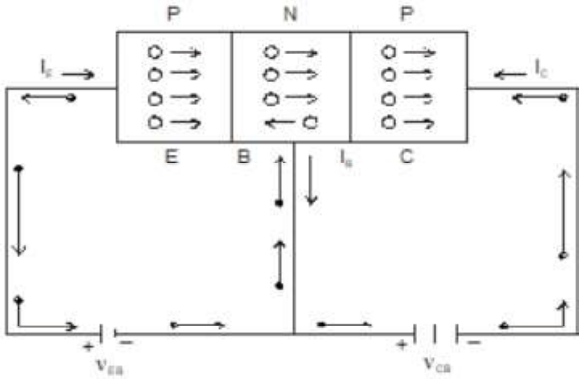


Fig. 10.18 PNP transistor



CHECK YOUR PROGRESS

Q 6: Why collector is made larger than emitter and base.

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Q 7: Why emitter is always forward bias.

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Q 8: What are the different operation modes of a transistor?

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Q 9: Distinguish between BJT and FET.

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10.9 LET US SUM UP

- All materials are classified into three categories- Conductor, insulator and semi-conducteur.
- Conductors have overlapping valence and conduction bands.
- Insulator have large forbidden gap.
- Semiconductor materials have partially filled conduction and valence band and a narrow energy gap.
- Semiconductors are classified as – Intrinsic and Extrinsic semiconductor.
- Extrinsic semiconductors are two types- P-type and N-type.
- Trivalent atoms are added to obtain P-typesemiconductor and pentavalent atome are added to get N-type semiconductor.
- The P-N junction offers low resistance in forward biasing and high resistance in reverse biasing.
- Zener diode always operate in reverse bias mode.
- Transistor is a bipolar device as both electrons and holes are responsible for current conduction.
- Field Effect Transistor is unipolar device because only the majority carriers are responsible for current conduction.
- Power transistors are mostly used in switching mode.
- Light dependent resistor is made of a high resistance semiconductor.



10.10 FURTHER READINGS

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2) **Principles of Electronics** –*V. K. Mehta &Rohit Mehta (S. Chand Publication)*

3) **Basic Electronics And Linear Circuits** –*N. N. Bhargava & S. C. Gupt (TATA McGraw-Hill Publication).*

4) **Electronic Devices and Circuits** –*J. B. Gupta (Kataria and sons).*



10.11 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: a) (iv) b) (i) c) (ii) d) (i) e) (ii)

Ans to Q No 2: a) True b) False c) False d) False
e) False f) True g) True

Ans to Q No 3: a) False b) True c) True d) True e) False

Ans to Q No 4: a) High b) Repelled

Ans to Q No 5: 1. Zener 2. reverse 3. Constant voltage source

Ans to Q No 6: Collector is made physically larger than emitter and base because collector is to dissipate much heat.

Ans to Q No 7: Emitter is always forward biased w.r.t. ground so as to supply majority charge carriers to the base.

Ans to Q No 8: The three different operation modes of Transistor are:
a) Active Mode b) Saturation Mode c) Cut-off Mode.

Ans to Q No 9: Difference between BJT and FET :

a. BJT is a current controlled device i.e. output characteristics are controlled by input current. Whereas FET is a voltage controlled device i.e. the output characteristics is controlled by the input voltage.



10.12 MODEL QUESTIONS

Q 1: What is transistor? Explain the transistor action for the NPN and PNP transistor.

Q 2: What do you understand by a semiconductor? Give some properties of semiconductor?

Q 3: What is Intrinsic and Extrinsic semiconductor?

Q 4: Discuss the behaviour of a P-N junction under forward and reverse biasing.

Q 5: Draw and Explain the V-I characteristics of a P-N junction.

Q 6: Give three applications of a Zener diode.

Q 7: What is the difference between avalanche and Zener breakdown?

Q 8: Write short notes on–

(i) FET (ii) Power transistor (iii) LDR

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UNIT 11 : INTRODUCTION TO THE ELECTRICIAN TRADE

UNIT STRUCTURE

11.1 Learning Objectives

11.2 Introduction

11.3 Electrician Trade

- 11.3.1 Scope of Electrician Trade
- 11.3.2 Employment opportunities

11.4 Responsibilities of Electrician and Wiremen

11.5 Training of Electrician

11.6 Let Us Sum Up

11.7 Further Readings

11.8 Answers to Check Your Progress

11.9 Model Questions

11.1 LEARNING OBJECTIVES

After going through this unit, you will be able to–

- describe the scope and employment opportunities of an electrician
- explain the responsibilities of electrician and wiremen
- discuss the training process of electrician.

11.2 INTRODUCTION

In the previous unit, we have focussed on the semiconductor devices. In this unit, we will introduce you about the scope of an electrician and the employment opportunities available for electrician. There is enough scope of an electrician for self-employment. Everyone needs the services of an electrician. The responsibilities of electrician and wiremen will be highlighted in this unit. In addition, the training process of electrician will also be focussed at the end of the unit.

11.3 ELECTRICIAN TRADE

The tasks performed by electricians were simpler earlier. Laying of conductors, service connection installation, fitting of energy meter and mains, distribution boards, switches, lights and fans, installation of earthing were the common tasks frequently electricians had to perform in domestic house wiring works. Now the tasks have become more challenging and demanding and at the same time more rewarding and attractive also. House wiring plans, layout and circuit diagrams are to be prepared. Related aspects like safety, type and nature of its use etc. are to be considered. Now energy meters are digital. Panel boards with control switches and digital meters to show voltage, current, power, frequency, etc. are installed. Several varities of circuit breakers are replacing the old distribution boards. Change over switches for generataros, provision for connecting inverters, voltage stabilizers, isolators and Uninterrupted Power Supplies (UPS) are to be provided. Provisions are to be made for connecting air conditioners, coolers, geysers, Heaters, water pumps, kitchenwares etc. Good quality earthing for sophisticated house hold equipment like computers etc. are to be provided. These present day requirements make the job of an electrician more challenging and rewarding.

11.3.1 Scope of Electrician Trade

People and industries are consuming more power than ever before, which demands more electricians to install and maintain electrical systems.Hence industries in a variety of works like electrical firms, parts manufacturers etc.are in need of skilled industrial electricians.

Electrician, Electrical Fitter, Technician, Operator are some of the common designations of a professional associated with the electrician trade. A professional of electrician trade has to perform technical and related tasks connected with the utilization of electrical energy while at the same time ensuring safety, economy and efficiency in the use of electricity. The tasks commonly and frequently

entrusted to a professional engaged in the electrician trade can be broadly divided into following categories

1. Installation: Installation of service connection, control panels and switchboards, house wiring, earthing, motors, transformers etc.
2. Operation, Maintenance and repair: Operation of machineries and equipment in power houses, factories and industries. Maintenance and repair of house wiring, electrical connections.Maintenance, fault finding and fault rectification in electrical power distribution systems. Repair of electrical items, devices. Repair and maintenance of electrical machineries.
3. Testing and Measuring: These include testing of electrical installations, house hold wiring insulation testing, earth resistance measurement, periodic testing and checking of electrical machineries. Calculation and distribution of loads are based on tests and measurements.
4. Study of drawing and specifications: It includes preparation, study and interpretation of plans, lay out diagrams, circuit diagrams, symbols and specifications etc.
5. Estimating and specifying: Preparation of estimates and specifications of jobs and materials and their specifications in terms of rating, quality brands etc.
6. Design, manufacture, assembly, construction: Participation as a member of a team in designing, manufacturing, assembling and construction of electrical items, products or equipment in an organization like factory or industry.
7. Record keeping: Taking readings of meters and moving instruments of various quantities in the control room, power house, industry, log book maintenance, reporting faults, problems etc.
8. Others: Lighting and decorations in events like festivals, puja, marriage ceremony etc; rewinding of motor, transformer,

troubleshooting of starter; demonstration of how to operate electrical machineries, devices, practical training to newcomers to the profession etc.

11.3.2 Employment Opportunities

There are some good employment opportunities for professionally sound electricians. Public sector organisation such asAPDCL, AEGCL, APGCL, National Thermal Power Corporation (NTPC), North east Electric Power Corporation (NEEPCO), National Power Grid, National Hydro Electric Power Corporation (NHPC), Oil and Natural Gas Corporation (ONGC), Oil India Limited (OIL), Indian Railways, Department of Telecom, etc. recruit a good number of professionals of electrician trade every year. Factories and Industries in both Public sector and Private sector also hire electricians. Hotels, Hospitals, Apartment Flatsetc engage electricians on regular basis. Firms and companies dealing with electrical products, material and equipment appoint electricians.

There are also very good opportunities for self-employment for the competent professional of electrician trade. One can start his own enterprise with minimum capital investment after acquiring necessary skills and expertise. An electrician gets ample work in the area he lives in;this can be extended to other areas. A very good relationship with a number of households including neighbours can be a basis to start with keeping regular contacts and then attending and solving day to day minor problems involving electricity. A knowledgeable and skilled electrician can undertake on contract basis house wiring jobs, maintenance jobs in hotels, offices, winding of motors, transformers, fans etc. and assembling of electrical products and equipment. There are some other options like opening unit for assembling panels, workshop for repair and servicing of electrical hardware and equipment, machineries etc and dealership or agency of electrical products, hardware and machineries.



CHECK YOUR PROGRESS

Q 1: Write down the full form of NTPC and NEEPCO.

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Q 2: Write down the full form of APDCL, AEGCL and APGCL

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10.4 RESPONSIBILITIES OF ELECTRICIAN AND WIREMEN

An electrician is a person whose function is the installation, maintenance, repair, or operation of electric equipment and circuitry. The wireman is a person who installs and maintains electric wiring. The job of an electrician is a regulated trade for safety reasons due to the many hazards of working with electricity, requiring testing, registration, or licensing. Licensing of electricians is controlled through government and/or professional societies. One must know some more duties and responsibilities before getting into this profession. One

- must have sufficient knowledge about the job an electrician is expected to do.
- must take care of all safety precautions.
- must know how to handle all the tools and equipment.
- have the ability to handle emergency situations.
- must have a proper idea about making plan and cost estimation.
- must know the Indian Electricity Rules, Acts and Wiring Standards.



CHECK YOUR PROGRESS

Q 3: Who is an electrician?

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10.5 TRAINING OF ELECTRICIAN

There are many electrical companies manufacturing different types of electrical appliances. Many types of new electrical appliances and devices are coming to the market day by day. Therefore it is essential for electricians to undergo training on new electrical products to know about the installation, operation and maintenances of these products. These appliances and devices are used in industries, motor vehicles, residential buildings, traction, warehouse etc. The electrical appliances and devices are batteries, house hold appliances, lighting equipments, industrial control products, motor and generator, switch, connector and other wiring devices,devices used for circuit protection, conductors, wire, cable etc. It also needs for the electrician to be acquainted with new electrical products. They should know about the tools used for electrical works. For all types of electrical works need skilled electrician. Therefore, training of electrician is essential. The industrial training and training in residential building and apartment at the time of electrification help the electrician.



11.6 LET US SUM UP

- Electrician, Electrical Fitter, Technician, Operator are some common designations of the personal handling electricians trade.
- There are very good self-employment opportunities for the professionals of the electrician trade. One can start his own enterprise with a minimum capital investment after acquiring necessary skills and expertise.
- The danger from electricity can come in any form. It may be a danger to the personnel, to the electrical equipment or to the environment.
- The job of an electrician is a regulated trade for safety reasons because he may be exposed to many hazards connected with electricity.The job comprises testing, registration, or licensing.



11.7 FURTHER READINGS

1) R. C. Mullin, Phil Simmons, *Electrical Wiring Residential*, Cengage learning.

2) R. C. Mullin, Robert L. Smith,*Electrical Wiring: Commercial [With Wiring Plans]*, Delmar Thomson Learning.

3) M. L. Anwani, Basic Shop Practicals in Electrical Engineering.



11.8 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No 1: House wiring refers to the tasks to be done to prepare a house, building or premises for providing electrical connection.

Ans to Q No 2: National Thermal Power Corporation (NTPC), North East Electric Power Corporation (NEEPCO)

Ans to Q No 3: An electrician is a person whose job is connected with the installation, maintenance, repair, or operation of electric equipment and circuitry.



11.9 MODEL QUESTIONS

Q 1: What are the tasks performed by an electrician?

Q 2: What are the common designations of an electrical professional?

Q 3: What are the scopes of an electrician?

Q 4: Training is necessary for an electrician. Why?

Q 5: Why demand for skilled electrician is increasing?

Q 6: What are the electrical appliances and devices to be handled by an electrician?

Q 7: What are the main responsibilities of an electrician and wiremen?

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