GOVERNMENT OF TAMIL NADU

HIGHER SECONDARY FIRST YEAR

VOCATIONAL EDUCATION

Basic Electrical Engineering

THEORY & PRACTICAL

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Department of School Education

Untouchability is Inhuman and a Crime

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in

Preface

We are living in a modern world where all the systems are interconnected and interdependent with electrical sciences. By the year 2050, the demand of electrical energy is double or even become triple due to the advancement in modern technology. Now-a-days, affordable knowledge is essential in the field of electrical sciences for better understanding of electrical appliances.

This book has been written primarily as a text book for the students and is designed to serve the introductory part of the subject, electrical engineering in school education under vocational stream. The basic concepts of electrical sciences are explained with neat diagrams for better understanding to the learners.

This Electrical Machines and Appliances (EMA) book has been written with the inspiration and interaction of scholars in electrical fields in India and abroad. The resource materials and ideas for making this book is obtained from experts in the field of electrical engineering in around the country to meet the curriculum to international standards. The design of this book is based on bloom's taxonomy which is a learning tool for all students. The theory and problems available in this text book obviously motivates the students for better understanding. The contents of this book are mainly confined to the content of syllabus fulfilling the objectives.

I along with team members originally undertook the task of writing the text book for the vocational group students as basic subject in the field of electrical engineering due to the knowledge which have experienced in three decades. My experience in teaching taught me two things about students; need for better understanding of concepts and relating the concepts to the real life cycle. This intention forced me in making this book as effective one as a learning material for the vocational group students. As a result, the students will definitely follow along with the subject teacher in demonstrating an example in handling classes. I hope this book will definitely satisfy the primary needs of the student's community to pursue secondary level courses.

Myself with our subject experts' team have provided this text book a more knowledgeable and readable one fulfilling the needs of students. Consequently, the teacher will feel more comfortable using the book because it reflects the electrical engineering concepts in a pedagogy way.

I would like to extend my sincere appreciation to the faculty from various academic institutions for the improvement of this text book writing.

Finally, it is an immense pleasure to express the gratitude and sincere thanks to all of them who has given this opportunity to take part in writing the book for vocational stream students.

How to Use the Textbook

Learning Objectives:	Learning objectives are brief statements that describe what students will be expected to learn by the end of school year, course, unit, lesson or class period.
Chapter Outline	Illustrate the complete overview of chapter
DO YOU KNOW?	Amazing facts, Rhetorical questions to lead students to biological inquiry
Activity	Directions are provided to students to conduct activities in order to explore, enrich the concept.
Infographics	Visual representation of the lesson to enrich learning .
Evaluation	Assess students to pause, think and check their understanding
TN_QR_ENG	To motivate the students to further explore the content digitally and take them in to virtual world
Career corner	List of professions related to the subject
References	List of related books for further details of the topic
Web links	List of digital resources
Glossary	Explanation of scientific terms
Competitive Exam Questions	Model questions to face various competitive exams

Career Guidance

VOCATIONAL STREAM

After completion of Higher Secondary course (+2), Vocational stream students undergo the following courses as detailed below:

LATERAL ENTRY FOR DIPLOMA IN ENGINEERING: (FOR +2 STUDENTS)

The Vocational stream students, on completion of Higher Secondary, are eligible to continue their educational career to Polytechnic colleges by lateral entry.

(i.e.) They can directly join in the **SECOND YEAR** of the concerned Diploma course.

After that, they can register their names in the "Board of Apprenticeship training, No. 4th Cross street, CIT Campus, Taramani, Chennai – 13" for employment opportunities.

LATERAL ENTRY FOR BE / B.TECH : (FOR DIPLOMA HOLDERS)

On completion of Diploma courses of any trade, the students can directly join in the SECOND YEAR of the Engineering course (BE / B.TECH) in Anna University and Affiliated colleges, by lateral entry.

Then, they can register their names in the "Board of Apprenticeship training, No. 4th Cross street, CIT Campus, Taramani, Chennai – 13" for employment opportunities.

NATIONAL CAREER SERVICE

The students who need for employment opportunities and career guidance, including counselling both in Government, Private and Public sector can see the website for further details.

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- Open the QR code scanner application
- Once the scanner button in the application is clicked, camera opens and then bring it closer to the QR code in the text book.
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Basic Electrical Engineering

THEORY

LESSON 1

Introduction To Electrical Engineering

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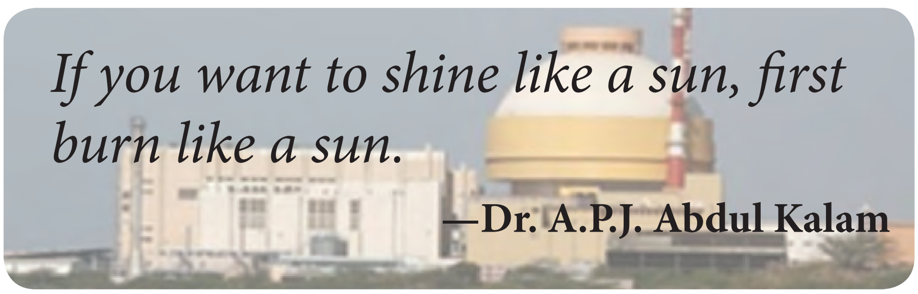

If you want to shine like a sun, first burn like a sun.

—Dr. A.P.J. Abdul Kalam

LEARNING OBJECTIVES

The objective of this lesson is to know about Electricity, the methods of power generation. Beyond this, about the safety precautionary measures of electricity and also what are the first aids to be given to a person who is affected by electric shock.

Table of Content

1.1 INTRODUCTION ABOUT ELECTRICITY, METHODS OF POWER GENERATION

This subject is introduced in the higher secondary level. In this subject, students are taught how to maintain and repair electrical appliances and electrical machines and how to connect electrical circuits and repairing minor or major faults in the circuits and motor, rewinding of electrical machines both theoretically and practically. So, by learning this subject, students are able to learn on their own by practicing such learning.

We know that the Earth consists of five big natural element such as water, land, air, fire and sky. The sixth important energy developed by human is called "Electricity". In this modern world, in our day today life, electricity plays a vital role. Simply to say, a man can live without food but cannot live without electricity. Thus in our life, the electrical goods play an important role. Hence the students must know about this source and how it is applied.

All matters whether solid, liquid or gaseous consist of minute particles known as atom. According to modern research, electric current means electrons movement only. So we need to know about atom.

1.1.1 Atom

It has a hard-central core known as nucleus. It contains two types of particles; one is known as proton and carries positive charge. The other is neutron, which is electrically neutral. i.e. it carries no charge. Around the nucleus, in an elliptical orbit, the electrons are revolving. Electrons carry the negative charge. The number of electrons and number of protons in an atom are equal. So the atom is electrically neutral. The number of protons in the nucleus of atom gives the atomic number. The total number of neutron and proton are known as atomic weight, because negligible weight of the electron is not taken to calculate atomic weight.

1.1.2 Methods Of Electricity Production

Electricity is produced by extraction of electrons from an atom. The energies which are used to produce electricity are:

a) Friction
b) Light
c) Pressure
d) Heat
e) Chemical Action
f) Magnetism

a) Electricity due to Friction

Due to the friction of two materials, electrons come out from one material to join with the other material. The material which loses the electron gets (+)ve charge and the material which attracted the electron gets (–)ve charge. This type of electricity is called Static Electricity.

Example :- Materials like glass, rubber, wax, silk, reyon, nylon etc.

BENJAMIN FRANKLIN

Born: January 17, 1706
Died: April 17, 1790

Franklin started exploring the phenomenon of electricity in 1746.

He was the first to label as positive and negative respectively and also the first to discover the principle of conservation of charge. In 1748, he constructed a multiple plate capacitor, that he called as "electrical battery".

He made important contributions to science, especially in the understanding of electricity, and is remembered for the wit, wisdom, and elegance of his writing

b) Electricity due to Light

When the light falls on the photo sensitive materials, the electrons from the surface produce the flow of current. The material which emits electrons due to the light fallen on the surface is called "photo sensitive material".

Example :- Sodium, Potassium, Lithium and Caesium.

c) Electricity due to Pressure

Electrons in the outermost orbit of an atom is extracted due to the pressure applied to an atom and thus electricity is produced. This is called "Piezo Electricity". In a telephone, diaphragm is pressured by the sound waves. Because of this, electric waves are produced depending upon the pressure of sound waves.

Do You Know?

A solar power plant in Kamuthi, Tamil Nadu has just became the world's largest plant. With a capacity to produce 648 MW of electricity, this plant comprises of 2.5 million individual solar modules and covers an area of 10 sq km.

d) Electricity due to Heat

If the ends of two dissimilar metal rods are joined together to form a junction and is heated, voltage is developed at the other ends and this effect is known as thermo electric effect.

In the above four methods, sufficient electricity is not produced and the energy of electricity is also less. The other two following methods are used to produce sufficient electricity with high energy.

e) Electricity due to Chemical Action

By using chemical action method, electrons are extracted from an atom and electricity is produced. The voltage developed in storage battery is due to this chemical action only.

f) Electricity due to Magnetism

In this method, electrons are extracted from an atom due to magnetism. In generators, conductors are moving within the magnetic field to generate electricity.

1.1.3 Power Generating Plants

Today, approximately seven electric power generating stations are available in our country.

TYPES OF POWER GENERATING PLANTS

a) Hydroelectric Power Plant
b) Thermal Power Plant
c) Atomic Power Plant
d) Gas Power Plant
e) Diesel Power Plant
f) Solar Power Plant
g) Wind Power Plant

a) Hydroelectric Power Plant

From the water reservoir, the water is taken through the joint tubes to the water turbine. For the rotation of turbine, the kinetic energy of water is converted into mechanical energy and is converted into electrical energy by using generator.

This type of plant is placed in Tamil Nadu at Mettur, Kunda, Pykara, Suruliyaru and Kadamparai.

b) Thermal Power Plant

Chemical energy is converted into heat energy by burning coal or lignite in boiler plant. Water in the boiler is converted into steam by heat energy. This steam is flowing through the steam turbine which is connected to the generator and this energy is converted into mechanical energy by the rotation of turbine. The mechanical energy is again converted into electrical energy by the use of generator.

This type of plant is placed in Tamil Nadu at Ennore (Chennai), Neyveli, Tuticorin and Mettur.

Thermal power plants play a major role for the requirement of electricity in Tamil Nadu.

c) Atomic Power Plant

By the diffusion of an atom of Uranium or Thorium, more heat is produced. The atomic power plant is working based on this principle. The heat energy produced is used to rotate the steam turbine and this energy is converted into mechanical energy. The generator converts the mechanical energy into electrical energy.

This plant is placed in Kalpakkam near Chennai,Koodangulam in Tirunelveli District and Tharapur in Rajasthan. Leakage of radiation by this plant may cause pollution and affect the health of the people.

d) Gas Power Plant

The process of generating electrical energy with the help of gas turbine (which acts as a prime motor) is known as Gas power plant. It is available in Ramanathapuram and Nagapattinam districts.

e) Diesel Power Plant

This type of plant is used in places where continuous supply of electricity is needed i.e. in big factories. Electricity is produced by the generator which is connected to a big diesel engine.

Depending upon the requirements, different capacities of small or large diesel generators are used in hotels, hospitals, jewellery shops, cinema theatres, shipyards, etc.

f) Solar Power Plant

For the purpose of minimum production of electricity, this type of plant is placed on the roof of the buildings. In this plant, electricity is produced by using sun-rays. This is used in houses, hotels, hospitals, traffic signal lights, etc.

g) Wind Power Plant

The Wind mill is rotated by heavy speed of wind. Electricity is produced by the generator which is operated by wind-mill. This plant is placed at Kayathar in Thirunelveli and Aralvaimozhi in kanniyakumari District.

Hydro Power Plant (Mettur)

Thermal Power Plant (Neyveli)

Atomic Power Plant (Kalpakkam)

Gas Power Plant (Chennai)

Diesel Power Plant (Chennai)

Solar and Wind Plant (Kamuthi)

Fig 1.1 *Types of Power Plants*

1.2 INTRODUCTION OF LT/ HT LINE

Generated power from power station is transmitted and is distributed through transformers, overhead lines and cables to the end users.

1.2.1 LT Lines

In India, low Tension (LT) supply is 440 volts for three-phase connections and 230 volts for single-phase connection. Consumer of electricity like individual houses, shops, small offices and smaller manufacturing units get their electricity on LT connection.

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Fig 1.2 *LT Line*

1.2.2 HT Line voltage

High tension (HT) supply is applicable for bulk power purchase which needs 11 Kv or above. Major industries are operating at High Tension supply only.

Fig 1.3 *HT Lines*

1.3 ELECTRICAL SAFETY AND PRECAUTIONS

A man who works in the electrical appliances must handle the work carefully without any damage to the equipment and workers. They must know all the operations of electrical equipment clearly. Electrical accident may occur only due to carelessness. Due to this, workers will get injured and cause damages. To avoid this, electrical workers must follow the rules and regulations while working.

1.3.1 Steps to be followed while handling Electrical Equipments

1. Before the use of equipment, one must know about the complete operation of the equipment. Electrical connections are made properly according to the connection diagram.
2. Only the skilled person is allowed to operate, testing and repairing machines.
3. A person who works in the electric post and tower post must wear safety belt and gloves.
4. After earthing, the overhead lines can be discharged by discharge rod.
5. Check the condition of all hand tools.
6. While changing the fuse wire, keep the main switch 'OFF'. Use proper rating of fuse wire for replacement.

7. Under faulty conditions, the appliances in houses must be checked and ensure that the equipment is disconnected from the supply.
   Example:- Fan, Grinder, Mixie etc.
8. If fire occurs in the electrical circuit, the main switch is turned OFF immediately. For extinguishing electric fire, use of carbon-di-oxide extinguisher or dry powder extinguisher is advised.
   (Water should not be used to extinguish electric fire because it conducts electricity and will cause severe accident.)
9. If any person gets electric shock by touching the electric wire, the supply should be disconnected immediately. The person must be removed from the wire using dry stick, drywooden plank or dry cloth.
10. Sweating hand should not be used to switch ON or work on the electric supply. If the person has sweating on the hand continuously, he must wear gloves.

1.4 ELECTRIC SHOCK

Human body has a electrical conducting property. Without sweating the resistance of human body is approximately 80000Ω (ohm) and during sweating, resistance of the human body is approximately 1000Ω (ohm). If we touch any current carrying conductor, the current is conducted through our body to earth and we get electric shock more over nervous structure, heart, lungs, and brain can also be affected. If the current is heavy, even death may occur. Therefore, we must know, even though current is essential, if it is used wrongly, it will cause heavy loss i.e death and economical loss.

To prevent such electrical shocks, we must know about the preventive measures and protective measures for safety precautions.

1.5 PREVENTIVE MEASURES TO AVOID ELECTRIC SHOCK

Some of the methods employed to avoid electric shock are listed below:

- The operation of electrical equipment must be clearly known.
- Damaged wire should not be used for wiring or electrical connection.
- The electrical instruments used for connection (i.e switch, plug, pushing etc). It should not have any scratch or break.
- The hand tools should be properly insulated.
- Proper earthing should be provided.
- For any reason, do not operate by overcoming the safety rules.

1.6 FIRST AID

When a man gets affected by an electrical shock in an unavoidable condition, he must be given first aid before taking to the hospital.

When a person is affected by current shock, the circuit should be disconnected first. If the main switch is nearer, put off the switch. Using any wooden stick, we could disconnect the person from the circuit. Then immediately take him to hospital.

If the affected person loses consciousness, but breathes normally, then

Do You Know?

A tall thunderstorm cloud can hold over 100 million volts of potential. The voltage potential in a lightning bolt is proportional to its length, and varies depending on the diameter of the bolt, air density and impurities of the air.

loosen his clothes and apply cold water on his face and keep him in open air.

If the person does not breathe, then immediately arrange artificial method of respiration for breathing.

There are two methods of artificial breathing.

1.6.1 Holger Nelson Method

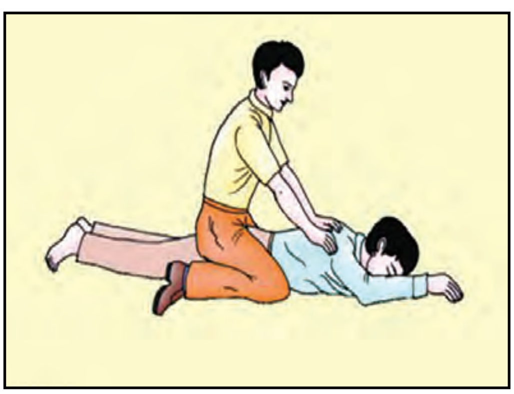


Fig 1.4 *Holger Nelson Method*

In this method, the victim should be kept in the bed facing the ground. The helper sitting at his head should massage his back using both hands. This is done within two seconds.

1.6.2 Mouth to Mouth Method

In this method, the helper pushes air by keeping his mouth on the victim's mouth. By closing his nose, the air is filled in lungs

Fig 1.5 *Mouth to Mouth Method*

Activities

Students are asked to do the concept of static electricity by seeing the picture shown.

Do You Know?

When was electricity first used in homes?

Edison's light bulb was one of the first applications of electricity to modern life. He initially worked with J. P. Morgan and a few privileged customers in New York City in the 1880s to light their homes, pairing his new incandescent bulbs with small generators.

Activities

1. Produce electricity by any two materials applying friction method.
2. How the supply leakage electric shock can be eradicated?

GLOSSARY

Hydroelectric Power Plant	—	நீர் மின் நிலையம்
Thermal Power Plant	—	அனல் மின் நிலையம்
Gas Power Plant	—	வாயு மின் நிலையம்
Diesel Power Plant	—	டீசல் மின் நிலையம்
Solar Power Plant	—	சூரிய ஒளி மின் நிலையம்
Wind Power Plant	—	காற்றாலை மின் நிலையம்
L.T – Low Tension Line	—	குறைவழுத்த மின்சாரம்
H.T – High Tension Line	—	உயர்வழுத்த மின்சாரம்

Q A

PART A

Mark 1

SRNPP6

Choose the Correct Answer:

1. The smallest particle of an element is known as
   a) Atom
   b) Molecule
   c) Nucleus
   d) Electron

2. The Atom is composed of
   a) Electrons only
   b) Protons only
   c) Neutrons only
   d) Electron, Proton and Neutron

3. HT Line means
   a) 230V
   b) 440V
   c) Above 11 Kv
   d) Below 11 Kv

4. LT Lines means
   a) 230 volts or 440 volts
   b) 440 Kv
   c) Above 11 Kv
   d) Below 11 Kv

5. In case of Electric fire, use
   a) Dry sand
   b) Wet sand
   c) Carbon powder
   d) Water

6. The number of electrons in an atom are
   a) Equal to the neutrons
   b) Equal to protons
   c) Equal to the atomic structure
   d) None of these

7. The supply voltage used for single phase domestic purpose is
   a) 110–120V
   b) 120–130V
   c) 220–230V
   d) 400–440V

8. Switch should always be connected with
   a) Neutral wire
   b) Earth wire
   c) Phase wire
   d) None of these

9. Without the sweating of human body, the resistance is approximately.
   a) 80 kΩ
   b) 40 kΩ
   c) 10 kΩ
   d) None of these

Q A

PART B

Mark 3

Answer the Questions in Briefly

1. Define Atom.
2. What is electricity?
3. What are the methods used for production of electricity?
4. Define L.T Line.
5. Define H.T Line.
6. What are the precautions taken to avoid electric shock?
7. What are the different methods of artificial respiration?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the method of preventing an electric shock.
2. Explain the different types of first aid given to electric shock.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the various methods adopted for power generation.
2. Write down the steps to be followed while handling electrical equipment.

Reference Book

1. 'A text book of Electrical Technology' Volume I and Volume III by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd

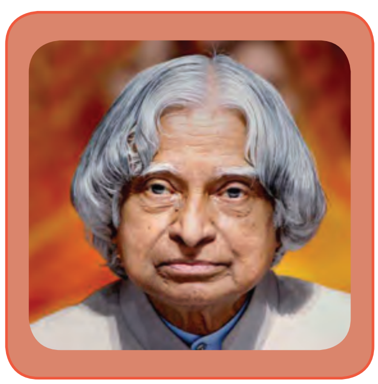
LESSON 2

Electrical Fundamental Terms

SRSCD3

"Black colour is sentimentally bad, but black board makes the student's life bright"

—Dr. A.P.J. Abdul Kalam



LEARNING OBJECTIVES

Fundamental terms are mostly important for doing Electrical circuits. This chapter deals about the properties, types of conductors and insulators. Basically each one should know about current, voltage, resistance, laws, emf and potential difference. The objective of this lesson is also to know about the types of electrical circuits.

Calculation of power consumption is easily explained in this chapter. It is used to calculate the power consumed (unit) in home, factory, etc. and the cost of expenses is also calculated. This is very much useful to the younger generation to learn how to minimize the usage of electricity. It is helpful to reduce the unwanted usage of electricity and the expense is reduced. Thereby it induces individual saving habit.

Table of Content

2.1 INTRODUCTION

In this modern world, electricity plays a major role in human life. This is because, electrical appliances play an important role in our day to day life. According to theory, the current flow is nothing but flow of electrons. The force required to move electrons from higher level to lower level is called voltage.

Hence conductors are required to conduct the current from one place to another place. They are classified in to three types, namely solid conductors, liquid conductors and gaseous conductors. The material which does not conduct current is called an insulator. Another one is a semi-conductor, which has the property in between the conductor and insulator. Semi-conductors are used in making electronic devices.

First, let us study the types and properties of conductors.

2.2 CONDUCTORS

The wire which carries or conducts the current from the supply to the load is called conductors. The example of loads are fan, bulb, mixie, motors etc. Based on the state the conductors, they are classified into three types:

i) Solid Conductors
ii) Liquid Conductors
iii) Gas Conductors

i) Solid Conductors

These conductors are converted into thin wire, thin rod or strap for the purpose of conduction.

Some of the examples of solid good conductors are Silver, Copper, Brass, Aluminium, Tungsten, etc.

ii) Liquid Conductors

The conductors in the form of liquids are called liquid conductors. Liquid conductors are mostly used in batteries.

Example: Mercury, Sulphuric Acid, Nitrate etc.

Mercury is used in high power vapour lamp and automatic circuit breakers.

iii) Gas Conductors

The conductors in the form of gas are called gas conductors. These are used in gas discharge lamps at high temperature which are used in big shops, malls, etc.

2.2.1 Properties of Conductors

So far we have studied about the types of conductors. Let's see the properties of good conductors.

- They conduct the current easily, because they have low resistance
- Have high tensile stress
- They are more flexible
- They are not affected by corrosion due to air, rain, heat, etc
- They are not affected by heat produced in conductor, when current flow takes place

- Easy to solder
- Cost of the conductor is low and is easily available to buy

2.3 INSULATORS

Insulator is a non-conducting material, i.e. it resists electricity. It has high resistance value normally in mega ohms.

Insulators should be good in condition, then only they prevent electric shock due to current leakage. Generally, insulators are classified into three types. Some examples of the three types of insulators are:

i) **Hard Insulators:** Bakelite, porcelain, wooden plank, glass, mica, etc.
ii) **Soft Insulators:** Rubber, poly-vinyl chloride, varnish coated papers, etc.
iii) **Liquid Insulators:** Mineral oil, shellac, varnish, etc.

Fig 2.1 *Hard Insulator*

Properties of Insulators

The following are the important properties of insulating materials. They are:

- High resistance and specific resistance
- High dielectric strength
- Good mechanical strength
- It withstands high temperature
- May not get change in the shape due to high temperature
- It does not absorb water
- It can be made to any shape
- It does not catch fire easily

2.4 ELECTRICAL TERMS

Here we study the electrical fundamental terms used in electrical engineering.

2.4.1 Current

Flow of electron in a conductor is called as current. It is represented by the letter 'I' and the unit is called ampere(A). Current can be measured by ammeter.

1 Ampere: "One coulomb charge crossing over the area of cross section of the conductor in one second is called 1 ampere.

1 Coulomb: A collection of $2\pi \times 10^{18}$ electrons has a charge of one coulomb.

Example :- For water to flow through a pipe from one end to the required place, some pressure is required. In the same way, electric pressure is required to move the electron from one end to another end. This flow of electron is called current and the pressure required to move the electron is called electric pressure or voltage.

2.4.2 Voltage

The electric pressure which is used to move electrons from one end to another end is called voltage. It is represented by the letter 'V' and the unit is volt. It is measured by volt-meter. The other parameters termed as volts are EMF, Potential and Potential Difference.

i) Electro Motive Force (EMF)

It is the force which causes the flow of electrons in any closed circuit. It is represented by volt.

ii) Potential and Potential Difference

The work done in bringing unit positive charge from infinity to that point against the application of electric field is called potential. It is also represented as volt.

The difference of potential between any two points in a electrical circuit is called potential difference and is expressed as volts only.

The following table represents the difference between electromotive force (EMF) and Potential Difference (PD).

Electro Motive Force (EMF)	Potential Difference (PD)
i) EMF refers to source of electricity only.	PD exists between any two points in a circuit.
ii) It is measured when the circuit is open.	It is measured on a closed circuit.
iii) It does not depend upon the resistance of the circuit.	It depends upon the resistance of the circuit and is directly proportional to it.
iv) It is greater than the potential difference in the same circuit.	It is less than the electromotive force.

2.4.3 Electric Power

Power is rate of doing work. The power is obtained by the following expressions.

$P = V \times I$. The unit is watt
P = Power
V = Applied Voltage
I = Current

2.4.4 Resistance

Resistance may be defined as the property of a substance to oppose the flow of current flowing through it. It is represented by the letter R and the unit is ohm(Ω). It is measured by ohm meter. Mega ohms value is measured by using megger

2.4.5 Laws of Resistance

The resistance of a conductor in a circuit depends upon the following:

- It depends upon the material used and its properties
- Resistance value of a conductor is directly proportional to the length of the conductor
- It is inversely proportional to the area of cross section of a conductor
- It also depends upon the temperature of the conductor when the current is flowing through it

2.5 OHM'S LAW

In an electrical circuit the current, voltage, and resistance are related to one another. The relationship was derived by the scientist ***Georg Simon Ohm***. So it is called Ohm's Law.

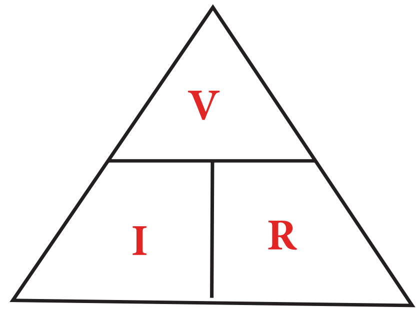
Ohm's law states that, *"At a constant* temperature *in any closed circuit, the current is directly proportional to the voltage applied and inversely proportional to the resistance of the circuit."*

i.e I α V and I α 1/R from this

$V = I\,R$ and $R = \dfrac{V}{I}$

Where, V = Voltage in volts. I = current in ampere and R = Resistance in ohm

$V = I \times R$



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

Georg Simon Ohm

Born: 1789

Died: 1854

Georg Simon Ohm (1789 – 1854) was a German physicist and mathematician. As a school teacher, Ohm began his research with the new electrochemical cell, invented by Italian scientist Alessandro Volta.

Ohm found that there is a direct proportionality between the potential difference applied across a conductor and the resultant electric current. This relationship is known as **Ohm's law**.

Problems

1) *Supply voltage of the circuit is 240V. The resistance value is 60Ω. Calculate the current flowing through this circuit.*

   Voltage (V) = 240V
   Resistance (R) = 60Ω
   Current (I) = ?
   According to ohm's law, $I = \dfrac{V}{R}$

   Current $I = \dfrac{240}{60} = 4A$

2) *An electrical circuit has 1000W power and the value of voltage is 240V. Find the value of current flowing through it.*

   Power (P) = 1000W
   Voltage(V) = 240V
   Current(I) = ?
   Power, $P = V \times I$
   $1000 = 240 \times I$
   $I = \dfrac{1000}{240} = 4.16$ A

3) *Voltage of the circuit is 230V and current 10A is flowing through it. Find the value of Resistance.*

   Voltage (V) = 230V
   Current (I) = 10 A
   Resistance (R) =?
   According to ohm's law, $I = \dfrac{V}{R}$

$$\text{i.e } 10 = \frac{230}{R}$$

$$R = \frac{230}{10} = 23\Omega$$

4) *An electrical circuit is having 40Ω resistance value. When 6A current is following through this circuit, find the voltage?*

Resistance (R)= 40Ω
Current (I) = 6A
Voltage (V) = ?
According to ohm's law, $I = \frac{V}{R}$

$$\text{i.e } 6 = \frac{V}{40}$$

Voltage (V) = 6 × 40 = 240V.

2.6 TYPES OF CIRCUITS

The circuit is defined as the current flowing from the supply points through the load to complete the path. In this chapter, we will study about the types of the electrical circuits. There are three types of electrical circuit namely;

i) Closed circuit,
ii) Open circuit and
iii) Short circuit.

These are explained below

i) Closed Circuit

When loads are connected in series between two terminals of electric supply, in such a way that the current passing through the load is to activate the circuit. It is called as closed circuit.

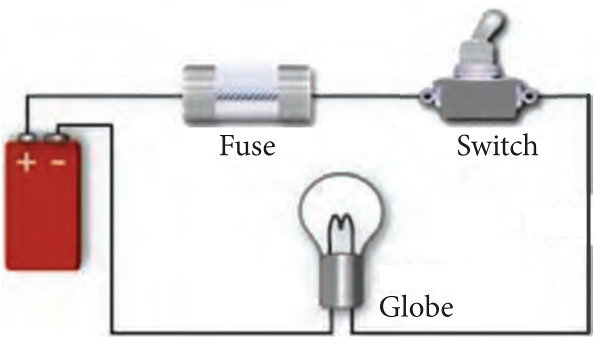


Fig 2.2 *Closed Circuit*

Example:- In our home, each room has different wiring circuit i.e lighting circuit, power circuit, etc.

For example, if we switch ON the light circuit, the light will glow, it is called a closed circuit.

ii) Open Circuit

In this circuit, if there is no way to the flow of current due to disconnection of wire or the switch is in OFF condition, then the circuit is called open circuit.

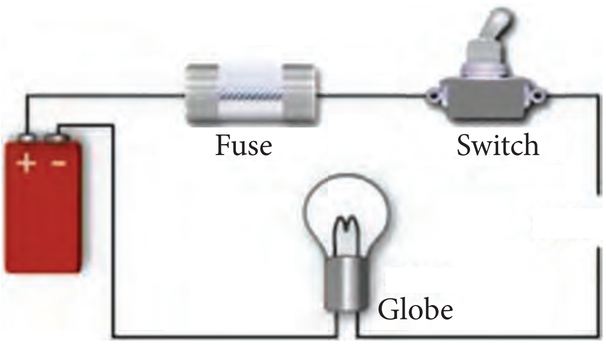


Fig 2.3 *Open Circuit*

Ex: In lighting circuit, if the switch is in OFF condition or the wire is broken in any place the lamp will not glow and it is called an open circuit.

iii) Short Circuit

In this circuit, the two terminals of the supply is connected directly without a load and the current flow is infinite because of very low resistance. It causes heavy damage to the load.

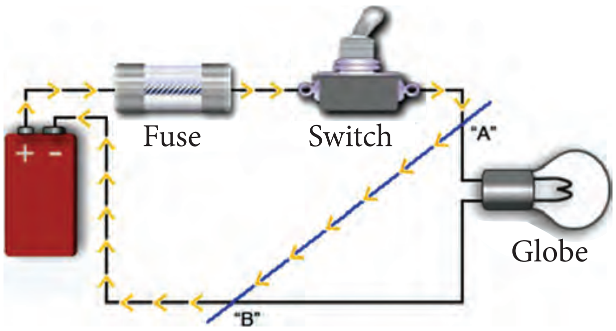


Fig 2.4 Short Circuit

Here we will study about the classification of the Electrical circuits. They are,

i) Series circuit
ii) Parallel circuit
iii) Series-parallel circuit
iv) Mesh (or) Network circuit

2.6.1 Series Circuit

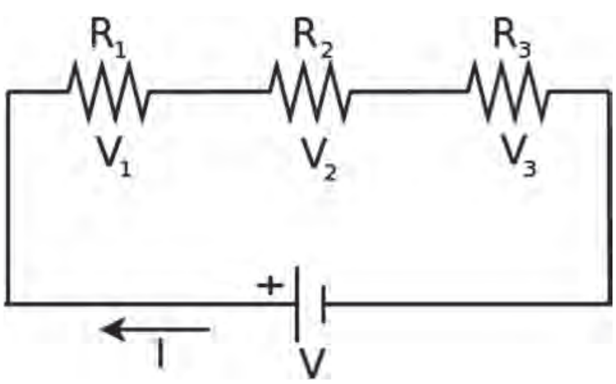


Fig 2.5 Series Circuit

When three resistors are connected in series with each other as shown in Figure 2.5, so that the same current passes through all of them is called series circuit.

Here the resistors R_1, R_2 and R_3 are connected in series. The current flowing in all three resistors is same as that of supply current. But across each resistor, it has a potential drop depending on their resistance value.

According to Ohm's law

$V_1 = I.R_1, V_2 = I.R_2, V_3 = I.R_3$

The sum of the three potential drops in equal to the supply voltage

$$I = I_1 = I_2 = I_3$$
$$V = V_1 + V_2 + V_3$$
$$V = IR_1 + IR_2 + IR_3$$
$$V = I(R_1 + R_2 + R_3)$$
$$\frac{V}{I} = R_1 + R_2 + R_3$$

Where $R = R_1 + R_2 + R_3$

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

❖ **Important rules for series circuit**

1. In series circuit, the current flows through only one path.
2. If one more resistance is to be added, the total value of resistance is increased. Total resistance is equal to the sum of all the resistance connected to this circuit.

i.e $R = R_1 + R_2 + R_3 + \ldots\ldots$

3. The current flows in all resistor is same

i.e, $I = I_1 = I_2 = I_3$

4. The sum of the potential drop across each resistor is equal to the supply voltage i.e $V = V_1 + V_2 + V_3$
5. If there is a fault in any place of the circuit, the total circuit will be inactive.

Example:- In many of the places like temple functions, malls, theatres and marriage halls, serial sets are used to make different decorative items using serial bulbs. In serial circuit, the path of the current flow is only one. So if any fault (brake in wire connection) occurs in any one place of the circuit, the total circuit (serial set) is inactive.

2.6.2 Parallel Circuit

When resistors are connected across one another so that the same voltage (supply voltage) is applied between the end point of each resistor, then they are said to be in parallel connection.

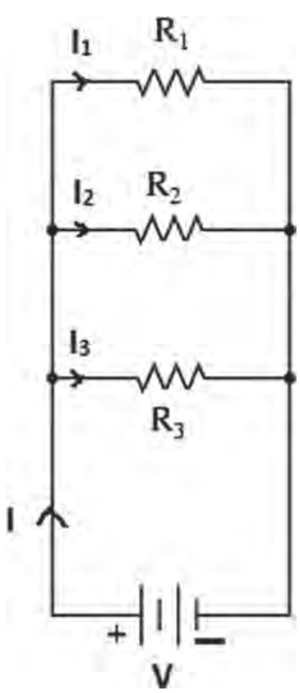


Fig 2.6 *Parallel Circuit*

In this circuit, the voltage across each resistor is same as supply voltage but the current in each resistor is different. In this circuit, the sum of the current I_1, I_2 and I_3 is equal to supply current I, i.e $I = I_1 + I_2 + I_3$

According to ohm's law

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

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

But $I = I_1 + I_2 + I_3$

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

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

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

$$\frac{I}{V} = \frac{1}{R}$$

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

$$= \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$$

$$R = \frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2}$$

Important rules of a parallel circuit

i) In parallel circuit, the current flows through two or more parallel paths at a junction.

ii) Current varies in different resistances i.e The sum of the current is equal to supply current.

$$I = I_1 + I_2 + I_3 + \ldots$$

iii) The voltage is same in all resistors as supply voltage.

$$V = V_1 = V_2 = V_3 = \ldots$$

iv) The total value of the resistance is reduced by adding one more resistor in the circuit. If resistances are connected in parallel then the total resistance

$$R = \frac{R_1R_2R_3}{R_2R_3+R_1R_3+R_1R_2}$$

v) If there is a fault in any one resistor, the other two resistors will work because the current will flow through these resistors.

Example: In our home or factories, different types of electrical appliances are used, i.e, fan, bulb, television, motor, heater, etc. Each one has a separate circuit. For example if there is a fault in fan circuit, the fan circuit alone is inactive. Other circuits like bulb, television etc will work continuously. So, in parallel circuits there are a number of current paths available.

PROBLEMS – (Series Circuit)

1) ***10Ω, 20Ω and 30Ω resistances are connected in series. The circuit voltage is 240V. Calculate the i) Total resistance ii) current of this circuit.***

$R_1 = 10\Omega$, $R_2 = 20\Omega$, $R_3 = 30\Omega$
$V = 240V$
$R = ?$
$I = ?$

When the resistors are connected in series
Then $R = R_1 + R_2 + R_3$
$=10 + 20 + 30 = 60\Omega$

Total Resistance $R = 60\Omega$
According to ohm's law

$$I = \frac{V}{R}$$
$$= \frac{240}{60} = 4A$$

Current I = 4A.

2) ***Three resistances 5Ω, 15Ω and R_3 are connected in series. Resistance of this circuit is 60Ω. Find the value of R_3.***

$R = 60\Omega$, $R_1 = 5\Omega$, $R_2 = 15\Omega$, R_3=?

When the resistance are connected in series

Then $R = R_1 + R_2 + R_3$

$60 = 5 + 15 + R_3$ and
$60 = 20 + R_3$ $R_3 = 60-20 = 40\Omega$.

PROBLEMS – (Parallel Circuits)

1) ***Two resistances 8Ω and 2Ω are connected in parallel. Voltage of this circuit is 240V. Find the value of***
i) Total Resistance
ii) Current.

$R_1 = 8\Omega$, $R_2 = \Omega$
R =?

In parallel circuit

$$R = \frac{R_1R_2}{R_1+R_2}$$
$$= \frac{8\times 2}{8+2} = \frac{16}{10} = 1.6\Omega$$

According to ohm's law

$$I=\frac{V}{R}, I=\frac{240}{1.6}=150A$$

2) ***Three resistors 6Ω, 3Ω and 2Ω are connected in parallel. The current flow of this circuit is 2A. Find out the value of***
   i) Total Resistance
   ii) Voltage.

$R_1 = 6\Omega$, $R_2 = 3\Omega$, $R_3 = 2\Omega$, $I = 2A$
$R = ?$ $V = ?$

When they are connected in parallel

Then
$$R=\frac{R_1R_2R_3}{R_2R_3+R_1R_3+R_1R_2}$$
$$=\frac{6\times3\times2}{(3\times2)+(6\times2)+(6\times3)}$$

$$R=\frac{36}{6+12+18}=\frac{36}{36}=1\Omega$$

According to ohm's law

$$I=\frac{V}{R}$$
$$2=\frac{V}{1}, V=2V$$

2.6.3 Series - Parallel Circuit

In series parallel circuit, one or more resistors are connected in series with more resistors connected in parallel. This is the combination of series parallel circuit.

Fig 2.7 represent, five resistors connected in series parallel circuit. Here R_1, R_2 are connected in series and R_3, R_4, and R_5 are connected in parallel. These parallelly connected resistors are connected in series with R_1 and R_2.

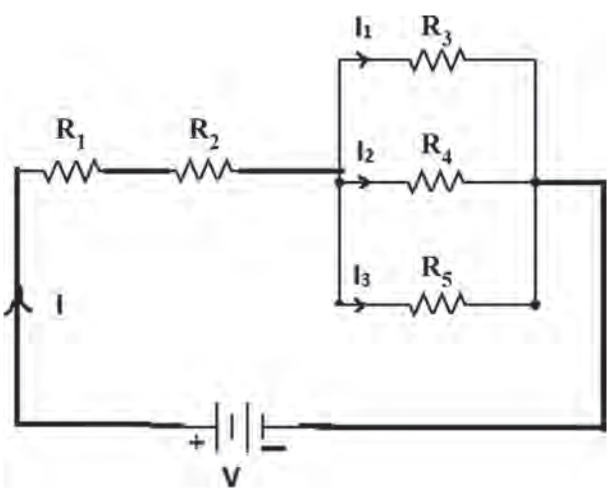


Fig 2.7 *Series - Parallel Circuit*

Hence the total resistance of the circuit is

$$R=R_1+R_2+\left[\frac{R_3\times R_4\times R_5}{R_4R_5+R_3R_5+R_3R_4}\right]$$

2.6.4 Kirchhoff's Laws

Scientist Kirchhoff derived two more laws based on ohm's law namely,

i) Kirchhoff's Current Law (KCL)
ii) Kirchhoff's Voltage Law (KVL)

Current law is based on the current and voltage law is based on the voltage. These laws are explained as follows.

Kirchhoff's Laws are used in determining the equivalent resistance of a complex network and the current flowing in the various conductors.

i) Kirchhoff's Current Law (KCL)

The sum of the current flowing towards a point (i.e junction) is equal to the sum of the current flowing away from the point. In other words, the algebraic sum of

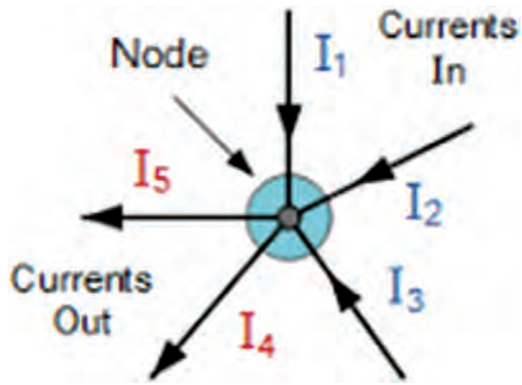


Fig 2.8(i) *Kirchhoff's Current Law*

the currents at any junction of a network is zero.

Fig 2.8(i) represents Kirchhoff's Current Law. In this, I_1, I_2 and I_3 represent the current flowing towards the junction point I_4 and I_5 represent the current flowing away from the junction point.

$$I_1 + I_2 + I_3 = I_4 + I_5$$

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

ii) Kirchhoff's Voltage Law (KVL)

In any closed electric circuit, the algebraic sum of the potential drop is equal to the supply voltage.

Fig 2.8(ii) represents, loads R_1, R_2, and R_3 connected in series. Potential drop across R_1 is IR_1, potential drop across R_2 is IR_2 and potential drop across R_3 is IR_3.

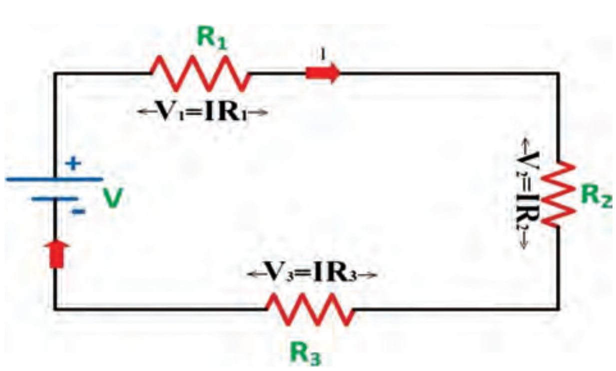


Fig 2.8(ii) *Kirchoff's Voltage Law*

$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$
$$V = V_1 + V_2 + V_3$$
$$IR = IR_1 + IR_2 + IR_3$$

Gustav Robert Kirchhoff

Born: 1824

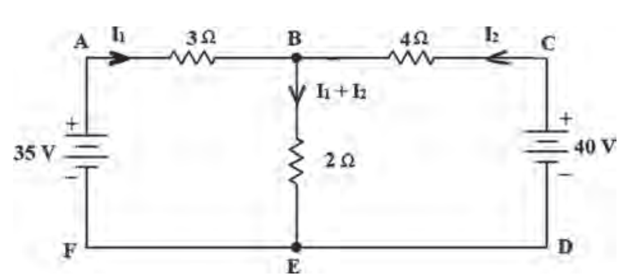
Died: 1887

Gustav Robert Kirchhoff (1824-1887) was a German physicist who contributed to the fundamental understanding of electrical circuits. Kirchhoff formulated his circuit laws, which are now ubiquitous in electrical engineering.

Problems:

Example: 1

Calculate the current in a 2Ω resistor using Kirchoff's law in the following circuit.



In the closed Loop ABEFA.

$$3I_1 + 2(I_1 + I_2) = 35$$
$$3I_1 + 2I_1 + 2I_2 = 35$$
$$5I_1 + 2I_2 = 35 \qquad (1)$$

In the closed loop BCDEB

$$4I_2 + 2(I_1 + I_2) = 40$$
$$4I_2 + 2I_1 + 2I_2 = 40$$
$$2I_1 + 6I_2 = 40 \qquad (2)$$
$$(1)\times 3, \quad 15I_1 + \cancel{6}I_2 = 105 \qquad (3)$$
$$2I_1 + \cancel{6}I_2 = 40$$
$$(3)-(2), \quad 13I_1 = 65$$
$$I_1 = \frac{65}{13} = 5A.$$

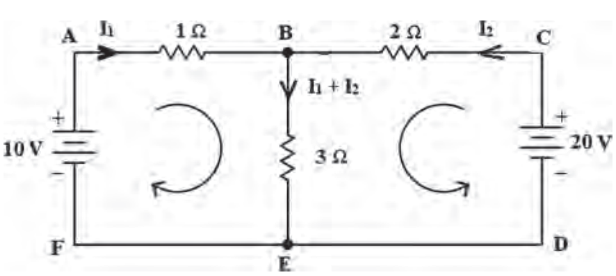
Substituting the value of I_1 in equation 2, we get

$$2I_1 + 6I_2 = 40 \qquad (2)$$
$$2 \times 5 + 6I_2 = 40$$
$$10 + 6I_2 = 40$$
$$6I_2 = 40 - 10 = 30$$
$$6I_2 = 30$$
$$I_2 \frac{30}{6} = 5A$$

Then current in 2Ω resistor is $I_1 + I_2$ = 5 + 5 = 10A

Example: 2

Find the current in the 3Ω resistor in the circuit as shown.



In the closed Loop ABEFA

$$I_1 + 3\ (I_1 + I_2) = 10V$$
$$I_1 + 3I_1 + 3I_2 = 10 \qquad (1)$$
$$4I_1 + 3I_2 = 10$$

In the closed Loop BCDEB

$$2I_2 + 3\ (I_1 + I_2) = 20V$$
$$2I_2 + 3I_1 + 3I_2 = 20 \qquad (2)$$
$$3I_1 + 5I_2 = 20$$

$$(1) \times 3 \Rightarrow 12I_1 + 9I_2 = 30 \text{ ------- } (3)$$
$$(2) \times 4 \Rightarrow 12I_1 + 20I_2 = 80$$
$$(3)-(4) \Rightarrow -11\,I_2 = -50 \qquad (4)$$
$$I_2 = \frac{-50}{-11} = 4.545A = 4.55A$$

Substituting the value of I_2 is equal to

$$3I_1 + 5I_2 = 20$$
$$3I_1 + 5 \times 4.55 = 20$$
$$3I_1 = 20 - 22.75$$
$$= -2.75$$
$$I_1 = -\frac{2.75}{3}$$
$$= -0.916A$$
$$I_1 = -0.916A$$

The value of current I_1 is negative, So the current flow in the curcuit, is in opposite direction.

The current in 3Ω resistor is $I_1 + I_2$ = −0.92 + 4.55 = 10A

2.6.5 Work, Power and Energy

We are going to study about the work, power and energy their inter-relation and calculation of power and energy in electric circuit.

i) Work

Work is said to be done by Force 'F' when the point of its application moves through a distance 'S'.

Mathematically, Work = Force × distance = F × S =FS.

The unit of force is Newton (N). If 1 Newton force moves a body to a distance of 1 metre, then the work done is 1Nm (Newton - metre)

In an electric circuit, if 1 volt electric potential causes 1 coulomb of electric charge to pass through it, then the work done is equal to 1 joule.

1 joule = 1 volt × 1 coulomb

Coulomb = Ampere × time

i.e $J = V \times I \times t$

ii) Power

Power is the rate of doing work. Its unit is watt (W).

$$\text{Power} = \frac{\text{work done}}{\text{time}} = \frac{\text{Joule}}{\text{time}} = \frac{V \times I \times t}{t}$$

$$\text{Power } P = \text{VI watt } [V = IR,\ P = I^2R]$$

$$1\text{ KW} = 1000\text{ watt}$$

$$1\text{ HP} = 746\text{ watt}$$

iii) Energy

The amount of work done by an equipment during a time period of 't' seconds. The unit of energy is joule.

Energy = power × time watt sec

The energy spent for the appliances in 1 kwh is called as one unit i.e

1 unit = 1kWh

The power of iron box is 1000 watt. when used for 1 hour, the energy consumed is, 1000 watts × 1 hour = 1000Wh = 1kWh = 1unit.

Example: 1

The resistance of a lamp is 10Ω and 2A current is flowing through it. Calculate the power of the lamp.

Solution:

Resistance (R) = 10Ω

Current (I) = 2A

Power = $I^2.R$

$=2^2 \times 10 = 40W$

Example: 2

In a factory, the following appliances are used

a) 3hp motor works 5 hours per day.
b) 100W capacity of 40 lamps glow 8 hours per day.
c) 1500W capacity of heater works 6 hours per day.

Calculate the cost of energy consumed in 30 days. (1unit cost is Rs. 6.00)

Solution:

a) 3hp motor works 5 hours per day

$$\text{Energy} = \frac{3 \times 746 \times 5}{1000} = \frac{11190}{1000}\text{Wh}$$

$$= 11.190\text{ kwh} = 11.190\text{ unit}$$

b) 100w capacity of 40 lamps glow 8 hours per day

$$\text{Energy} = \frac{100 \times 40 \times 8}{1000} = \frac{32000}{1000}\text{Wh}$$
$$= 32\text{kWh} = 32 \text{ units per day}$$

c) 1500w heater works 6 hours per day

$$\text{Energy} = \frac{1500 \times 6}{1000} = \frac{9000}{1000}\text{Wh}$$
$$= 9\text{kWh} = 9 \text{ units per day}$$

The total number of units consumed in 30 days

$$= (11.190 + 32 + 9) \times 30$$
$$= 52.19 \times 30$$
$$= 1565.7 \text{ units}$$

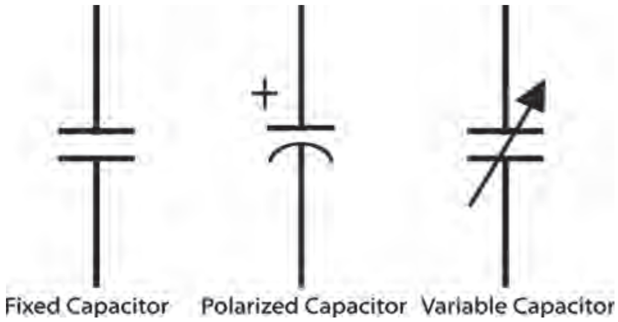
Cost of electricity by for 30 days (1 unit=Rs.6)

$$= 1565.7 \times 6$$
$$= 9394.2$$
$$\text{Cost} = \text{Rs.}9394$$

2.7 CAPACITORS

Capacitor can be defined as, two electrodes are separated by an insulating di-electric medium. It is a device to store electrical energy and to release it when required.

The charge in the capacitor is denoted by capacitance (Q) and the unit is farad (F). The Di-electric medium can be air, mica, wax coated paper or oil etc.



Symbols of Capacitor

2.7.1 Working Principle

In Fig 2.9, a simple parallel plate capacitor is connected with a battery.

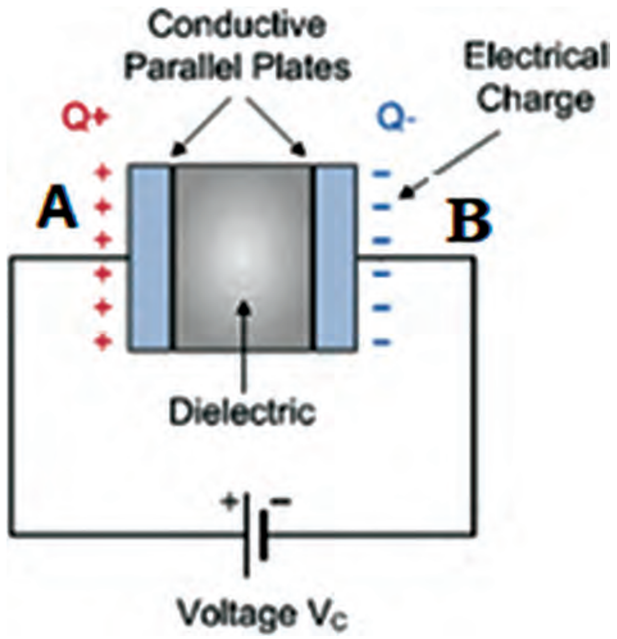


Fig 2.9 *Parallel Plate Capacitor*

Suppose plate 'A' is connected to the +ve terminal and plate 'B' is connected to –ve terminal of DC supply. On closing the switch there will be momentary flow of electrons from positive to negative. Some electrons are withdrawn from the plate 'A', leaving positively charged and transferred to plate 'B' giving it a negative charge. This flow of electrons gives charging current which decreases and finally ceases when the voltage across the capacitor plate has become equal and opposite the applied voltage. The charged capacitor is now full of stored energy. This stored energy can be used again when needed.

The factors on which the capacity of capacitor depends are:

a. Directly proportional to the area of the plate of the condenser.
b. Inversely proportional to the distance between the plate.
c. The nature of di-electric insulating material.

2.7.2 Capacitance(C)

Capacitance of capacitor is defined as the ratio between the charge given to the condenser and supply voltage. It is denoted by the letter C.

Suppose a charge +ve 'q' units is given to condenser, the potential will then be raised. The greater the charge given to the condenser, the greater is the rise in its potential.

we have q α v (or) $\frac{q}{v}$ constant.

$$C = \frac{q}{v} \text{ farad}$$

Hence, c is the capacity of the condenser.

q is the charge given to the condenser

v potential difference between the plates.

The unit of capacity is 'Farad'. A capacitor is said to posses a capacity of one farad, when its potential is raised by one volt, and when one coulomb of charge is given to it.

$$1 \text{ Farad} = \frac{1 \text{ coloumb}}{1 \text{ volt}}$$

$2\pi \times 10^{18}$ number of electrons is mentioned as one coulomb.

2.7.3 Types Of Capacitor

Usually there are three types of capacitor. They are

1) Fixed capacitor
2) Variable capacitor and
3) Electrolytic capacitor

Figure 2.10 *Capacitors*

i) Fixed Capacitor

a) Mica Capacitor

Mica capacitor is widely used in ratio circuit where fixed value condensers are required. These have metal foil sheets forming the coating and separated by a flat mica sheet as the dielectric medium

b) Paper Capacitor

Paper is rolled in the form of cylinder and dipper in wax solution in order to exhaust the air placed in between two thin aluminium plates. This type of capacitor is used in de-coupling circuits.

c) Ceramic Capacitor

These are the modern capacitors. In this, ceramic is used as di-electric medium. The performance of this capacitor may not be affected even it get heated.

ii) Variable Capacitor

These capacitors are used in radio receivers for tuning the receiver to a particular transmitting station. In this type, air is used as dielectric medium between Aluminium plates.

iii) Electrolytic Capacitor

Another type of capacitors, which can have a very large capacity of 10 to 100 µF in the electrolytic capacitor, is used in Radio circuit and Electric circuit. This is made by very thin Aluminium sheets which are separated by a thin layer of Aluminium Borate as Dielectric medium.

2.7.4 Uses of Capacitors

1. Capacitors in Fluorescent Tube

(i) When connected parallel with the supply, it improves power factor.

(ii) When connected in series with one of the two tube connected in parallel, it minimise the stroboscopic effect.

(iii) It helps to avoid radio interference when connected parallel with the two contacts of tube starter. Here, it eliminates the sparkling due to the opening of two contacts.

2. In motors

When connected in series with starting winding of the single phase motor, it splits one phase into two phases and gives starting torque to the motor.

Example: Table fan, ceiling fan, and small one phase motors.

3. In parallel with the supply lines

To improve the power factor because it takes leading current.

4. In eliminators

(An appliance which reduces 230 v Ac to 3, 6, 9v Dc)

Capacitor is connected in parallel with Dc side to filter remaining A.C.

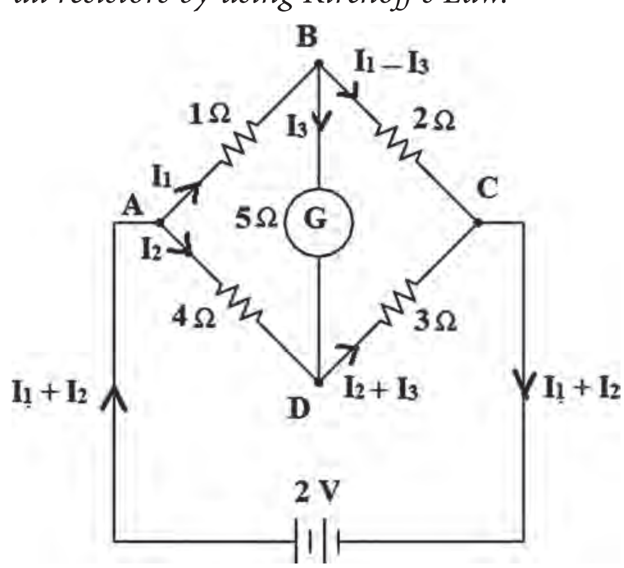
5. In petrol cars

It is connected in parallel with the two contacts of a distributor to avoid sparking due to opening of these contacts.

These are the uses of capacitors in various places.

Worked example:

Example:1 In an unbalanced bridge circuit, calculate the current flowing through all resistors by using Kirchoff's Law.



In Closed Loop ABDA,

$I_1 + 5I_3 - 4I_2 = 0$

$I_1 - 4I_2 + 5I_3 = 0$ (1)

Closed Loop BCDB

$2(I_1 - I_3) - 3(I_2 + I_3) - 5I_3 = 0$

$2I_1 - 2I_3 - 3I_2 - 3I_3 - 5I_3 = 0$

$2I_1 - 3I_2 - 10I_3 = 0$ (2)

Closed Loop ABCA

$I_1 + 2(I_1 - I_3) + (I_1 + I_2) - 2=0$

$I_1 + 2I_1 - 2I_3 + I_1 + I_2=2$

$4I_1 + I_2 - 2I_3 = 2$

$$\begin{bmatrix} 1 & -4 & 5 \\ 2 & -3 & -10 \\ 4 & 1 & -2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 1 & -4 & 5 \\ 2 & -3 & -10 \\ 4 & 1 & -2 \end{bmatrix}$$

$$= 1(6+10) + 4(-4+40) + 5(2+12)$$

$$= 16 + 144 + 70 = 230.$$

$$\Delta_1 = \begin{bmatrix} 0 & -4 & 5 \\ 0 & -3 & -10 \\ 2 & 1 & -2 \end{bmatrix}$$

$$= 0(6+10) + 4(0+20) + 5(0+6)$$

$$= 80 + 30 = 110$$

$$\Delta_2 = \begin{bmatrix} 1 & 0 & 5 \\ 2 & 0 & -10 \\ 4 & 2 & -2 \end{bmatrix}$$

$$= 1(0+20) + 0(-4+40) + 5(4+0)$$

$$= 20 + 20 = 40$$

$$\Delta_3 = \begin{bmatrix} 1 & -4 & 0 \\ 2 & -3 & 0 \\ 4 & 1 & -2 \end{bmatrix}$$

$$= 1(-6+0) + (4+0) + 0(2+12)$$

$$= -6 + 16 = 10$$

$$I_1 = \frac{\Delta 1}{\Delta} = \frac{110}{230} = 0.4782A$$

$$I_2 = \frac{\Delta 2}{\Delta} = \frac{40}{230} = 0.174A$$

$$I_3 = \frac{\Delta 3}{\Delta} = \frac{10}{230} = 0.0434A$$

Current through 1Ω resistor I_1 = 0.4782A

Current through 2Ω resistor $(I_1 - I_3)$ = 0.4782 – 0.043 = 0.4352A

Current through 3Ω resistor = $(I_2 + I_3)$ = 0.174 + 0.043 = 0.217A

Current through 4Ω resistor I_2 = 0.174A

Current through battery $(I_1 + I_2)$ = 0.4782 + 0.174 = 0.6522A

Example.2

In a house, the following equipment are used.

1) 1HP motor works 3 hours per day.
2) 40w, 10 lamps glow 5 hours per day.
3 900w capacity of heater works 2 hours per day.

Calculate the cost of energy consumed in 60 days.

[For domestic purpose unit rate is (1–100)-NIL,(101–200) Rs.3.50 (201–500) = Rs. 4.60, > 500 units = Rs. 6.60

1) 1HP motor works 3 hours per day.

$$\text{Energy} = \frac{1 \times 746 \times 3}{1000} = \frac{2238}{1000}\text{Wh}$$
$$= 2.238 \text{ kwh}$$
$$= 2.238 \text{ unit per day}$$

2) 40w, 10 lamps glow 5 hours per day.

$$\text{Energy} = \frac{40 \times 10 \times 5}{1000} = \frac{2000}{1000}\text{Wh}$$
$$= 2 \text{ kwh}$$
$$= 2 \text{ units per day}$$

3) 900w heater works 2 hours per day.

$$\text{Energy} = \frac{900 \times 2}{1000} = \frac{1800}{1000}\text{Wh}$$
$$= 1.8 \text{ kwh}$$
$$= 1.8 \text{ units per day}$$

4) Total number of units consumed in 60 days = 60 (2.238 + 2 + 1.8)

$$= 60(2.238 + 2 + 1.8)$$
$$= 60 \times 6.038$$
$$= 362.28$$

Total number of unit = 362

Unit limit	Charge per unit	Usage unit	Cost in Rs
1–100	NIL	100	NIL
101–200	3.50	3.50 × 100	350
201–500	4.60	4.60 × 162	745.20
		Total	1095.20

Cost of electric charge for 60 days = Rs. 1095.20/-

Important note

Current - I – Ampere
Voltage – V – Volts
Resistance – R – Ω(ohms)
Emf – Volts
P.D – Volts
Power – P – watts
Ohms Law I = V/R
V = IR
R = V/I
Power $P = I^2R$
P = V × I

Series circuit I is common to all load, $V = V_1 + V_2 + V_3 + \ldots$, $R = R_1 + R_2 + R_3 + \ldots\ldots$

Parallel circuit V is common to all load.

$$I = I_1 + I_2 + I_3 \ldots$$

$$\text{Resistance } R = \frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2}$$

(if 3 loads)

Kirchoff's

i) Current Law $= I_1 + I_2 + I_3 = I_4 + I_5$ (or) $I_1 + I_2 + I_3 - I_4 - I_5 = 0$

ii) Voltage Law $V = IR_1 + IR_2 + IR_3$ ie $V = V_1 + V_2 + V_3$

Power Calculation

Power consumed = KW × hour = Kwh = 1unit.

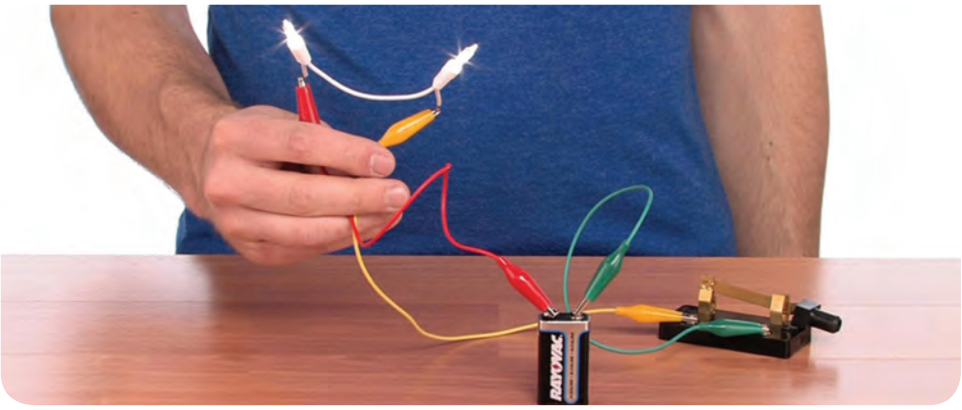
Current Tariff Calculation for Domestic Purpose					
	Tariff Charges		Units		Cost
Units	Fixed	Subsidy	From	To	Rs.
Upto 100	0	150	1	100	1.50
Upto 200	20	150	1	200	1.50
Upto 500	30	150	1	100	1.50
			101	200	2.00
More than					
500	50	150	1	100	1.50
			101	200	3.50
			201	500	4.60
			501	onwards	6.60

Do You Know?

Some Animals use electricity to survive in nature. Many of these animals are found in the ocean where some use electricity to detect objects around them and others use electricity to fend off predators or even hunt for food. One of the most famous of the electric animals is the electric eel. The electric eel can produce large amounts of electricity, even enough to kill a human or stun a large horse. The eels typically swim into a school of fish, discharge a large amount of electricity, and then dinner is served!

Activities

1. Do the following by practice.



2. To make the simple wiring circuits
   i) One bulb is controlled by one switch in parallel connection. One bulb is controlled by 2 switches.
   ii) In series connections, more than one lamp i.e series bulb connection is controlled by single switch.

GLOSSARY

Conductors	—	மின் கடத்திகள்
Insulators	—	மின் கடத்தா பொருட்கள்
EMF	—	மின்னியக்கு விசை
Resistor	—	மின் தடை
Capacitor	—	மின்தேக்கி
Specific Resistance	—	இனத்தடை
Inductance	—	மின்தூண்டி
Power	—	மின் திறன்
Energy	—	மின் ஆற்றல்

Q A

PART A

Mark 1

SRXKQT

Choose the Correct Answer:

1. The material that does not conduct current is
   a) conductor
   b) insulator
   c) semiconductor
   d) none of these
2. Good conductor has a property of
   a) low resistance
   b) high resistance
   c) medium of these two
   d) none of these
3. Mineral oil is a
   a) solid conductor
   b) liquid conductor
   c) soft Insulator
   d) liquid Insulator
4. The value of current is measured by
   a) ammeter
   b) voltmeter
   c) wattmeter
   d) energy meter
5. The unit of current is
   a) voltage
   b) watts
   c) ohms
   d) ampere
6. The value of voltage is measured by
   a) voltmeter
   b) ammeter
   c) wattmeter
   d) megger
7. The unit of volt is
   a) watts
   b) volt
   c) ampere
   d) ohms
8. The value of resistance is measured by
   a) voltmeter
   b) wattmeter
   c) ohm meter
   d) none of these
9. The units of resistance is
   a) ohms
   b) watts
   c) ampere
   d) volt
10. EMF is measured in
    a) volt
    b) ohms
    c) ampere
    d) watts
11. Unit of power is
    a) volt
    b) ampere
    c) watts
    d) none of these
12. The power is measured by
    a) wattmeter
    b) ampere
    c) voltmeter
    d) none of these

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13. According to ohm's law I is equal to
    a) V^2/R
    b) I^2R
    c) V/I
    d) V/R
14. The value of resistance in short circuit is
    a) low
    b) very low
    c) high
    d) medium
15. Number of current path in a series circuit is
    a) two
    b) three
    c) one
    d none of these
16. The unit of force is
    a) newton
    b) ampere
    c) volts
    d) joule
17. The value of 1HP is
    a) 1000w
    b) 750W
    c) 900w
    d) 746w
18. The unit of capacitance is
    a) volt
    b) ampere
    c) farad
    d) watts
19. Copper is a good
    a) conductor
    b) insulator
    c) semi conductor
    d) none of these
20. capacitor is denoted by the letter
    a) q
    b) v
    c) i
    d) c

Q A

PART B

Mark 3

Answer the Questions in Briefly:

1. What is called as a conductor?
2. What are the types of conductor?
3. What is called as an insulator?
4. What are the types of insulators?
5. Define current.
6. Define voltage.
7. Define Resistance.
8. What is called Electromotive force (EMF)?
9. What is called Potential Difference?
10. Explain the term 'Electric power'.
11. Define ohm's Law.
12. Voltage of circuit is 240v and 12 A current is flowing through it. Find the value of Resistance.
13. Explain 'open circuit'.
14. Two resistance 3Ω and 6Ω are connected in parallel Voltage of the circuit in 240v. Find the value of total resistance.
15. What is called Work?
16. Explain the factors on which the capacity of condenser depends.
17. Define 'capacitance' of a capacitor.

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the properties of a conductor.
2. Explain the properties of insulators.
3. Explain the difference between Electromotive force and Potential Difference.
4. What are the important rules for series circuit?
5. What are the important rules for parallel circuit?
6. Three resistors 3Ω,6Ω and 18Ω are connected in parallel. The current flow of the circuit is 3A. Find the value of i)Total Resistance ii)voltage.
7. Explain the laws of Resistors.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. What are the types of conductors Explain.
2. Explain the construction and working of series circuit.
3. Explain the construction and working of parallel circuit.
4. Explain the Kirchoff's Laws.
5. Explain the construction and working principle of condenser.
6. What are the types of capacitors? Explain.

Reference Book

1. A text book of Electrical Technology' Volume I by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 3

Electro Magnetism

SS3U4J

355

LEARNING OBJECTIVES

To know the classification of properties of magnetic materials, terming it makes it easy to read the concepts of magnet and also the types of electromagnetic induction, Hysteresis and its laws are the scope and objective for learning.

Table of Content

3.1 MAGNETISM - INTRODUCTION

Magnetism is a force field that acts on some materials. A physical device which possesses this force is called as a magnet.

The force to attract iron is known as Magnetism. The substance which possesses magnetism is called Magnet. The materials attracted by a magnet are known as Magnetic materials.

Magnetism plays an important role in electricity. Without the aid of magnet, it is impossible to operate devices like generator, electric motors, transformers, electrical instruments, etc. Magnetism is also used in the functioning of radio, television, phones and ignition system of auto mobiles. In this chapter salient features of magnetism and function of magnetism in the electrical equipment are explained.

3.2 PROPERTIES OF MAGNETS

- Magnets attract magnetic substances such as iron, nickel, cobalt and its alloy.
- If a magnet is freely suspended, its pole will always tend to set themselves in the direction of north and south.
- Like poles repels and unlike poles attracts each other.

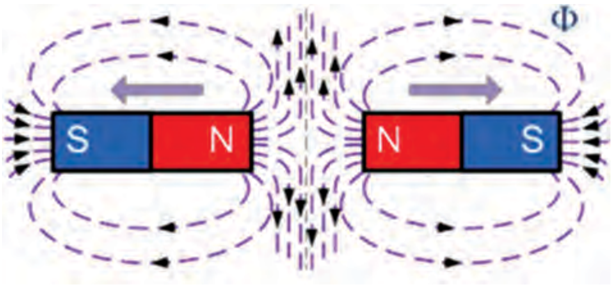


Fig 3.1 *Like Poles*

- If a magnet is broken into number of pieces, each piece becomes an independent magnet which has North and South.
- A magnet can impart its properties by induction to any magnetic material.

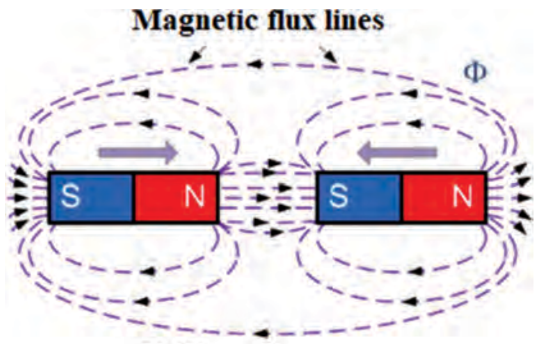


Fig 3.2 *UnLike Poles*

- A magnet loses its properties when it is heated, hammered or dropped from height.

3.2.1 Classification of Magnets

1. Natural Magnet

The magnet found in nature is known as lodestone. The natural magnet is one of the iron ore magnetite with chemical composition Fe_3O_4

2. Artificial Magnet

The magnets prepared by artificial method are called artificial magnets. It can be made in different shape, size and strength only in certain metals. There are two types of artificial magnet.

a) Permanent Magnet

In a permanent magnet, the magnetic materials can retain magnetic property permanently for a long time. Bar magnet, Horse Shoe magnet, Ring Magnet, Cylindrical magnet are some types based on shapes.

Fig 3.3 *Permanent Magnets*

ALNICO (Aluminium-Nickel-Cobalt) is an alloy metal specifically used as permanent magnet because it can be lifted up to 50 times weight load compared to its own weight. Permanent magnets can be formed by touch method, electric current method and induction method.

b) Temporary Magnet (or) Electro Magnet

When an electric current is passed through a coil of wire wrapped around a soft iron core, a very strong magnetic field is produced.

This is called as electro magnet. If the current is cut off, the core will be demagnetized, and hence known as temporary magnet.

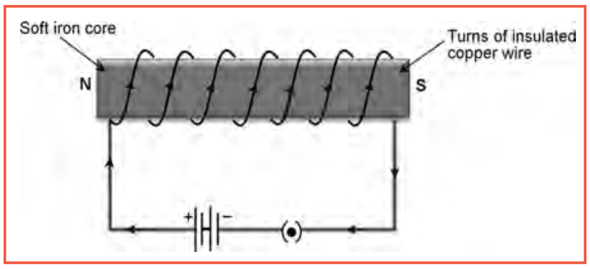


Fig 3.4 *Electro magnet*

3.2.2 Comparison of Electromagnet & Permanent Magnet.

ELECTRO MAGNET	PERMANENT MAGNET
1. Polarity can be changed easily.	Polarity cannot be changed easily.
2. Strength can be varied.	strength cannot be varied.
3. More cost.	Less cost
4. Suitable for motor & generator of large size.	Not suitable for large size.
5. Used in electric bells, signals, escalators, cranes.	Not used in any of these.
6. Cannot be used in navigation	Mostly used in navigation as magnetic needle
7. Cannot be used in cycle and Motor cycle dynamo.	Used in cycle and Motor cycle dynamo.

3.3 MAGNETIC MATRIALS

Magnetic materials are classified based on permeability property by three types.

a) Dia-Magnetic Materials
b) Para Magnetic Materials
c) Ferro Magnetic Materials

a) Dia – Magnetic Materials

- The materials which are repelled by a magnet are known as dia-magnetic materials. Ex: zinc, mercury, lead, sulphur, copper, silver, Bismuth, wood, etc.
- The permeability value of these materials is less than one.

b) Para Magnetic Materials

- The materials which are not strongly attracted by a magnet are known as paramagnetic materials. Ex: (aluminium, tin, platinum, magnesium etc.).
- The permeability value of these materials is just greater than one.

c) Ferro -Magnetic Materials

- The materials which are strongly attracted by a magnet are known as ferromagnetic materials. Ex: (iron, steel, nickel, cobalt, etc.)
- The permeability value of these materials is very high (varies from several hundreds to thousands).
- Materials which are easily magnetized with a high relative permeability, low coercive force (small hysteresis) are called soft ferromagnetic materials.
- Materials which are difficult to magnetize, but retain magnetism with great tenacity, with low relative permeability, high coercive force are called hard ferromagnetic materials.

3.3.1 Magnetic Terms and Properties

a) Magnetic Field:

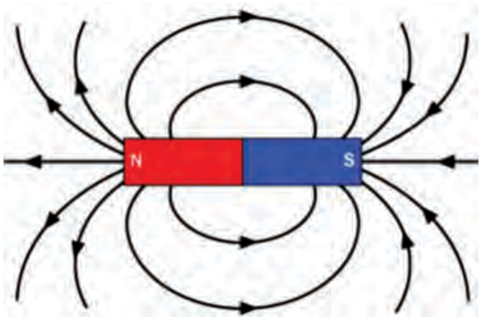


Fig 3.5 *Magnetic Field Lines*

- The magnetic field around a magnet is represented by imaginary lines called magnetic line of force.
- The magnetic line of force emerges from north pole to south pole and it continues through the body of magnet to form a closed loop.
- Two magnetic lines of force will not intersect each other.
- If magnetic lines of force are rows together, the field is strong. If they are spaced out the magnetic field is weak.

b) Magnetic Flux

- The amount of magnetic field produced by a magnetic source is called magnetic flux.
- It is denoted by Greek Letter ϕ and its unit is weber.

c) Magnetic Flux Density

- The magnetic flux density is the flux per unit area at right angles to the flux.

Magnetic flux density, $B = \phi/A$ wb/m²

d) Permeability

- Permeability of a material means, the conductivity for magnetic flux. The greater the permeability of material, the greater is its conductivity of magnetic flux and vice-versa. Air or Vacuum is the poorest conductor of magnetic flux. The absolute (actual) permeability μ_0 (Greek Letter 'mu') of air is $4\pi\times10^{-7}$ Henry/metre. The absolute (actual) permeability of magnetic material(μ) is much greater than μ_0.

The ratio between permeability of material and permeability of air (μ_0) is called relative permeability(μ_r)

$$\mu_r = \mu/\mu_0$$

The relative permeability for air is 1 ($\mu_r = \mu_0/\mu_0$)

The value of μ_r for all non- magnetic material is also 1.

The relative permeability of magnetic materials is very high. For example, soft iron (i.e pure iron) has a relative permeability of 8000, whereas its value for perm alloy (22% Iron, +78% nickel) is as high as 50,000.

e) Magneto Motive Force (MMF)

It is a magnetic pressure which tends to set up magnetic flux in a Magnetic circuit.

The work done in moving a unit magnetic pole once round the magnetic circuit is called MMF. It is equal to the product of current and number of turns of the coil.

MMF = Number of turns × current.
Its unit is Ampere-turns

f) Reluctance

The opposition that the magnetic circuit offers to magnetic flux is called reluctance. Magnetic materials (eg iron, steel) have low reluctance, on the other hand non-magnetic materials have a high reluctance.

Reluctance $S = l/\mu_0 \mu_r A$

g) Magnetic Neutral Axis (MNA)

The imaginary line which is perpendicular to the magnetic axis and passes through the centre of the magnet is called magnetic neutral axis. There is no magnetic influence along this line.

Magnetic Axis (MA) is the imaginary straight line joining North to South pole. There is maximum magnetic influence along this line.

i) Magnetic Saturation

The limit beyond which the strength of magnet cannot be increased is called magnetic saturation.

ii) Residual Magnetism

It is the magnetism which remains in a material when the effective magnetizing force has been reduced to zero.

iii) Magnetic Retentivity

The property of retaining magnetism by a magnetic material is called Magnetic Retentivity.

iv) Hysteresis

The energy required to demagnetize the residual magnetism of material is known as hysteresis.

v) Leakage Flux

Leakage flux is defined as the magnetic flux which does not follow the particularly intended path in a magnetic circuit.

Taking the example, solenoid you can explain the leakage flux and the fringing both. When a current is passed through solenoid, magnetic flux is produced by it.

vi) Coercivity

Coercivity is a measure of the ability of a ferro magnetic materials to withstand an external magnetic field without becoming demagnetized.

3.4 ELECTRO MAGNETISM

When current is passed through a coil of wire, a magnetic field is set up around the coil. If soft iron bar is placed inside the coil of wire carrying current, the iron bar becomes magnetized. This process is known as electro magnetism.

The iron remains as a magnet as long as the current is flowing in the circuit. It looses its magnetism when current is switched off.

The polarity of an electromagnet depends upon the direction of the current flowing through it.

If the direction of current is altered, the polarity of the magnetic field will also be changed.

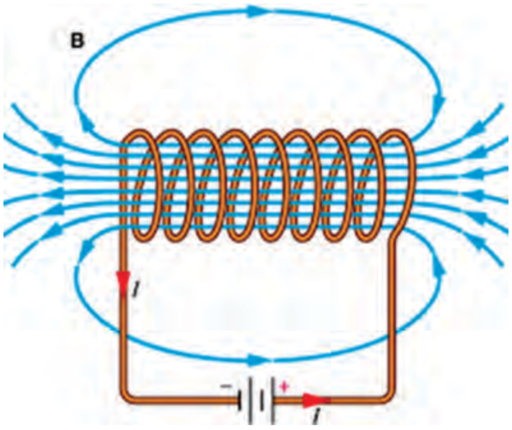


Fig 3.6 *Magnetic Field Lines*

3.4.1 Electro Magnetism in a Current Carrying Conductor

A magnetic field is formed around a conductor carrying current. The direction of the magnetic field depends on the direction of the current flow.

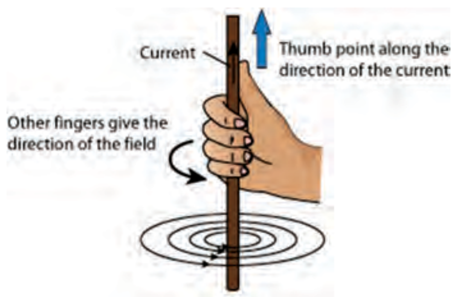


Fig 3.7 *Right Hand Grip Rule*

Right Hand Grip Rule

- It is used to determine the direction of the magnetic field in a current carrying conductor.
- If you wrap your fingers around the wire with your thumb pointing direction of current flow, your index finger will point the direction of magnetic field.

Right Handed Cork Screw Rule

- Assume a right handed cork screw to be along the wire to advance in the direction of current.
- The motion of handle gives the direction of magnetic lines around the conductor.

Force Between Parallel Conductors

When two current carrying conductors are parallel to each other, a mechanical force act on each conductor. This force is due to magnetic field produced in the two conductors. If the currents are in the same direction, the forces are attractive. If the currents are in the opposite direction, the forces are repulsive.

i) Current in The Same Direction

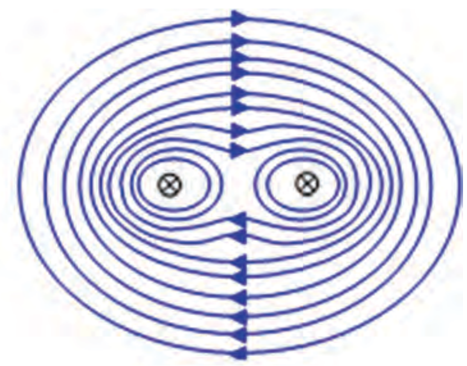


Fig 3.8 *Currents in Same Direction*

- If two wires (A, B) carrying current in same direction are brought together, their magnetic fields will aid one another and attracts.
- Since the flux lines around two conductors are going in the same direction, the flux lines join and the field brings the wire together.

ii) Current in The Opposite Direction

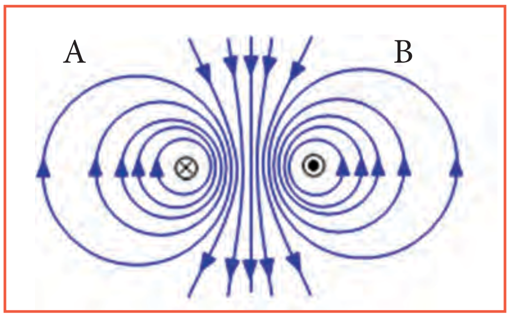


Fig 3.9 *Currents in Opposite Direction*

- If two wires (A, B) carrying current in opposite directions are brought together their magnetic field will oppose one another.
- Since the flux lines around two conductors are going in the opposite direction, the flux lines cannot cross and the field moves the wires apart.

3.4.2 Solenoid

A current carrying wire is made to form a loop and a number of loops are wound in the same direction to form a coil. More magnetic fields will add to make the flux lines through the coil stronger and dense.

A helically wound coil that is made to produce a strong magnetic field is called a solenoid.

The flux lines in a solenoid act in the same way as in a magnet. They leave the north pole and go around to the south pole.

The directions of the magnetic field in a solenoid is known by the following rules.

End Rule

Look at the end of the solenoid of the electromagnet. If the current in the coil is clock wise the end is Southpole . If the current in the coil is counter-clockwise the end is North pole.

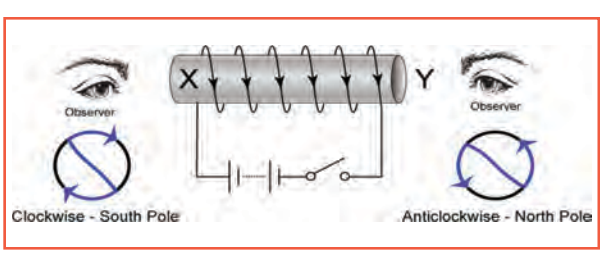


Fig 3.10 *End Rule*

Helix Rule

Hold the right hand palm over the solenoid in such a way the fingers point in the direction of current in the solenoid conductors. Then the thumb indicates the direction of magnetic field (North) of the solenoid.

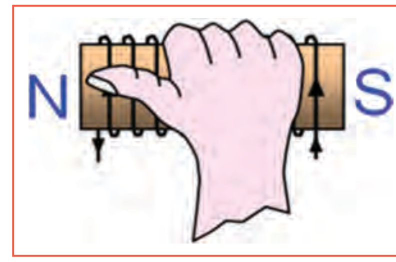


Fig 3.11 *Helix Rule*

Uses of Solenoid

- Used for Circuit Breaking.
- Voltage Regulating Device.
- Automatic Motor Starter.
- Contactor, Elevator, Crane.

Toroid

A helix bent into a circular form is known as Toroid (i.e coiled coil)

Fig 3.12 *Toroid*

3.5 ELECTROMAGNETIC INDUCTION

Electricity induced by the magnetic field is known as Electro Magnetic Induction.

3.4.3 Comparision Between Magnetic and Electric Circuits

S.NO	PROPERTIES	MAGNETIC CIRCUIT	ELECTRIC CIRCUIT
1	Definition	The closed path followed by magnetic flux is called magnetic circuit.	The closed circuit followed by electric current is called electric circuit.
2	Driving Force	MMF is the pressure required to set up the magnetic flux in magnetic circuit (Ampere-Turn)	EMF is the pressure required to set up the current in an Electric circuit (Volt).
3	Response	$\text{FLUX } (\text{Ø}) = \frac{MMF}{Reluctance}(weber)$	$\text{CURRENT}(\text{I}) = \frac{EMF}{Resistance}(Ampere)$
4	Impendance	$\text{RELUCTANCE(S)}=l/(\mu_0\mu_r A)$ [AT/Weber]	RESISTANCE (R)=ρl/A(ohms)
5	Admittance	$\text{PERMEANCE} = \frac{1}{Reluctance}[wb/AT]$	$\text{CONDUCTANCE} = \frac{1}{Resistance}(Siemens)$
6	Proportionality	$\text{RELUCTIVITY}=\frac{1}{Permeability}(M/H)$	$\text{RESISTIVITY}=\frac{1}{Conductivity}(ohm-meter)$
7	Density	FLUX DENSITY $B = \mu H(wb/m^2)$	CURRENT DENSITY $J=I/A(Amp/m^2)$
8	Field Intensity	MAGNETICFIELD INTENSITY(H)=NI/l(AT/m)	ELECTRIC FIELD INTENSITY=E/l(volt/m)

Whenever a conductor or coil is moved or rotated in a magnetic field and cut the magnetic line of force (flux), an EMF will be induced in that conductor or coil.

SS7GSG

3.5.1 Faraday's Law of Electromagnetic Induction

FIRST LAW: Whenever a conductor cuts magnetic flux, an EMF is induced in that conductor.

SECOND LAW: The magnitude of the induced EMF is directly proportional to the rate of change of flux linked with the conductor.

The two types of EMF induced are:

i) Dynamically induced EMF.
ii) Statically induced EMF.

3.5.2 Dynamically Induced EMF

Moving a coil/conductor in a uniform magnetic field will induce an EMF which is known as dynamically induced EMF. Generators work on this principle.

Consider a conductor of length l (meters) placed in a uniform magnetic field of density B(wb/m²), moved with a velocity V(m/s) perpendicular to the direction of the

Do You Know?

- ❖ The north pole of a magnet points roughly toward Earth's north pole and vice-versa. That's because Earth itself contains magnetic materials and behaves like a gigantic magnet.
- ❖ If you cut a bar magnet in half, it's a bit like cutting an earthworm in half! You get two brand new, smaller magnets, each with its own north and south pole. (This is, of course, a joke. You don't get two worms if you cut a worm in half. But you do get two magnets.)
- ❖ If you run a magnet a few times over an unmagnetized piece of a magnetic material (such as an iron nail), you can convert it into a magnet as well.

magnetic field. Then the flux is cut by the conductor and an EMF is induced.

The magnitude of EMF inducede is $e = BlV \sin\theta$

3.5.3 Statically Induced Emf

By keeping a conductor or coil in statically and varying the magnetic field will induce an EMF in the conductor or coil which is statically induced EMF.

Statically induced EMF can be classified as self inductance and mutual inductance.

(a) Self Induction

- This is the EMF induced in a coil due to the change of its own flux linked with it.
- If current through the coil is changed, then the flux linked with its own turns will also change, which will produce self induced EMF.
- The induced EMF is always opposite in direction to the applied EMF.

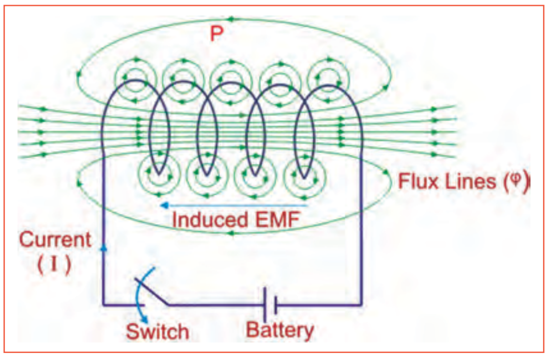


Fig 3.13 *Self Induction*

(b) Mutual Induction

It is the ability of one coil to produce an EMF by induction. When the current in the second coil changes, both coils are placed nearer.

- When two coils are placed nearer and current is passed through one of the coil, magnetic flux will be produced which is common to both coils.
- When current through first coil is varied, the magnetic flux will vary, which will induce an emf in second coil.

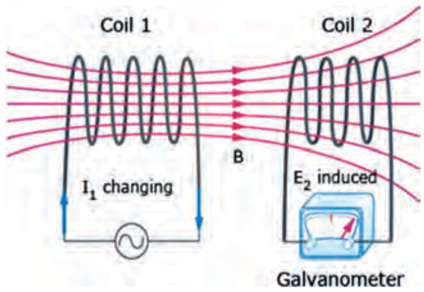


Fig3.14 *Mutual Induction*

LENZ'S LAW

A change in current produces an emf, whose direction is in such a way that it opposes the change in current.

Fleming's Right Hand Rule

The direction of induced EMF in generators and alternators (Dynamically induced emf) is known by Fleming's Right hand rule.

Stretch the thumb, forefinger and middle finger mutually at right angles [90°] to each other.

If the thumb indicates the direction of motion of the conductor, the forefinger indicates direction of the magnetic flux, then the middle finger indicates the direction of the induced EMF.

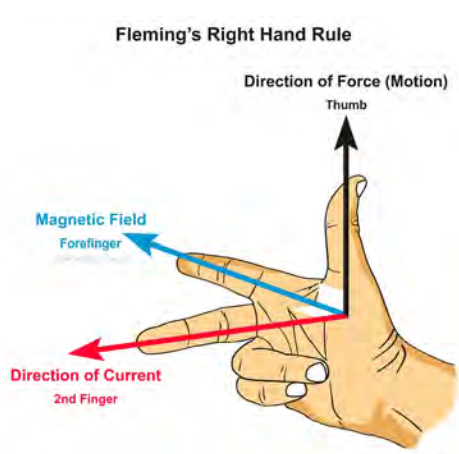


Fig 3.15 *Right Hand Rule*

3.6 HYSTERESIS LOOP

Take a piece of iron bar AB and magnetise the same by placing it within the field of solenoid. The field H produced by the solenoid is called the magnetising field. The field (H) can be increased (or) decreased by increasing (or) decreasing the current through it. Let 'H' be increased slowly from zero to a maximum value and the corresponding value of flux density (B) be noted. If we plot the relation between H and B, OA is obtained. The material becomes magnetically saturated at point A and has the maximum flux density induced in it (H = OM).

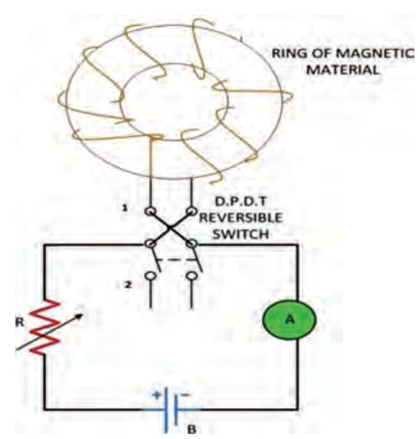


Fig 3.16 *Hysteresis Loop circuit*

Now if 'H' is decreased slowly by decreasing the current in the solenoid, the flux density(B) will not decrease along AO but will decrease less rapidly along AR_1. When H is made to be zero, at that time, B will not be zero but will have the value OR_1. It means that on removing the magnetising force, H the iron bar is not completely demagnetized. This value ($B = OR_1$) is the retentivity of the material (Residual magnetism).

To demagnetise the bar, we have to supply the force H in the opposite direction.

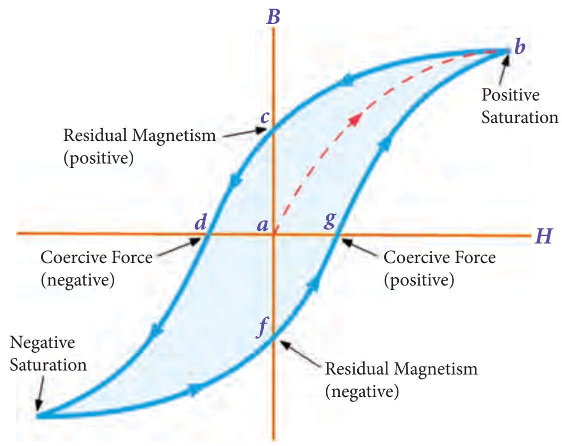


Fig 3.17 *Hysteresis Loop*

When H is reversed by reversing the current through the solenoid, then B is reduced to zero at point C where H = OC. This value is required to clear off the residual magnetism. This is known as the coercive force and is a measure of the coercivity of the material.

After reducing the magnetism to zero, if the value of H is further increased in the negative direction (i.e reversed direction), the iron bar reaches a state of magnetic saturation at point A_1, which is negative saturation (H = OL). By taking H back from its value corresponding to negative saturation (OL) to its value for positive saturation (OM), the closed loop which is obtained when iron bar is taken through one complete cycle of magnetism. This loop is called Hysteresis Loop .

In this BH curve, it is seen that B always lag behind H. The two never attain zero value simultaneously .Hysteresis literally means to lag behind . The closed loop OAR_1, $CA_1R_2C_1A$ which is obtained when iron bar is taken through one complete cycle of reversal of magnetisation is known as Hysteresis loop.

Hysteresis Loss

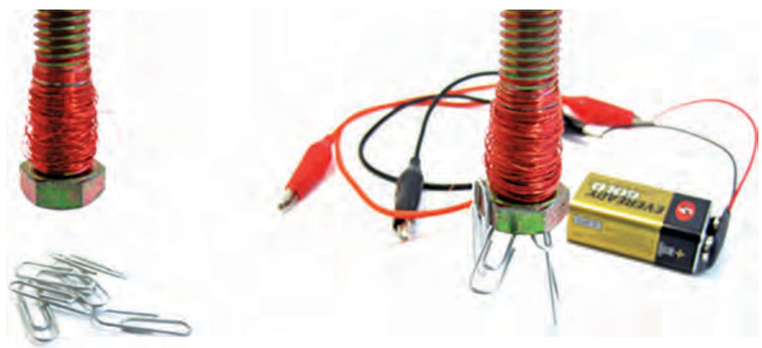
- It is the loss of power due to hysteresis and expressed in watts or KW.
- Hysteresis cannot be avoided but can be minimised by selecting proper metal.
- Lesser the hysteresis constant, better the metal for A.C electromagnet.
- So, usually silicon steel is used for A.C circuit as it's hysteresis constant is 0.001.

3.7 RULES/LAWS RELATED TO MAGNETISM

Rule or Law	Uses
Cork Screw Rule	To find out the direction of line of force (magnetic field) around a straight current carrying conductor.
Helix Rule	To find out polarity of the poles of an electromagnet (solenoid)
End Rule	To find out polarity of the poles of an electromagnet (solenoid)
Fleming’s Right Hand Rule	To find out the direction of current in the conductor of a generator.
Fleming’s Left Hand Rule	To find out the direction of rotation of the armature of D.C motor.
Lenz’s Law	To find out the direction of the counter current produced in the armature.
Ampere rule	To find out the direction of line of force around the current carrying conductor.

Activities

1. Apply the magnetic rule by using two magnets.
2. How can the induced current be known by mutual induction method.
3. Do the magnetism practice observed from the diagram.



GLOSSARY

Permanent Magnets	—	நிலைக் காந்தம்
Artificial Magnets	—	செயற்கைக் காந்தம்
Electro Magnets	—	மின்காந்தம்
Mmf- Magneto-Motive-Force	—	மின் இயக்கு விசை
Magnetic Flux	—	காந்தப் புலம்
Magnetic Saturation	—	காந்தப் பூரிதம்
Residual Magnetism	—	தங்கிக் கொண்ட காந்த சக்தி
Hysteresis Loop	—	காந்தத் தயக்க வளையம்

Q A

PART A

Mark 1

SSCQ67

Choose the Correct Answer:

1. Magnetic field lines
   a) intersect each other
   b) cannot intersect.
   c) are crowded near poles
   d) All of the above.

2. In an electro magnet, when current is switched off, the Iron bar
   a) holds its magnetism
   b) gains voltage
   c) losses its magnetism
   d) gains current

3. The direction of magnetic lines of force is
   a) from south pole to north pole
   b) from north pole to south pole
   c) from one end of the magnet to other
   d) none of the above.

4. The permanent magnet is used in
   a) Dynamo
   b) Energy meters
   c) Transformers
   d) Loud Speaker

5. Magnetic properties in a magnet can be destroyed by
   a) heating
   b) hammering
   c) by inductive action of another magnet
   d) by all above methods.

6. A permeable substance is one
   a) which is a good conductor
   b) which is a strong magnet.
   c) which is a bad conductor
   d) through which the magnetic line of forces can pass very easily.

7. A material which is slightly repelled by magnetic field is known as
   a) Ferro magnetic material
   b) Para magnetic material
   c) Dia magnetic material
   d) Conducting material.

8. Total number of magnetic field lines passing through an area is called
   a) Magnetic flux density
   b) EMF
   c) Magnetic flux
   d) Voltage.

9. The commonly used material for shielding or screening magnet is
   a) Copper
   b) Aluminium
   c) Soft Iron
   d) Brass

10. The unit of magnetic flux density is
    a) weber/m^2
    b) lumens
    c) tesla
    d) none of the above.

11. Indicate which of the following material does not retain magnetism permanently.
    a) Soft iron
    b) Stainless steel
    c) Hardened steel
    d) None of the above.

12. The material having low retentivity are suitable for making a
    a) weak magnet
    b) temporary magnet.
    c) permanent magnet
    d) none of the above.

13. The absolute permeability (μ_o) of air or vacuum is
    a) $4\pi \times 10^{-7}$ H/M
    b) $4\pi \times 10^{-3}$ Henry/Metre
    c) $4\pi \times 10^{3}$ H/M
    d) $4\pi \times 10^{7}$ H/M

14. Which of the following circuit element stores energy in an electromagnetic field?
    a) Capacitor
    b) Inductance
    c) Resistance
    d) Variable Resistance.

15. EMF induced by motion of conductor across magnetic field is called
    a) emf
    b) dynamic emf
    c) static emf
    d) rotational emf

16. The magnitude of the induced emf in a conductor depends on the
    a) flux density of the magnetic field.
    b) amount of flux cut
    c) amount of flux linkages
    d) rate of change of flux linklages.

Q A

PART B

Mark 3

Answer the Questions in briefly

1. What is magnetism?
2. Why is ALNICO used for permanent magnet?
3. State any three uses of permanent magnets.
4. State Maxwell cork's screw rule.
5. What is solenoid and Toroid?
6. What are the uses of solenoid?
7. Define End Rule.
8. Define Faraday's laws of electromagnetic induction.
9. State Flemings right hand rule.
10. Define Lenz's law.
11. What is hysteresis loss?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Compare electro magnet and permanent magnet.
2. Explain magnetic materials?
3. Define Flux, MMF and Reluctance.
4. Define Magnetic saturation, Retentivity and Residual magnetism.
5. Compare magnetic and electric circuit.
6. How to do you increase the magnitude of induced emf.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the types of electro magnetic induction with neat diagram.
2. Explain hysteresis loop with a neat diagram.

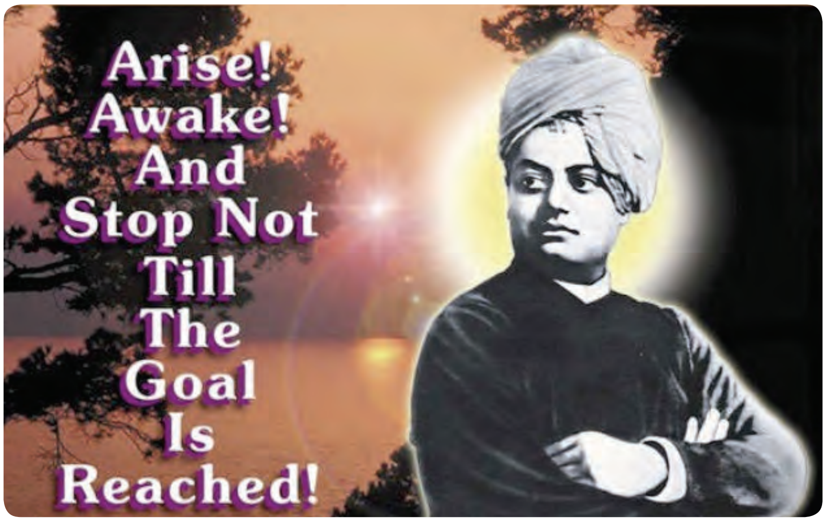
Reference Book

1. 'A text book of Electrical Technology' Volume B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 4

Batteries

SSGCU4



— Swami Vivekananda

LEARNING OBJECTIVES

The main objective of a battery is to know the classifications of the various types of cells, also to know about the chemical reactions during charging and discharging, maintenance, and tips for care of battery.

Table of Content

4.1 INTRODUCTION AND DEFINITION

Battery is a device that transforms chemical energy into electrical energy. Batteries consist of electro chemical cells that are electrically connected.

Every battery has two terminals. The positive one is called 'Anode' and negative one is called 'Cathode' as shown in and Fig 4.1.

Battery is a storage device used for the storage of chemical energy and for the transformation of chemical energy into electrical energy.

Battery consists of a group of two or more electric cells connected together electrically in series. Battery acts as a portable source of electrical energy.

Battery or cell is an electrochemical device consisting of two electrodes made up of different material and an electrolyte. The chemical reactions between the electrodes and the electrolyte produce voltage.

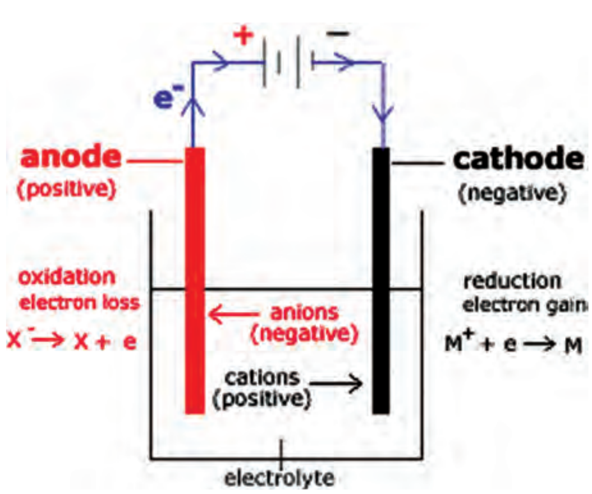


Fig 4.1 *Simple Battery Structure*

Cells are Classified as Dry and Wet Cells.

CELL

DRY CELL   WET CELL

4.1.1 Dry Cell

Dry cell is one that has a paste (or) gel electrolyte. It is semi sealed and can be used in any position. Nowadays the term 'Dry cell' refers to a cell that can be operated in any position without leakage.

4.1.2 Wet Cell

Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charging or discharging to escape. The most common wet cell is the Lead-Acid cell.

4.1.3 Primary Cells

Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharges is not easily reversed. When the chemicals used in the reactions are all converted, the cell is fully discharged. It must then be replaced by a new cell.

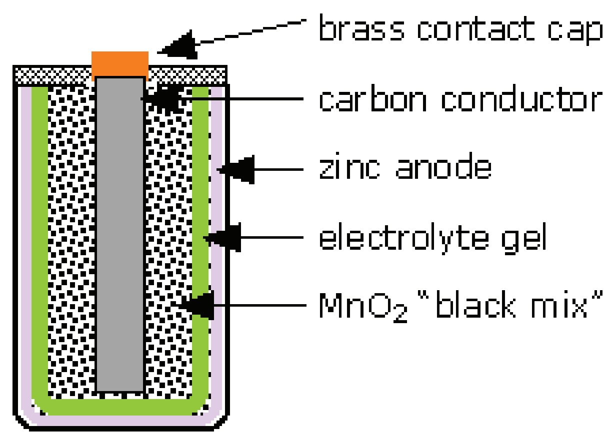
Example:-

Voltaic cell, Leclanche cell, Alkaline cell, Mercury cell, Lithium cell.

4.2 DRY CELL

The most common and the least expensive type of a dry cell battery in the Zinc-carbon type as shown in figure 4.2.

Fig 4.2 *Dry Cell.*



The Zinc-carbon consists of a zinc container which acts as the negative electrode. In the center, carbon rod which is a positive electrode is present. The electrolyte takes the form of a moist paste, made up of a solution containing ammonium chloride. As with all primary cells, one of the electrode becomes decomposed as part of chemical reaction. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the other parts.

Zinc-carbon cells are produced in common standard sizes. These include 1.5v AA, C, D cells.

(AA-pen type cell, C-minimum size, D-large/Economy size.)

4.2.1 Uses of Primary Cell

Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemaker torches, hearing aids, transister radios, etc.

4.2.2 Series Cell Connection

Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell. (See the connection diagram in fig. 4.3)

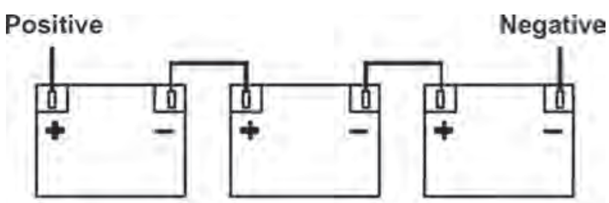


Fig 4.3 *Batteries Series Connection*

Identical cells are connected in series to obtain a higher voltage is available as a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages in the cells.However, the ampere hour (A-h) rating remains equal to that of a single cell.

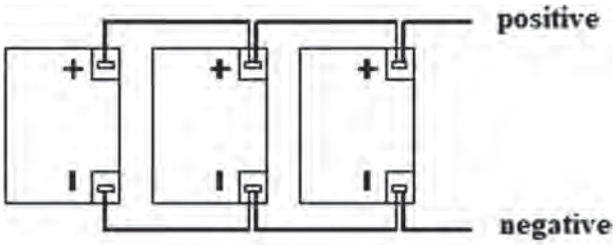


Fig 4.4 *Batteries Parallel Connection*

4.2.3 Parallel Connection

Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together as shown in the figure 4.4.

Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere-hour rating is equal to the sum of the ampere-hour rating of all the cells. However, the output voltage remains the same as that of a single cell.

When connecting groups of cells or batteries in parallel, each group must be in the same voltage level paralleling two batteries of unequal voltage levels set up a difference of potential energy between the

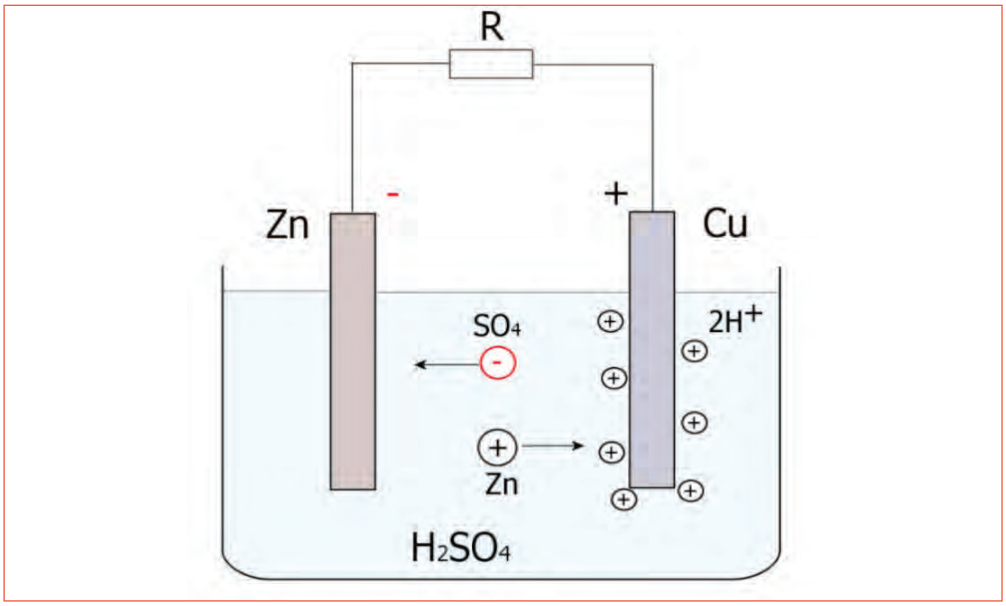


Fig 4.5 *Voltaic Cell*

two. As a result, the higher voltage battery will discharge its current into the other battery until both are at equal voltage value.

A voltaic cell is an electrochemical cell that uses a chemical reaction to produce electrical energy. In this cell, Anode is an electrode where oxidation occurs. Cathode is an electrode where reduction occurs.

In a voltaic cell, copper and zinc are the two electrodes and sulphuric acid is an electrolyte. When placed together, a chemical reaction occurs between the electrodes and the sulphuric acid.

This reaction produces a negative charge on the zinc (surplus of electron) and a positive charge on the copper (deficiency of electrons). If an external circuit is connected across the two electrodes, electrons will flow from the negative zinc electrode to the positive copper electrodes as shown in fig 4.5.

The electric current will flow as long as the chemical action continues. In this type of cell, the zinc electrode is eventually consumed as a part of the chemical reaction.

The voltaic cell is also known as wet cell, because in this, a liquid solution is used as an electrolyte.

We learn that most of the primary cell except rechargeable ones are used one time only. It does not supply current continuously. The secondary cells overcome this disadvantage.

4.3 VOLTAIC CELL

In a secondary cell, the charging and discharging processes are taking place according to Faraday's law of electrolysis.

4.4 SECONDARY CELL

A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell. Secondary cells are Storage batteries since, after it is charged, it stores the energy until it is used or discharged.

4.4.1 Secondary Cell Classification

Secondary cells may be classified as

(i) Lead acid cell
(ii) Alkaline cell

Example: Nickel iron cell, Nickel cadmium cell

Secondary cell is a type of electrical battery, which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discharged after use. It is composed of one or more electro chemical cells. The term 'accumulator' is used, as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to mega watt systems connected to stabilize an electrical distribution network.

Several different combinations of electrode materials and electrolytes are used, including Lead-acid, Nickel-cadmium, Nickel-metal hydride, and Lithium ion.

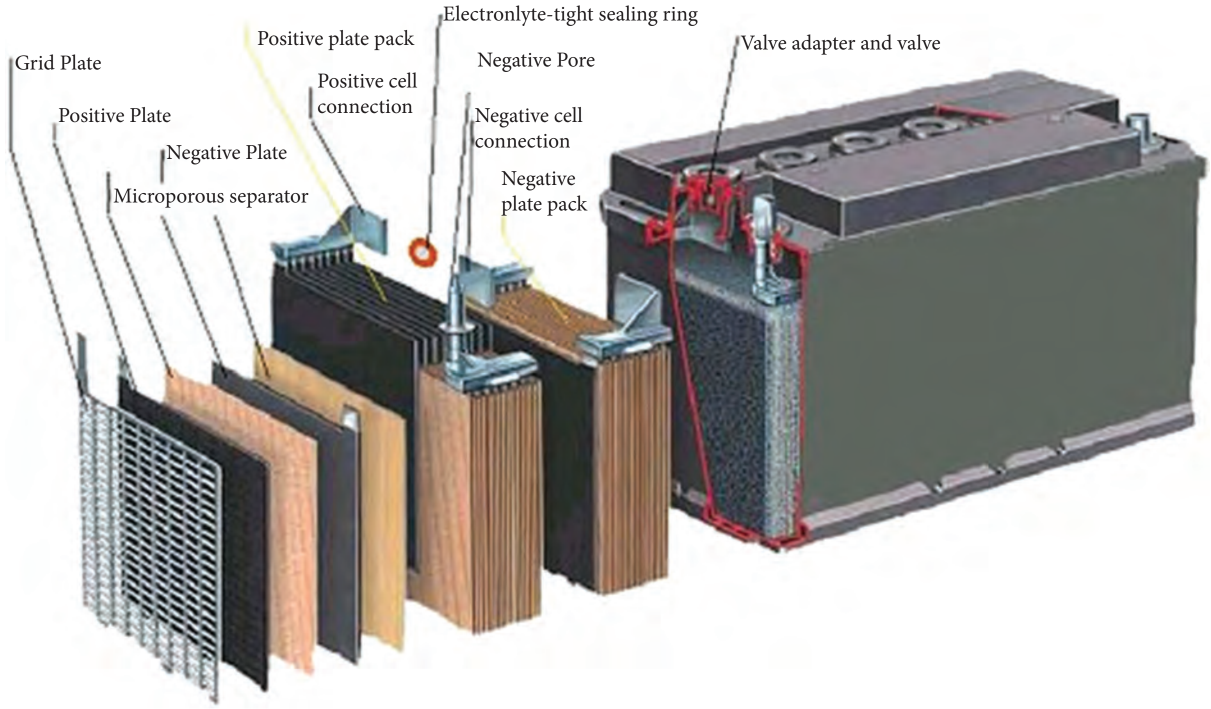


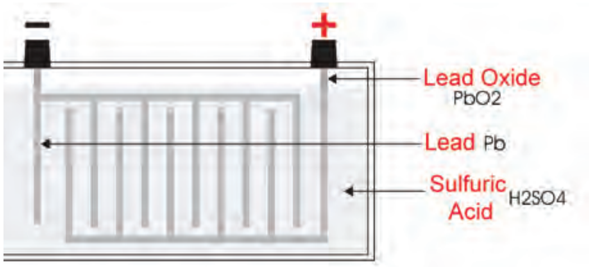
Fig 4.6 *Lead Acid Battery*

Initial cost of rechargeable batteries will be more than the disposable batteries, but have a much lower total cost of ownership.

Storage battery is a cell or a connected group of cells which converts chemical energy into electrical energy by reversible chemical reaction and may be recharged by passing a current through in the direction opposite to that of its discharge.

4.4.2 Lead Acid Battery

The battery which uses sponge lead and lead peroxide for the conversion of the chemical energy into electrical energy is called lead acid cell battery. This type of battery is most commonly used in the power stations and substations, because it has higher cell voltage and lower cost.



Construction

First of all, we shall see the various parts of the lead acid cell battery with the help of fig 4.6 . The container and the plates are the main parts of the lead acid cell battery.

SSLL7U

1. Container

The container stores chemical energy which is converted into electrical energy with the help of plates. The container is made of glass, lead lined wood, ebonite, hard rubber of bituminous components, ceramic materials or moulded plastic and are seated at the top to avoid the discharge of electrolyte. At the bottom of the container, there are four ribs, on two of them rest on the positive plate and the others support the negative plate.

The prism serves as the support for the plates, and at the same time protects them from short-circuit. The material which the battery containers are made should be resistant to sulphuric acid.

2. Plate

The plates of the lead acid cell is of diverse designs and they all consist some form of a grid which is made up of lead and the active material. The grid is essential for conducting the electric current and for distributing the current equally on the active material. If the current is not uniformly distributed, then the active material will loosen and fall out.

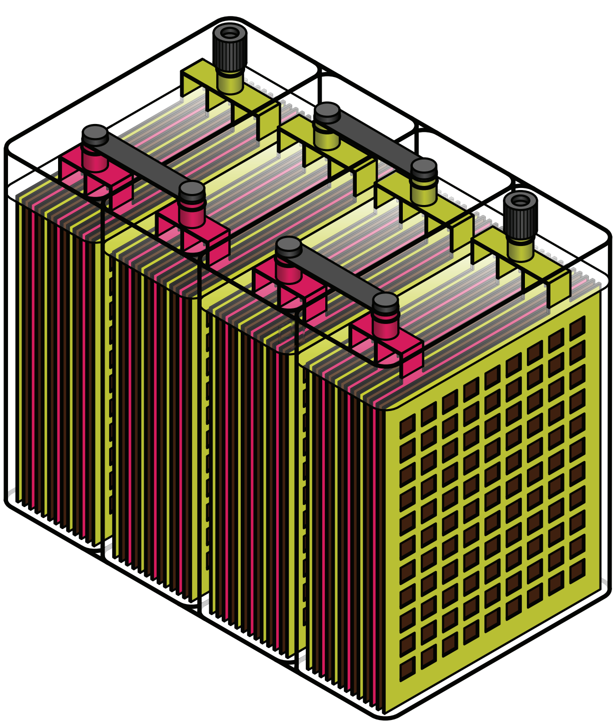


Fig 4.7 *Plate Arrangements of Lead-Acid Battery*

The grids are made up of an alloy of lead and antimony. The grid for the positive and negative plates are of the same design, (as shown in fig. 4.7) but the grids from the negative plates are made lighter because they are not as essential for the uniform conduction of the current.

The number of negative plates in a cell is always more than one number of positive plates in a cell, so that end plates at both the sides of the group remain negative.

3. Active Material

The material in a cell which takes active participation in a chemical reaction during charging or discharging is called the active material of the cell. The active element of the lead acid cells are

(a) Lead Peroxide (PbO_2)

It forms the positive active material. The PbO_2 is dark chocolate brown in colour.

b) Sponge Lead (Pb)

It forms the negative active material. It is grey in colour.

(c) Dilute Sulphuric Acid (H_2SO_4)

It is used as an electrolyte. It contains 31% of sulphuric acid.

4.Separators

The separators are thin sheets of non-conducting material made up of chemically treated leadwood, porous rubbers or mats of glass fibre and are placed between the positive and negative to insulate from each other. Separators are grooved vertically on one side and are smooth on the other side.

5. Battery Terminals

A battery has two terminals:–

Positive and Negative

A) Working Principle

In a lead acid cell, sulphuric acid is used as an electrolyte. In this H_2So_4, electrolyte is poured after pouring water in it. Then, sulphuric acid dissolves and the molecules of hydrogen and sulphate are formed. In this, hydrogen ions are positive and sulphate ions are negative.

Two electrodes of battery are dipped in an electrolyte and DC supply is given as an input. Hydrogen positive ions go towards negative plate of electrode. Sulphate negative ions go towards positive plate of the electrode. In this way lead acid battery functions.

The sign(+) indicates positive terminal and sign(–) indicates negative terminal

Positive terminal-17.5mm dia

Negative terminal-16mm dia

b) Chemical Reactions During Discharging

When the cell is discharging, current flow in the external circuit is from positive to negative. (See fig. 4.8) The flow of current through the electrolyte (H_2SO_4) splits into positive hydrogen ion (H_2^+) and two negative sulphate ions (SO_4^{-2}).

Each sulphate ions move towards the cathode and on reaching there, give up two electrons to become radical SO_4, attack the metallic lead cathode and form lead sulphate, whitish in colour according to the chemical equation.

At Anode, H_2 combines with oxygen of PbO_2 and H_2SO_4 attacks lead to form $PbSO_4$.

At Anode:

$$PbO_2 + H_2 + H_2SO_4 \rightarrow PbSO_4 + 2H_2O$$

At cathode: $Pb + SO_4 \rightarrow PbSO_4$

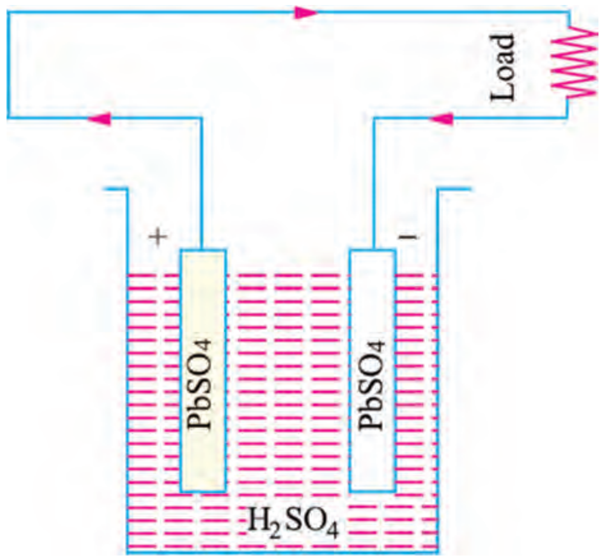


Fig 4.8 *Discharging Process*

Physical Changes While Discharging

1. Both the positive and negative plates are slowly converted into lead sulphate $PbSO_4$ (white in colour)
2. Water is formed during discharge. So the acid becomes more and more dilute. Specific gravity of sulphuric acid solution decreases.
3. Decrease in emf

c) Chemical Reaction During Charging

For recharging, the anode and cathode are connected to the positive and the negative terminal of the DC main supply.The hydrogen ions are positively charged move towards the cathode. (as in fig 4.9)

Sulphate ions move to the anode, and the following chemical reaction occurs.

At Anode: $PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$

At Cathode:

$$PbSO_4 + SO_4 + 2H_2O \rightarrow PbO_2 + 2H_2SO_4$$

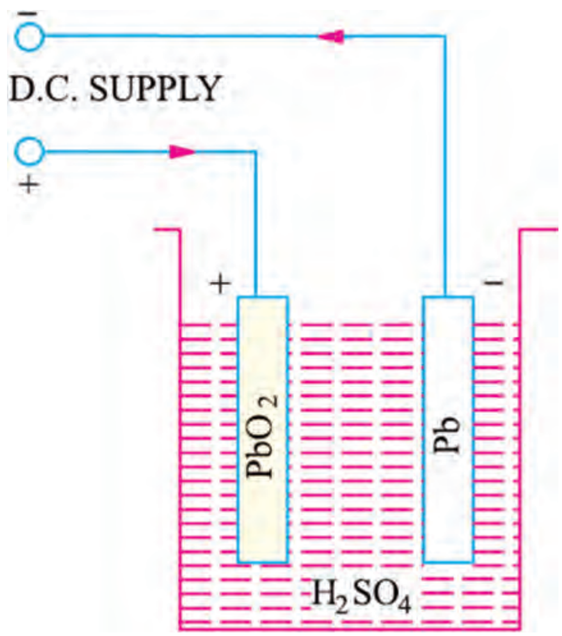


Fig 4.9 *Charging Process*

Physical Changes While Charging

1. Anode and cathode return back to their original colour (i.e positive plate dark brown and negative plate grey).
2. Specific gravity of an electrolyte is increased due to absorption of water.
3. Increase in emf values.

d) Difference Between Primary And Secondary Cells

Primary Cell	Secondarycell
1. Primary cell cannot be recharged.	Secondary cell can be recharged.
2. Chemical energy is converted into electrical energy.	In this, Electrical energy is converted into chemical energy.
3. Internal resistance is high.	Internal resistance is low.
4. It is light in weight.	It is heavy in weight.
5. It is less expensive.	More expensive.
6. It is disposable.	Not disposable and needs regular maintenance and periodic recharging.
7. Short life.	Long life.
8. Low efficiency.	High efficiency.
9. Less maintenance.	High maintenance.

4.5 LITHIUM - ION BATTERY

A Lithium-ion battery is a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and lithium ions move from positive electrode to the negative electrode when charging.

The three primary functional components of a lithium ion battery are the positive electrode, negative electrode and electrolyte. The negative electrode is made from carbon. The positive electrode is a metal oxide and electrolyte is a lithium salt in an organic solvent.

Nominal Cell Voltage

Fig 4.10 *Lithium Ion Battery*

NMC: 3.6/3.85 Volt

Lithium ion battery is a primary cell type battery. (see fig 4.10) It is available in variety of sizes and configurations. Depending on the chemicals used with lithium, the cell voltage is between 2.5 to 3.6volt.

Advantages of Lithium Battery

The are many advantages of using lithium-ion battery.

i) High Energy Density

The main advantage of lithium ion battery is high energy density. In mobile phones, it needs to operate for a long time between charges while still charging more power, there is always a need to batteries, with a much higher energy density. It is a distinct advantage.

ii) Self Discharge

One issue with batteries is that they loose their charges overtime. The main advantage is that the rate of self-discharge is very low than that of the other batteries.

iii) No Requirement For Priming

In this, lithium ion battery does not need to be primed, but the other batteries require priming.

iv) Low Maintenance

Lithium ion battery does not require any maintenance to ensure the performance.

Disadvantages

The disadvantages of lithium ion battery are as follows:

i) Protection Required

Lithium ion cells require protection from being overcharged and discharged too much. In addition, they need to have the current maintained within safe limits. Accordingly, lithium ion battery disadvantage is that they require protection to ensure that is it kept within the safe operating limits.

ii) Ageing

Another disadvantage of this battery is ageing. The battery is dependent upon the number of charge and discharge cycles that the battery has undergone. Lithium ion battery should be kept in a cool storage area, that will increase the life of battery.

iii) Transportation

Lithium ion battery applications are restricted on their transportation, especially by air. These batteries require care and protection while on transportation.

iv) Cost

The cost of lithium ion battery is high compared with other types of batteries.

4.6 SEVEN FEATURES ABOUT THE DISPARITY BETWEEN LEAD ACID AND LITHIUM ION BATTERIES

1. Weight

Lithium ion batteries are one third the weight of lead acid batteries

2. Efficiency

Lithium-ion batteries are of nearly 100% efficiency both charge and discharge, allowing the same ampere hours both in and out. But lead acid cell battery is 85% efficiency.

3. Discharge

Lithium-ion batteries are discharged 100%, but lead acid batteries discharge less than 80%.

4. Life Cycle

Life cycle of the lithium-ion battery is 400–1200 cycles, whereas lead acid battery life cycle is 400 to 500 cycles

5. Voltage

Lithium-ion batteries maintain their voltage throughout the entire discharge cycle. This allows greater and longer lasting efficiency of electrical components. Lead acid cell battery voltage drops consistently throughout the discharge cycle.

6. Cost

Despite the higher upfront cost of lithium ion batteries, the true cost of ownership is less than lead acid battery when considering the life span and performance.

7. Environmental Impact

Lithium ion batteries are a much cleaner technology and are safer for the environment.

Applications

Lithium-ion batteries are one of the most popular types of rechargeable batteries for portable electronics with a high energy density, tiny memory effect and low self-discharge. Also used in electric vehicle and aerospace application.

4.7 UPS BATTERY

Fig 4.11 *UPS Battery*

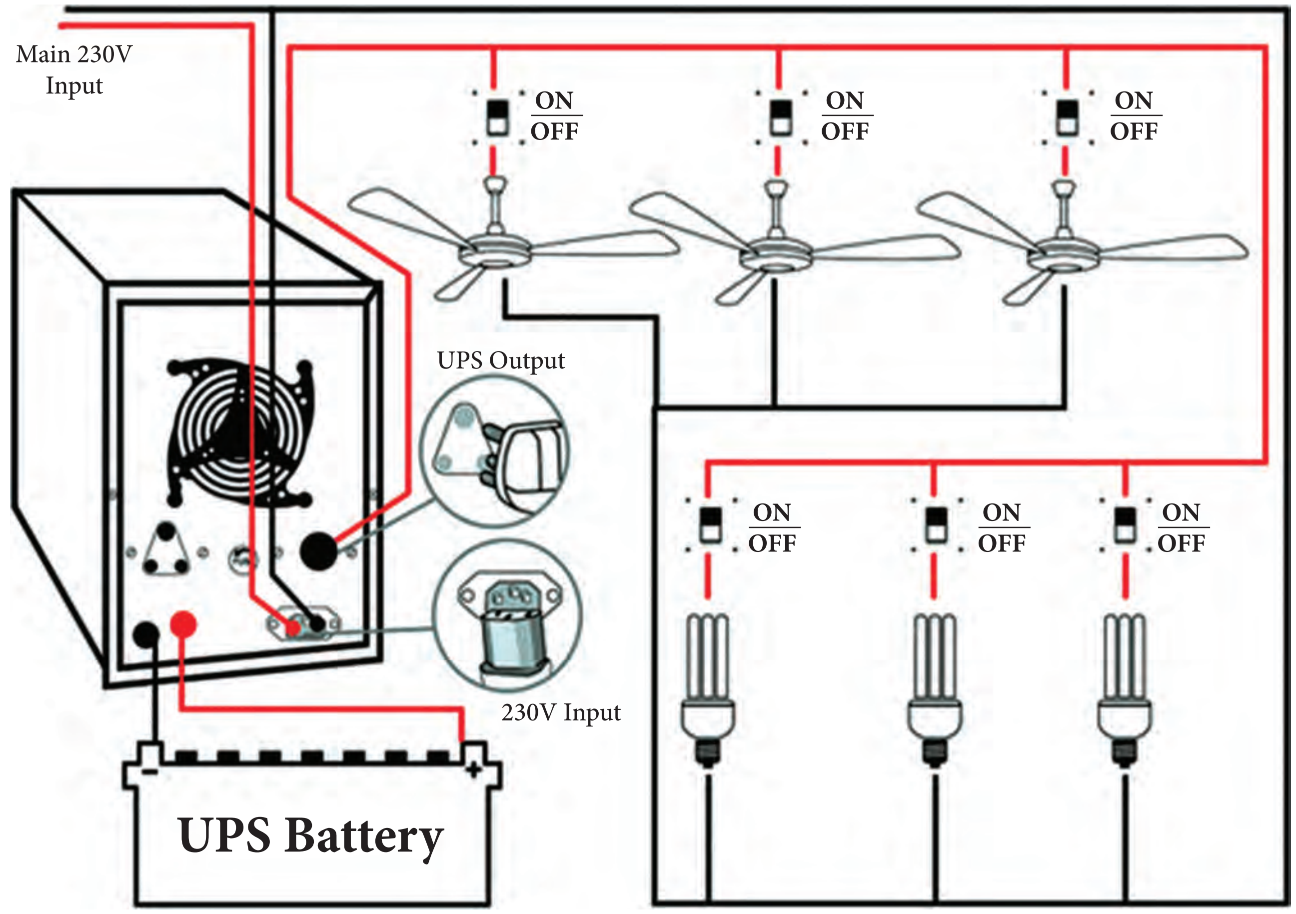


Fig 4.12 *Components of UPS System*

An uninterruptible power supply is called UPS. It is a device that permits supply to keep on running for a short period of time, when the primary power is off.

UPS contains a battery that "kicks in" when the device senses a loss of power from the primary source (as in fig. 4.11).

If you are using computer, when the UPS notifies you of the power loss, you have time to save and data you are working on and exit, before the secondary power source runs out. When all power runs out, any data in computers Random Access Memory (RAM) is erased when power surges occur, a UPS intercepts the surge, so that it doesn't damage the computer.

4.8 MAINTENANCE OF BATTERIES

How does UPS work?

In a continuous UPS, the computer is always running short of battery power and the battery is continuously being recharged. The battery charger continuously produces DC power, which the inverter continuously turns back into 120 volt AC power. If the power fails, the battery provides power to the inverter.

Components of UPS (Ref. fig. 4.12)

1. The Static Bypass
2. The Rectifier
3. The Battery
4. The Inverter

Types of UPS

Range		Types
0.5 to 3 KVA	-	Line interactive
0.5 to 5 KVA	-	Stand by Online Hybrid
3.0 to 15 KVA	-	Stand by Ferro Double
5.0 to 5000KVA	-	Conversion Online

1. Battery should be cleaned properly
2. Cable connection of the battery needs to be clean and tightened, Many battery problems are caused by dirty and loose connection.
3. The fluid level of the battery will always be higher at a full charge.
4. Distilled water alone is the best for filling because other types of water are loaded with chemicals and minerals that are harmful to the battery. Don't over fill the battery especially in warm weather.
5. Use silicon seals in the cable leads. Coat the cable washer end with grease or petroleum jelly (vaseline).

4.9 DO'S AND DON'T OF STORAGE BATTERY

Do's

1. Store batteries in a clean, ventilated and dry area.
2. Store batteries in a fully charged state.
3. Ensure the correct polarity connection when recharging.
4. Follow proper recharging schedules to prevent overcharging.
5. Keep the battery away from spark, heat and sources of fire.
6. Use proper size of cables along with correct plugs.
7. Charge the batteries immediately after it is discharged.

8. Terminal bolts are to be tightened with spring washers and apply torque. The tightness is to be checked.

Don'ts

1. Do not add any acid or distilled water in battery, during supply.
2. Do not tamper the vent plug.
3. Do not over tight or make loose the terminal bolts which may cause terminal breakage or fire due to loose contact.
4. Do not keep any metal object to rest on battery. It may cause short circuit.
5. Do not keep the battery in direct sunlight, dust or moist area.
6. Do not allow discharged battery for more than 12 hours in idle condition.

Precautions

1. Always handle a battery and its parts after wearing hand gloves, as the acid is corrosive.
2. Always pour the acid into water and not the water into the acid. Heat is produced when the acid is mixed with water.
3. Since the electrolyte is highly corrosive, the storage of electrolyte is used only glass or lead lined container If the batteries are handled with the above precautionary measures, the life of the battery will be prolonged. Follow the correct procedures and be safe while handling the battery.

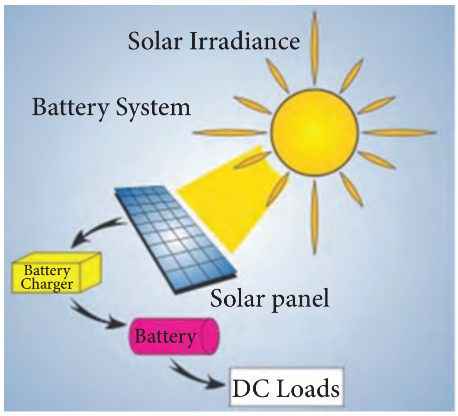
4.10 NINE TIPS FOR PROPER BATTERY CARE

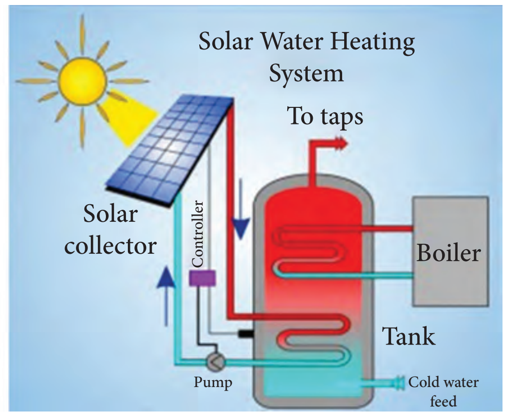
1. Size your battery correctly.
2. Periodically check the voltage of your batteries.
3. Don't try to charge alkaline batteries.
4. Prevent alkaline batteries from leaking.
5. Take care with parallel connections.
6. Give VRLA (Valve-Regulated Lead-Acid) battering breathing space.
7. Don't leave Lead-Acid batteries in a discharged state.
8. Take off golden ornaments when connecting a battery.
9. Protect from cold temperatures and snowy climates.

Activities

1. Test the supply voltage from lemon?
2. Test the voltage produced in carrot?
3. How to produce electricity from orange?

Do You Know?





Applications of Solar Battery System

Solar Battery Systems

Solar panels absorbs sunlight as a source of energy to generate electricity (or) heat. A photo voltaic modules, an inverter, a battery park for storage inter connection wiring, and optionally a solar tracking mechanism.

Solar Water Heating Systems

It is the conversion of sunlight into heat for water heating using a solar thermal collection. A variety of longitudes are available of varying cost to provide solution in different climates and latitudes. Solar water heating systems are widely used for residential and industrial applications.

GLOSSARY

Battery	—	மின்கலம்
Dry cell	—	உலர் மின்கலம்
Wet cel	—	பசை மின்கலம்
Separators	—	பிரிப்பான்
Charging	—	மின்னேற்றம்
Discharging	—	மின்னிறக்கம்
UPS-Battery-Un-Interrupted Power Supply	—	தடையில்லா மின்சாரம் தரும் சாதனம்

Q A

PART A

Mark 1

Choose the Correct Answer:

1. Battery is a storage of ________ energy
   a) Heat energy
   b) Electrical energy
   c) chemical energy
   d) Solar energy
2. In battery, chemical energy is transformed into _________ energy.
   a) Electrical energy
   b) Light energy
   c) Sound energy
   d) Heat energy.

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3. Primary cells are _______
   a) not rechargeable
   b) chargeable
   c) partly chargeable
   d) none
4. In dry cell, carbon rod is _________ electrode
   a) Positive electrode
   b) Negative electrode
   c) Phase
   d) Neutral
5. In a voltaic cell, the electrolyte used is __________
   a) Hydrochloric acid
   b) Nitric acid
   c) Sulphuric acid
   d) Dilute nitric acid
6. Voltaic cell is _____ type of cell
   a) Dry
   b) Wet
   c) Solid
   d) None
7. Charging and discharging process in secondary cell is by which law?
   a) Ohm's law
   b) Faraday's laws of electrolysis
   c) Lenz's laws
   d) current law
8. Lead acid battery is commonly used in _______
   a) Railway station
   b) Radio station
   c) T.V.Station
   d) Power station and substation
9. Separators in battery is a ________ material
   a) conductive
   b) non –conductive
   c) partly conductive
   d) heavy conductive
10. The voltage range of lithium-ion battery is _______
    a) 2 to 2.5V
    b) 2.5 to 3.6V
    c) 3.6 to 5V
    d) 5 to 6.6V
11. Advantage of using lithium ion battery is _____
    a) High energy density
    b) low energy density
    c) medium energy density
    d) poor energy density
12. The battery used in electric vehicles and Aerospace applications is________
    a) Lead acid cell battery
    b) Lithium-Ion battery
    c) UPS battery
    d) charger battery

QA

PART B

Mark 3

Answer the Questions in briefly

1. What is meant by battery?
2. State the different types of battery?
3. Write about the primary cell?
4. State the uses of a primary cell?
5. What is called a secondary cell?
6. What is a Lead Acid cell battery?
7. What is a the use of separators?
8. What is a Lithium-ion battery?
9. Write short notes on a UPS Battery?
10. Write down the types and range of UPS?
11. What are the precautions to be followed in battery?

QA

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Write about a voltaic cell and its constructional details?
2. State the differences between primary and secondary cell?
3. State the advantages of lithium-ion battery?
4. Write seven features about the disparity between a lead Acid and a Lithium ion battery?
5. State the Do's and Don'ts of a storage battery?
6. What are the maintenances to be observed in batteries?

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. With a neat sketch and explain dry cell.
2. Explain the construction of Lead Acid battery.
3. Explain the chemical reactions and physical changes during discharging in Lead-Acid battery.
4. Explain the chemical reactions and physical changes during charging in Lead-Acid battery.
5. Explain in detail about Lithium ion battery with diagram.
6. Draw and explain about an UPS battery with circuit diagram.

Reference Book

1. A text book of Electrical Technology' Volume I and Volume III by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 5

AC Circuits

SSVH9H

291

If "What is truth? the question be,
It is to speak out evil – free.

— Thiruvalluvar

LEARNING OBJECTIVES

The learning objective of AC circuit is preferably to know RLC-circuits, its advantages and disadvantages, and digital energy meter. According to the trend of applications, it is necessary to know the various types of connections in AC circuits.

Table of Content

5.1 AC CIRCUITS - INTRODUCTION

An alternating voltage may be generated in two methods:

(i) By rotating a coil at constant angular velocity in a uniform magnetic field

(ii) By rotating a magnetic field constant angular velocity within a stationary coil

In either case the generated voltage will be of sinusoidal waveform. The magnitude of generated voltage depends upon:

(i) Number of turns of the coil
(ii) The strength of magnetic field
(iii) The speed of rotation

The first method is used for small A.C generators and the second method is used for large type of A.C generators.

In figure 5.1, an Alternating current shows the change in the direction of current and magnitude at regular intervals of power system. Alternating current plays a vital role in today's energy generation.

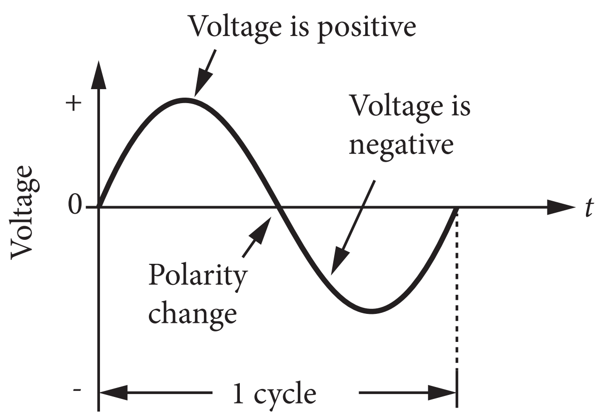


Fig 5.1 *Voltage vs Time*

5.2 AC WAVE FORM AND IT'S CHARACTERISTICS

A wave form is a representation of low alternating current (AC) that varies with time. The most familiar AC waveform is the sine wave, which derives its name from the fact that the current (or) voltage varies with the sine of the elapsed time.

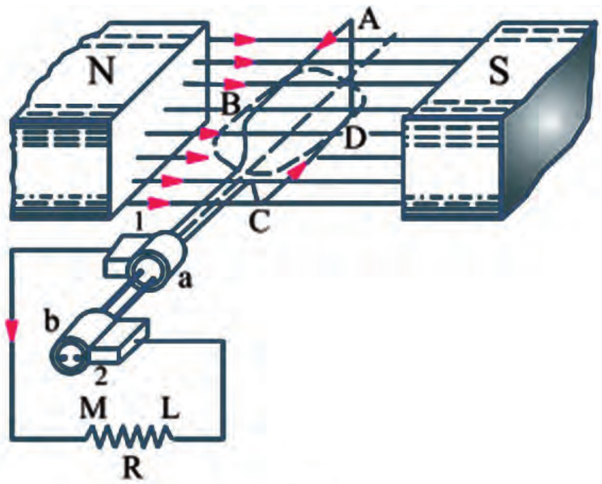


Fig 5.2 *(a)*

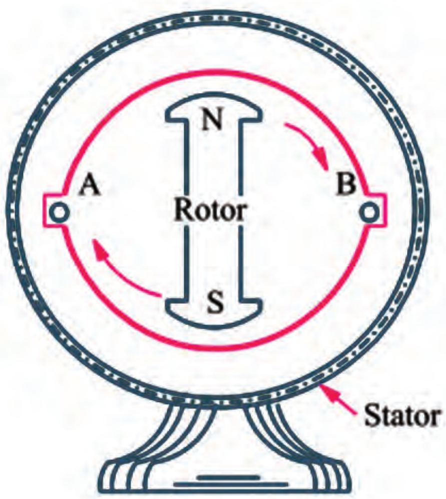


Fig 5.2 *(b)*

In fig 5.2 (a) A stationary magnetic field and rotating coil

In fig 5.2 (b) A stationary coil and magnetic field rotating

If a coil rotates in the magnetic field or rotates inside the coil, there is an alternating emf induced in the coil. The generated alternating emf depends upon the number of turns of coils, magnetic field and the angle between the coil and magnetic field.

Induced emf e = BlV sinθ

Where

B = flux density in weber/m^2

l = length of the conductor in meter

V = velocity of the conductor in meter/second

Ø = angle between magnetic field and conductor

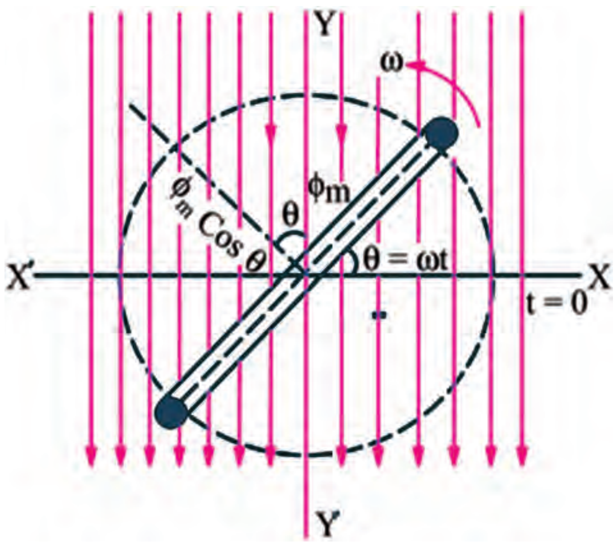


Fig 5.3 *Rotating Coil in a Magnetic Field*

In the figure above, a rectangular coil having 'N' turns and rotating in counter clock wise direction in a uniform magnetic field with an angular velocity of 'ω' radians/sec is shown.

So, the generated A.C e.m.f. value is also depends upon the value of the angle between the magnetic field and the coil.

The sine wave may be drawn by taking the Electro motive force in 'Y' axis and time in 'X' axis.

In figure 5.4, a coil is rotating in a magnetic field in anti-clock wise direction. Let us assume that the coil is in the position 'O'. Now the angle between the magnetic field and coil is zero. Then, the e.m.f in the coil is also zero (ie, sin Ø = 0)

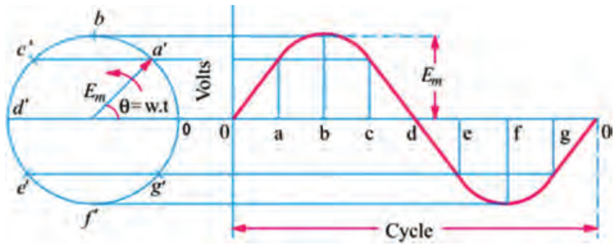


Fig 5.4 *Generation AC Waveform*

Now the coil moves to the position 'a' and the angles between the magnetic field and coil is Θ. Then, e.m.f. is equal to BlVsinθ.

Now the coil moves to the position 'b' and the angle between the magnetic field and coil is 90°. Then sin 90 = 1. The emf is maximum. This emf is called as positive maximum.

Now the coil moves to the position 'd' and the angle between the magnetic field and coil is zero. In this position emf is zero.

Now the coil moves to the position 'f' the angle between magnetic field and coil is 90º, sin 90 = 1 and the e.m.f is maximum in magnetic side, so it is called as negative maximum.

Now the conductor moves to the position '0', the emf is zero.

Similarly, the conductor rotates one revolution in the magnetic field. This rotation produces the sine wave form.

a) Cycle

One complete set of positive and negative values of alternating quantity is known as cycle. One complete cycle is said to spread over 360° or 2π radians.

b) Time Period

Time period is denoted by 'T'. The time taken for any wave to complete one full cycle is called the time period.

c) Frequency

The frequency of a wave is defined as the number of cycles that a wave completes in one second. It is denoted by the letter 'F' and its unit is cycles/second or Hertz(Hz). In India, the supply frequency is 50Hz. Frequency is calculated by

$$\boxed{F = \frac{PN}{120} Hz}$$

Where

F = Frequency in Hertz

P = Number of poles

N = Revolution in r.p.m

d) Instantaneous Value

At any given time, it has some instantaneous value. This value is different at different points along the waveform. During the positive and negative cycle, these values are positive and negative respectively.

e) Peak Value

The peak value of the sine wave is the maximum value of the wave during positive half cycle or negative half cycle.

f) Peak Factor

The ratio of maximum value to the r.m.s. value of an alternating quantity is known is peak factor

$$\boxed{\text{Peak factor} = \frac{\text{Max.Value}}{\text{R.M.S. value}} = 1.414}$$

g) Average Value

The average value of the sine wave is the ratio of total area under the half-cycle curve to the distance of the curve

$$\boxed{\text{Average Value} = \frac{\text{Area under the Curve}}{\text{Base Length}}}$$

$$\boxed{\text{Average Value} = \frac{2Im}{\pi} \text{ or } \frac{2Vm}{\pi}}$$

h) Effective Value or RMS Value

The value of an Alternating Current (or) Voltage is equal to the square root of the arithmatic mean of the squares of the instantaneous values taken through one complete cycle.

$$\boxed{\text{R.M.S. Value} = \frac{Im}{\sqrt{2}} \text{ or } \frac{Em}{\sqrt{2}}}$$

A.C ammeters and voltmeters are calibrated to record r.m.s. values.

i) Form Factor

The ratio of r.m.s value to the average value of an alternating quantity is known as form factor

$$\boxed{\text{Form factor} = \frac{\text{(R.M.S.Value)}}{\text{(average value)}} = 1.11}$$

The form factor is useful in rectifier service because it enables to find the r.m.s.value from average value and vice versa.

j) Power Factor

Cosine value of angle between voltage and current is called as power factor. Power factor is also defined as the ratio of true power to apparent power

Power factor = cos Θ (Θ is angle between voltage and current)

$$\boxed{\text{Power factor} = \frac{VI\cos\theta}{VI} = \frac{\text{True power}}{\text{Apparent power}}}$$

The power factor can never be greater than the value 1. If the powerfactor is 1, it is called as unity power factor. The word lagging or leading with the numerical value of power factor should be noted to signify whether the current lag or leads the voltage.

5.2.1 Phase

Phase of a particular value of an alternating quantity is the fractional part of the time period or cycle through which the quantity has advanced from the selected zero position of reference.

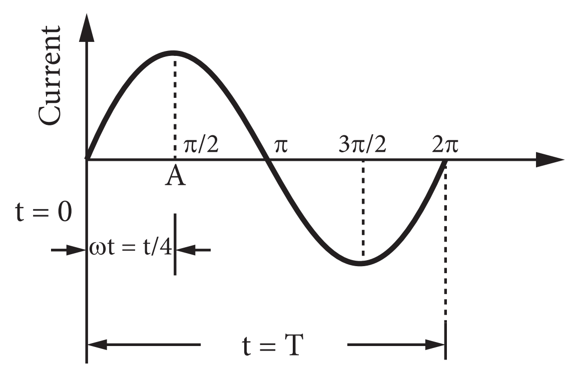


Fig5.5 *Phase*

5.2.2 Phase Difference

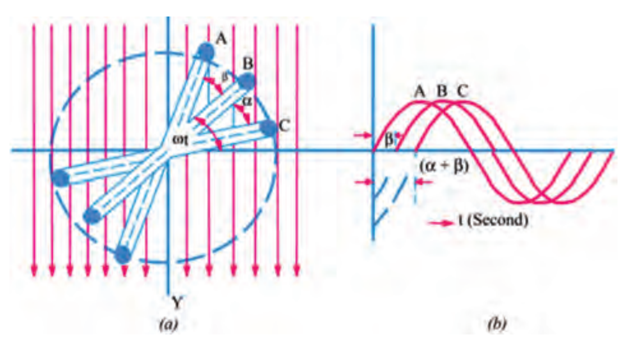


Fig 5.6 *Phase Difference*

When two alternating quantities of the same frequency have different zero points, they are said to have a phase difference.

SSZ4XE

The angle between zero point is the angle of phase difference ϴ. It is generally measured in degrees or radians. The quantity which passes through its zero point earlier is said to be leading while the other is said to be lagging.

5.3 ADVANTAGES AND DISADVANTAGES OF AC SUPPLY

Advantages

1) It is easy to transmit alternating current from one place to another place.
2) High voltage can be generated easily.
3) The cost of AC equipment is low.
4) It is possible to convert into DC.
5) Step down, step up voltage can be easily done by transformer.
6) A.C Motors are cheap.

Disadvantages

1) A.C cannot be stored in Batteries.
2) Compared to DC, A.C circuit should have good insulation because of high output voltage which causes electric shock.
3) The voltage drop is occurred due to high starting current in AC.
4) The speed of the AC motor depends upon the frequency.
5) In Inductive load, power factor will be low.

5.4 R-L-C SERIES CIRCUITS

In this circuit, the three (R,L,C) components are all in series with the Voltage source.

5.4.1. AC circuits with pure resistance

A circuit having only resistance and without inductance and capacitance is called pure resistance circuit

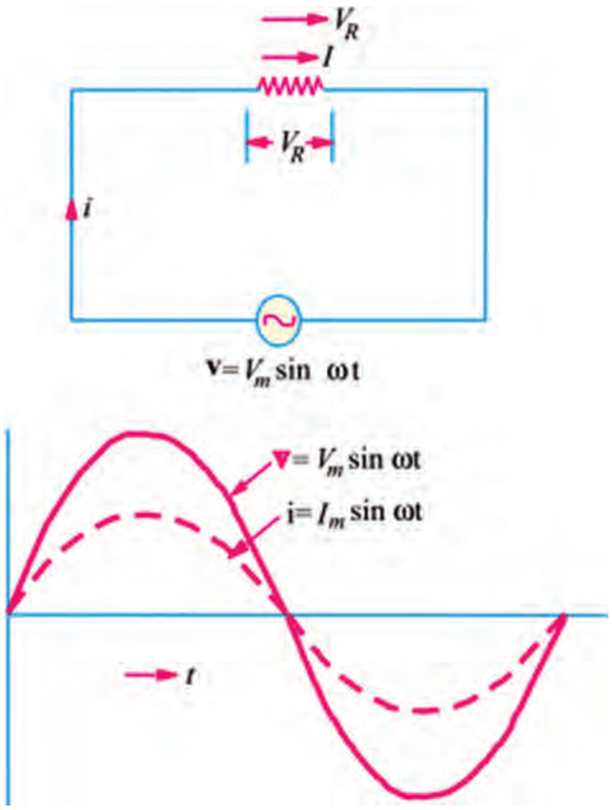


Fig 5.7 *AC through Resistance*

Let

The value of resistance is R

The value of current is I

The value of Electro motive force is E

Then

$$\text{Current}(I) = \frac{\text{Electromotive Force}(E)}{\text{Resistance}(R)}$$

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

$$\text{Power} = \text{Current} \times \text{EMF}$$

In this circuit power factor is unity, because the angle between current and voltage is zero (cosØ = 1).

5.4.2. AC circuits with pure Inductance

A circuit having only inductance and without resistance and capacitance is called pure Inductance circuit.

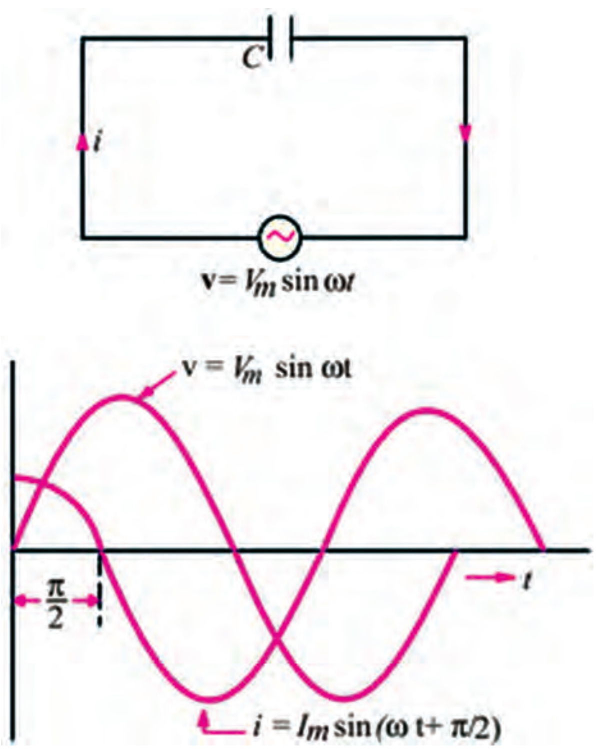


Fig 5.8 *AC through Inductance*

If A.C current flows through a coil, Back emf is induced due to inductance of the coil. This Back emf opposes supplied voltage in a pure inductance coil. Back emf is equal to supply voltage. In inductive circuit only, the frequency is same for voltage and current, but they are out of phase and current is lagging by 90º to the voltage.Therefore powerfactor (cos 90=0)is zero.

5.4.3. Inductive Reactance

Inductive reactance means the opposition due to self inductance to the A.C current through a coil. It's unit is ohm and it is denoted by the letter "XL"

$$XL = 2\pi fL$$

Where

XL-Inductive reactance in ohm
f-frequency in Hertz
L-Inductance in Henry

5.4.4. AC Circuits with pure capacitance

Two conducting plates separated by insulating material is called as capacitor. The insulating materials are be air, mica and paper.

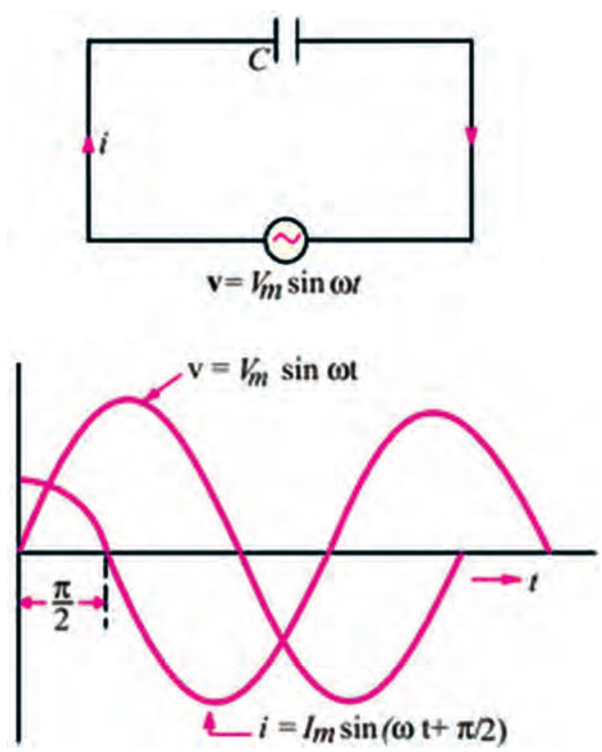


Fig 5.9 *AC through Capacitance*

In the first half cycle (up to 90º) capacitor is charged and from 90º to 180º the capacitor is discharged. Similarly in the second half cycle, capacitor is charged first and discharged next, in opposite direction. So, in one cycle, capacitor is charged and discharged two times, in capacitor only. In A.C circuit, the current is leading by the voltage at 90º

5.4.5 Capacitive Reactance

The resistance offered by a capacitor is called as capacitive reactance. The unit of capacitive reactance is ohm(Ω) and it is denoted by letters Xc.

$$Xc = \frac{1}{2\pi fc}$$

Where

Xc = capacitive reactance in ohm
C = capacitance in farad
F = frequency in Hertz

5.4.6 AC – RL SERIES CIRCUITS

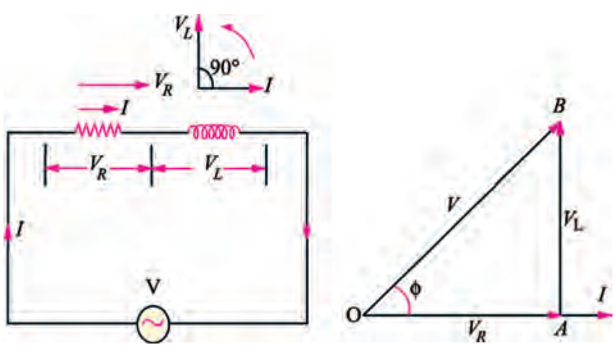


Fig 5.10 *AC through RL Series Circuit*

Resistance and inductance are connected in series as in fig. 5.10. In resistance there is no phase difference between Current and Voltage. But in inductance, current leads 90° by voltage.

V_R = Voltage across the resistance (Volts)
V_L = Voltage across the inductance (Volts)
R = Resistance (in ohms)
X_L = Inductive reactance

$$V_R = I \times R$$
$$V_L = I \times X_L$$
$$V_2 = V_R^2 + V_L^2$$
$$V = \sqrt{V_R^2 + V_L^2}$$
$$V = \sqrt{(IR)^2 + (I\,X_L)^2}$$
$$V = \sqrt{I^2R^2 + I^2\,X_L^2}$$
$$V = I\sqrt{R^2 + X_L^2}$$
$$\frac{V}{I} = \sqrt{R^2 + X_L^2}$$
$$Z = \sqrt{R^2 + X_L^2} \left(Z = \frac{V}{I} \right)$$

5.4.7 AC-RC CIRCUITS

In fig. 5.11 resistance and capacitance are connected in series. In resistance there is no phase difference between current and voltage. But in capacitance, voltage is 90° lagging by current.

V_R = Voltage across the resistance (Volts)

V_L = Voltage across the inductance (Volts)

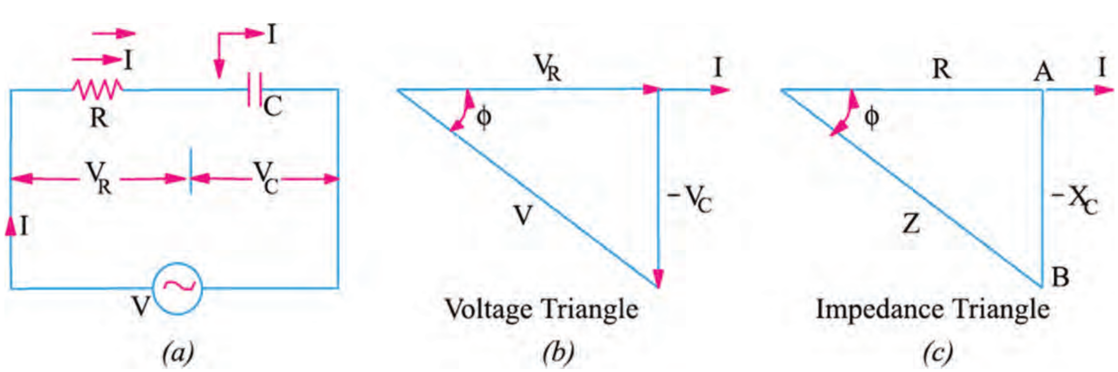


Fig 5.11 *AC through RC Series Circuit*

$$R = \text{Resistance (in ohms)}$$
$$X_C = \text{Inductive capitance.}$$
$$V_R = I \times R$$
$$V_C = I \times X_C$$
$$V^2 = V_R^2 + V_C^2$$
$$V = \sqrt{V_R^2 + V_C^2}$$
$$V = \sqrt{(I_R)^2 + (I\,X_C)^2}$$
$$V = \sqrt{I^2R^2 + I^2\,X_C^2}$$
$$V = I\,\sqrt{R^2 + X_C^2}$$
$$\frac{V}{I} = Z = \sqrt{R^2 + X_C^2}$$

5.4.8 IMPEDANCE

Impedance is the total opposition offered by the circuits elements [ie, Resistance, Inductance and capacitance] simply, Impedance is defined as the ratio of the voltage to current

$$\boxed{\text{Impedance}(Z) = \frac{\text{Voltage}(V)}{\text{Current}(I)}}$$

5.4.9 RLC Series Circuit

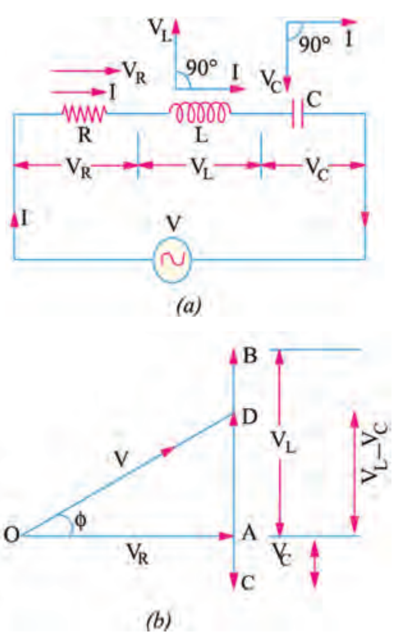


Fig 5.12 *AC through RLC Series Circuit*

In this RLC circuit resistance, inductance and capacitance are connected in series. In this the current is same. The voltage is differed by circuit elements, Total supply voltage is 'V'

$$I = I_R = I_L = Ic$$

And

$$V = V_R + V_L + V_C$$

V_R = Voltage across the resistance

V_L = Voltage across the inductance

V_C = Voltage across the capacitance

And also

V_R is in phase with current

V_L leads current by 90º

V_C lags current by 90º

(i) If inductive reactance is greater than capacitive reactance ($X_L > X_C$)

$$V^2 = V_R^2 + (V_L - V_C)^2$$
$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$
$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$
$$V = \sqrt{I^2R^2 + I^2(X_L - X_C)^2}$$
$$V = I\sqrt{R^2 + (X_L - X_C)^2}$$
$$\frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\text{Impedance } Z = \sqrt{R^2 + \left(X_L > X_c\right)}\,2\,\text{ohms}$$
$$\left(\frac{V}{I} = Z\right)$$

$$\text{Power factor } \cos\theta = \frac{R}{Z}$$

$$\text{and power } P = VI\,\cos\theta \text{ watts}$$

(ii) If capacitive reactance is greater than Inductive reactance ($X_C > X_L$)

$$\text{Impedance } Z = \sqrt{R^2 + (X_C > X_L)^2} \text{ ohms}$$

$$\text{Power factor } \cos\theta = \frac{R}{Z}$$

$$\text{And power } P = VI\,\cos\theta \text{ watts}$$

Do You Know?

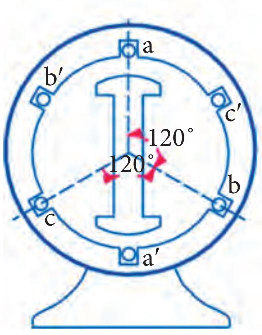
- ❖ Electricity travels at the speed of light - more than 186,000 miles per second!
- ❖ Electricity always tries to find the easiest and shortest path to the ground.
- ❖ Electricity can be made from wind, water, the sun and even animal poop.
- ❖ A 600-megawatt natural gas plant can power 220,000 homes.
- ❖ The first power plant - owned by Thomas Edison - opened in New York City in 1882.

5.5 THREE PHASE STAR/ DELTA CONNECTIONS

3 phase A.C generator is shown in Fig 5.13. Three identical windings A,B and C are placed 1200 electrical degree apart. It rotates in anti-clock wise direction. It generates 3 phase supply. Three phases are indicated in Red (R), Yellow (Y) and Blue (B) colors.

5.5.1 Poly Phase System

If the armature of an alternator generating AC apply is having only one winding, it generates single phase supply. Instead of one winding, if the alternator has two or three windings, then two or three phases are generated respectively. So a system produces more than one phase is called poly-phase system.



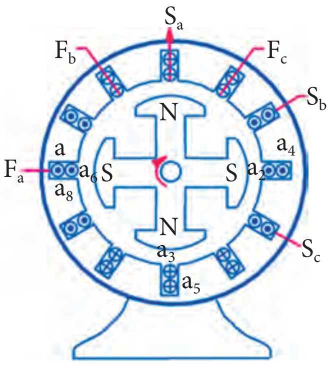


Fig 5.13 *Poly Phase System Generation*

5.5.2. Reasons for the Use of Three-Phase System

Three phase system is preferred over single phase system for the following reasons.

i. Three phase power has a constant magnitude whereas single phase power pulsates from zero to peak value at twice the supply frequency.

ii. A three phase system can set up a rotating magnetic field in stationary windings. This cannot be done with a single phase current.

iii. For the same rating, Three phase machines (generators, motors, transformers) are smaller, simpler in construction and have better operation than single phase machines.

iv. To transmit the same amount of power to a fixed distance at a given voltage. The three phase system requires only three-fourth weight of copper that is required by the single phase system.

v. The voltage regulation of a three phase transmission line is better than that of a single phase line.

5.5.3. Phase Sequence

It is the term which is used to represent in what sequence the three phase voltage or current attains maximum value. If the phase sequence is said to be R, Y, B then first red phase attains maximum value with a phase difference of 120° each, the yellow phase and blue phase attains their peak value.

5.5.4. Inter Connection of Three Phases

In a three phase alternator, there are three windings or phases. Each phase has two terminals. If a separate load is connected across each winding six conductors are required to transmit power. This will make the system complicated and expensive. In practice, three windings are interconnected to give two methods of connection.

Star (Y) connection

Mesh (Δ) connection.

5.5.5. Star Y Connection

In this method, similar ends of the three phases are joined together to form a common junction (N) supply is taken from other three ends. The common junction (N) is called the star point or netural point. The voltage between any one line and netural is called phase voltage. The current flows through that phase is called phase current. Voltage between any two lines is called line voltage and current through that line is called line current.

In this connection,

Phase current = Line current

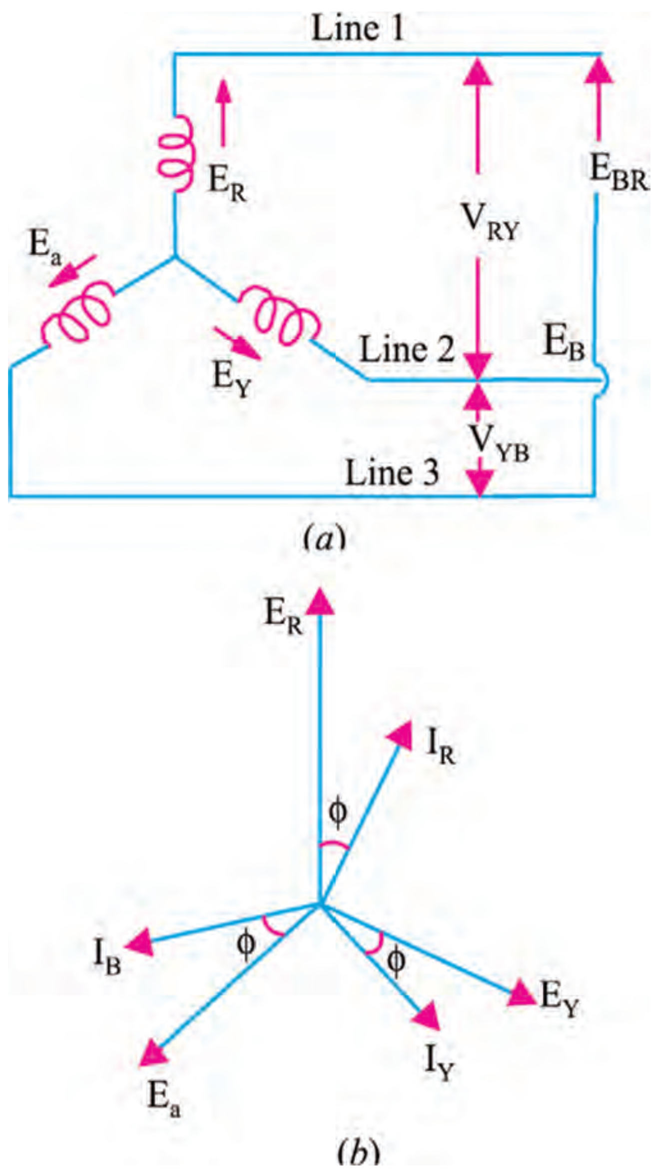


Fig 5.14 Star Connection

$$I_{ph} = I_L$$

$$\text{Phase voltage} = \frac{\text{Line Voltage}}{\sqrt{3}} = \frac{E_L}{\sqrt{3}}$$

If the neutral wire is taken for external connection, then the system is called a three-phase four wire star connected system. If the neutral wire is not taken for external connection, then the system is called a three phase three wire star connected system.

Total power p = 3 × power in each phase

Power in each phase P = $V_{ph}\ I_{ph}\ \cos\theta$

$$P = 3 \times \frac{V_L}{\sqrt{3}} \times I_L \cos\theta$$

$$(\text{where as } I_{ph} = I_L,\ V_{ph} = \frac{V_L}{\sqrt{3}})$$

$$\therefore P = \sqrt{3} V_L I_L \cos\theta$$

5.5.6. Delta or Mesh Connection(Δ)

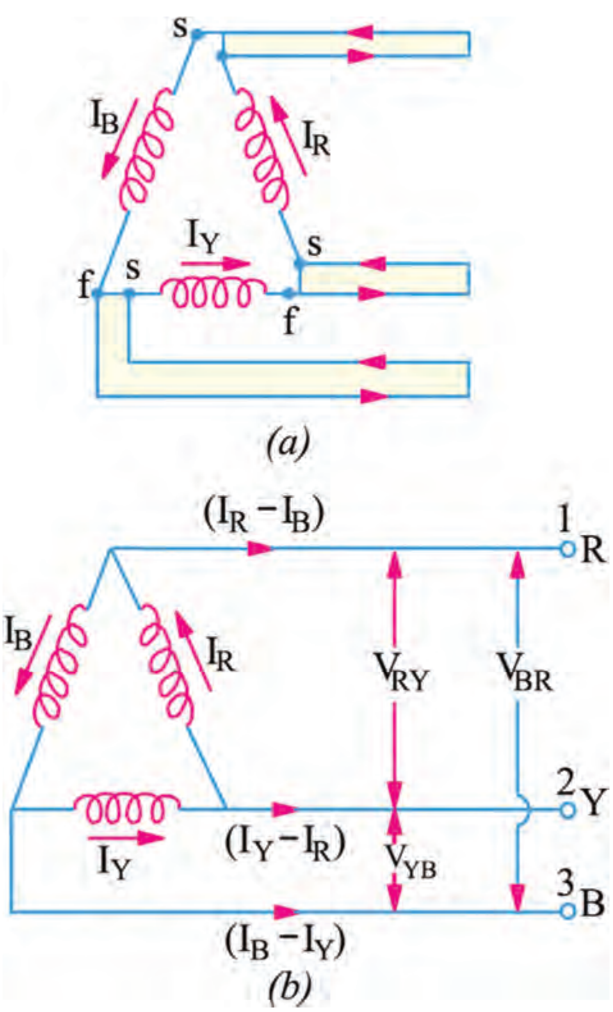


Fig 5.15 Delta Connection

In this method of interconnection, the dissimilar ends of the three phase windings are joined together. The finishing end of one phase is connected to the starting end of the other phase so as to obtain Mesh or Delta connection. The three line conductors are taken from the three junctions of the Mesh or Delta and they designated as R, Y and B. This is called three phase three wire delta connected system. Since no neutral exists in a Delta connection, only three phase, three wire system can be formed.

In this connection, the line voltage is equal to the phase voltage.

Phase Volltage = Line voltage

$$V_{ph} = V_L$$

Phase Current = Line current

$$I_{ph} = \frac{I_L}{\sqrt{3}}$$

POWER

Total power P = 3 × power per phase

$$P = 3\ V_{ph}\ I_{ph}\ \cos\theta$$

$$P = 3 \times V_L \times \frac{I_L}{\sqrt{3}} \times \cos\theta$$

$$V_{ph} = I_L,\ I_{ph} = \frac{I_L}{\sqrt{3}}$$

$$\text{i.e., Power} = \sqrt{3}\ V_L I_L \cos\theta$$

Where cosθ is power factor.

5.5.7 Advantages of Star Connection Over Delta Connected System

A star connected alternator will require less number of turns than a delta connected alternator for the same line voltage.

A star connected alternator requires less insulation over a Delta connected alternator for the same line voltage.

In star connection, Three-phase, Four-wire system permits to use two voltage ie, Phase voltage as well as line voltage.

In star connection single phase loads can be connected between any one line and the neutral. Such a flexibility is not available in Delta connections.

In star connection, the neutral point can be earthed. Moreover, earthing of neutral permits to use protective devices to protect the system in case of ground faults.

5.6 DIGITAL ENERGY METER

Digital energy meters display the energy used on an LCD or LED display, and some can also transmit readings to remote places. In addition to measuring energy used, these meters can also record other parameters of the load and supply, such as instantaneous and maximum demands, voltage, power factor and reactive power etc. They can also support to record the amount of energy used during on-peak and off-peak hours.

The digital energy meter has a power supply, metering circuit, a processing and communication circuit (microprocessor/microcontroller) and other add on modules such as RTC (Real Time Clock), LCD (Liquid Crystal Display), communication ports, modules and so on.

In the metering circuit, the voltage and current inputs through current transformer and potential transformer has a voltage reference followed by an ADC (Analog to Digital Convertor) section, to convert the analog inputs into digital forms. These inputs are then processed using a digital signal processor, to calculate various metering parameters.

The processing and communication section has the responsibility of calculating various desired quantites, from the digital values generated by the metering section. This has the responsibility of communicating and interfacings with other 'add on modules' connected as slaves to it.

RTC (Real Time Clock) and other add-on modules are attached as slaves to the processing and communication sections

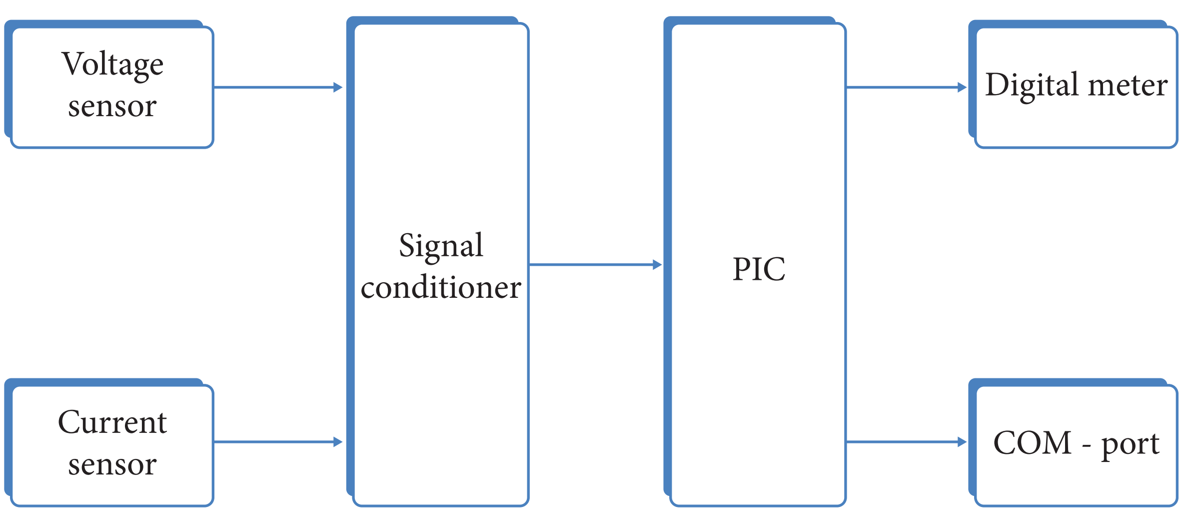


Fig 5.16 *Block Diagram of Digital Energy Meter*

for various input/output functions. In some meters, most of these modules RTC, LCD controller, Temperature sensor, memory, ADC (Analog Digital Converter) may be implemented inside the processing and communication circuit.

Fig 5.17 *Digital Energy Meter*

Advantages of Digital Energy Meters

i) High accuracy

ii) Robustness

iii) No moving parts

iv) Easy to gauge readings through digital display

v) Over current protection

vi) Readings can be stored and print out may be taken

vii) Smaller in size

viii) Consumes less power

ix) Long life

x) Easy to carry anywhere

xi) Remote control is possible

Points to Remember

✶ Induced E.M.F $e = Blv \sin\theta$

✶ Frequency $f = \frac{PN}{120}$ Hz

✶ Average value $= \frac{2I_m}{\pi}$ or $\frac{2V_m}{\pi}$

✶ R.M.S. value $= \frac{I_m}{\sqrt{2}}$ or $\frac{V_m}{\sqrt{2}}$

✶ Form factor $= \frac{\text{RMS Value}}{\text{Average Value}} = 1.11$

✶ Peak factor $= \frac{\text{Max. Value}}{\text{RMS Value}} = 1.414$

✶ Power factor$= \frac{V_I \cos\theta}{V_I}$

✶ In pure resistance circuit, power factor is one (unity)

✶ In pure inductive or capacitive circuit, power factor is zero

✶ Inductive reactance $X_L = 2\pi fl$

✶ Capacitive reactance $X_C = 1/2\pi f_C$

✶ Impedance $Z = \frac{V}{I}$

In RLC series circuit powerfactor $\cos\theta = \frac{R}{Z}$

Both in RLC series and RLC parallel circuit

✶ Power $P = VI \cos\theta$ watts

In Star Connection

Phase current = Line current

$$I_{ph} = I_L$$

Phase voltage $= \frac{(\text{Line Voltage})}{\sqrt{3}}$

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

In Delta Connection

Phase voltage = Line Voltage

$$V_{ph} = V_L$$

$$\text{Phase current} = \frac{\text{Line current}}{\sqrt{3}}$$

$$I_{ph} = \frac{I_L}{\sqrt{3}}$$

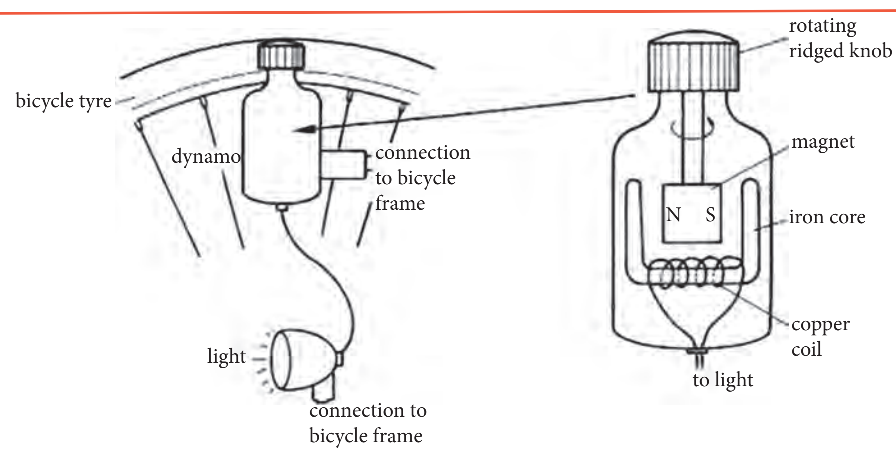
Both in star and Delta connection in three phase system

$$\text{Power } p = \sqrt{3} V_L I_L \cos\theta$$

Digital energy meters displayed the energy consumption accurately.

Activities

1. Practice the following (dynamo) type of voltage generation.



GLOSSARY

AC Supply	–	மாறுதிசை மின்சாரம்
Frequency	–	அலைவு வேகம்
Average Value	–	சராசரி மதிப்பு
Peak Value	–	உச்சமதிப்பு
Time Period	–	கால அளவு
Instantaneous Value	–	கன மதிப்பு
Effective Value	–	பயன் மதிப்பு
Form Factor	–	வடிவுக்காரணி
Peak Factor	–	உச்சக்காரணி
Power Factor	–	திறன்காரணி
Voltage Sensor	–	மின்னழுத்த உணர்வி
Current Sensor	–	மின்னோட்ட உணர்வி

PART A

Mark 1

Choose the Correct Answer:

1. The unit of the flux density is
   a) Ampere b) Volt
   c) Weber d) Weber/m_2

2. The unit of the frequency is
   a) Henry b) Hertz
   c) Cycles d) Ampere

3. The value of form factor is
   a) $2/\pi$ b) $\pi/2$
   c) 1.414 d) 1.11

4. The value of peak factor is
   a) $2/\pi$ b) $\pi/2$
   c) 1.414 d) 1.11

5. In the value of power factor, which is incorrect
   a) Unity b) 0.8 leading
   c) 0.8 lagging d) 1.5

6. Power factor of pure resistive circuit is
   a) Unity b) Leading
   c) lagging d) None of the above

7. Power factor of pure Inductive circuit, with respect to current is
   a) unity b) leading
   c) lagging d) none of the above

8 Power factor of pure capacitive circuit, with respect to current is
   a) unity b) leading
   c) lagging d) none of the above

9. The unity of Inductance is
   a) Henry b) Hertz
   c) Farad d) Ohm

10. The unit of capacitance is
   a) Henry b) Hertz
   c) Farad d) Ohm

11. The unit of Impedance
   a) Henry b) Hertz
   c) Farad d) Ohm

12. The unit of Capacitive reactance and Inductive reactance is
   a) Henry b) Hertz
   c) Farad d) Ohm

13. Inductive reactance X_L is equal to
   a) $2\pi fc$ b) $1/2\pi fc$
   c) $2\pi fl$ d) $1/2\pi fl$

Q A

PART A

Mark 1

Choose the Correct Answer:

14. Capacitive reactance X_C is equal to
    a) $2\pi fc$ b) $1/2\pi fc$
    c) $2\pi fl$ d) $1/2\pi fl$

15. Star connection is also known
    a) Delta b) Y
    c) Mesh d) None of the above

16. Delta connection is also known as
    a) Star b) Y
    c) Mesh d) None of the above

17. X_L denotes
    a) Resistance
    b) Inductive reactance
    c) Capacitive reactance
    d) Impedance

18. X_C denotes
    a) Resistance
    b) Inductive reactance
    c) Capacitive reactance
    d) Impedance

19. Four wire system can be obtained from
    a) Series connection
    b) Parallel connection
    c) Star connection
    d) Delta connection

20. In three phase, phase difference is
    a) 90° b) 180°
    c) 120° d) 360°

21. In star connection, phase current Iph is equal to
    a) V_L b) I_L
    c) Vph d) $\frac{I_L}{\sqrt{3}}$

22. In Delta connection, phase voltage Vph is equal to
    a) V_L b) I_L
    c) Vph d) $\frac{I_L}{\sqrt{3}}$

23. Digital energy meters are used for the following reason
    a) High accuracy
    b) Small size
    c) Long life
    d) All of the above

Q A

PART B

Mark 3

Answer the Questions in briefly

1 Define 'cycle' in alternating current.
2. Define frequency.
3. Define Amplitude or maximum value.
4. Define effective value or RMS value.
5. Write short notes on Average value.
6. Define form factor.
7. Define peak factor.
8. Write short notes on 'phase'.
9. What is Inductance and it's unit?
10. What is Capacitance and it's unit?
11. What are the uses of capacitors?
12. What is Impedance and it's unit?
13. What is Inductive reactance?
14. What is Capacitive reactance?
15. What is phase sequence?
16. What are the two connections of three phase system?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the power factor with vector diagram.
2. Briefly explain the AC circuit which is having only resistance.
3. Briefly explain the AC circuit which is having only Inductance.
4. Briefly explain the AC circuit which is having only capacitance.
5. Explain the reasons for the use of three phase system over single phase system.
6. What are the advantages of star connection over Delta connected system?
7. What are the advantages of digital energy meter?

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain RLC series circuit with neat diagram.
2. Explain the star connection of three phase system with neat diagram.
3. Explain the Delta connection of three phase system with neat diagram.
4. Explain how alternating current and voltage is generated with neat diagram.

Reference Book

1. 'A text book of Electrical Technology' Volume I, by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 6

Transformer

ST8ZZ2

299

All lights are not lights for the wise;
Truth light is light bright like Sun-light.

— Thiruvalluvar

LEARNING OBJECTIVES

The main objective of learning this lesson is to know in detail about Transformer, its construction, operation, losses, testing method, protective devices of transformer, which are existing under new technique.

Table of Content

6.1 TRANSFORMER- INTRODUCTION

A Transformer is a static device which transfers electrical energy from one circuit to another circuit at the same frequency. It works on the principle of mutual induction. The transformer works only on A.C supply.

Generating stations generate electricity at a voltage of 11KV. The electric power from the generating station is to be brought to the consumers end from 33KV, 66KV etc through various transmission stages.The transformer is used to step down (or) step up the voltage required according to the requirement as shown in fig. 6.1.

Fig 6.1 *Transformer in Transmission Line.*

6.2 CONSTRUCTION OF TRANSFORMER CORE

Based on the construction, it is classified into 3 types. They are:

i. Core type

ii. Shell type and

iii. Berry type

6.2.1 Core Type

The winding surrounds the core is called core type transformer. The Figure 6.2 represents the core type.

The magnetic circuit is made up of laminated iron core. Silicon steels are used to reduce the hysteresis loss in the iron core, also laminated sheets are insulated from one another by a layer of varnish insulation.

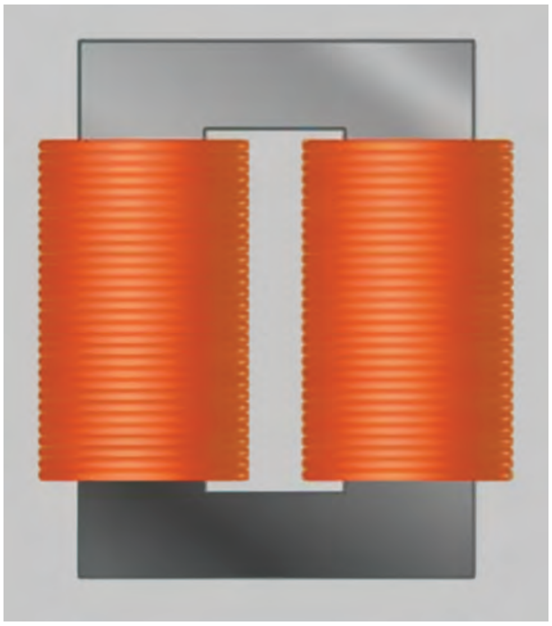


Fig 6.2 *Core Type Construction*

Advantages

i) Easily handled and maintained.

ii) The coils are in the outside, so it will get cooled easily.

Disadvantages

i) High magnetic loss.

ii) High leakage flux.

6.2.2 Shell Type

The core surrounds the winding is known as shell type transformer. The Figure 6.3 represents the shell type.

The primary and secondary windings are placed on the central limb one above the other. This gives a better magnetic coupling.

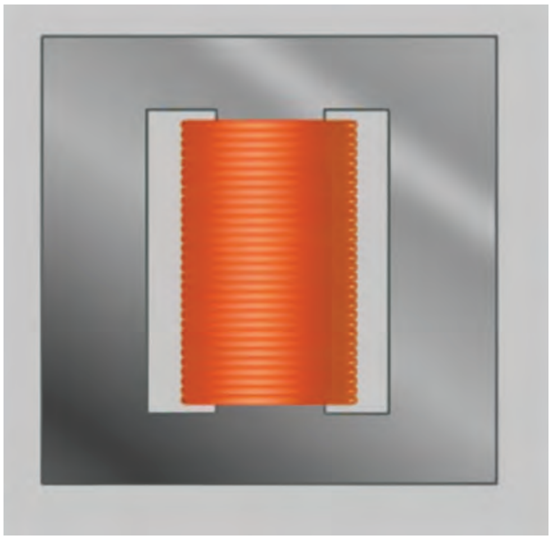


Fig 6.3 *Shell Type Transformer*

Advantages

i) More economical for low voltage.

ii) Low current at the time of no load.

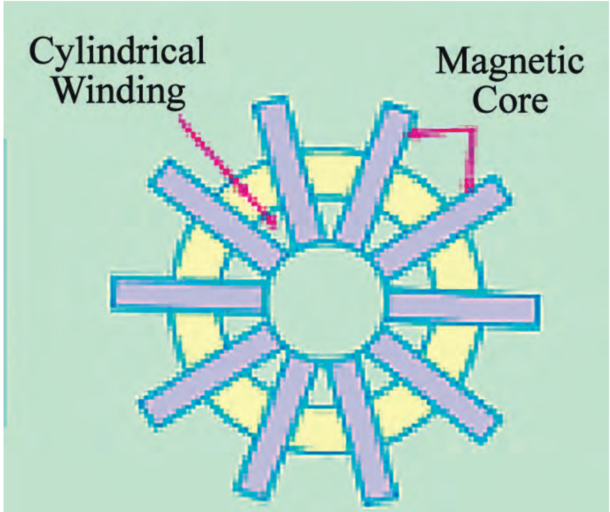
Disadvantages

i) Little complicated to make winding.

ii) Less cooling.

6.2.3 Berry Type

Berry type is similar to shell type. In berry type magnetic path is placed around the coil. Normally this type is not used.



6.2.4 COMPARISON OF CORE AND SHELL TYPE TRANSFORMER

Core Type Transformer	Shell Type Transformer
1. The winding encircles the core.	The core encircles most part of the winding.
2. It has single magnetic circuit.	It has double magnetic circuit.
3. The cylindrical coils are used.	The multilayer disc (or) sandwichs type of coils are used.
4. The coils can be easily removed for maintenance.	The coils cannot be removed easily.

6.3 WORKING PRINCIPLE (OR) OPERATION OF A TRANSFORMER

A Transformer is a static (stationary) apparatus by means of which electric energy in one circuit is transformed into another circuit without changing the frequency.

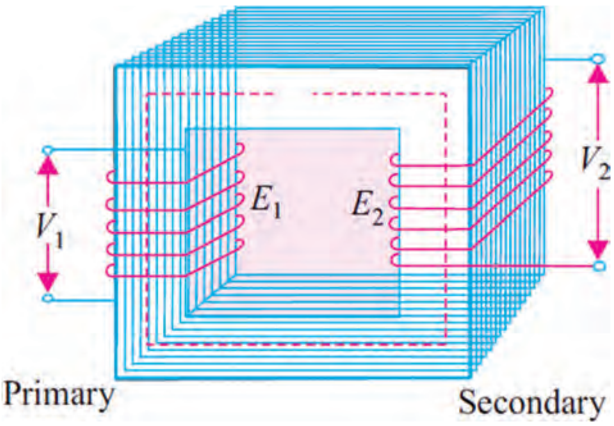


Fig 6.4 *Construction of an Ideal Transformer*

It consists of two inductive coils which are electrically separated but magnetically coupled to a core as shown in Fig. 6.4. It operates on the principle of mutual induction between two (or) more inductively coupled coils. If the coil is connected to a AC source, an alternating flux is setup. Most of the flux is linked with the other coil. This flux is called mutual flux.

As per Faraday's laws of electromagnetic induction, an emf is induced in the second coil. The coil (First coil) which is connected to the A.C supply is called as primary winding. The coil (Second coil) which is connected to the load is called as secondary winding.

6.3.1 STEP UP/ STEP DOWN TRANSFORMER:

Step up Transformer – If the output voltage in secondary winding is higher than the input voltage, it is called step up transformer. (See Figure 6.5)

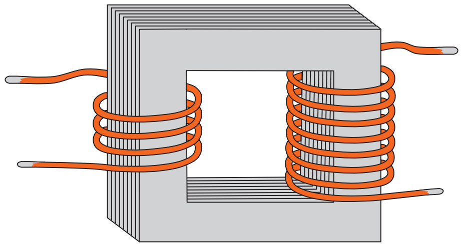


Fig 6.5 *Step-up Transformer*

Step down Transformer – If the output voltage in the secondary winding is lesser than the input voltage, it is called step down transformer as in fig. 6.6.

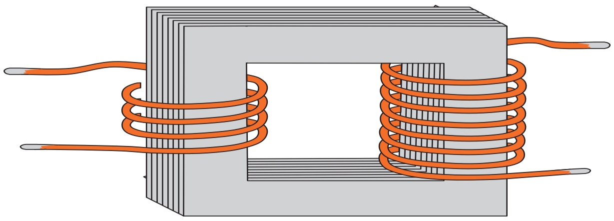


Fig 6.6 *Step-down Transformer*

6.3.2 ADVANTAGES OF TRANSFORMERS

i. The transformer is a static machinery. Hence there is no wear and tear and no friction losses in it.
ii. Maintenance cost is low.
iii. As there is no rotating part in it, extra high voltage can be transferred easily by providing a good insulation to its winding.

6.4 E.M.F EQUATION OF A TRANSFORMER

a) Construction b) Wave Form

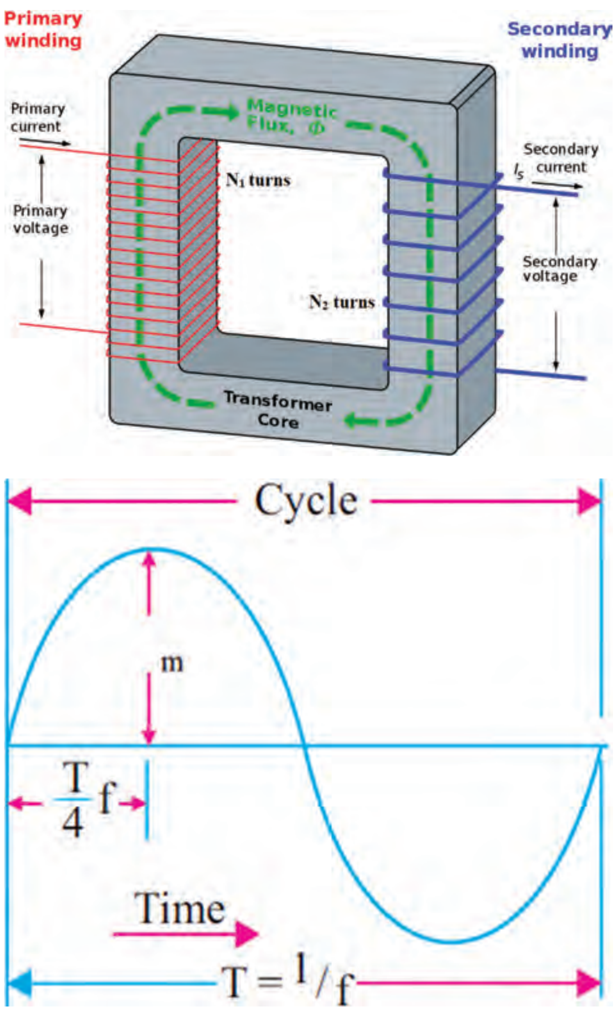


Fig 6.7 *Single Phase Transformer and Wave Form*

No. of turns in primary winding = N_1

No. of turns in secondary winding = N_2

Maximum value of flux = $Ø_m$ webers

Frequency of A.C input = f in Hz

The flux in the core will vary sinusoidally as shown in the above fig 6.7.

The flux in the core increases from zero to a maximum value in one quarter cycle (1/4f second)

i.e, Average rate of change of flux

$$= \frac{Øm}{\frac{1}{4f}} = 4fØm$$

i.e average E.M.F induced per turn = 4f $Ø_m$ volts.

The flux varies sinusoidally. Hence the, R.M.S value of induced voltage is obtained by multiplying the average value by form factor which is equal to 1.11 for a sine wave.

i.e, R.M.S value of induced E.M.F per turn= 1.11 × 4f Φm volts.

= 4.44 f Φm volts.

The primary/secondary windings have N_1/N_2 turns respectively,

R.M.S value of induced e.m.f in primary E_1=4.44 f Φm N_1 Volts R.M.S value of induced e.m.f in secondary E_2= 4.44 f Φm N_2 Volts

6.4.1 Voltage Transformation Ratio (k)

The ratio of secondary voltage to primary voltage is called voltage transformation ratio. It is represented by 'k'.

$$\frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = k$$

6.4.2 Current Ratio

By neglecting the losses

Input volt ampere = output volt ampere

$$V_1 I_1 = V_2 I_2 \quad \text{or} \quad \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{1}{K}$$

6.4.3 Application of Transformer

- It is used to step up or step down the voltages and currents in an electrical circuit.
- Used in modern electrical transmission and distribution systems.
- It boost voltage levels so as to decrease line losses during transmission.

6.5 TYPES OF INSTRUMENT TRANSFORMERS

6.5.1 Potential Transformer

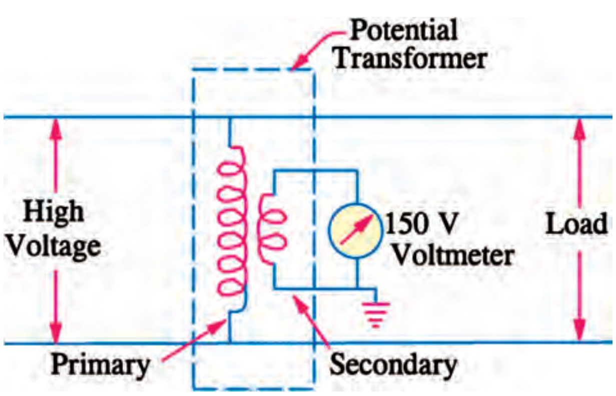


Fig 6.8 *Potential Transformers*

Potential transformer do not differ much from the ordinary two windings transformers (Refer Figure 6.8). These are step down transformers. The primary winding is connected directly across the power circuit. The secondary is usually rated for 110 (or) 220 volts. Voltage ratio is depenting upon primary voltage .

6.5.2 Current Transformer

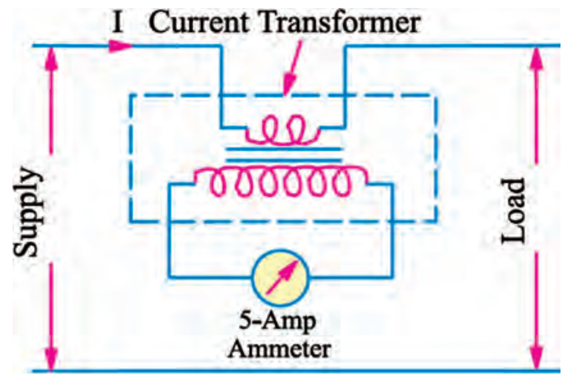


Fig 6.9 *Current Transformers*

The current transformer has a primary coil of only few turns of thick wire connected in series with the line whose current is to be measured. The secondary coil consisting large number of turns is connected to the terminals of a low range ammeter (See Figure 6.9). The ammeter is thus entirely insulated from the line. Mostly the secondaries of all C.T are wound for 5 amperes.

6.5.3 Auto Transformer (VARIAC)

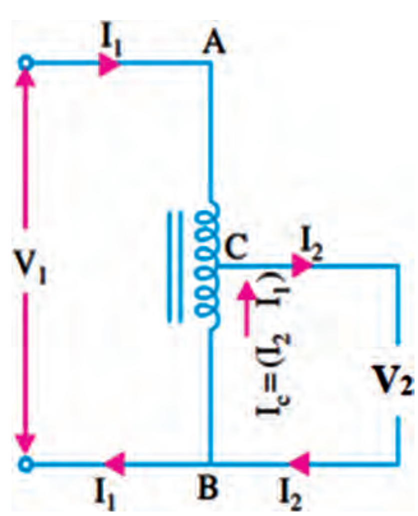


Fig 6.10 *Auto Transformer*

An auto transformer is a single winding transformer which is used to get varying AC voltage. Consider a single winding BA of N_1 turns wound on an iron core as shown in Figure 6.10. If core loss, copper loss, magnetizing current and leakage reactance are neglected. If this winding is connected to an A.C Voltage V1, a flux will set up in the core and e.m.f E1 will be induced in the winding. Such induced e.m.f is taken by tapping at point C. There are N2 turns between B and C, an e.m.f E2 is induced B and C.

When load is connected across the terminals B and C a current I2 flows. The m.m.f due to I2 will be balanced by m.m.f due to I1. This arrangement is referred as an Auto transformer. If point C is sliding contact, a continuously variable output voltage can be made available.

So,

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = K$$

Advantages

1. Copper required is very less.
2. The efficiency is higher.
3. Required less conducting material and hence cost is less.
4. More smooth & continuous variation of voltage.

Disadvantages

1. Direct link between high voltage and low voltage sides there is no isolation as in the case of a two winding transformer.
2. The short circuit current is greater than that of a two winding transformer.

6.5.4 Applications of Auto Transformer

1. As a booster of supply voltage to a small extent.
2. Auto transformers are used to start the induction motor.
3. It can be used to vary the voltage to the load, smoothly from zero to the rated voltage.

6.6 LOSSES IN A TRANSFORMER

The losses in a transformer consists of I^2R loss (or) copper loss and iron loss (or) core loss.

I^2R Loss (or) Copper Loss

These losses occur in primary and secondary windings. Copper loss in a transformer is a variable loss. It varies as the square of the load current (From short circuit test this can be determined).

Iron Loss (or) Core Loss

Iron loss consists of hysteresis and eddy current losses. They occur in the transformer core due to the alternating flux (from open circuit test, this can be determined.)

Hysteresis Loss

When the iron core is subjected to an alternating flux hysteresis loss takes place.

Eddy Current Loss

Eddy current is induced in the cores. This loss is due to the flow of eddy current. Thin laminations are used to reduce the eddy current loss.

6.6.1 Efficiency of a Transformer

The efficiency of a transformer is the ratio of output power to input power.

Input = output + losses

$$\% \text{ Efficiency } (\eta) = \frac{\text{output power}}{\text{input power}} \times 100$$

$$= \frac{\text{output power}}{\text{output power + losses}} \times 100$$

(iron loss + copper loss)

$$= \frac{\text{input power} - \text{losses}}{\text{input power}} \times 100$$

6.6.2 Why Transformer Rating in KVA?

As seen Cu loss of a transformer depends on current and iron loss depends on voltage. Hence total transformer losses depends on volt ampere (VA) and not on phase angle between voltage and current i.e, it is independent of load power factor. Therefore rating of transformer is in KVA and not in KW.

$$KVA = \frac{KW}{\cos\theta}$$

6.6.3 Why Transformer does not Work on DC Supply?

The transformer works on the principle of mutual induction, for which current in one coil must change uniformly. If DC supply is given, the current will not change due to constant supply and transformer will not work. This may cause the burning of windings due to extra heat generated and may cause permanent damage to the transformer. Thus DC supply should not be connected to the transformers.

6.7 TESTING METHODS OF TRANSFORMER

There are two tests are performed on a transformer to determine the power. They are:

1. Open circuit test
2. Short circuit test

These two tests are used for finding out the power loss occurring in the transformer.

6.7.1 Open Circuit Test on Transformer

The open circuit test on transformer is used to determine core losses in transformer.

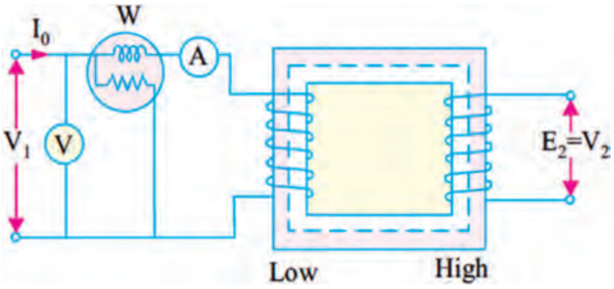


Fig 6.11 *Open Circuit Test*

The connection diagram for open circuit test on transformer is shown in Figure 6.11. A voltmeter, wattmeter, and an ammeter are connected in primary side of the transformer. The voltage at rated frequency is applied to the primary side with the help of a variac (or) variable ratio auto transformer.

The secondary side of the transformer is kept open. Now with the help of variac, applied voltage gets slowly increased until the voltmeter gives reading equal to the rated voltage of the primary side. After reaching at rated primary side voltage, all three instruments reading **(voltmeter, ammeter and wattmeter readings)** are recorded.

The ammeter reading gives no load current (I_o) being secondary is open the transformer draws very less current. Hence copper loss are negligible. As no load current

DO YOU KNOW?

William Stanley *(1858-1916)* was an inventor and engineer. He developed the first practical **transformer** (which spurred the development of AC power) as well as other developments; like an improved **electric meter** and the first metal **thermos bottle** (vacuum flask). He lived most of his life and ran his businesses in Western Massachusetts during the golden age of electric development.

Stanley is one of the most important inventors of AC power, his work puts him on a par with Edison, Westinghouse, Tesla, Elihu Thomson, Charles Brush and other major personalities of the time. Like the other great pioneers of the time he loved to tinker and design, held a disdain for legal quagmires of patent proceedings, and had his own set of friends and rivals in the industry.

(I_o) is quite small compared to rated current of the transformer, the voltage drop due to this current that can be taken as negligible. As the transformer is open circuited, there is no output. Hence the input power consist of core losses and copper loss in transformer during no load condition.

6.7.2 Short Circuit Test on Transformer

The short circuit test on transformer is used to determine copper loss in transformer.

The connection diagram for short circuit test on transformer is shown in Figure 6.12. A voltmeter, wattmeter, and an ammeter are connected in primary side of the transformer as shown. A reduced voltage at rated frequency is applied to the primary side with the help of a variac of variable ratio auto transformer.

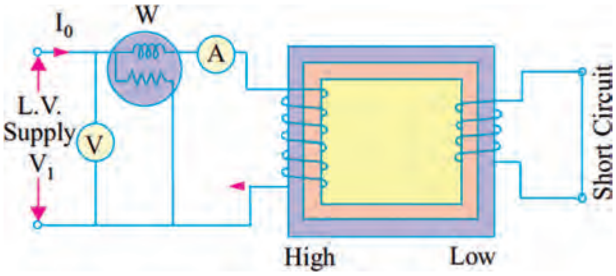


Fig 6.12 *Short Circuit Test*

The secondary side of the transformer is short circuited. Now with the help of variac applied voltage is slowly increased until the ammeter gives reading equal to the rated current in the primary side. Then three instruments reading (voltmeter, ammeter and watt-meter) are recorded. The voltmeter reading is very small compared to the rated primary voltage of the transformer. Here the core losses in transformer can be taken as negligible.

Let the, voltmeter reading is V_{sc}. The input power during test is indicated by wattmeter reading. As the transformer is short circuited, there is no output, hence the input power consist of copper loss in transformer.

6.8 PROTECTIVE DEVICES OF TRANSFORMER

The following are the protective devices in transformer and are explained below:

a) Conservator
b) Breather
c) Explosion vent
d) Buchholz relay
e) Transformer oil

Fig 6.13 *Protective Devices of Transformer*

a) Conservator

Transformer oil losses its insulating properties and is oxidised when it is in contact with the atmosphere. For this reason, the oil must not come in direct contact with the air outside. Conservators or oil expansion chambers are provided to prevent this absorption.

The conservator is cylindrical vessel. It is fitted on the top of the tank. The tank is entirely filled up with oil. The conservator is filled with oil partly (about 50%). The transformer oil gets heated due to the losses in a transformer. The volume increases due to heat and the level of oil in conservator increases. Air is expelled from the conservator through the breather. When the coil cools down, the volume decreases and the level of the oil in the conservator comes down.

This is referred to a "breathing". The oil surface in the conservator is only exposed to oxidation. The sludge is thus confined to the oil surface in the conservator. If there is no conservator the sludge will stick to the cooling tubes. This will spoil the cooling effort.

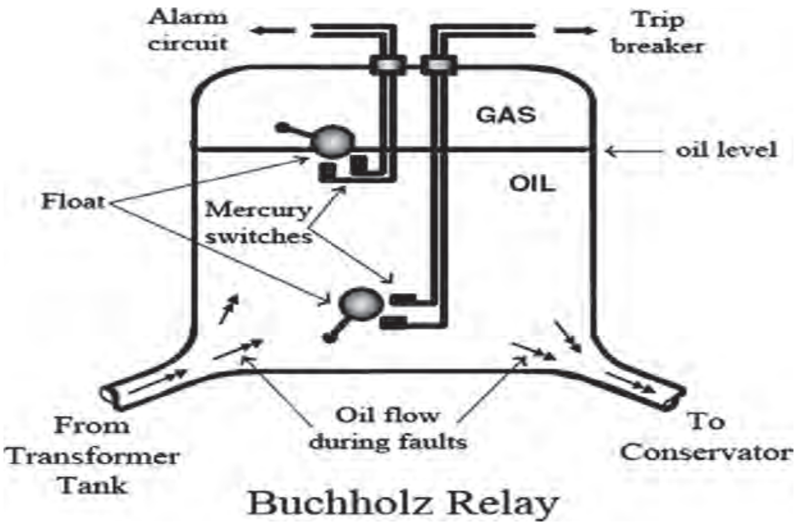


Fig 6.14 *Buchholz Relay*

b) Breather

The breather is a small vessel. It is connected between conservator and air outlet. It contains silica gel. It is a dehydrating agent. The moisture in the incoming air is removed. The colour of the silica-gel is **blue** and **pink,** when wet or damp.

c) Explosion Vent

In the event of an accidental internal short circuit in the transformer, an arc is formed between the turns of the winding. Heat is produced by the arc. Due to this, a large volume of gas is produced. Provision must be made for rapid release of gas. Otherwise high pressure will be built up inside leading to the lip of the tank blown off. For this reason an explosion vent is provided on the tap of the tank. Under normal conditions air is not allowed to come in contact with the oil. Under short circuit conditions, the diaphragon is ruptured due to high pressure. The gas is expelled to atmosphere. If the high pressure gas releasing a portion of the hot oil may get splashed and cause injury to the workers in the transformer yard. The explosion vent's mouth is covered by a glass or aluminium.

d) Buchholz Relay

This is a device which is attached to an oil immersed transformer. It is fitted in the pipe connecting the transformer tank with the conservator.

It consists of two floats as shown in Fig. 6.14.

Two pairs of electrical contacts are provided. These contacts may get short circuited under certain situations.

When an insulation breaks down in a transformer, gas is generated in the oil. Quick generation of this gas leads to a serious fault. The gas rushes through the pipe and pushes the lower float to the right. The two lower contacts bridge together and closes to trip the circuit of circuit breaker. Now the transformer is disconnected from the supply. If the fault develops slowly, gas will also generated slow. This may not be sufficient to move the lower float. This gas gets collected gradually in the top of the relay chamber. The oil level gets lowered. This causes the upper float to sink. It finally closes the second pair of contacts. This trips the circuit breaker or it makes ring an alarm bell for caution. A fault can thus be detected and the transformer is disconnected from the circuit.

e) Transformer Oil

Transformer oil is a mineral oil. It is obtained by refining crude petroleum. It is a good insulator. Its tendency to form, a sludge is very much less. The dielectric strength of oil is affected to a great extent by the presence of moisture. So it should be kept dry. Transformer oil serves two functions,

1. Cooling
2. Insulation

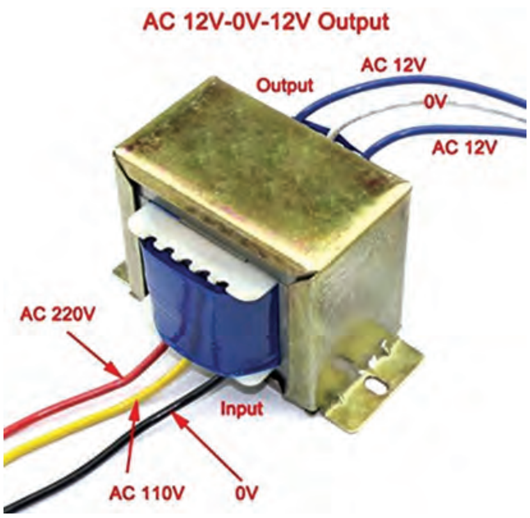
Points to Remember:

1. Transfer electrical energy from one circuit to another circuit.
2. It works without changing the frequency.
3. Transformer works on the principle of mutual induction.
4. Transformer works on AC supply only, not in DC.
5. E.M.F induced in primary winding $= (E_1) = 4.44\ N_1\ f\text{Ø}_m$ Volts.
6. E.M.F induced in secondary winding $= (E_2) = 4.44\ N_2\ f\text{Ø}_m$ Volts.
7. $\%\ \text{Efficiency}\ (\eta) = \dfrac{\text{output power}}{\text{input power}} \times 100$
8. Voltage transformation ratio (K)

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = k = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

Activities

1. Measure the output voltage of given transformer below.
2. Construct 6V transformer with centre tapping connection.
3. Calculate the losses occuring in the transformers by OC and SC tests.



GLOSSARY

Transformer	–	மின்மாற்றி
Step-up transformer	–	உயர்வழுத்த மின்மாற்றி
Step-down transformer	–	குறைவழுத்த மின்மாற்றி

Q A

PART A

Mark 1

STHW1P

Choose the Correct Answer:

1. The transformer may represent as
   a) rotating device
   b) electronic device
   c) static device
   d) none of these
2. Transformer operates on the principle of
   a) self induction
   b) mutual induction
   c) ohm's law
   d) len's law
3. To find the R.M.S value of transformer, E.M.F is to be multiply with
   a) 2.22
   b) 1.12
   c) 1.11
   d) 1.14
4. Transformer core is laminated to reduce the
   a) Copper loss
   b) Eddy current loss
   c) Wintage loss
   d) Hysteresis loss
5. Transformer oil serves the function of
   a) Lubrication
   b) Insulation and cooling
   c) Only insulation
   d) None of these
6. Silicon steel sheets are used to reduce the
   a) Frictional loss
   b) Mechanical loss
   c) Hysteresis loss
   d) Eddy current loss
7. The transformer will work on
   a) AC only   c) Both AC & DC
   b) DC only   d) None of these
8. The iron core is used to …… of the transformer,
   a) increase the weight
   b) provide tight magnetic coupling
   c) reduce core losses
   d) none of the above
9. The primary and secondary of a transformer are ….. coupled
   a) electrically
   b) magnetically
   c) electrically and magnetically
   d) none of these
10. Conservator is a
    a) main tank of transformer
    b) protective device of transformer
    c) earthing system of transformer
    d) none of these
11. The purpose of conducting open circuit test (O.C) is to determine
    a) eddy current loss
    b) core loss
    c) hysteresis loss
    d) copper loss

Q A

PART B

Mark 3

Answer the following questions in briefly:

1. What is transformer?
2. What is meant by step up transformer?
3. What is meant by step down transformer?
4. What are the advantages of transformer?
5. What is the voltage transformation ratio of transformer?
6. Mention the advantages of core type transformer.
7. Write down the types of instrument transformer.
8. Write down the applications of auto transformer.
9. What are the protective devices of transformer?
10. Why transformer is rating in KVA?
11. Define efficiency of a transformer.
12. What are the type of transformer according to cooling method?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the constructions of shell type transformer.
2. Explain why transformer not works on DC supply.
3. Compare between core & shell type transformer.
4. Explain about auto transformer.
5. Explain losses occur in transformer.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the working principle of a transformer.
2. Derive the EMF equation of a transformer.
3. Explain the working principle of potential and current transformer.
4. Explain the procedure to perform various tests conducted in transformer.

Reference Book

1. 'A text book of Electrical Technology' Volume IIand Volume III by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 7

DC Generator and DC Motor

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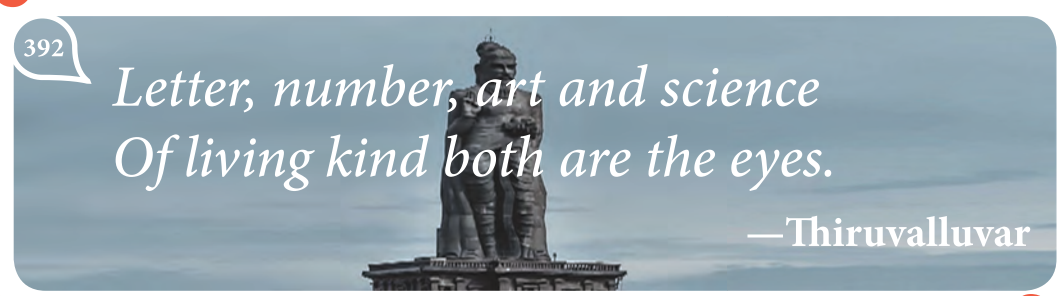

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Letter, number, art and science
Of living kind both are the eyes.

—Thiruvalluvar

LEARNING OBJECTIVES

Learning objective of this chapter will enables the student to:

- Understand the various parts of DC machines
- Know the generation of DC voltage
- Understand the expression for the generated voltage
- Know DC motor working principle
- Know the applications of DC motor

Table of Content

7.1 INTRODUCTION

DC machines are electro mechanical energy conversion devices which can operate as generators converting mechanical energy given to them from a prime mover to electrical energy. They can also operate as DC motors, taking electrical energy from DC supply and converting it into mechanical energy to drive a mechanical load. Nowadays DC motors are widely used because of their simpler and flexible drive systems such as electric traction, cranes, etc. The extension of these DC machines leads to the development of brushless DC machines which are mostly used in modern scenario.

As said above, an electrical machine which converts mechanical energy into electrical energy is called an electrical generator, while the electrical machine which converts electrical energy into mechanical energy is called an electrical motor.

The electrical machines which work on AC supply are AC machines whereas the electrical energy of direct type are called DC machines. In this chapter we are going to study about DC machines.

DC machines are classified into two types:

1) DC generator
2) DC motor

First, we will study the basic principle of DC generators.

7.2 BASIC PRINCIPLE OF OPERATION DC GENERATOR

According to Faraday's law of electromagnetic induction, 'when a conductor is rotated in a magnetic field, to cut the magnetic lines of flux, dynamically induced emf is produced in the conductor. This emf causes a current to flow if the conductor circuit is closed'. The direction of the current is found by Fleming's Right-hand rule.

Hence, the basic requirements for the dynamically induced emf to exits are:

1) A steady magnetic field
2) A conductor or coils
3) Relative motion between the magnetic field and the conductors.

To understand the principle of EMF generation, consider the following Fig 7.1.

7.2.1 Elementary DC Generator

Consider a single-turn rectangular copper coil ABCD rotating clockwise in a magnetic field provided by N and S magnets or electromagnets are shown in fig 7.1. The two ends of the coil are joined to two split-rings 'a' and 'b' which are insulated from each other and from central shaft. Two collecting brushes (of carbon or copper) press against the split-rings. Their function is to collect the current produced in the coil and to carry it to the external load resistance R. The rotating coils are called as 'armature ' and the magnets as "field magnets" or "poles". The coil is rotated in clockwise direction at a uniform magnetic field.

STRS3C

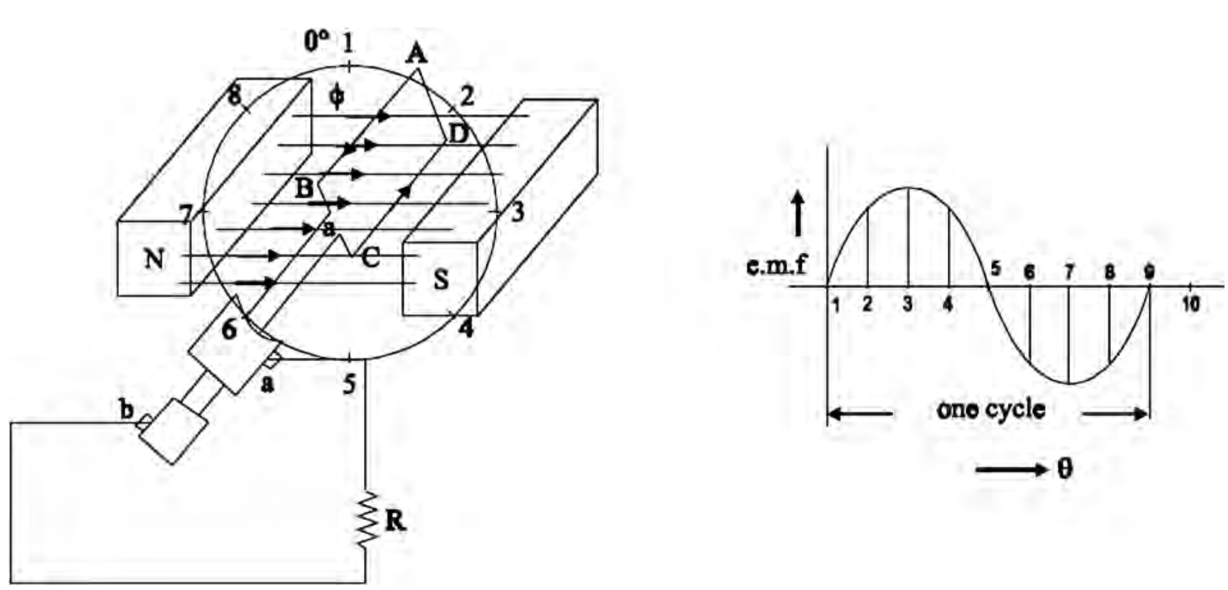


Fig 7.1 *Principle of EMF Generation*

At position 1, where θ = 0 degrees, the plane of the coil is perpendicular to the direction of lines of the flux. Now, the flux linked with the coil is maximum, but the rate of change of the flux linkages is minimum. So, no emf is induced in the coil. i.e., is at the starting position the emf induced is zero.

When the coil is rotated further, the rate of change of flux linkage increases up to the position 3, where θ = 90 degrees. At this position, the plane of the coil is parallel to the lines of flux. Now, the flux linked with the coil is minimum, but rate of change of flux linkage is maximum. Therefore, at this position emf induced in the coil is maximum. On further rotation the value of generated emf continues to decrease from maximum to minimum value.

At position 5, where θ = 180 degree, the generated emf is reduced to zero. The magnitude of emf with respect to the coil position is represented in fig 7.1. from position 5 to position 7 (that is 180 degrees to 270 degrees), the induced emf value starts again from zero to maximum and from position 7 to positon 1 (from 270 degrees to 360 degrees) maximum to zero in opposite direction.

In this way the generated emf goes on one cycle as alternating emf. The two halved split-rings make the bidirectional emf into unidirectional emf to behave as DC generator. This set up is shown in fig 7.2. In the first half revolution current flows along the path A-B-a-M-L-b-C-D-A, (fig 7.2a). The coil in the second half rotation, the induced currents are reversed. But the positions of brushes 'a and b' are also reversed so that current through the load remains the same direction, that is the loop D-C-b-M-L-a-B-A-D (fig 7.2b). The device making the alternating supply into unidirectional supply is by means of a device called 'commutator'.

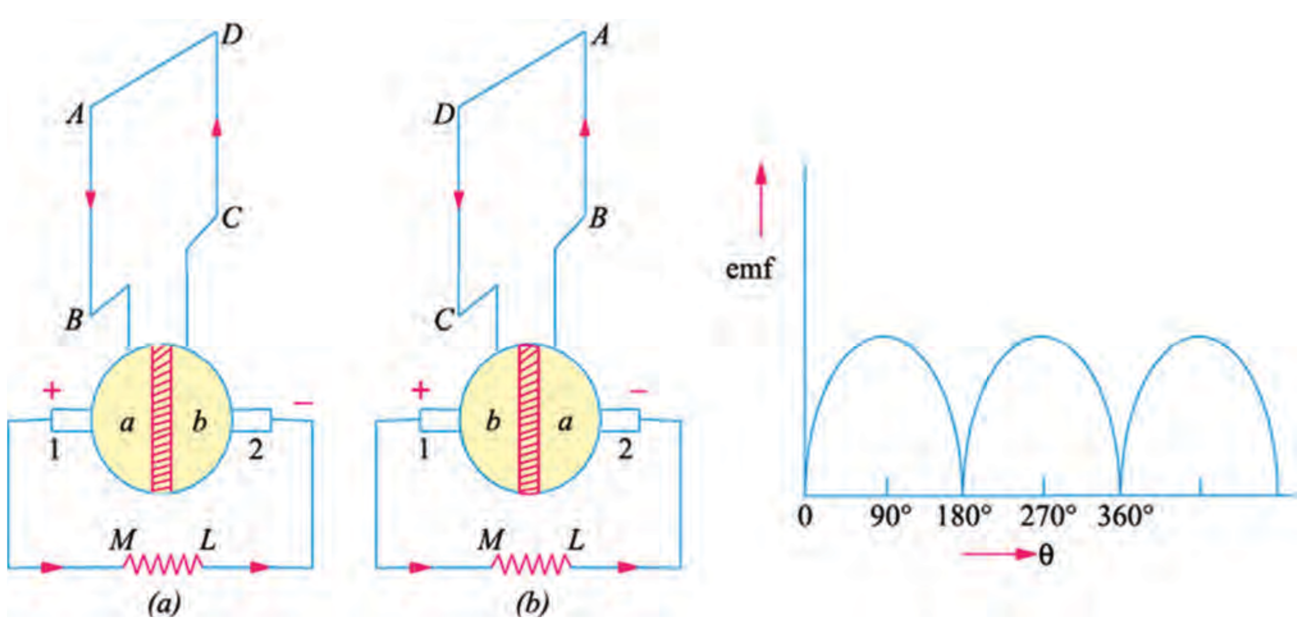
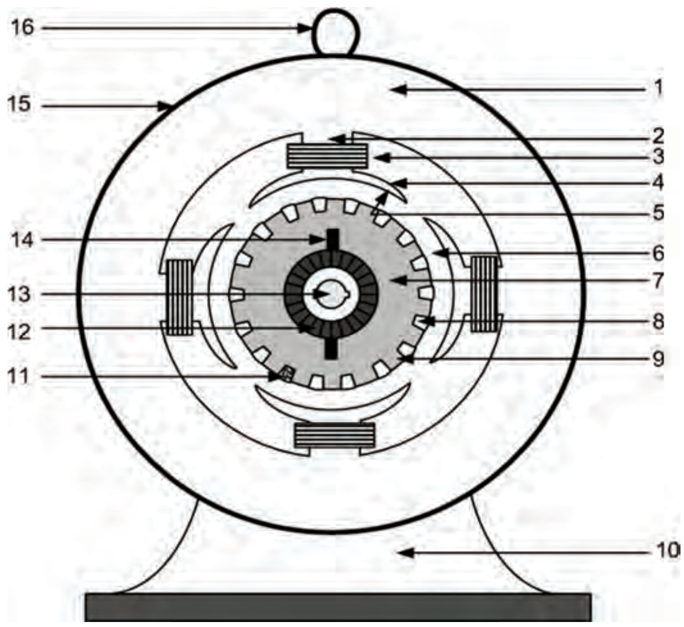


Fig 7.2 *AC into DC Waveform*



1. Yoke
2. Pole core
3. Pole winding
4. Pole shoe
5. Pole face
6. Air gap
7. Armature core
8. Slot
9. Tooth
10. Foot
11. Armature winding
12. Commutator
13. Shaft
14. Brush
15. Frame
16. Lifting leg

Fig 7.3 *Parts of DC Machines*

7.3 CONSTRUCTION OF DC MACHINES

Invariably speaking, the construction of the DC generator and DC motor are same. So any DC generator can be treated as DC motor. The construction of a 4-pole DC machine is given in the fig 7.3.

All DC machines have mainly two parts:

1) Stator (outer stationary part)
2) Rotor (inner rotating part)

The Stator consists of Yoke or Magnetic frame, poles, pole shoe, field winding.

Rotor has the following parts:
Armature – Armature core, Armature winding
Commutator – Brushes, Bearing.

7.3.1 Yoke

The Functions of Yoke are:

1) It provides mechanical support to the poles and acts as a protecting cover for the whole machine.
2) It carries the magnetic flux produced by the poles.

7.3.2 Field System

Field system consist of two main parts, poles and field winding.

i) Poles

Each pole is divided into two parts, namely:

1) Pole core
2) Pole shoe

The functions of pole core and pole shoe are:

1) Pole core carries field winding which is necessary to produce the flux.

2) Pole shoes spread out the flux in the air gap uniformly.
3) They support the exciting coils (or field coils).
4) It is made up of magnetic material like cast-iron or cast-steel.

ii) Field Winding

The field winding is placed on the pole core. It is made up of aluminium or copper. Their functions are to carry the current to produce the required magnetic flux. The pole structure of a DC machines is illustrated in fig 7.4.

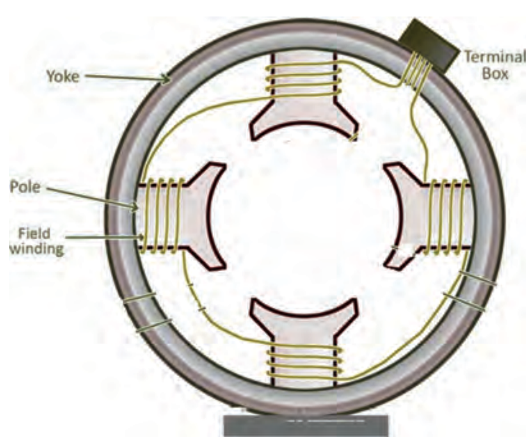


Fig 7.4 *Yoke and Poles*

7.3.3 Armature System

It is further divided into two parts namely:

1) Armature core
2)) Armature winding

i) Armature Core

It is cylindrical in shape with slots on its outer periphery. It is mounted on the shaft. They are used to house the armature conductors in the slot. It is made of cast-steel laminations to reduce the eddy current loss.

ii) Armature Slots and Windings

The armature windings are placed into the slots on the armature surface. When the armature rotates, an emf is induced in the armature conductors in case of generators. The ends of the coils are soldered with commutator segments. These segments are made up of copper materials.

7.3.4 Commutator

The emf induced in the armature conductor is alternating in nature. This alternating emf is made into unidirectional by means of a device called as commutator. It is made up of copper segments.

7.3.5 Brushes and Bearings

The function of brushes is to collect current from commutator. They are usually made up of carbon or graphite and in the shape of rectangular block. These brushes are housed in brush-holders usually of the box-type variety. Ball bearings are frequently employed because of their reliability. But for heavy duty machines, roller bearing is preferable. The complete structure is shown in fig 7.5.

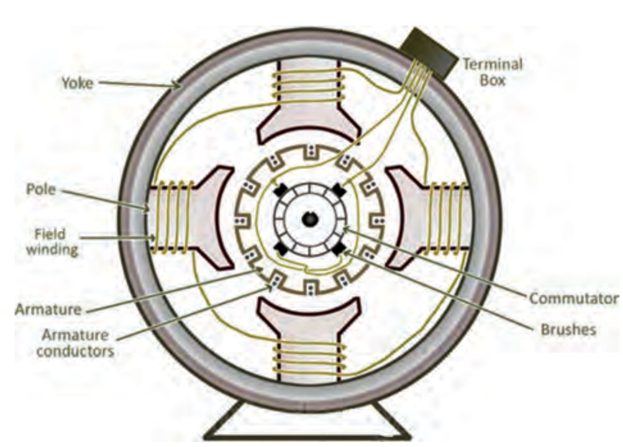


Fig 7.5 *Poles and Armature of DC Machines.*

7.4 TYPES OF DC GENERATOR

DC generators are classified according to the manner in which field windings are connected. The process of giving DC voltage to the field winding for producing magnetic field is called field excitation. The generators are classified based on the exciation, as:

1. Separately Excited DC Generator

In separately excited generator, the exciation to the field winding is given by an external DC supply as shown in Fig 7.6.

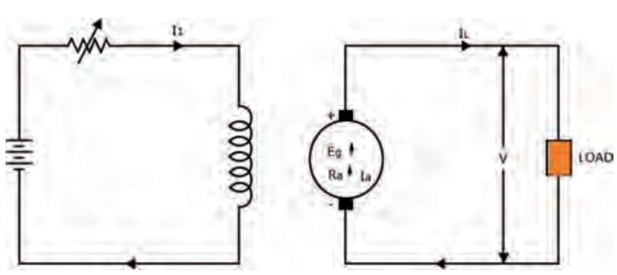


Fig 7.6 *Separately excited DC generator*

2. Self-Excited DC Generator

In this type of DC generators, the generation of emf is due to its property of residual flux or residual magnetism present in the field winding. They are mainly of three types:

a) DC series generator
b) DC shunt generator
c) DC compound generator

a) DC Series Generator

In DC series generators the field winding (R_{se}) is connected in series with the armature winding (R_a). Therefore, the series current (I_{se}) is equal to the armature current (I_a) and the load current (I_L), as shown in the Fig 7.7.

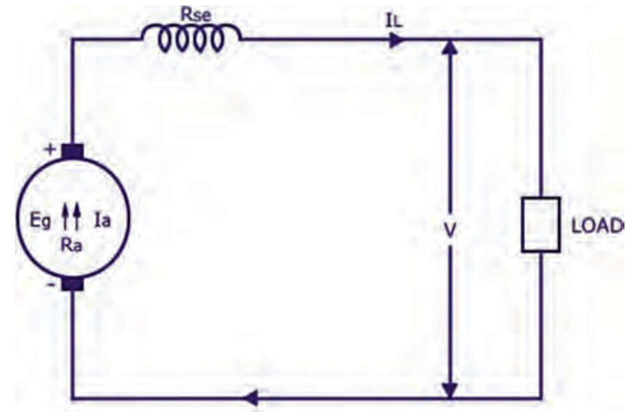


Fig 7.7 *DC Series Generator*

The current equation is $I_a = I_L = I_{se}$
The Voltage equation is $E_g = V + I_a(R_a + R_{se})$
V=load voltage

b) DC Shunt Generator

In shunt generator the field winding is across (shunt) the armature winding. Here the armature current (I_a) is the sum of shunt field current (I_{sh}) and load current (I_L) as shown in Fig 7.8.

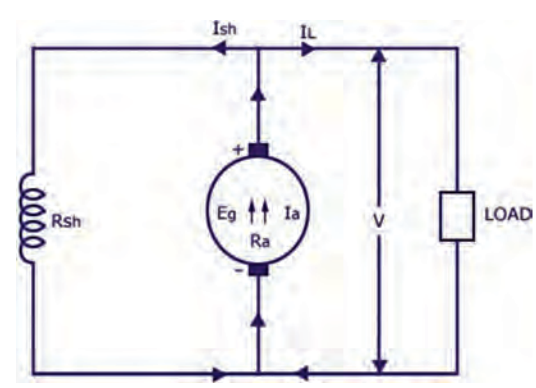


Fig 7.8 *DC Shunt Generator*

The current equation is $I_a = I_L + I_{sh}$
The voltage equation is $E_g = V + I_a R_a$

c) DC Compound Generator

These types of generators are again classified into long shunt generator and short shunt generator based on the field winding connections. In long shunt compound generator, the shunt field winding

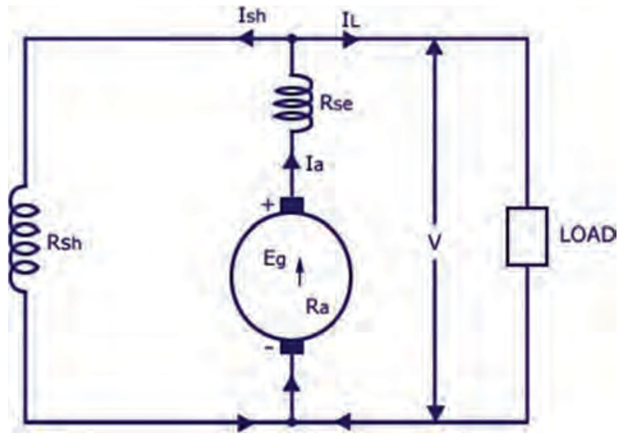


Fig 9.(a) *DC Long Shunt and*

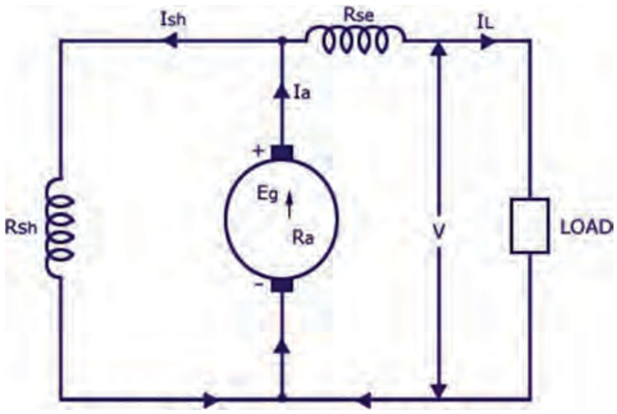


Fig 9.(b) *Short Shunt Compound Generator*

is connected in parallel with the series combination of series field winding and armature winding. (fig 7.9a)

In short shunt compound generator, the series field winding is connected in series with the parallel combination of armature and shunt field winding. (Fig 7.9 b)

Where,

I_a = Armature current
R_a =Armature resistance
I_L = Load current
I_{sh} =Shunt field current
I_{sc} =Series field current
R_{se} =Series field resistance
R_{sh} =shunt field resistance
V_L = load voltage
E_g = Generated voltage from armature.

7.5 EMF EQUATION OF DC GENERATORS

Let Ø = flux in webers.
Z = no. of armature conductors
N = speed in RPM
P = no of poles
A = no.of parallel paths
(A=P)- for lap winding
(A=2)- for wave winding

According to Faraday's law of electromagnetic induction, the value of generated

EMF, $E_g = \dfrac{d\text{Ø}}{dt}$

Flux cut/conductor in one revolution for 'P' poles 'dØ'=ØP

The time for one revolution 'dt'=60/N.

The value of induced emf per conductor,

$$E_g = \frac{d\text{Ø}}{dt} = \frac{\text{Ø}P}{\frac{60}{N}} = \frac{\text{Ø}PN}{60}$$

For 'Z' number of conductors, and for 'A' parallel paths,

$$E_g = \frac{\theta ZN}{60} X \frac{P}{A} \text{volts}$$

DO YOU KNOW?

Universal motors are known to sometimes over-speed, perhaps dangerously and destructively, when run with no load. This article deals with different methods of universal electric motor speed control.

A motor which can be operated either on DC (direct current) or on single phase AC (alternating current) is called a universal motor. On both AC and DC, it gives approximately the same speed and output. Universal motors often run at dangerously high speed when operated at no load. This means that motor speed will be low at full load, but the speed of the motor will start increasing as the load on the motor decreases. Finally at no load, the motor will run at very high speed (perhaps about 20,000 rpm in some cases) and cannot made to run at less than about 2,000 rpm. The speed of universal motor varies just like that of a DC series motor. Being a series wound motor, it has a high starting torque and variable speed characteristics, and if the motor is started at no load, due to its high starting torque it will attain high speed quickly. Thus it is not advisable to start a universal motor at no load.

7.6 APPLICATIONS OF DC GENERATORS

1. DC Series Generators

i) They are used for series arc lighting

ii) They are used as boosters, for the purpose of compensating the drop in voltage in the lines on loading.

iii) Used for regenerative braking of DC locomotives.

2. DC Shunt Generators are Used

i) In shunt generator, terminal voltage is more or less constant. So these are used for supplying loads needing constant voltage.

ii) In Electroplating

iii) In Battery charging purpose.

iv) As Exciters for AC generators.

3. DC Compound Generators

i) By means of compound generator it is possible to give constant voltage at the line end by proper compounding.

ii) Differentially, compound generator may be used for welding purpose.

iii) They are used to supply power to railway circuits, elevator motors etc.

4. Separately Excited Generators

These generators are used for:

i) Supplying DC motors whose speed is to be varied widely.

ii) Where a wide range of DC voltage is required for testing purpose.

7.7 DC MOTOR

7.7.1 Motor Principle

An electric motor is a machine which converts electrical energy into mechanical energy. Its action is based on the principle that when a current-carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of this force is given by Fleming's left-hand rule and magnitude is given by:

$$F = BIl \ (N)$$

B = flux density due to the flux produced by the field winding

I = Magnitude of current passing through the conductor

l = Active length of the conductor

By construction, there is no basic difference between DC generator and DC motor. In fact, the same DC machine can be used interchangeably as a generator or as a motor. In generator the input is mechanical energy by a prime mover and develops a voltage, while in a DC motor the input is electrical energy and it develops rotating torque.

7.7.2 Fleming's Left Hand Rule

Keep the forefinger, middle finger and thumb of the left hand mutually perpendicular to one another. If the forefinger indicates the direction of the magnetic field (B), the middle finger indicates the direction of current (I) in the conductor, and the thumb points to the direction of motion (F) of the conductor.

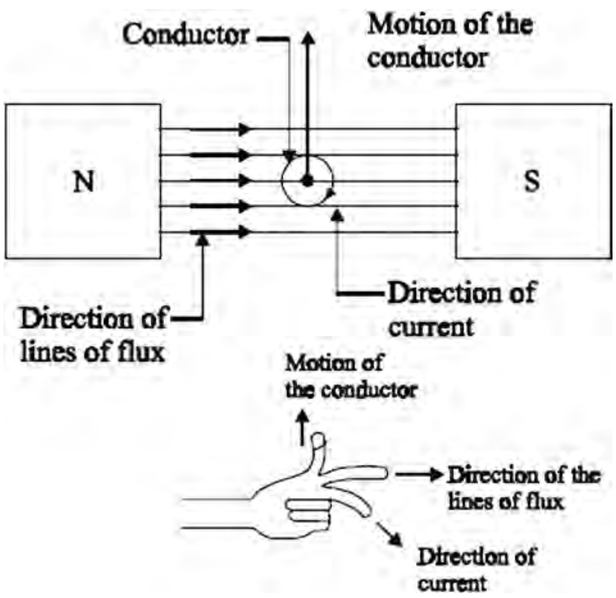


Fig 7.10 *Fleming's Left Hand Rule*

7.7.3 Principle of Operation of DC Motor

A motor is a mechanism by which electrical energy is converted into mechanical energy. Both in principle and design, a DC motor is the reverse process of DC generator.

Consider a single conductor placed in a magnetic field as shown in fig 7.10. The two diagrams indicate the direction of magnetic fluxes considering separately.

How the resultant rotation takes place in a DC motor is clearly understood from the following descriptions in the Fig 7.11.

A steady current is passed through the armature coil from the commutator and the brushes are so arranged as to reverse the current every half revolution. When a coil, carrying a current is placed in magnetic field, it experiences forces, given by Fleming's left-hand rule, which

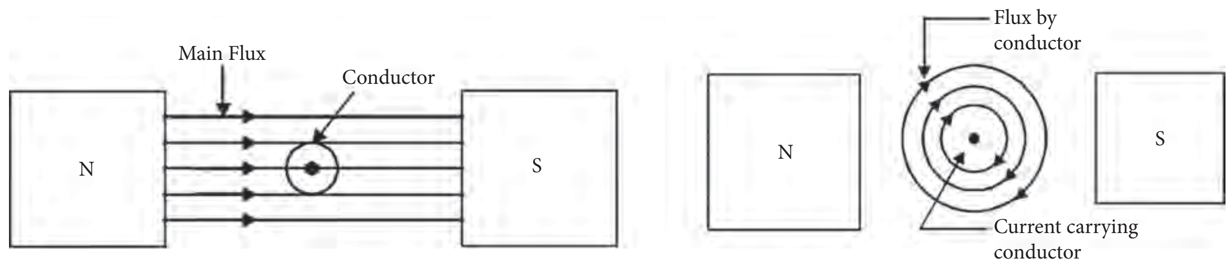


Fig 7.11 *Resultant Force developed*

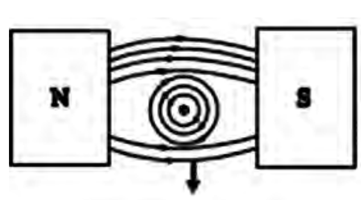
turn it about in a direction perpendicular to both the field and the current.

The fig 7.12a shows the upper side of the conductor, the magnetizing force of the field due to the current are additive while on the lower side these are subtractive. The result is to increase the flux density into the region directly above the conductor and to reduce flux density below the conductor.

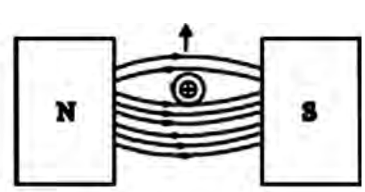
If the current is reversed in the conductor, the strengthening of flux lines occur below the conductor and the conductor will be pushed upwards as shown in fig 7.12b.

As for the reasons above, one of the coil side 'A' will be forced to move downwards while 'B' moves upward. These two forces are equal in magnitude and opposite to each other. (7.12c). These twisting forces make the armature to rotate through the two ends, that are supported by bearings.

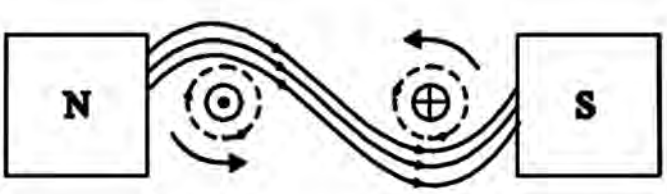
But practically, a DC machine will have multiple conductors and each conductor will be experiencing a force F=BI l newton. These forces collectively produce a driving torque which sets the armature rotating. The machine is then said to be motoring.



(a)



(b)



(c)

Fig 7.12 *Torque Development in DC Motors*

7.8 BACK EMF OF DC MOTOR (E_B)

When the armature of a DC motor rotates in the magnetic field, the armature conductor cuts the magnetic flux. Hence an EMF will be induced in the conductor. According to Faraday's law of electromagnetic induction. This induced EMF acts in opposite direction to the applied voltage and it is referred as the back emf or counter emf E_b.

The back emf is given by,

$$E_b = \frac{\theta ZN}{60} \times \frac{P}{A} \text{ volts}$$

which is same as that emf induced in a DC generator.

The relationship between the current, back emf and the applied voltage for a DC shunt motor is given by $E_b = V - I_a R_a$.

Where,

E_b = back emf in volts

V = supply voltage in volts

I_a=armature current in amperes

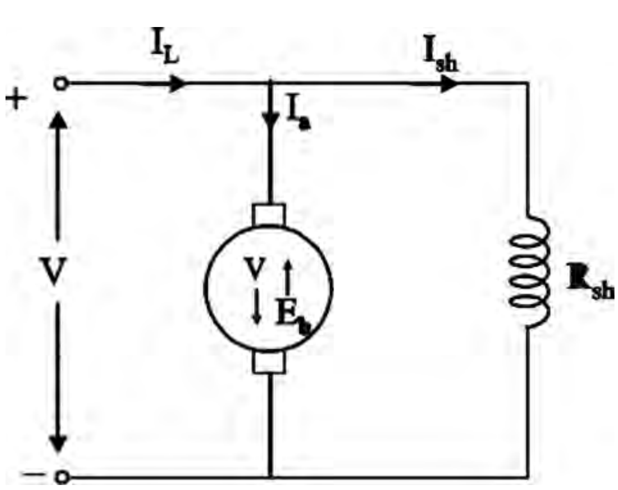


Fig 7.13 *DC Motor Circuit*

R_a=armature resistance in ohms.

The back emf E_b is always less than that of the applied voltage and hence the current is flowing against the direction of back emf.

7.9 TYPES OF DC MOTORS

The DC motor is classified into three types based on the field winding connection with the armature.

i) DC series motor
ii) DC shunt motor
iii) DC compound motor

DC compound motor is classified as,

a) Long shunt compound motor
b) Short shunt compound motor

7.9.1 DC Series Motor

In DC series motor, the field winding is connected in series with the armature as shown in Fig 7.14. The series field

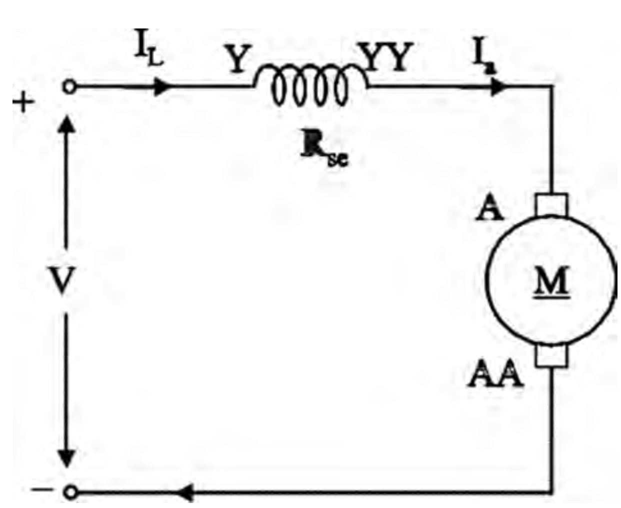


Fig 7.14 *Equivalent Circuit of DC Series Motor*

winding carries the input current, $I_L=I_a=I_{se}$. The series field winding is relatively small in number to give minimum value of resistance drop.

7.9.2 DC Shunt Motor

In DC shunt motor, the field winding is connected parallel (shunt) with the armature as shown in fig 7.15. The field winding has a large number of turns and relatively smaller cross sectional area. Therefore, the shunt field winding has high resistance and hence shunt field current is relatively small compared with armature current. The speed of DC shunt motor is almost constant during no-load to full-load.

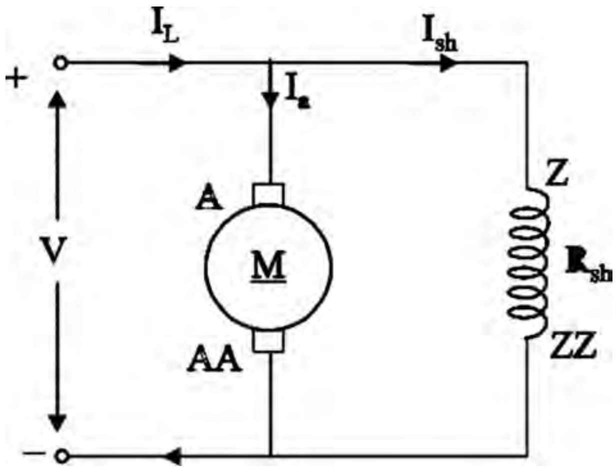


Fig 7.15 *Equivalent Circuit of DC Shunt Motor*

7.9.3 DC Compound Motor

In compound motors both series and shunt windings are connected according to their name of long shunt and short shunt compound motor.

a) Short Shunt Compound Motor

In short shunt compound motor, the series field winding is connected in series with the parallel combination of armature and shunt field winding. The connection diagram for this compound motor is as shown in Fig 7.16.

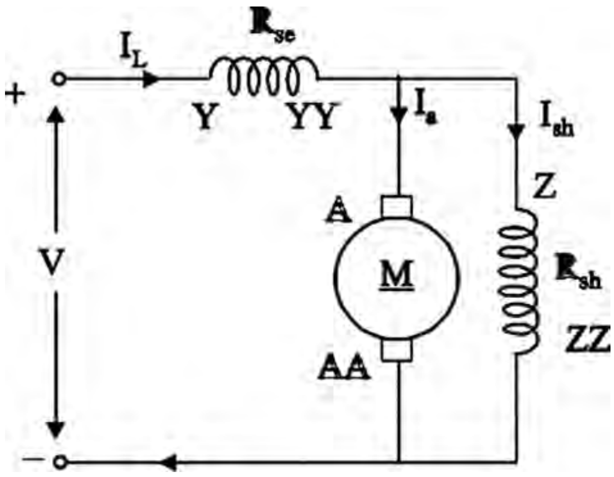


Fig 7.16 *Equivalent Circuit of DC Short Shunt Compound Motor*

b) Long Shunt Compound Motor

In long shunt compound motor, the shunt field winding is connected in parallel with the series combination of series field winding and armature winding.

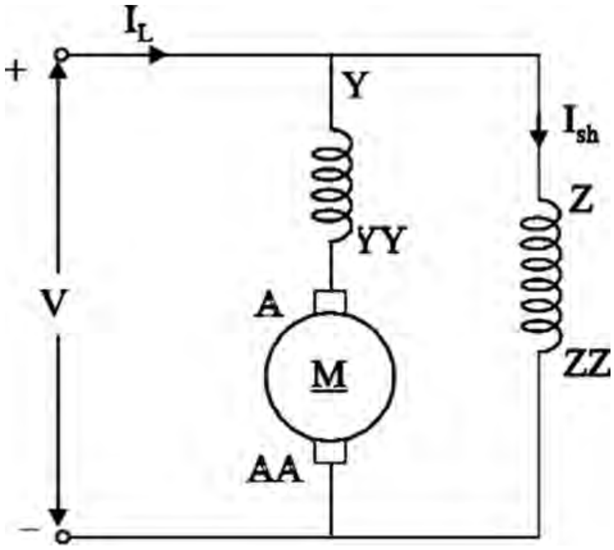
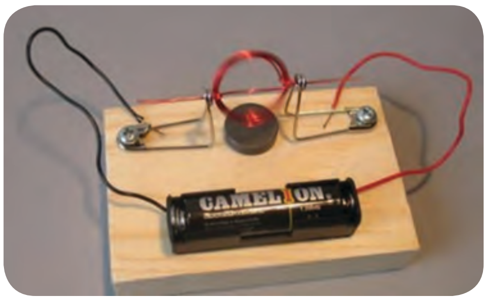


Fig 7.17 *Equivalent Circuit of DC Long Shunt Compound Motor.*

7.10 APPLICATIONS OF DC MOTORS

Type of Motor	Characteristics	Applications
1. DC Series Motor	i) Variable speed ii) Speed can be controlled iii) No load condition is dangerous iv) High starting torque	i) Electric traction ii) Cranes hoists iii) Conveyors Elevators Trolleys
2. DC Shunt Motor	i) Speed is fairly constant ii) Adjustable speed iii) Medium starting torque	i) Lathe machines ii) Blowers and fans iii) Centrifugal pumps iv) Reciprocating pumps v) Machine tools vi) Drilling machines
3. DC Compound Motor	i) Variable speed ii) Speed can be controlled iii) High starting torque	i) Punches ii) Elevators iii) Shears iv) Rolling mills v) Printing presses vi) Air compressors

Activities



Test the DC supply and practice the following DC motor to rotate.

GLOSSARY

Generator	—	மின்னாக்கி
Motor	—	மின்னோடி
Magnetic poles	—	காந்த துருவங்கள்
Carbon brush	—	கரிதூரிகை
Bearings	—	தாங்கிகள்

Q A

PART A

Mark 1

STX1G3

Choose the Correct Answer:

1. Initially the emf generated is an alternating one. But this alternating emf is converted into direct emf by
   a) Slip-ring
   b) Commutator
   c) Carbon brush
   d) End rings

2. The direction of induced emf in DC generator is found by
   a) Fleming's left-hand rule
   b) Fleming's Right-hand rule
   c) Faraday's law
   d) Kirchhoff's law

3. The Yoke of a DC machine is made up of
   a) Copper
   b) Aluminium
   c) Zinc
   d) Cast-iron

4. Which of the following is a function of brushes?
   a) To convert AC to DC
   b) To convert DC to AC
   c) To collect the current and to deliver to load
   d) None of the above

5. The armature is made up of
   a) Solid aluminium
   b) Solid steel
   c) Laminated aluminium
   d) Laminated steel

6. The principle DC motor is based on
   a) Fleming's left-hand rule
   b) Fleming's Right-hand rule
   c) Faraday's law
   d) None

7. For electric traction, the motor used is
   a) DC shunt motor
   b) DC series motor
   c) DC compound motor
   d) AC motor

8. Which of the following motor is constant speed motor?
   a) DC shunt motor
   b) DC series motor
   c) AC series motor
   d) None

9. DC compound motor is having .... winding
   a) series winding only
   b) shunt winding only
   c) series or shunt winding only
   d) series and shunt winding only

10. Commutator is made up of ----------
    a) Copper
    b) Brass
    c) Aluminium
    d) Silver

Q A

PART B

Mark 3

Answer the Questions in briefly

1. What are the main parts of DC machines?
2. Write some short notes on commutator.
3. What are the functions of yoke?
4. What are the types of DC generators?
5. State Fleming's left-hand rule.
6. State the applications of DC series motor.
7. Mention the applications of DC shunt motor.
8. Draw the equivalent circuit diagram of DC shunt motor.

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Derive the emf generated in DC generators.
2. Give circuit diagram of the different types of DC generators.
3. List out the applications of DC generators.
4. Give circuit diagram of the following types of DC motors.
5. Explain the force developed in case of DC motors.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the process of emf generation in DC generators.
2. With neat diagrams explain the construction of DC machines.
3. How the rotating force is developed in DC motors?
4. Explain the different types of DC generators with neat diagram.

Reference Book

1. 'A text book of Electrical Technology' VolumeII B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 8

Alternators and AC Motors

SU1N4Z

291

If "What is truth? the question be,
It is to speak out evil – free.

— Thiruvalluvar

LEARNING OBJECTIVES

This chapter enable the students to know about basic principle, construction, operation of single phase, three phase AC motor and stepper motor.

Table of Content

8.1 ALTERNATOR - INTRODUCTION

The machine which generates alternating current is called as alternator or synchronous generator.

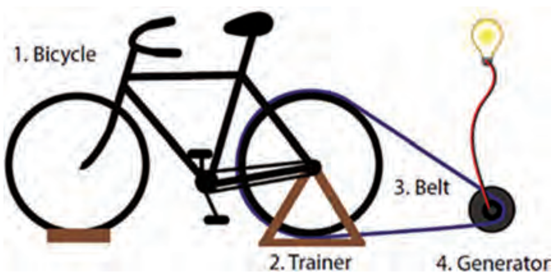


Fig 8.1 *Principle of AC Generation*

In Power Supply System alternating current is supplied to a greater extent that direct current supplies, because of the following reasons.

1. AC power can be generated in bulk quantity without much difficulty
2. AC requirements are cheaper in cost
3. AC voltage can be step up or step down by using transformers
4. AC can be easily converted into DC

8.1.1 Requirement of Alternator

For the generation of AC emf by the alternator the following basic systems are required:

1. Magnetic field system to produce the magnetic field.
2. Armature system which house the conductor on which emf is to be induced.
3. A prime mover is required which gives necessary rotational power for the generation of emf in the alternator.

8.1.2 Types of Alternator

According to the position of armature and field, alternators are classified into two types

a) Stationary field and rotating armature type.
b) Stationary armature and rotating field type.

a) **Stationary field and rotating armature type**

It is commonly used in small size generators and for the lower voltages. The DC supply given to the field windings and the alternating current generated is delivered to the slip ring. The mechanical construction of the revolving armature alternator is similar to that of the DC generator except that there is no commutator.

b) **Stationary armature and rotating field type**

Alternator with the stationary armature and revolving field type is used in the generation of high voltages.

The main reason for rotating armature type is the difficulty of using sliding contact brushes on slip rings at high voltages. With a stationary armature, the power from the generator is delivered through copper to copper connections firmly bolted together. The revolving fields are supplied with DC normally at 110V, through a pair of slip rings.

Advantages

1. It is easy to insulate the armature winding, because they are placed in the stator.
2. Output Current can be easily collected and easily supplied to the load circuit.

3. Rotating field system has two slip rings only and it can be easily insulated.
4. Rotating field is light in weight and hence it can run at high speed.
5. In stationary armature the winding may be cooled more efficiently.

8.2 BASIC PRINCIPLE

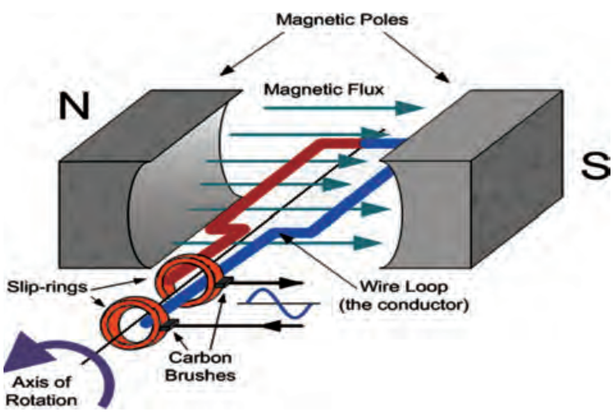


Fig 8.2 *Basic Principle of Alternator*

An alternator works on the same fundamental principle of electromagnetic induction as D.C. Generator i.e. when the flux linking a conductor changes, an emf is induced in the conductor. Like a D.C generator, an alternator has an armature winding and field winding.

The frequency of output ac voltage of a synchronous generator is directly proportional to the rotor speed. To maintain constant frequency, the rotor must always move at synchronous speed.

8.3 CONSTRUCTION OF ALTERNATOR

Alternators are constructed in two types

1. Salient Pole alternator
2. Non – Salient Pole alternator (or) Turbo Alternator

8.3.1 Salient Pole Alternator

(a) STATOR

It is the stationary part of the machine and it is built up of silicon steel laminations having slots on its inner periphery to house the armature conductors. The armature core in the form of a ring is fitted to a frame which may be of cast iron or welded steel frame which is called stator frame.

The armature core is laminated to reduce the eddy current loss. The laminations are stamped out and insulated from each other with paper or varnish. The stampings also have holes which make axial and radial ventilating ducts to provide efficient cooling.

Armature Slot

Slots provided on the stator core are mainly of three types.

1. Wide-Open Slots
2. Semi-closed slots
3. Closed slots

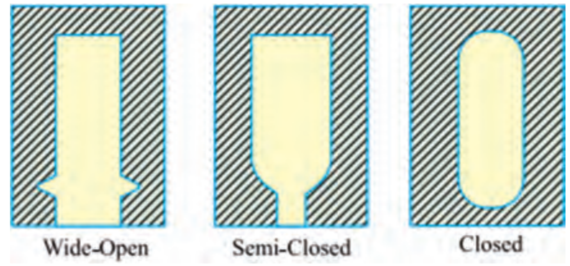


Fig 8.3 *Types of Slots*

1. **Wide Open Slots**

The open slots are more commonly used because the coils can be form-wound and pre – insulated before placing in the slots. This type of slots also facilitates easy removal and replacement of defective coils. But this type of slots create uneven distribution of flux, there by producing ripples in the emf wave.

2. **Semi-Closed Slots**

The semi closed type slots are better in this respect but don't permit the use of forms wound coils, there by complicating the process of winding.

3. **Closed Slots**

Totally closed slots don't disturb the air gap flux and they are rarely used.

(b) ROTOR

Salient Pole type rotor is used in low and medium speed alternators. It has a large number of projecting poles, having their cores bolted on to a heavy magnetic wheel of cast iron or steel. The diameter of this kind of alternator is large and the length is small. The poles and pole shoes are laminated to reduce the heat due to eddy currents. In large machines, field winding consists of rectangular copper strip wound on edge.

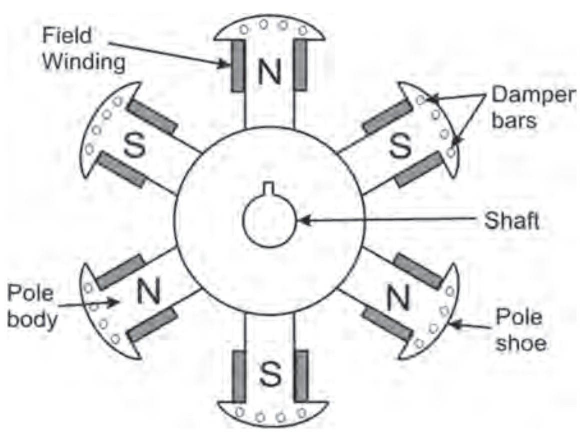


Fig 8.4 *Salient Pole Construction*

8.3.2 Non-Salient Pole Alternator or Turbo Alternator

(i) STATOR

The stator diameter of Non salient pole Alternator is small and the length is long. Stator is the stationary part of the machine, and it is built up of silicon steel laminations having sloth on its inner periphery to house the conductors. Normally this type of alternator has double layer winding. But in high voltage machines, single layer winding is used in semiclosed sloth. Lengthy ventilating ducts are provided for cooling purpose.

(ii) Smooth Cylindrical Type Rotor

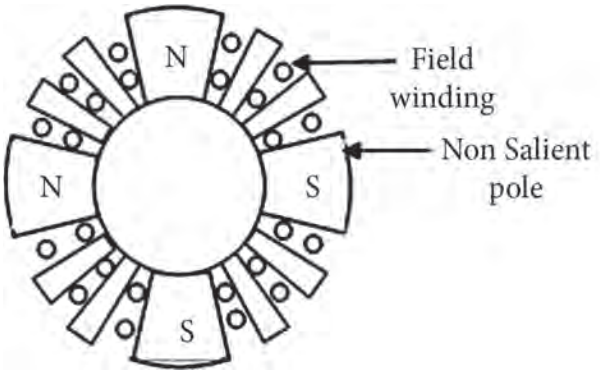


Fig 8.5 *Cylindrical Pole Rotor*

This rotor is used in very high speed alternators driven by steam turbines. The rotor of turbo alternator physically is in the form of smooth cylinder, having long axial length and smaller diameter.

Poles are not projected out from the surface of the rotor. The outer periphery of the rotor stampings has radial slots.

Comparison of Salient Pole Type Rotor and Smooth Cylindrical Type Rotor

Sl.No	Salient Pole Rotor	Cylindrical Rotor
1	The diameter of rotor is large	The diameter of rotor is small
2	Poles are projecting outside	Poles are not projecting outside
3	Length of rotor is short	Length of rotor is long
4	Damper winding is required	No damper winding is required
5	Runs at slow speed. (100 rpm to 1500 rpm)	Runs at very high speed. (1500 rpm to 3000 rpm)
6	Suitable for hydro generators	Suitable for turbo alternators run by steam turbines

The field windings are accommodated in these slots. Generally copper strips are used for the field winding, Radial ducts are provided for ventilation purposes.

8.3.3 Parts of A.C Motors

1. Frame: It is made up of alloy cast iron.
2. Stator and Rotor core: It is built from high quality, low loss silicon steel laminations.
3. Stator and Rotor windings: They have moisture proof insulation embodying mica and high quality varnishes. They are carefully spaced for most effective air circulation.
4. Air gap: The stator is machined carefully to ensure uniformity of air gap.
5. Shafts and Bearings: The motor shaft is fixed with in the rotor and rotates with it. The rotor shaft is held in place by bearings at either end of the motor casing. Ball and roller bearings are used.
6. Fans: Light aluminum fans are used for adequate circulation of cooling air.

8.4 SINGLE PHASE AC MOTOR

Single phase and three phase system is widely used for domestic and commercial purpose. As the single-phase system is more economical and the power requirement in most of the houses, shops, offices are small, which can be easily met by three phase system.

Normally single phase motors are used for domestic purposes. Generally below 1 HP (1HP = 746 watts) motors are used for domestic purpose and they are called as fractional Horse Power motors (FHP)

Advantages

i) Simple in construction
ii) Cheap in cost
iii) Very reliable
iv) Easy to repair and maintenance

Applications

Due to all the above advantages, the single phase motor find its applications in i.mixer

ii.grinders

iii.vacuum cleaners

iv.fans

v.washing machines

vi.centrifugal pumps

vii.egg beaters

viii.Hair drier and

ix.blowers.

8.4.1 Why Single Phase Induction Motor' is not a Self Starting? How to Make Single Phase Induction Motor Self-Starting?

Single phase induction motor has distributed stator winding and squirrel cage rotor. When fed from a single phase supply, its stator winding produces a flux which is only alternating. It is not a synchronously revolving (or) rotating flux as in the case of a two or three phase stator winding fed from a two or three phase supply. Now, an alternating or pulsating flux acting on a stationary squirrel cage rotor cannot produce rotation (only a revolving flux can produce rotation).

To make itself starting, it can be temporarily converted into a two phase induction motor while starting. This can be achieved by introducing an additional starting winding also called as auxiliary winding.

(i) Stator Winding

Stator of a single-phase Induction motor has two windings

1. Main winding (Running winding)
2. Starting winding (auxiliary winding)

These two windings are connected in parallel across single phase supply and are spaced 90° electrical degrees apart, phase difference of 90° electrical degree can be achieved by connecting capacitor in series with the starting winding. Hence the motor behaves like a two phase motor and the stator produces revolving magnetic field which causes rotor to run. Once motor speed, say up to 80% of its normal speed, the starting winding gets disconnected from the circuit by means of a centrifugal Switch and the motor runs only on main winding.

(ii) Rotor

it consists of a laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal ring called end rings. The entire construction resembles like a squirrel cage and hence the name called like that. The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator.

8.4.2 Classification of Single Phase Motor

a) Split phase induction motor
b) Capacitor start capacitor run motor
c) Universal motor

a) Split Phase Induction Motor

As the starting torque of this type of motor is relatively small and it's starting current is high. These motors are most commonly used for rating up to 0.5 HP where the load could be starting easily

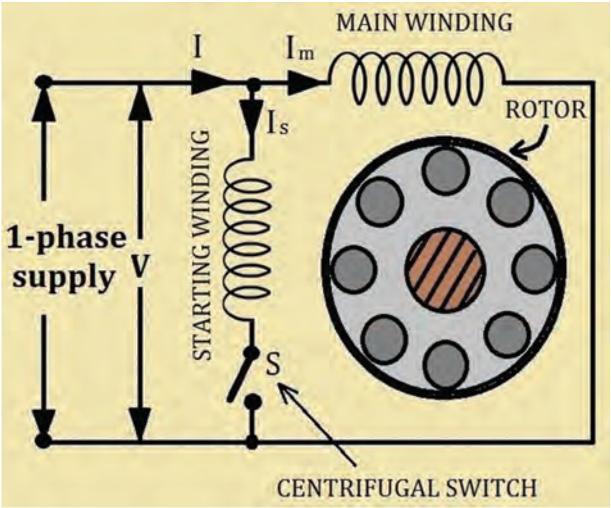


Fig 8.6 *Split Phase Induction Motor*

CONSTRUCTION

The above figure 8.6 shows the schematic diagram of single phase split phase induction motor. The starting winding is designed to have a higher resistance and lower reactance than the main winding. The main winding will have higher inductance when surrounded by more iron which could be made possible by placing it deeper into the stator slots.

WORKING PRINCIPLE

The starting current I_s will lag the main supply voltage V_L by 15° and the main winding current I_m lags main supply voltage by about 80°. Therefore, these currents will differ in time phase and their magnetic fields will combine to produce a rotating magnetic field.

When the motor has come up to about 75% of synchronous speed the starting winding is opened by a centrifugal switch and the motor will continue to operate as a single phase motor. At the point the starting winding is disconnected, the motor develops nearly as much torque with the main winding alone as with both windings connected.

Changing the Direction of Rotation

The direction of rotation of a split phase motor is determined by the way the main winding and auxiliary windings are connected either by changing the main winding terminals or by changing the starting winding terminals, the reversal of direction of rotation could be obtained.

APPLICATIONS

These motors are widely used on easy starting loads of $^1/_3$HP or less

1. Washing machines
2. Driving fans
3. Grinders
4. Wood working tools

b) Capacitor Start Capacitor Run Motor

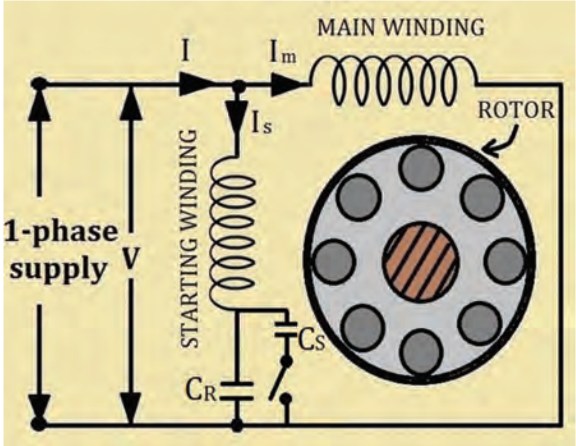


Fig 8.7 *Capacitor Start - Run Motor*

WORKING PRINCIPLE

This motor starts with a high capacitor in series with the starting winding, so that the starting torque is high. When a motor is running, run capacitor is in supply. Both the running and starting windings remain in circuit. At the start, when the centrifugal switch is closed the two capacitors are put in parallel. After the motor has reached 80% full load speed, the centrifugal switch opens and running capacitor remains in the circuit. It is used to disconnect the starting capacitor from the supply after attaining almost 75% of full load speed.Either by changing the main winding terminals or by changing the starting winding terminals, the reversal of direction of rotation could be obtained.

APPLICATIONS

These motors are mainly used for low noise and high starting torque applications

1. Compressors
2. Pumps
3. Air Conditioners
4. Refrigerators.

c) Universal Motor

The universal motor is defined as a motor which may be operated on D.C supply or single phase A.C supply at approximately the same speed and output.

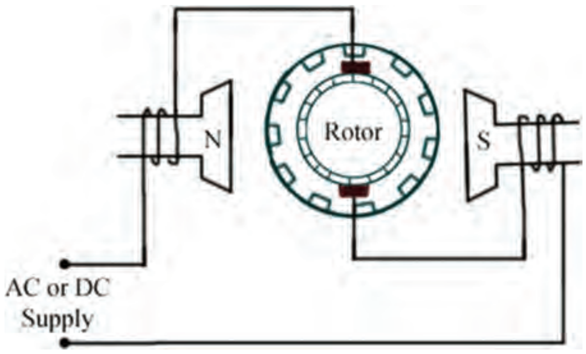


Fig 8. 8 *Universal Motor*

CONSTRUCTION

Basically universal motor is similar to D.C series motor. The universal motor is usually two poles and a winding of few turns which gives opposite magnetic polarity. The armature is of wound type and it consists of a laminated core having either straight (or) skewed slots and a commutator to which the leads of the armature winding are connected.

WORKING PRINCIPLE

Universal motor develop unidirectional torque, whether they operate on D.C or A.C. Supply Universal motor works on the same principle as a D.C motor, i.e. force between the main pole flux and the current carrying armature conductors.

Comparision of various types of single phase motors

Sl. No	Types of the Motor	Starting Torque	Speed	Windings	Applications
1	Split – phase motor	Low	Low	Main winding Starting winding	Driving fans, wood working tools
2	Capacitor start capacitor run motor	High	Constant	Main winding Starting winding	Compressors, refrigerators, air -Conditioners
3	Universal motor	Very high	Varies according to load	Field winding armature winding	Vacuum cleaners, mixie, portable drills, sewing machine

In A.C operation, both field and armature currents change their polarities, at the same time resulting in unidirectional torque.

APPLICATION

Universal motor is used in:

1. Vacuum cleaners
2. Food mixer
3. Portable drills and
4. Domestic sewing machines

8.5 TYPES OF THREE PHASE MOTORS

Three phase induction motors are widely used in industrial and domestic drives. The rotor of induction motor receives the power from the stator by means of induction. Most of the operating principles resembles to the working of transformer only. So, it can also be treated as a rotating transformer. That is, primary winding is stationary part and secondary winding is rotating part.

According to the rotor construction, three phase induction motors are classified as

i) 3-phase squirrel cage induction motor

ii) 3-phase slip-ring induction motor

8.5.1 Principle of Operation

Three phase supply is given to the stator winding. Due to this, current flows through the stator winding and produces a rotating magnetic field in the space between stator and rotor. This magnetic field rotates at synchronous speed given by

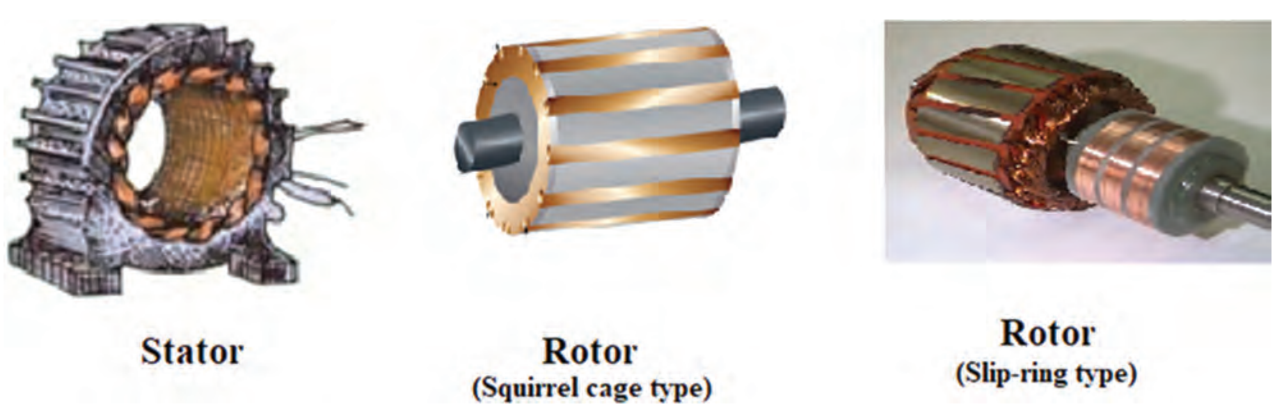
$$N_s = \frac{120f}{p}.$$

Where N_s = Synchronous speed

f = Supply frequency

p = Number of poles for which the stator is wound

This rotating magnetic field cuts the rotor conductors, an emf is induced in the rotor. This induced emf produces current and this current produces a rotor field.



Stator

Rotor (Squirrel cage type)

Rotor (Slip-ring type)

Fig 8.10 *Stator and Rotor of 3 Phase Induction Motor*

Do You Know?

Electric motors are used to "actuate" something in your robot: its wheels, legs, tracks, arms, fingers, sensor turrets, or weapon systems. There are literally dozens of types of electric motors (and many more if you count gasoline and other fuelled engines), but for amateur robotics, the choice comes down to these three:

In a stepping motor, applying power causes the shaft to rotate a few degrees, then stop. Continuous rotation of the shaft requires that the power be pulsed to the motor. As with continuous DC motors, there are sub-types of stepping motors. Permanent magnet steppers are the ones you'll likely encounter, and they are also the easiest to use.

Both these stator and rotor fields develop a torque. Then the rotor is rotating in the same direction as the rotating magnetic field. In an induction motor, the rotor speed is always less than the synchronous speed.

8.5.2 Construction of 3 Phase Induction Motor

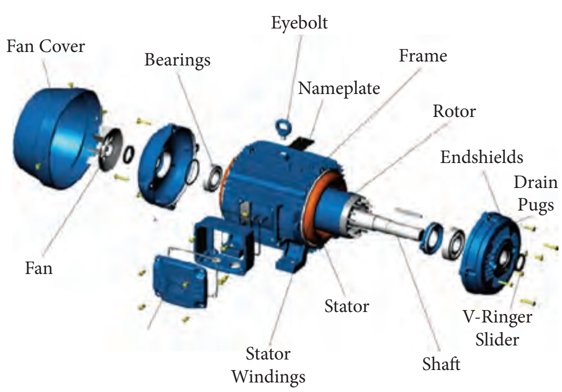


Fig 8.9 *Parts of 3 Phase Induction Motor*

Stator

The stator is made up of number of stamping, with alternate slot and tooth. Stampings are insulated from each other. More number of stampings are stamped together to build the stator core. The stator core is fitted in a casted or fabricated steel frame. The slots in the stator, houses the three phase winding and produces the required rotating magnetic field.

Rotor

Two types of rotor are used in Induction motors. They are:

a. Squirrel cage rotor
b. Slip ring (or) Wound rotor

a) Squirrel Cage Rotor

This is made up of a cylindrical laminated core with slots to carry the rotor conductors. The rotor conductors are heavy bars of copper or aluminum, short circuited in both ends by end rings. The entire rotor resistance is very small. No supply is given or taken. Motors having such type of rotors are extremely rugged in construction. The majority of induction motors are cage rotors.

Advantages

1. Cheaper
2. Light weight
3. Rugged construction
4. Higher efficiency
5. Requires less maintenance

Disadvantages

1. Moderate starting torque
2. Starting torque cannot be controlled

Applications

1. Lathes
2. Drilling machines
3. Fans
4. Blowers
5. Water pumps
6. Grinders and
7. Printing machines

b) Slip Ring (or) Wound Rotor

In this type of rotor, rotor windings are similar to the stator winding. The rotor winding may be star or delta connected, distributed winding. The rotor is wound for as many poles as the member of stator poles and is always wound three phase even when the stator is wound two phase. The three phases are brought out and connected to slip rings mounted on the rotor shaft. It is possible for introduction of additional resistance in the rotor circuit during the starting period for increasing the starting torque of the motor. By varying the external resistance in the rotor circuit, the motor speed and torque can be controlled.

Advantages

1. The starting torque can be controlled by varying the rotor circuit resistance
2. The speed of the motor can also be controlled by varying the rotor circuit resistance

Disadvantages

1. Slip-ring type motor is heavier.
2. High cost
3. High rotor inertia
4. High speed limitation
5. Maintenance problems due to brushes and slip – rings

Applications

These motors are used when speed control and high starting torque is required. Mainly used in:

1. Lifts

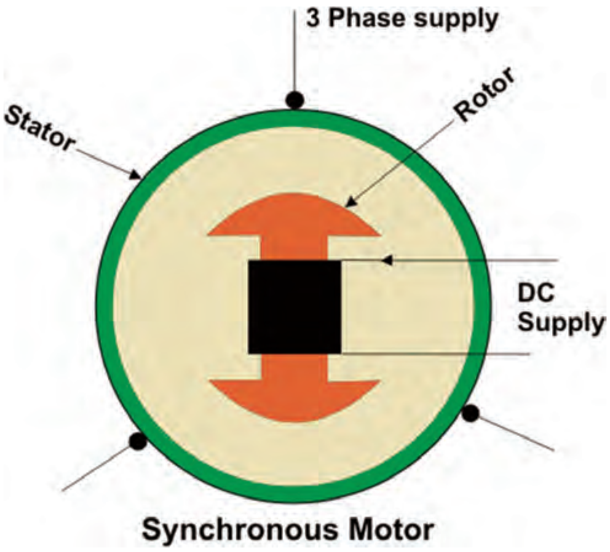


Fig 8.11 *Stator and Rotor Synchronous Motor*

2. Hoists
3. Cranes
4. Compressors

8.5.3 Slip

The difference between synchronous speed and rotor speed is called the slip speed. It is usually expressed as a percentage of synchronous speed (N_s) and represented by the symbol 'S'.

Slip Speed= $N_S - N$

$$\text{Slip } S = \frac{N_S - N}{N_S}$$

$$\% \text{ Slip} = \frac{N_S - N}{N_S} \times 100$$

8.5.4 Synchronous Motor

A motor which is running in its synchronous speed is called as synchronous motors.

1. For a given frequency, the synchronous motor runs at a constant average speed, whatever the load.
2. Synchronous motor can be operated over a wide range of power factors, both lagging and leading.
3. The synchronous motor is not a self-starting motor.
4. The changes in applied voltage do not affect synchronous motor torque.
5. For synchronous motor, D.C excitation is required.
6. Synchronous motors are usually more costly and complicated

Applications of Synchronous Motor

1. Power factor correction
2. Constant speed, constant load drives
3. Constant voltage

8.6 STEPPER MOTOR

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movement.

8.6.1 Step Angle

Step angle is defined as the angle which the rotor of a stepper motor moves when one pulse is applied to the input of the stator.

The position of a motor is decided by the step angle and is expressed in degrees

Step angle, $(\theta_S) = 360/mn$

m - number of phases.
n – number of rotor teeth.

Stepper motor can be divided into the following three categories.

1. Variable Reluctance (VR) stepper motor
2. Permanent Magnet (PM) stepper motor
3. Hybrid stepper motor

8.6.2 Variable Reluctance Stepper Motor

It is the most basic type of stepper motor. The VR stepper motor has stator and rotor. The stator windings are wound on the stator poles. The rotor carries no windings. Rotor poles are of a ferromagnetic material. The rotor is a salient pole type. This motor may be single stack or multi stack type. This is called variable reluctance motor because the reluctance of the magnetic circuit formed by the rotor and stator teeth varies with the angular position of the rotor. The direction of motor rotation is independent of the polarity of the stator current.

8.6.3 Permanent Magnet Stepper Motor

In this motor also stator winding are wound on the stator poles. The stator is multipolar. The rotor is generally cylindrical and rotor poles are permanently magnetized. The direction of motor rotation depends on the polarity of the stator current.

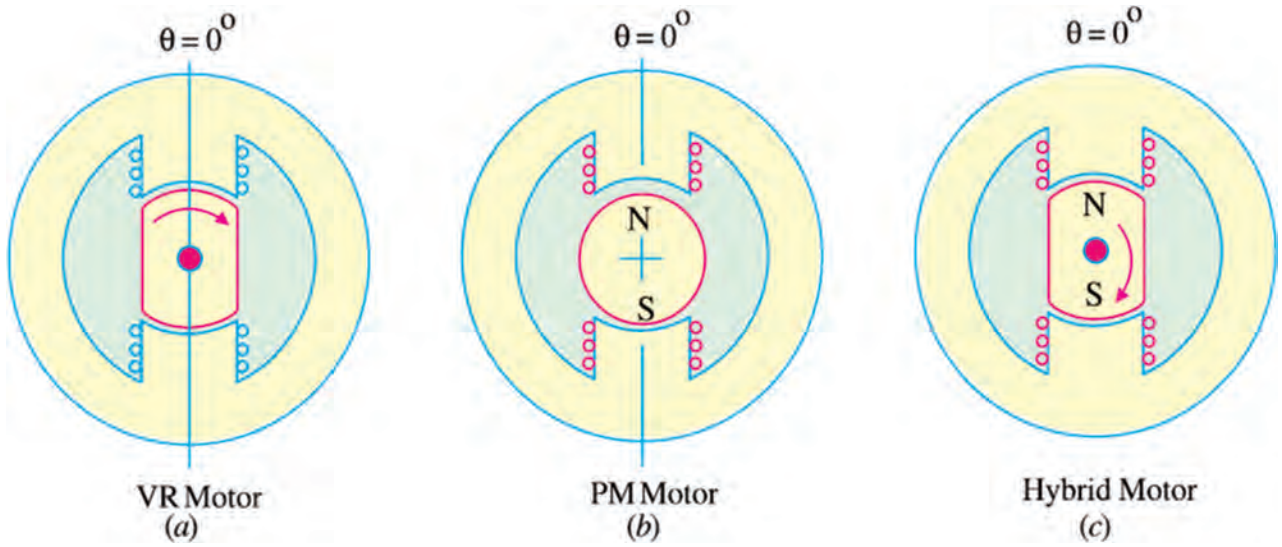


Fig 8.12 *Types of Stepper Motor*

8.6.4 Hybrid Stepper Motor

It combines the features of variable reluctance and permanent magnet stepper motors. This is the most popular type of stepper motor. It has wound stator pole and permanently magnetized rotor poles.

The important features of the hybrid motors are its rotor structure. A recent type motor, a disc rotor is used which is magnetically, axially to give a small stepping angle and low inertia.

Advantages of Stepper Motor

1. The rotating angle of the motor is proportional to the input pulse
2. The motor has full torque at stand
3. Excellent response to starting, stopping and still reversing

Disadvantages of Stepper Motor

1. Resonances can occur if not properly controlled
2. Not easy to operate at extremely high speeds

Uses of Stepper Motor

1. It can be held at a particular position of the shaft
2. Ideal for many autonomous robots requiring higher precision

Points to Remember

1. A.C. generator is also called as alternator or A.C Synchronous generator.
2. Stationary armature and rotating field is most advantageous one.
3. Stator is the stationary part and rotor is the rotating part.
4. Alternator are constructed in two types
   a) Salient pole alternator
   b) Non- salient pole alternator
5. Salient pole type the diameter of stator is large and length is short
6. Non – Salient pole type the diameter of stator is short and length is long
7. A.C motors are classified into
   a) Synchronous motor
   b) Induction motor
8. Synchronous motor is running at synchronous speed which is $N_S = 1500$
9. Synchronous motors are used for power factor correction
10. Induction motor can also be treated as rotating transformer

11. Induction motors are widely used in industrial drives

12. For cooling purpose, light aluminum fans are used in three phase A.C motors

13. No external supply is given or taken in squirrel cage rotor

14. In a single phase motor, stator windings are:

1) Main Winding, and

2) Auxiliary Winding

15. Either by changing main winding terminals or by changing auxiliary winding terminals, the reversal of direction of rotation is obtained in capacitor type motors

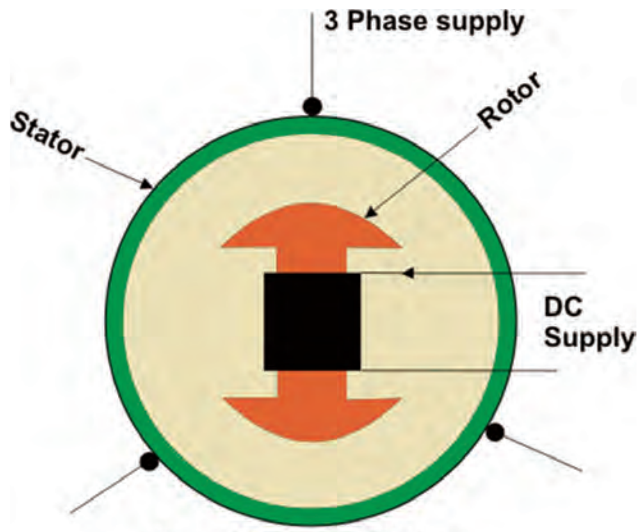
16. Stepper motor is an electromechanical device

GLOSSARY

Alternator (or) AC generator	–	மாறுதிசை மின்னாக்கி
Stator	–	நிலையி
Rotor	–	சுழலி
Slot	–	பள்ளம்
Squirrel cage motor	–	அணில் கூடு வகை மின்னோடி

Activities

1. Construct a small working model by using stepper motor (children toy)



Synchronous Motor

1. Identify the motors which is used in the following domestic appliance.

a) Mixie b) Grinder c) Washing Machine d) Fan

Q A

PART A

Mark 1

Choose the Correct Answer:

1. The AC generator is also called as
   i) Alternator
   ii) DC generator
   iii) Synchronous motor
   iv) Synchronous generator
      (a) (i) and (ii) only
      (b) (i) and (iii) Only
      (c) (i) and (iv) only
      (d) (ii) and (iii) only

2. Armature Core is laminated
   a) To reduce hysteresis loss
   b) To reduce eddy current loss
   c) To reduce copper loss
   d) To reduce mechanical losses

3. Slot types in the stator core of an alternator are
   a) Wide – open slots
   b) Semi – closed slots
   c) Closed slots
   d) All of the above

4. Which type of rotor is used in low and medium speed alternators?
   a) Salient – pole type rotor
   b) Cylindrical type rotor
   c) Squirrel cage type rotor
   d) None of the above

5. Size of stator of an alternator is small in diameter and large in axial length, is called as
   a) Salient – pole type alternators
   b) Turbo alternators
   c) D.C. generator
   d) None of the above

6. Which type of rotors isused for very high speed in alternators?
   a) Salient pole type
   b) Smooth cylindrical type
   c) Squirrel cage type
   d) None of the above

7. Axial Ventilating holes are provided to
   a) Increase eddy current
   b) Increase cooling effect
   c) Reduce eddy current
   d) Reduce cooling effect

8. Stationary field and rotating armature type is used in
   i) Small size generators
   ii) For low voltages
   iii) Large size generators
   iv) For high voltages
      (a) (i) and (ii)
      (b) (ii) and (iii)
      (c) (iii) and (iv)
      (d) (iv) and (i)

9. Stationary armature and rotating field type is used in
   i) small size generators
   ii) For low voltages
   iii) Large size generators
   iv) For high voltages
      (a) (i) and (ii)
      (b) (ii) and (iii)
      (c) (iii) and (iv)
      (d) (iv) and (i)

10. A motor which is running in its synchronous speed is called as
   a) Synchronous motor
   b) Induction motor
   c) Three phase motors
   d) Single phase motors

11. The rotor used in three phase induction motor is
   a) Squirrel cage rotor
   b) Salient – pole type rotor
   c) Non- salient pole type rotor
   d) None of the above

12. Advantage of three phase Induction motors are
   a) Very simple in construction
   b) It's cost is low
   c) Very reliable
   d) All of the above

13. Slip is designed as
   (a) Ns –N
   (b) $\frac{Ns-N}{Ns}$
   (c) $\frac{Ns-N}{N}$
   (d) $\frac{N-Ns}{N}$

14. Squirrel cage induction motors are used in
   a) Lathes
   b) Drilling machines
   c) Fans
   d) All of the above

15. Slip ring induction motors are used in
   a) Lifts
   b) Hoists
   c) Compressors
   d) All of the above

16. One horse power is equal to
   a) 736 watts b) 756 watts
   c) 746 watts d) 766 watts

17. In India, frequency is
   a) 25 Hz b) 50 Hz
   c) 60 Hz d) 40 Hz

18. Which one is in correct?
   a) Single phase motors are not self starting
   b) Single phase motors are self starting
   c) Three phase motors are not self starting
   d) None of the above

19. Normally, which motor is used in Electric Mixie?
   a) Split phase motors
   b) Shaded pole motors
   c) Capacitor start motors
   d) Universal motors

20. Which motor is used in both A.C. and D.C supply?
   a) Split phase motor
   b) Shaded pole motor
   c) Universal motor
   d) Capacitor start motor

Q A

PART B

Mark 3

Answer the Questions in briefly

1. What are the advantages of A.C. generator?
2. State the types of armature slots.
3. What are the types of three phase induction motors?
4. Mention some advantages of three phase induction motor.
5. What are the advantages single phase motor?
6. State the applications of synchronous motor.
7. Name the two types of rotors used in three phase Induction motors.
8. Define 'Slip'.
9. Write some of the applications of squirrel cage Induction motor.
10. State the advantages of slipring induction motors.
11. Write down the few applications of slip ring Induction motor.
12. Why Single phase motor is not a self starting?
13. Name two windings in stator of single phase induction motor.
14. What is meant by 'Slip speed'?
15. Write some of the disadvantages of squirrel cage induction motor?
16. State the different types of stepper motor.
17. What are the advantages of stepper motor?
18. What are the disadvantages of stepper motor?
19. Write down the applications of stepper motor?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Compare the salient pole type rotor with smooth cylindrical type rotor.
2. Explain the advantages of stationary armature and rotating field system.
3. What are the type of single phase motors?
4. Explain double field revolving theory.
5. Explain the construction of squirrel cage rotor.
6. What are the application of following motors?
   a. Spilt phase motor
   b. Universal motor

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the salient pole and non salient pole alternator with neat sketch.
2. With neat sketch, explain the operation of an alternator.
3. Explain the construction and operation of single phase capacitor start Induction run motor.
4. Explain with neat sketch about universal motor.
5. Briefly explain the various types of stepper motor.

Reference Book

1. 'A text book of Electrical Technology' Volume II by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

LESSON 9

Engineering Materials

SUFSJD

> *If the boys and girls do not learn discipline in their school days, money and time spent on their education is so much national loss.*
>
> **—Mahatma Gandhiji**

LEARNING OBJECTIVES

The learning objective of this chapter is to know about engineering materials, classifications, electrical, mechanical properties and types of materials.

Table of Content

9.1 INTRODUCTION– PROPERTIES OF MATERIALS

A material is a substance used to make physical things. The term property means quality, which defines the specific characteristic of a material. Materials have different properties and characteristics depending on what they are used for. Examples of certain materials and their properties are given below.

Materials Properties

Pencil	– Hard, Light, Opaque.
Window	– Transparent, Brittle.
Paper	– Light, Malleable.
Fork	– Shiny, Hard, Conductor, Magnetic.

Figure 9.1 *Properties of Materials*

Do You Know?

Insulation works in both directions: if it is well insulated, a building is **more comfortable** whatever the season, warmer in winter and cooler in summer. It is therefore **more economical** as regards heating and air conditioning.

Uses of materials

Materials	**Uses**
Steel	- Construction of Bridges/ Building
Wrought/Cast iron	- Manufacturing of Tools
Gold, Silver, Copper	- Making Coins
Plastic, Wood	- Making Chairs

Why copper suitable for wiring? Copper is a good conductor of electricity, strong and ductile.

Why cooker is made up of metals? Metals are good conductor of heat, strong and does not melt with high temperature.

Hence a detailed study of properties of materials provide a steady knowledge to select things depending on their uses and nature.

9.2 ENGINEERING MATERIALS

The substances which are useful in the field of engineering are called Engineering Materials. A particular material is selected on the basis of following considerations.

1. Availability of Material
2. Cost of Material
3. Sustainability
4. Ease of Manufacture
5. Compatibility
6. Reliability
7. Recyclability

SUJF8A

9.2.1 Classification of Engineering Materials

Metals and Non- metals plays an important role in the engineering industry. The materials mainly used in practice are metals which may be divided into ferrous, non-ferrous and alloy. Non- metals are classified as polymer and ceramics.

9.2.2 Ferrous Metal

- The metal which contain iron as its main constituent are Ferrous metal.
- Cast iron, wrought iron and steel are some examples of ferrous metals.
- Hematite, magnetite, limonite and siderite are basically iron ores. The main ore is hematite.

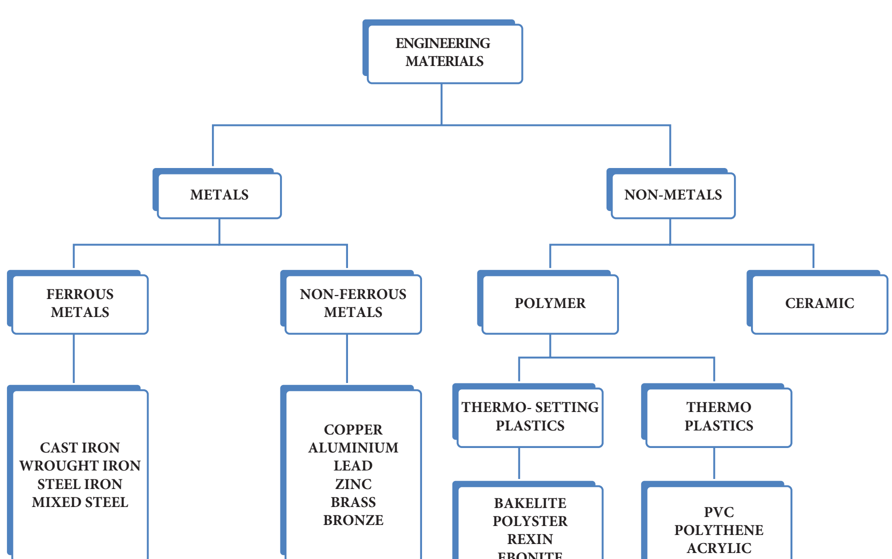


Fig 9.2 *Classification of Materials*

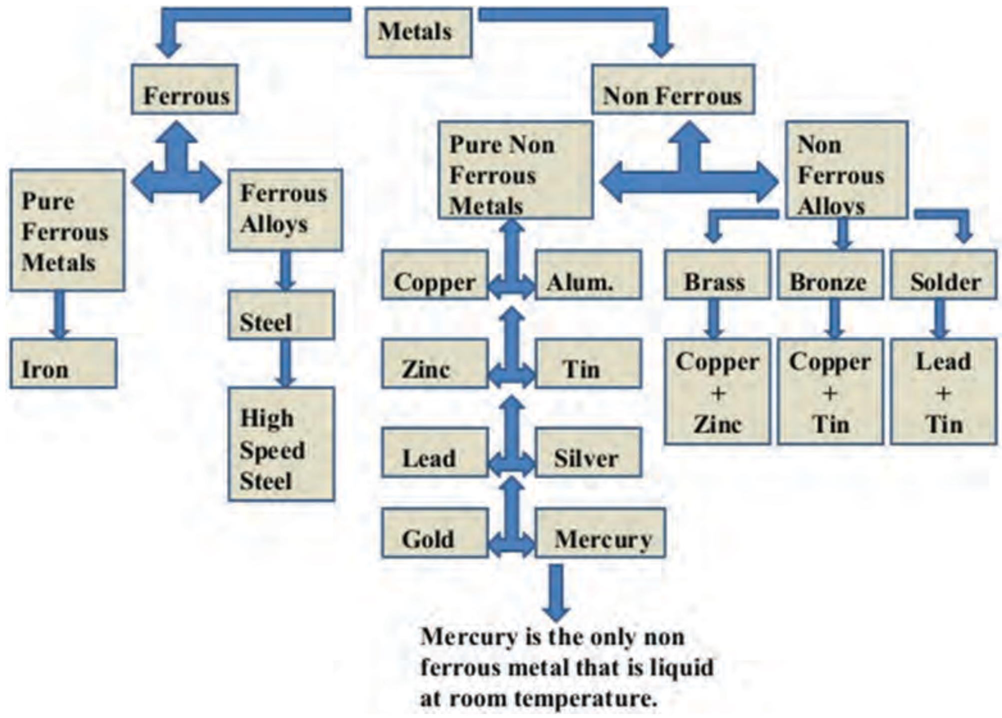


Fig 9.3 *Classification of Metals*

- Indians have specialized in metallurgy of iron and steel manufacturing.
- Ashoka's pillar at Delhi, Puri temple's iron joints speak the glory of our skill.

9.2.3 NON- FERROUS METAL

- The metal which contains metals other than iron as main constituent is non-ferrous metal.
- Copper, Aluminium, Zinc, Lead, Tin, Platinum, Silver, Gold, Tungsten are some examples of non- ferrous metals.

9.2.4 ALLOY METAL

- Combining of two or more metals to obtain special properties are called as alloy metal.
- Brass, Bronze, Stainless steel, Nichrome are some example of alloy metal.

9.3 CLASSIFICATION OF MATERIALS AND PROPERTIES

Properties of materials can be classified under several heads. As a matter of fact the following, classification of materials are important for an engineer, to select a suitable material for a desired purpose.

9.3.1 PHYSICAL PROPERTIES

Physical properties determine the micro and macro structure of the materials such as shape, size, colour, lustre , density , structure, finish , etc..

9.3.2 MECHANICAL PROPERTIES

These properties deals with behaviour of materials while force or load is acting on it, such as elasticity, plasticity, ductility, brittleness, strength, stiffness, machinability, malleability, hardness, toughness etc.

9.3.3 ELECTRICAL PROPERTIES

Electrical properties determine the ability of material to permit or resist the flow of electricity. Ex: conductivity, resistivity, di- electric, insulation, etc..

9.3.4 MAGNETIC PROPERTIES

Magnetic properties determine the behaviour of the materials with presence of applied magnetic field. Ex: permeability, retenativity, hysteresis, curie temperature, etc..

9.3.5 OPTICAL PROPERTIES

Optical properties of a material determine the behaviour of a material under the action of light. Ex: emission of light, absorbance, color luminosity, photo sensitivity, reflecting, refractive index, scattering, transmission etc.

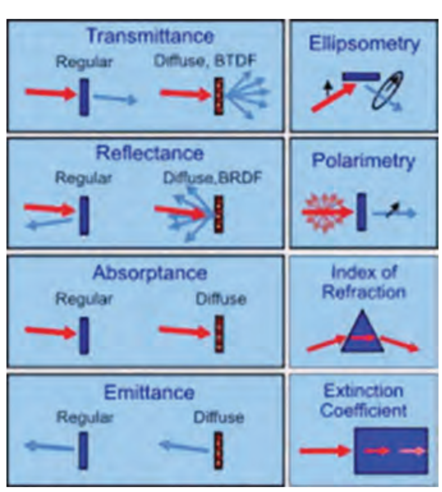


Fig 9.4 *Optical Properties*

9.3.6 CHEMICAL PROPERTIES

Chemical properties determine the corrosion rate, chemical reaction rate of material. Ex: corrosion resistance, reactivity, chemical composition, PH, hydroscopy etc.

9.3.7 THERMAL PROPERTIES

Thermal properties determine the behaviour of the materials when they are subjected to thermal changes. Ex: specific heat, thermal conductivity , thermal expansion, thermal stress, thermal shock, latent heat, specific heat , etc..

9.4 MECHANICAL PROPERTIES

Mechanical property defines the behaviour of material under an act of force or load.

Fig 9.5 *Mechanical Properties*

i) Strength

It is defined as the ability of a material to resist loads without failure and fracture.

ii) Stiffness

It is defined as the ability of a material to resist deformation or deflection under load. Stiffness within the elastic limit is known as modulus of Elasticity.

iii) Elasticity

The ability of a material to deform under load and return to its original shape when the load is removed.

iv) Plasticity

The ability of a material to deform under load and retain its new shape when the load is removed.

v) Ductility

The ability of a material to be deformed plastically without rupture under tensile load. Materials possesing ductility can be drawn into fine wire.

vi) Brittleness

It is the property of sudden fracture without any visible permanent deformation.

vii) Machinability

The ease with which a given material may be worked or shaped with a cutting tool is called machinability.

viii) Hardness

The ability of material to resist scratching or indentation by another hard body.

ix) Toughness

The ability of material to absorb energy up to fracture during the plastic deformation.

x) Malleability

The ability of material to be deformed plastically without rupture under compressive load. Malleable metals can be hammered and rolled into thin sheets.

xi) Creep

The slow and progressive deformation of a material for long time with a constant stress.

xii) Fatigue

Failure of materials under repeated or reversal stress is called Fatigue.

xiii) Resilience

The capability of a strained body to recover its side and shape, after deformation caused. Especially by compressive stress.

9.5 CONDUCTING MATERIALS

Conductivity is the property of a material by which it allows the flow of electric current. Conducting materials can be classified into low resistivity, high resistivity and zero resistivity.

9.5.1 Conducting Materials and Its Uses

Silver – Used in contact surface of switch gears and circuit breaker points

Copper – winding in electrical wires, and transformer, in wires, hard drawn copper in transmission lines.

Aluminium – flexible wires, bus bars, domestic wiring.

Tungsten – to make filament in bulbs.

Platinum – thermo couple and constant material

Manganese – standard resistances and shunts.

Constantine – thermo couples, rheostats and starters for electric motors.

Nichrome (Ni,ch) – Heating element in Iron box, heater.

Kanthan (Fe-er-Al) –Heating element in furnaces.

Carbon – Brushes in electrical machines.

9.5.2 Comparison of Copper and Aluminium

FactorS	Aluminium	Copper
Colour	Silverly white	Reddish brown
Density	2700 kg/m^3	8900° kg/m^3
Melting point	660°C	1085°C
Resistivity	2.65 x $10^{-6}\Omega$-m	1.72 x $10^{-6}\Omega$-m

9.5.3 Advantage of Aluminium

- Cheaper - Low Cost
- Lighter - 1/3 weight of copper.
- Softer.
- Non-Reactive to acids.
- Availability - Aluminium is third most abundant element in nature. 7.28% of earth crust is aluminium.

9.5.4 Disadvantage of Aluminium

- Higher Resistivity : Hence aluminium is not used for winding. If used, the wire must be of large size to reduce I^2R losses and machine size also increases.
- High contact Resistance.
- Poor Tensile Strength - Aluminium cannot be used directly as overhead transmission line as it cannot be stretched.
- Possibilities for Loose contacts - Aluminium cannot be soldered by conventional method.

9.6 INSULATING MATERIALS

9.6.1 Solid Insulating Materials

A) Plastics

- It is an organic polymer, which can be moulded into and desired shape and size with the help of heat, pressure or both.

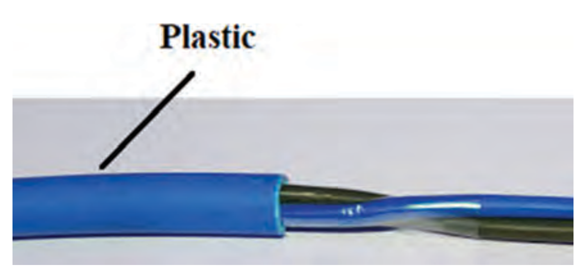


Fig 9.6 *Application of Plastic*

- The plastic in liquid forms is known as resin.
- There are two types of plastics namely Thermo plastic and Thermo set plastic .
- Thermo plastic can be softened and hardened by heating and cooling by any number of times. (e.g) Polythene, PVC, Acrylic.
- Thermo set plastic cannot be softened once they are moulded. It is formed by condensation and polymerization. Eg. Polyester, Bakelite, Epoxy

b) Ceramics

- Ceramics are inorganic, non-metallic, covalent compounds.
- They are produced from earthy material (clay) by the action of fire
- Clay product, refractories and glasses are types of ceramics.

- Porcealin is (clay product) used in line insulators. Transformer bushing pin, switches, Fuse Holder and socket, discs of Electric stove & Kettle and beads are used to insulate heating element. Aluminium is an important refractory material used in furnaces.

  Silica glass, Fiber glass, Pyrex are important glass insulation materials used in Capacitor, Radio & TV tubes, Lamps, Laminated boards.

c) Rubber

Rubber is an organic polymer, which elongates on stretching and regains its original shapes after the removal of the stress. Rubber may be classified as natural rubber and synthetic rubber.

d) Mica

Mica is a mineral compound of aluminium silicate with soda potash and magnesium.It has high dielectric strength and low power loss. Mica is used in tapping stator coils, electric irons, hotplates, toasters, motor slot lining and transformer insulation.

e) Asbestos

- It is natural mineral material of fibrous structure and low dielectric.
- It has high dielectric loss and low dielectric strength.
- It is used in electrical machines to withstand temperature, cloth tape, Paper boards, covering on wire of heating element, arcing barrier in switches and breakers.

9.6.2 Liquid Insulating Materials

A) Mineral Insulating Oils

- These oils are obtained from distillation of crude petroleum.It has high oxidation resistance and good thermal stability.
- Transformer oil is used for insulating and cooling transformer (winding and core)
- Cable oil and capacitor oil are other mineral insulating oils.

b) Synthetic Insulating Oils

- Compared to mineral oil, these oils are very cheap and inflammable.
- Askarel is used as coolant in High Voltage Transformer (upto 110° C)
- Aroclors,sovoland sovtol are other synthetic insulating oils.

9.6.3 Gaseous Insulating Materials

A) Air

It is an important insulating material available in nature. It is used in HT lines and capacitor as an insulating material.

b) Nitrogen

- It is chemically inert, prevent oxidation and reduce deterioration.
- It is used in oil filled transformers, capacitors and in cables under pressure.

c) Inert Gases

- They are used in electronic tubes and discharge tubes as insulators

9.7 OPTICAL MATERIALS

Optical materials are becoming increasingly important for communication. In communication, an entire network of optical fibre, LED'S, LASER and detectors has already been installed for transmission of voice and data. Optical disk recording with semi conductor, laser playback are replacing the conventional piezo electric pickups.

Various optical materials and their Application

Technology	Application
1. Optical communication	
i) Wave guides	To guide the light inside the fibre by total internal reflection (eg. optic fibre cable)
ii) Optical modulator	To modulate the intensity or phase of light by an electric field / magnetic field /ultrasonic waves
iii) Optical switches	
iv) Optical Source	To do fast switching To produce light
2. Energy convertors	To convert light energy into electrical energy (solar panel, silicon, selenium sulphate)
3 Thermal energy detectors	To detect thermal radiation
4 Display device	To display electrical signal in the visual (eg LED, LASER)
5 Optical Fiber Sensor	To measure mechanical quantities like displacement, acceleration, pressure & electrical quantities likes field strength, current

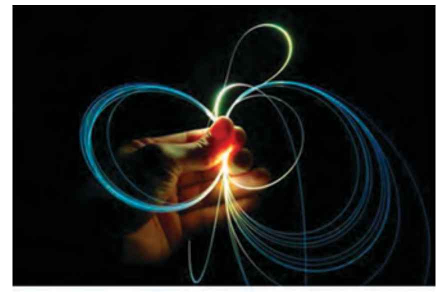


Fig 9.7 *Examples of Optical Fibres*

Activities

1. Collect 15 insulating Materials?

GLOSSARY

Engineering Materials	—	பொறியியல் பொருட்கள்
Metal Alloy	—	உலோகக் கலவை
Stiffness	—	விறைப்புத்தன்மை
Elasticity	—	நெகிழ்வுத்தன்மை
Plasticity	—	உருமாறும் தன்மை
Ductility	—	கம்பியாக நீளும் தன்மை
Brittleness	—	நொறுங்கும் தன்மை
Hardness	—	கடினத்தன்மை
Toughness	—	கெட்டிப்புத் தன்மை
Malleability	—	தகடாகும் தன்மை
Creep	—	தொய்வு
Fatique	—	நொந்தக் களைப்பு

PART A

SUPNL1

Mark 1

Choose the Correct Answer:

1. Steel is an example for_________
   a) Non Metal
   b) Ferrous Metal
   c) Non-Ferrous Metal
   d) Alloy Metal

2. Which one of the following is an alloy___________
   a) Cast Iron
   b) Copper
   c) Brass
   d) Platinum

3. Which of the following are the thermal properties of materials?
   i) Fatigue
   ii) Specific Heat
   iii) Thermal Conductivity
   iv) Creep

   a) Both (i) and (iv)
   b) Both (ii) and (iii)
   c) All the above
   d) None of the above

4. Zinc is an example of ________
   a) Non Metal
   b) Ferrous Metal
   c) Non-Ferrous Metal
   d) Alloy
5. Refractive index and Reflectivity are properties of material is known as ________________
   a) Mechanical
   b) Thermal
   c) Chemical
   d) Optical
6. Which of the following are the chemical properties of materials?
   a) Corrosion Resistance
   b) Reactivity
   c) Chemical Composition
   d) All the above
7. Which one of the following is an organic material________
   a) Zinc
   b) Iron
   c) Silicon Carbide
   d) Wood
8. Shape and density are properties of materials is known as _____
   a) Physical
   b) Chemical
   c) Mechanical
   d) Electrical
9. Which state of material resist Tension, Compression and shear stress?
   a) Gaseous
   b) Liquid
   c) Solid
   d) None of the above
10. Which of the following metals are both malleable and ductile_________
    a) Copper
    b) Cast Iron
    c) Porcelain
    d) Zinc
11. Which of the following conductoris used in over head distribution lines?
    a) Aluminium
    b) Copper
    c) ACSR
    d) Steel
12. Which of the following is used for making the resistance of heating element ________
    a) Invar
    b) Nichrome
    c) Mangani
    d) Constantan
13. The following list gives the four metals Gold(Au), Silver(Ag), Aluminium(Al) and Copper (Cu) increasing order of resistivity.____
    a) Ag, Cu, Au, Al
    b) Au, Ag, Cu, Al
    c) Ag, Au, Cu, Al
    d) Cu, Ag, Au, Al

14 Aluminium is found ______ percentage of earth crust
   a) 7.28
   b) 8.27
   c) 7.82
   d) 8.72

15 Which one of the following is used as energy convertor in optical materials____
   a) Optic Fibre Cable
   b) LED
   c) LASER
   d) Solar Panel

16 Most widely used conducting materials are____
   a) Gold and Silver
   b) Copper and Aluminium
   c) Copper and Silver
   d) Gold and Platinum

Q A

PART B

Mark 3

Answer the Questions in briefly

1. List out the broad classification of the properties of engineering materials.
2. Write short notes on types of metals.
3. Differentiate Thermo setting plastic and Thermo plastic.
4. State the different properties of material.
5. Write down the thermal properties of materials.
6. What is meant by optical properties and give some examples?
7. Write short notes on optical energy convertor.
8. Name the insulating material available at free of cost and where it is used.
9. State the factor to be considered for the selection of materials for engineering applications.

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the various properties of engineering materials.
2. Tabulate the applications of optical materials and technology.

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the mechanical properties of materials.
2. Explain the types of conducting materials.
3. Compare the properties of copper and aluminium.
4. Explain the types of insulating materials.

Reference Books

1. 'An introduction to Electrical Engineering Materials' by Dr. C.S. Indulkar and Dr. S. Thiruvengadam, 4th edition, S. Chand & company.

LESSON 10

Electronics

SUTB9X

Do all the good you can,
By all the means you can,
In all the ways you can,
In all the places you can,
At all the times you can,
To all the people you can,
As long as ever you can.

—JOHN WESLEY

LEARNING OBJECTIVES

This chapter enables the students to study in detail about atomic structure, types of conductors, classification of rectifiers, filtering circuits. LED, LCD, display, camera and mobile phone workings.

Table of Content

10.1 INTRODUCTION

In the modern era of fast-developing society, electronics is the most important branch of Engineering. Electronics is the branch of engineering which deals with current flow through a vacuum, gas and semiconductors.

10.1.1 Atomic Structure

According to modern theory, matter is electrical in nature. All the materials are composed of very small particles called atoms. The atoms are the building bricks of all matter. An atom consists of a central nucleus of positive charge around which small negatively charged particles, called electrons revolved in different paths or orbits.

Nucleus is the central part of an atom which contain protons and neutrons. A proton is a positively charged particle, while the neutron has the same mass as the proton, but has no charge. Therefore, the nucleus of an atom is positively charged. So all the materials are in stable condition. The sum of protons and neutrons constitutes the entire weight of an atom and is called atomic weight. The number of electrons is equal to the number of protons in an atom and is called as atomic number.

i.e, Atomic number=number of protons (or)number of electrons.
Atomic weight=number of protons + number of neutrons.

10.1.2 Structure of Electron in An Atom

The electrons in an atom revolve around the nucleus in different orbits or paths. The number of electrons in any orbit is determined by the following rules.

The number of electrons in any orbit is given by $2n^2$ where n is the number of the orbit.

For example

i) First orbit contains = $2 \times 1^2 = 2$ electrons
ii) Second orbit contains = 2×2^2 = 8 electrons
iii) Third orbit contains = 2×3^2 = 18 electrons
iv) The last orbit cannot have more than 8 electrons
v) The last but one orbit cannot have more than 18 electron

10.1.3 Structure of Elements

We have seen that all atoms are made up of protons, neutrons and electrons. The difference between various types of element is due to the different number and arrangement of these particles within their atom. For example, the structure of copper atom is different from that of carbon atom and hence the two elements have different properties. (Ref Fig. 10.1)

The atomic structure can be easily formed if we know the atomic weight and atomic number of the element.

Ex:copper→Atomic weight = 64
Atomic number = 29,
Number of protons=Number of electrons=29,
And Number of neutrons=64–29=35

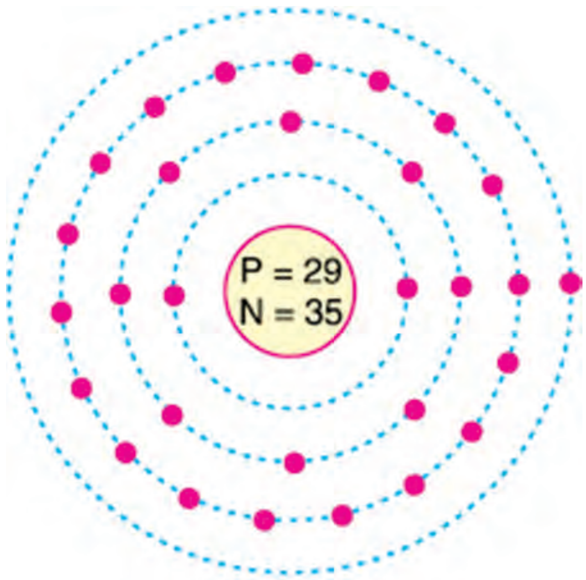


Fig 10.1 *Atomic Structure of Copper*

Fig shows the structure of copper atom.It has 29 electrons which are arranged in different orbits as follows.

1 orbit = $2 \times 1^2 = 2$
2 orbit = $2 \times 2^2 = 8$
3 orbit = $2 \times 3^2 = 18$
4 orbit will have 1 electron

The atomic structure of all known elements can be shown in this way.

10.2 RECTIFIERS - TYPES

It has already been discussed in the previous chapter that a pn-junction conducts current easily when forward bias and practically no current flows when it is reverse biased.

"A pn-junction is known as a semiconductor or crystal diode"

For reasons associated with economics of generation and transmission, the electric power available is usually an a.c. supply. The supply voltage varies sinusoidally and has a frequency of 50 Hz. It is used for lighting, heating and also in electric motors.

Mostly all electronic devices require d.c. power for this proper operation. DC batteries are used for vehicles and rarely in commercial appliances. They are costly and require frequent charging or replacement. So we can get d.c. power from, a.c. power by using regulated d.c. power supply. It consists of transformer, rectifier filter and regulator.

Classification of Rectifiers

The unidirectional characteristic active element ie., diode is used for this purpose. The rectifier convert an AC signal into DC signal. Rectifiers are classified into two types namely (i) Half wave rectifier (ii) Full wave rectifier. They are explained as below

10.2 (i) Half wave Rectifier

In half-wave rectification, the rectifier conducts current only during the positive half-cycle of input ac supply. The negative half-cycle of a.c. supply are suppressed ie., during negative half-cycle, no current is conducted and hence no voltage appears across the load.

Circuit details

Fig 10.2 shows the circuit where a single crystal diode acts as a half-wave rectifier. The a.c. supply is applied in series with the diode and load resistance R_L through a transformer.

Operation

The a.c. voltage across the secondary winding AB changes polarities after every half-cycle. During the positive half-cycle of input a.c. voltage, end 'A' becomes positive with respect to 'B'. This makes the diode forward biased and hence it conducts current. During the negative half cycle, end A is negative with respect to B. Under this condition, the diode is reverse biased and it conducts no current. Therefore, current flows through the diode during positive half-cycle of inputs ac voltage only. It is blocked during the negative half cycle as shown in fig 10.15. In this way, current flows through load R_L always in the same direction. Hence d.c. output is obtained across R_L and this output is pulsating d.c.

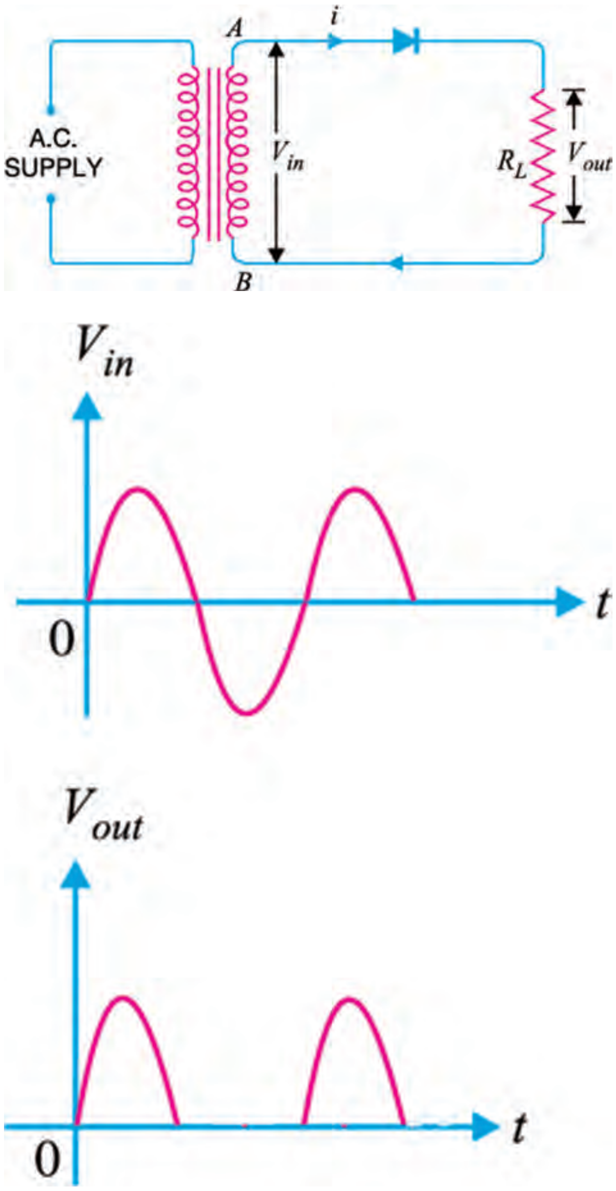


Fig 10.2 *Half wave Rectifier-wave form*

These pulsations in the output are further smoothened with the help of "Filter circuit". The peak inverse voltage of the diode should be at least equal to V_m

10.2.(ii) Full Wave Rectifier

In full wave rectification, current flows through the load is the same direction for both half-cycle of input a.c. voltage. This can be achieved with two diodes working alternately. Therefore, a full-wave rectifier utilize both half-cycle of input a.c voltage to produce the d.c.output. The following two circuits are commonly used for full wave rectification.

(i) Centre tap full wave rectifier
(ii) Full-wave bridge rectifier

(a) Centre Tap Full-Wave Rectifier

Circuit Details

The circuit employs two diodes D_1 and D_2 as shown in fig 10.16. A centre tapped secondary winding AB is used with two diodes connected so that each uses one half-cycle of input a.c. voltage.

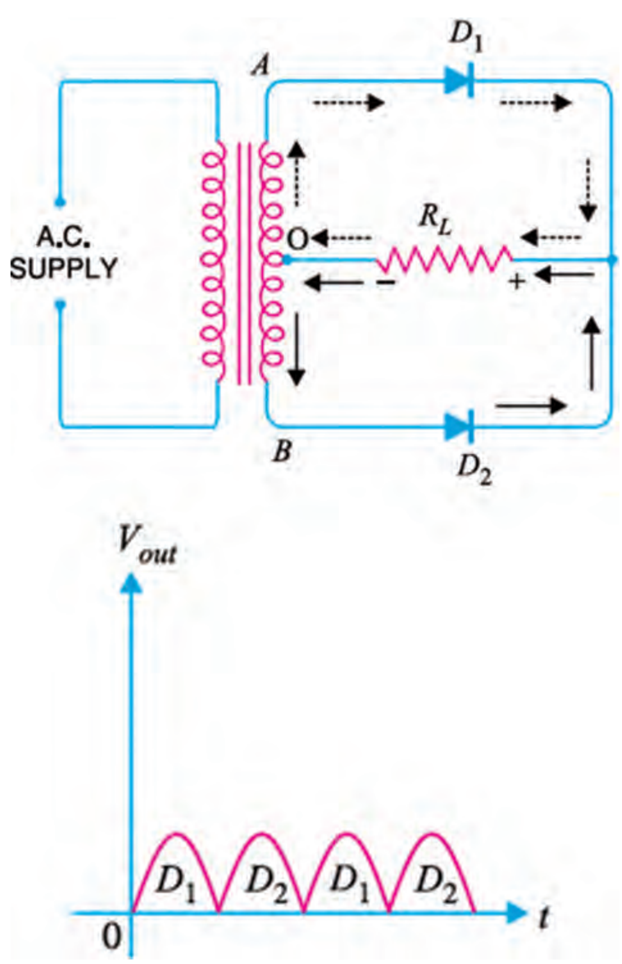


Fig 10.3 *Full wave Rectifier- Wave Form*

Operation

During the positive half cycle of secondary voltage, the end A of the secondary winding becomes positive and end B negative. This makes the diode D_1 forward biased and diode D_2 reverse biased. There fore diode D_1 conducts while diode D_2 does not. The conventional current flow is through diode D_1, load resistor RL and the upper half of secondary winding as shown by the dotted arrows.

During the negative half cycle, end A of the secondary winding becomes negative and end B positive. Therefore diode D_2 conducts while diode D_1 does not. The conventional current flow is through diode D_2, load R_L and lower half winding as shown by solid arrows. Referring to fig 10.3 it may be seen that current in the load R_L is in the same direction for both half-cycle of input a.c. voltage. Therefore d.c. is obtained across the load R_L. The peak inverse voltage (piv) of this rectifier is $2V_m$

In recent days center tap full wave rectifier is not used. It is replaced by full wave bridge rectifiers. Because of its application, full wave bridge rectifier is mostly used.

(b) Full wave Bridge Rectifier

Circuit Details

The need for a center tapped power transformer is eliminated in the bridge rectifier. It contains four diodes D_1, D_2, D_3 & D_4 connected to form bridge as shown in fig 10.4. The a.c supply to be rectified is applied to the diagonally opposite ends of the bridge through the transformer. Between other two ends of the bridge, the load resistance R_L is connected.

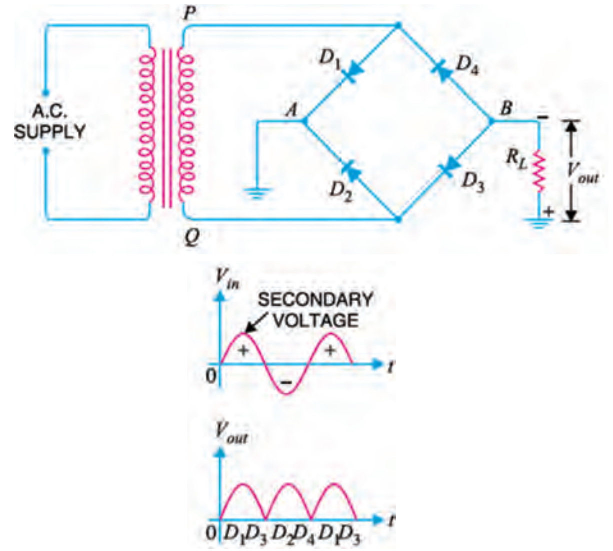


Fig 10.4 *Full Wave Bridge Rectifier-Wave Form*

Operation

During the positive half cycle of secondary voltage, the end P of the secondary winding becomes positive and end 'Q' negative. This makes diode D_1 and D_3 forward biased while diodes D_2 and D_4 are reverse biased. Therefore, only diodes D_1 and D_3 will conduct. These two diodes will be in series through the load R_L as shown in fig 10.5 (i). The conventional current flow is shown by dotted arrows. It may be seen that current flows from A to B through the load R_L

During the negative half-cycle of secondary voltage, end P becomes negative and end Q positive. This makes diodes. D_2 and D_4 forward biased whereas diodes D_1 and D_3 are reverse biased .Therefore, only diodes D_2 and D_4 conduct. These two diodes will be in series through the load R_L as shown in fig 10.5(ii). The current flow is shown by the solid arrows. It may be seen that again current flows from A to

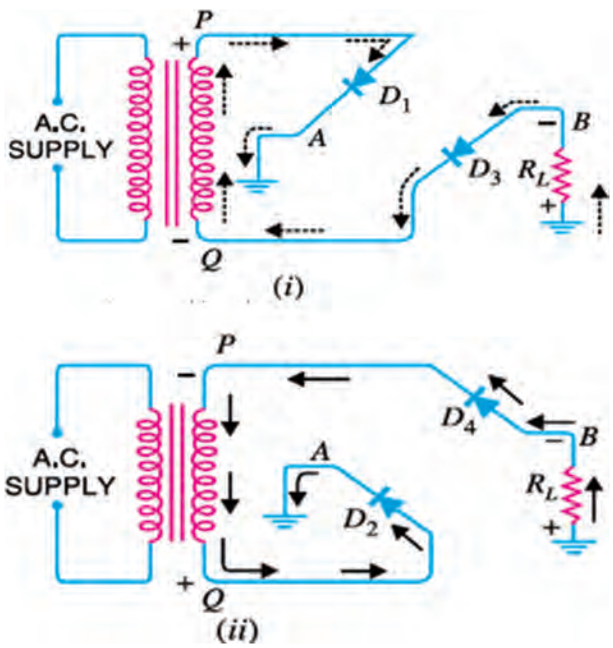


Fig 10.5 *Full Wave Bridge Rectifier*

B through the load.ie in the same direction as for the positive half-cycle. Therefore d.c output is obtained across load R_L

The peak inverse voltage (piv) of each diode is equal to the maximum secondary voltage of transformer.

10.3 FILTER CIRCUITS

Generally a rectifier is required to produce pure d.c supply for using at various places in the electronic circuits. However, the output of a rectifier has pulsating character. ie it contains a.c and d.c components. The a.c. component is undesirable and must be kept away from the load. So a filter circuit is used to remove the a.c component.

"A filter circuit is a device which removes the ac component of rectifier output but allows the d.c component to reach the load"

The most commonly used filter circuits are capacitor filter, choke input filter and capacitor input filter (or) π Filter.

10.4 ZENER DIODE

Zener Diode is a specially designed pn-junction diode. The symbol of the Zener diode in as shown in fig10.6. When forward biased, its characteristics are just those of ordinary diode. A Zener diode is always reverse connected, i.e. it is always reverse biased. When the reverse bias on a crystal diode is increased, a critical voltage

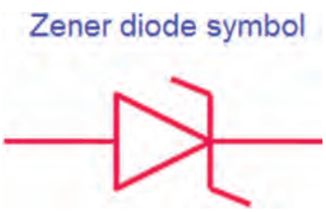


Fig 10.6 *Zener Diode*

called breakdown voltage is reached where the reverse current increase sharply to a high value. The breakdown region is the knee of the reverse characteristic as shown in fig 10.7. Therefore the breakdown voltage

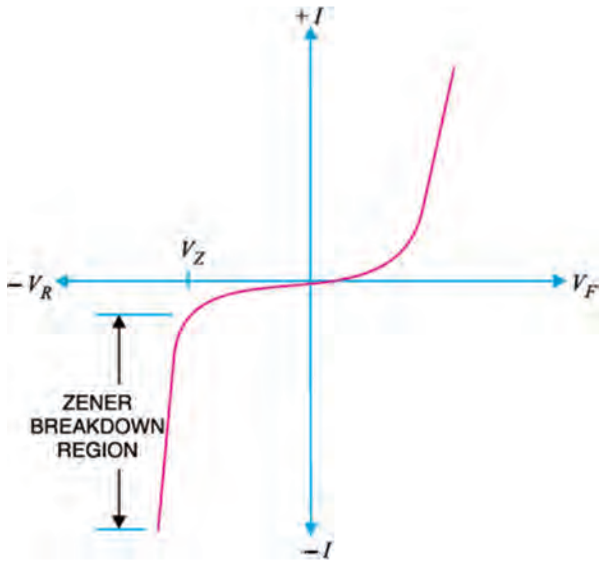


Fig 10.20 *Zener Diode Characteristics*

is sometimes called ‘Zener voltage’ and sudden increase in current is known as Zener current.

The breakdown or Zener voltage depends upon the amount of doping. If the diode is heavily doped, depletion larger will be thin and consequently the breakdown of the junction will occur at a lower reverse voltage. On the other hand, a lightly doped diode has a higher breakdown voltage. When an ordinary crystal diode is properly doped, so that it has a sharp breakdown voltage and it is called a Zener diode.

„A properly doped crystal diode which has a sharp breakdown voltage is known as a Zener diode”

10.5 TRANSISTOR

“When a third doped element is added to a crystal diode in such a way that two pn junction formed, the resulting device is known as a transistor

The transistor is a new type of electronic device and is capable of achieving amplification of weak signals.

There are two types of transistors, namely (i) n-p-n transistor (ii) p-n-p transistor.

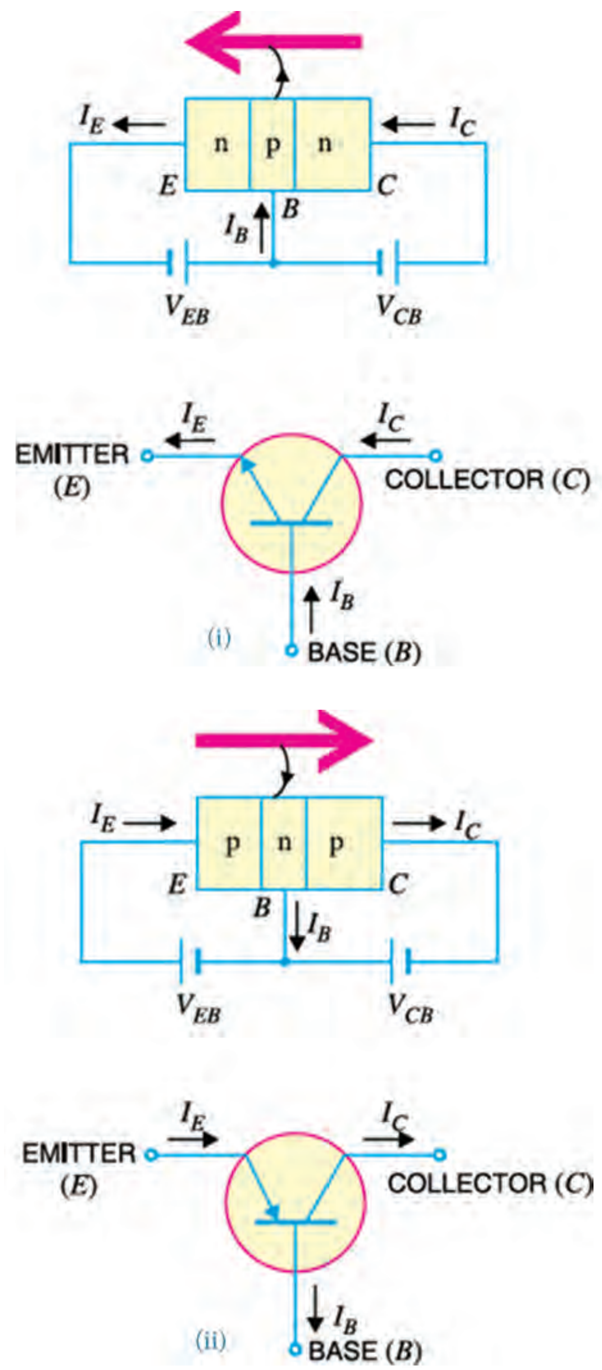


Fig 10.8 *Transistor Configuration*

The n-p-n transistor is composed of two n-type semiconductors seperated by a thin section of p-type as shown in fig 10.8(i). However a p-n-p transistor is formed by two p-sections seperated by a thin section of n-type as in fig 10.8 (ii).

A transistor (p-n-p or n-p-n) has three section of doped semiconductors.

The section on one side is the emitter and the section on the opposite side is the collector. The middle section is called the base and forms two junctions between the emitter and collector. The above fig 10.8 (i) & (ii) shows the symbols of n-p-n & p-n-p transistors.

Note that emitter is shown by an arrow which indicates the direction of conventional current flow with forward bias. For n-p-n connection, it is clear that conventional current flow out of the emitter as indicated by the outgoing arrow in fig 10.8(i). Similarly, for p-n-p connection, the conventional current flows into the emitter as indicated by inward arrow in fig 10.8(ii).

Transistor Action

The emitter base junction of a transistor is forward biased where as collector base junction is reverse biased. If for a moment, we ignore the presence of emitter base junction, then practically no current would flow in the collector circuit because of the reverse bias. However, if the emitter base junction is also present, then forward bias on it causes the emitter current to flow. It is seen that this emitter current almost entirely flows in the collector circuit. Therefore, the current in the collector circuit depends upon the emitter current. If the emitter current is zero, then collector current is nearly zero. However if the emitter current is 1ma, then collector current is also about 1ma. This is precisely what happens in a transistor.

We shall now discuss the transistor action for npn and pnp transistors.

10.5(i) Working of npn – Transistor

Fig 10.9 shows the npn-transistor with forward bias to emitter base junction and reverse bias to collector base junction. The forward bias causes the electrons in the n-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the p-type base, they tend to combine with holes. The base is lightly doped and very thin. Therefore, only a few electrons less than 5% combine with holes to constitute base current I_B. The remainder more than 95% cross over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit. It is clear that emitter current is the sum of collector and base currents. ie, $I_E=I_B+I_C$.

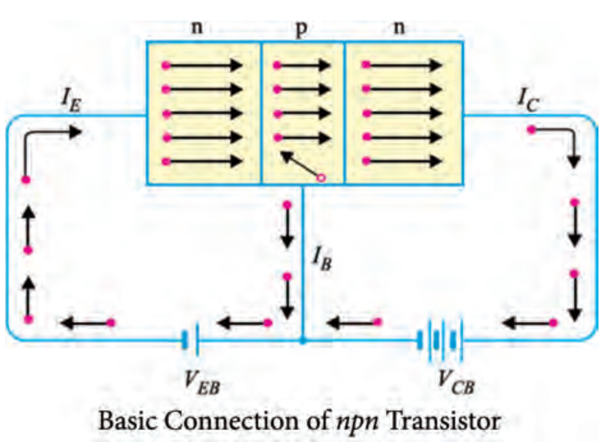


Fig 10.9 *n-p-n Transistor*

10.5(ii) Working of pnp - Transistor

Fig 10.10 shows the basic connection of a pnp transistor. The forward bias causes the holes in the p-type emitter to flow towards the base. This constitutes the emitter current I_E. As these holes cross into n-type base, they tend to combine with the electrons. As the base is lightly doped and very thin. Therefore, only a few

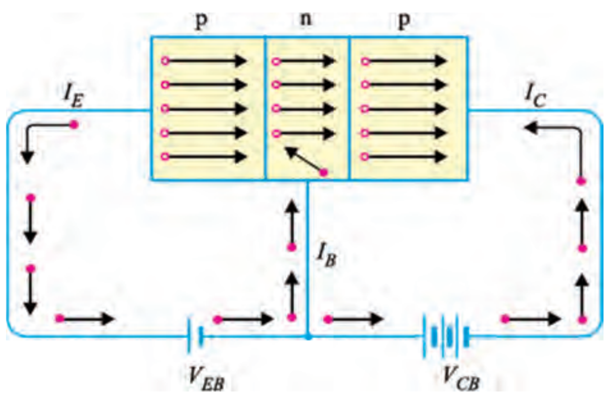


Fig 10.10 *p-n-p Transistor*

holes 5% will combine with the electrons. The remainder 95% cross into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuits. It may be noted that current conduction within pnp-transistor is by holes. However, in the external connecting wires, the current is still by electrons.

10.6 LIGHT EMITTING DIODE (LED)

The Light emitting diode(LED) is a PN junction device which emits light when forward biased. In all semiconductor PN junctions, some of the energy will be radiated as heat and some in the form of photons. In silicon and germanium, greater percentage of energy is given out in the form of heat and the emitted light is insignificant. In other materials such as gallium phosphide (Gap) or gallium arsenide phosphide (Ga As P) the number of photons of light energy emitted is sufficient to create a visible light source. Here, the charge carrier recombination takes place when electrons form the n-side cross the junction and recombine with the holes on the p-side.

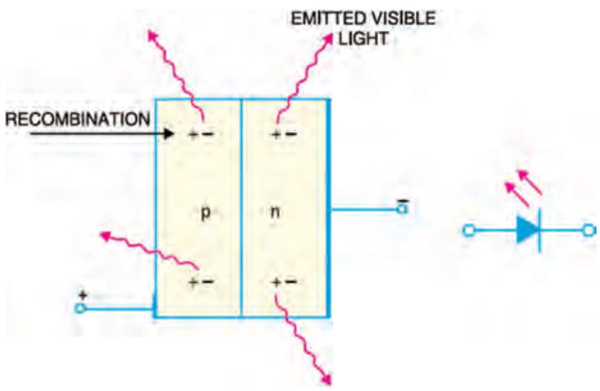


Fig 10.11 *LED Display*

LED under forward bias and its symbol are shown in the Fig 10.11. When an LED is forward biased, the electrons and holes move towards the junction and recombination takes place. As a result of recombination, the electrons lying in the conduction bands of n-region fall into the holes lying in the valance band of a p-region. The difference of energy between the conduction band and the valance band is radiated in the form of light energy. Each recombination causes radiation of light energy. Light is generated by recombination of electrons and holes where by their excess energy is transferred to an emitted photon. The brightness of the emitted light is directly proportional to the forward bias event.

Applications

- LEDs can be switched 'on' and 'off' at a very fast speed of one nano second (1ns).
- They are used in burglar alarm systems, picture, phones, multimeters, calculators, digital meters, microprocessors, digital computers, etc.

- Used in solid state video displays and optical communication system.
- Used in programmable advertisement boards.
- Used in image sensing circuit.

10.7 LIQUID CRYSTAL DISPLAY(LCD)

Liquid crystal display (LCDs) are used for display of numberic and alphanumeric character in dot matrix and segmental displays. The two liquid crystal materials which are commonly used in display technology are nematic and cholesteric.

Advantages of LCD

1) The voltage required are small.
2) They have a low power consumption. A seven segment display requires about 140W (20W per segment), whereas LCDs require about 40mw per numeral.
3) They are economical.

Disadvantages of LCD

1) LCDs are very slow device. The Turn 'on' and 'off' times are quite large.
2) When used in dc, their life span is quite small. Therefore, they are used with ac supplies having a frequency less than 50 HZ.
3) They occupy a large area.

10.8 SEVEN SEGMENT DISPLAY

One way of producing an alphanumeric display is to make a seven segment monolithic device as shown in fig 10.12 which can display all numerals. Each segment contains LED which can be turned 'on' or 'off' to form the desired digit. Each segment of the array has to be switched in response to a logic signal.

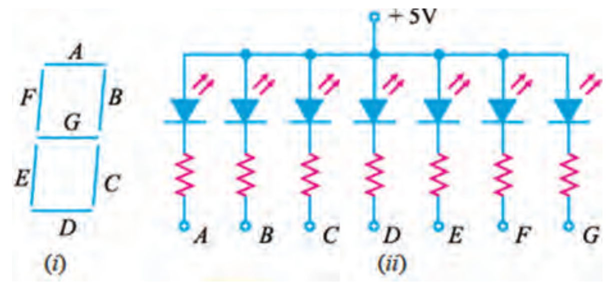


Fig 10.12 *7-Segment LED Display Common Anode*

For example Fig 10.12 (i) shows the response to a logic signal corresponding to 2, in which segments a ,b, g, e and d have been switched 'on' and c and f remains 'off'. Similarly when all segments are 'on', the digit formed is 'off' 8. If only the center segment g is the digit will be zero. Common anode and common cathode seven segment LED displays are shown in Fig 10.12 (ii) common anode type LED displays an active 'low' configuration, where as an active 'high' circuitry is necessary for the common cathode type LED display.

10.9 CCTV CAMERAS

CCTV systems have become extremely popular over a decade as the technology has improved and become more affordable. Themajority of CCTV camera in use nowdays are usually for surveillance and security purposes. CCTV systems can be found in almost every bank, casino, mall and large departmental store. In fact, CCTV systems have become so affordable, most smaller mom and pop stores etc. apartments also have CCTV systems in them for security purpose.

Different types of CCTV Camera

There are many types of CCTV camera. Here we run through these types of camera and what makes them unique and more suitable for some venues over others. They are

i) Dome camera
ii) Bullet camera
iii) C-mount camera
iv) Day/night camera
v) PTZ camera

(i) Dome Camera

The dome camera is one of the most commonly useful for indoor security and surveillance. The shape of the camera makes it difficult for onlookers to tell which way the camera is facing, which is a strong piece of design, deterring criminals by creating an of uncertainty.

Fig 10.13 *Dome Camera*

Advantages

a) Ease of installation
b) Vandal proof features
c) Infrared capability

SUYJHN

(ii) Bullet Camera

Bullet cameras are long and cylindrical in shape, and are ideal for outdoor use. Their strengths lie specifically in applications which require long distance viewing. Installed within protective casings, the cameras are protected against dust, dirt and other natural elements. The cameras can easily be mounted with a mounting bracket, and come fitted with either fixed or varifocal lenses depending on the requirements of its intended application.

Fig 10.14 *Bullet Camera*

Advantages

a) Adaptability can use indoors and out doors
b) Compact size aids installation.
c) High quality image resolution

iii) C-mount Camera

This type of camera Coming with detachable lenses. C-mount cameras allow simple lense changes to fit different applications. C–mount cameras, were standard CCTV lenses can only cover distances of 35-40ft, can also cover distances beyond 40ft, to the possibility to use special lenses with these cameras.

Fig 10.15 *C-mount Camera*

Advantages

a) It can support changes in technology.
b) Effective for indoor use.
c) Bulky size makes them noticeable.

iv) Day/Night Camera

Capable of operating in both normal and poorly lit environment. These cameras benefit from not requiring inbuilt infrared illuminators as they can capture clean video images in the dark thanks to their extra sensitive imaging chips. For this reason, these cameras are ideal for outdoor surveillance applications in which IR cameras are unable to function optionally.

Fig 10.16 *Day/Night Camera*

Advantages

a) Record in both color and black & white
b) Wide variety of sizes available
c) Infrared capability

DO YOU KNOW?

How Neon Lamps work!!!

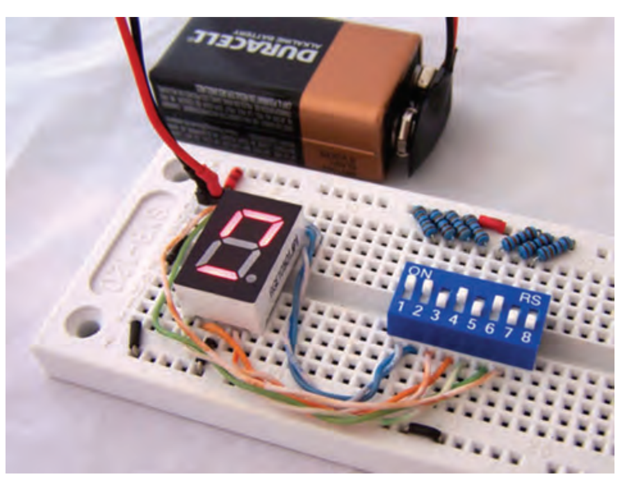
When an electric voltage is applied to the terminals (about 15,000 volts), enough energy is supplied to remove an outer electron from the neon atoms. If there is not enough voltage, there will not be enough kinetic energy for the electrons to escape their atoms and nothing will happen. The positively charged neon atoms (cations) are attracted to the negative terminal, while the free electrons are attracted to the positive terminal. These charged particles, called plasma, complete the electric circuit of the lamp

GLOSSARY

Atomic Structure	—	அணு அமைப்பு
Valance Electron	—	இணைதிறன் எலக்ட்ரான்
Free Electron	—	கட்டுறா எலக்ட்ரான்
Energy Band	—	ஆற்றல் நிலைகள்
Impurity	—	மாசு
Forward Bias	—	முன்னோக்கு சார்பு
Reverse Bias	—	பின்னோக்கு சார்பு
Emitter	—	உமிழ்வான்
Collector	—	ஏற்பான்
Base	—	அடிவாய்
Depletion Layer	—	சிதைவு அடுக்கு
Filter Circuit	—	வடிப்பான் சுற்று
LED – Light Emitting Diode	—	ஒளி உமிழும் டையோடு
LCD – Liquid Crystal Diode	—	திரவ படிக காட்சிதிரை

Activities

1. How to test the effectiveness of the battery by LED?
2. Identify the types of the transistor using multimeter.
3. Test the LED 7- segment display using the following picture.



Q A

PART A

SV37BK

Mark 1

Choose the Correct Answer:

1. An atom consist of
   a) Proton
   b) Neutron
   c) Electron
   d) All of the above
2. The number of electrons in any orbit is calculated by the Formula
   a) 2n
   b) $2n^2$
   c) $2n^3$
   d) n^2
3. In half wave rectifiers, the number of diodes used as
   a) One
   b) Two
   c) Three
   d) Four
4. In bridge rectifier, the number of diodes used as
   a) 1
   b) 2
   c) 4
   d) 3
5. Filter circuit is used to remove
   a) dc components
   b) ac components
   c) combination of these two
   d) none of these
6. In forward biasing, the emitter current in npn transistor is
   a) I_B
   b) I_C
   c) I_B+I_C
   d) none of these
7. The number of segments in seven segment display is
   a) 6
   b) 5
   c) 7
   d) 3

Q A

PART B

Mark 3

Answer the Questions in briefly

1. What is called atom?
2. What are the types of rectifiers?
3. What are the different types of CCTV camera?

Q A

PART C

Mark 5

Answer the following questions not exceeding one page

1. Briefly Explain "Atomic Structure".
2. Explain the use of Filter circuits.

Q A

PART D

Mark 10

Answer the following questions not exceeding two page

1. Explain half-wave rectifier with neat circuit diagram.
2. Explain full-wave bridge rectifier with neat circuit diagram.
3. Explain the operation of Zener diode.
4. Explain the working of pnp transistor.
5. Explain the working of npn transistor.
6. What are the advantages of using (i) LED (ii) LCD?
7. Explain seven segment display with diagram.

Reference Books

1. 'A text book of Electrical Technology' Volume I and Volume IV by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.
2. Principles of Electronics by V.K. MEHTA and SHALU MEHTA, S. Chand & Company Ltd.

MODEL QUESTION PAPER

Basic Electrical Engineering Theory

TIME: 3.30 hrs **STD:11th** **MARKS:90**

QA

PART A

Mark 1

Choose the correct answer:

1. In case of electric fire use
   a) dry sand
   b) wet sand
   c) carbon powder
   d) water
2. Good conductor has a property of
   a) low resistance
   b) high resistance
   c) medium of these two
   d) none of these
3. According to ohm's law I is equal to
   a) V^2/R
   b) I^2/R
   c) V/I
   d) V/R
4. The permanent magnet is not used in
   a) horse shoes magnet
   b) energy meters
   c) transformers
   d) loud speaker
5. Which magnetic field is like a magnetic field of a bar magnet?
   a) Current carrying wire
   b) Current carrying ring
   c) Current carrying solenoid
   d) Current carrying rectangular bar
6. Charging and discharging process in secondary cell is by which law?
   a) Ohms law
   b) Faradays laws of electrolysis
   c) Lenz's law
   d) Current law
7. Advantage of using lithium-ion battery is
   a) high energy density
   b) low energy density
   c) medium energy density
   d) poor energy density
8. Digital energy meters is used for the following reason
   a) High accuracy
   b) Small size
   c) Long life
   d) All the above
9. Transformer operates on the principle of
   a) self-induction
   b) mutual induction
   c) ohm's law
   d) len's law
10. The function of DC machine is of
    a) Fleming's left-hand rule
    b) Fleming's right hand rule
    c) Faraday's law
    d) Krichhoff's law

11. Which type of rotor is used for very high speed in alternators?
    a) Salient pole type
    b) Smooth cylindrical type
    c) Squirrel cage type
    d) None of the above
12. One horse power is equal to
    a) 736 watts
    b) 756 watts
    c) 746 watts
    d) 766 watts
13. Which one of the following is an organic material
    a) Zinc
    b) Iron
    c) Silicon carbide
    d) Wood
14. The number of electrons in any orbit is calculated by the formula
    a) 2n
    b) $2n^2$
    c) $2n^3$
    d) n^2
15. The Camera which covers a distance of more than 40 feet is
    a) Dome Camera
    b) Bullet Camera
    c) C Mount Camera
    d) Day/Night Camera

Q A

PART B

Mark 3

Answer the Questions in briefly

1) What are the methods used for production of electricity?
2) Define ohm's law?
3) Two resistance 3Ω and 6Ω are connected in parallel voltage of the circuit in 240V. Find the value of total resistance?
4) What is electro magnetism?
5) Define End Rule?
6) Write short notes on UPS Battery?
7) Define effective value or RMS value?
8) What are the protective devices of transformer?
9) State Fleming's left hand rule?
10) Why single phase motor is not a self-starting?
11) State the factor to be considered for the selection of materials for engineering applications?
12) What are the different types of CCTV camera?

Q A

PART C

Mark 5

Answer the Questions not Exceeding one page

1. Explain the method of preventing an electric shock?
2. Explain the properties of a conductor?
3. Compare magnetic and electric circuit.
4. What are the advantages of digital energy meter?
5. Explain about auto transformer?
6. What are the types of single phase motor?
7. Explain the various properties of engineering materials?

Q A

PART D

Mark 10

Answer the Questions not Exceeding two page

1. Explain the Kirchoff's laws?
   (or)
   Explain in detail about Lithium ion battery with diagram?
2. Explain the process of emf generation in DC generators?
   (or)
   Explain Half-wave rectifier with neat circuit diagram.

Basic Electrical Engineering

PRACTICAL

CONTENTS

CLASS XI

1 STUDY OF HAND TOOLS FOR WIRING

Aim

Usually, in the field of electricity, so many electric tools (both hand and machine tools) are now-a-days being utilised. A person becomes more efficient, when he knows the proper way of handling the tools. In domestic side, repairs, maintenance and electrical wiring work, various types of hand tools are used. In this topic, Line diagram is given to know about the study of hand tools for wiring purpose.

Cutting Plier

Uses

It is made up of forged steel and is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work. Non-insulated plier is also available. Insulated pliers are used for work on live lines.

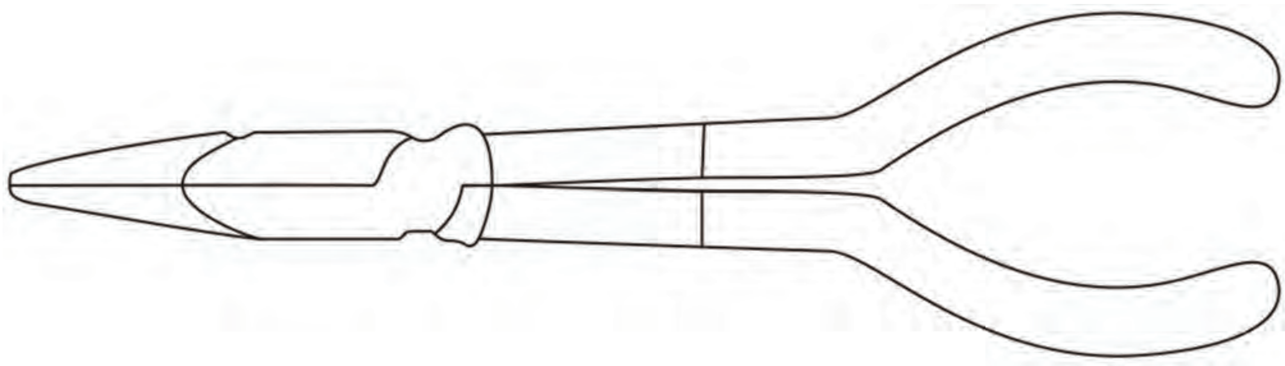
They are specified with their overall dimensions of length in mm. Mostly, the pliers used for electrical work will be of insulated grip.

Long Nose Pliers

Uses

Long nose pliers are used for holding small objects in places where fingers cannot reach.

Round Nose Plier



Uses

Wire hooks and loops could be made using the round nose pliers.

Cutter

Uses

It is used for cutting copper or aluminium wires having smaller diameter.

Care and Maintenance of Pliers

1. Do not use pliers as hammers.
2. Do not use pliers to cut large size of copper or aluminium wires and hard steel wires of any size.
3. While using the pliers avoid damage to the insulation of hand grips.
4. Lubricate hinged portions.

Screw Driver

Uses

Screw drivers are used for tightening or loosing screws. The screw driver tip should snugly fit the grooves of the screw to have maximum efficiency and to avoid damage of the screw heads. The screw driver is used for electrical works, generally have plastic handles and the stem is covered with insulating sleeves. As the length of the screw driver is proportional to the turning force, for small work choose a suitable small sized screw driver.

Electrician Knife

Uses

It is used for removing the insulation of cables and cleaning the wire surface. One of the blade having sharp edge is used for skinning the cable and rough edged blade is used for cleaning the surface of wires.

Line Tester

Uses

It consists of a glass tube filled with neon gas and electrodes at the ends. To limit the current within 300 micro- amps at the maximum voltages, a high value resistance is connected in series with one of the electrode. It may have tip like probe or like screw driver at one end. The presence of supply is indicated by the glow of the lamp. When the tip is touched on the live supply and the brass contact in the other end of neon tester is touched by hand, then completes the circuit and the neon bulb will glow.

Ball Peen Hammer

Uses

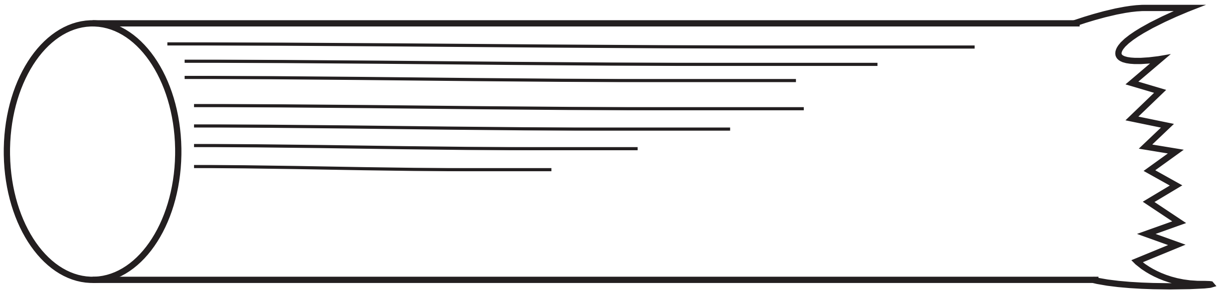
The hammer is made up of special steel and the striking face is tempered and is used for nailing, straightening and bending work. The handle is made up of hard wood.

Rawl Jumper

Uses

A rawl plug tool has two parts, namely the tool bit and holder. The tool bit is made of tool steel the holder is made of mild steel. It is used for making holes in bricks, concrete wall and ceiling. Rawl plugs are inserted in them to fix accessories.

Pipe Jumper



Uses

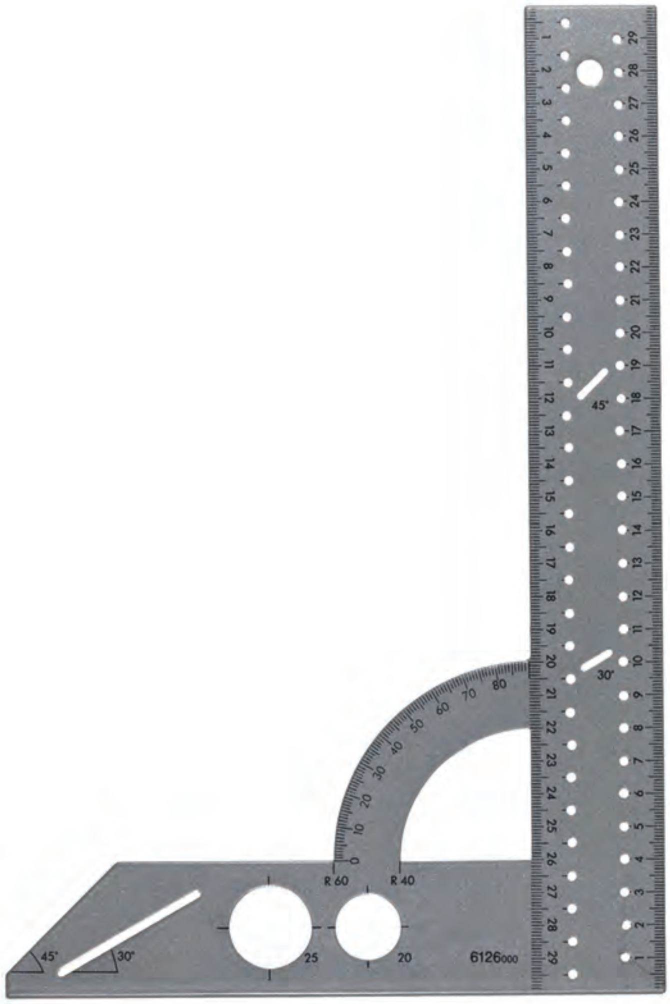
A pipe jumper is used along with a hammer to make holes in wall which is required for wiring. The diameter of the pipe jumper depends upon the diameter of the pipe to be accommodated in wall, and the length depends upon the wall thickness.

Mallet

Uses

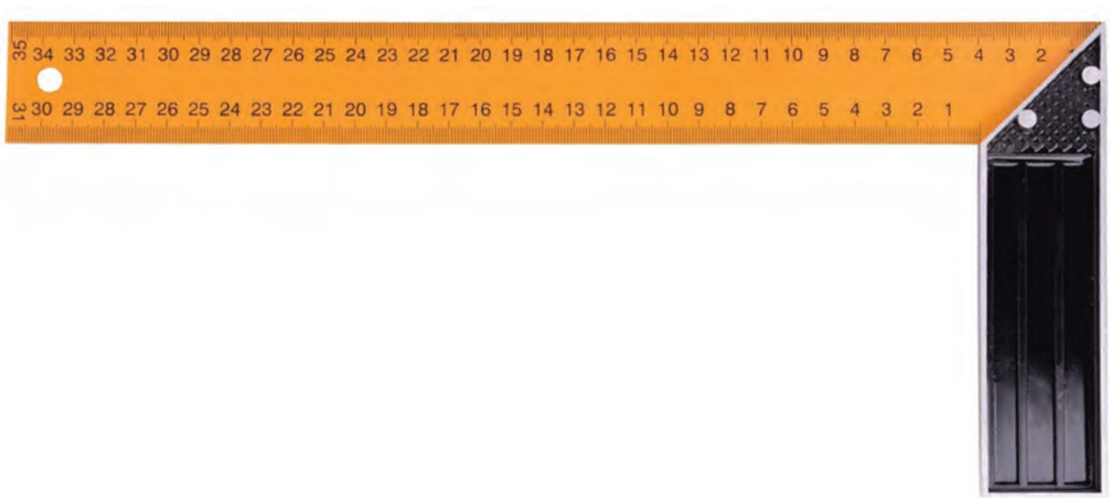
It is made up of hard wood or nylon. It is used for driving the firmer chisel for straightening and bending of thin metallic sheets. Also it is used in motor assembly work.

Try Square



Uses

It is used to check whether the object is plane, perpendicular or at right angle. Two straight blades set at right angle to each other constitute the try square. The steel blade is riveted to the stock. The stock is made up of cast iron. The stock should be set against the edge of the job.



Measuring Steel Tape

Uses

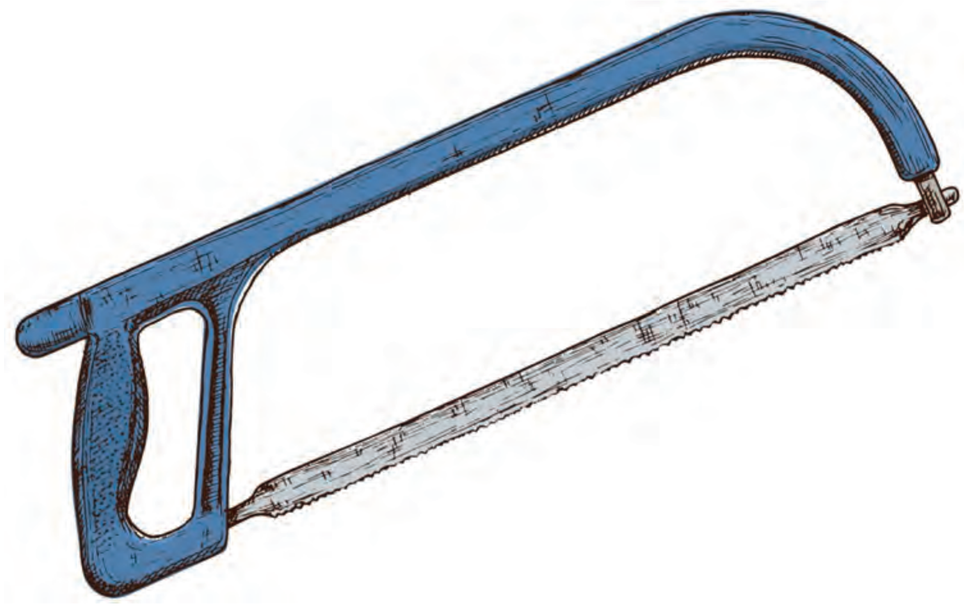
The measuring tape is made up of thin steel blade, bearing dimensions on it. It is used for measuring the dimension of the wiring installation and general measurements.

Hacksaw

Uses

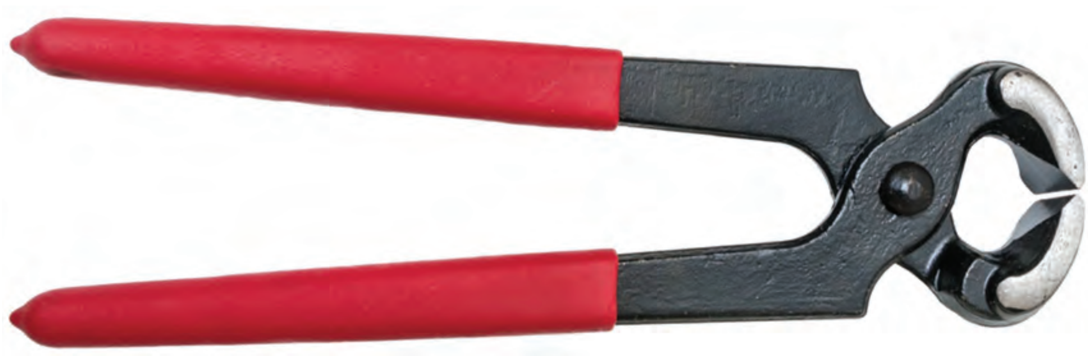
It is made up of a sturdy nickel plated steel frame. The frame can be adjusted between 250mm to 300mm blades. It should be fixed on the frame with its teeth pointing away from the handle in order to the cutting in forward stroke. It is mainly wood saw (or) tenon saw.

Generally the length of a tenon saw is 250 to 300mm and has 8 to 12 teeth per 25.4mm and the blade with 10cm. It is used for cutting thin, wooden accessories like wooden batten, casing capping, boards and round blocks.



Pincers

Uses



It is used for extracting nails from the wood. The size is given by its length, e.g. 100mm, 150 mm and 200 mm.

Firmer Chisel

Uses

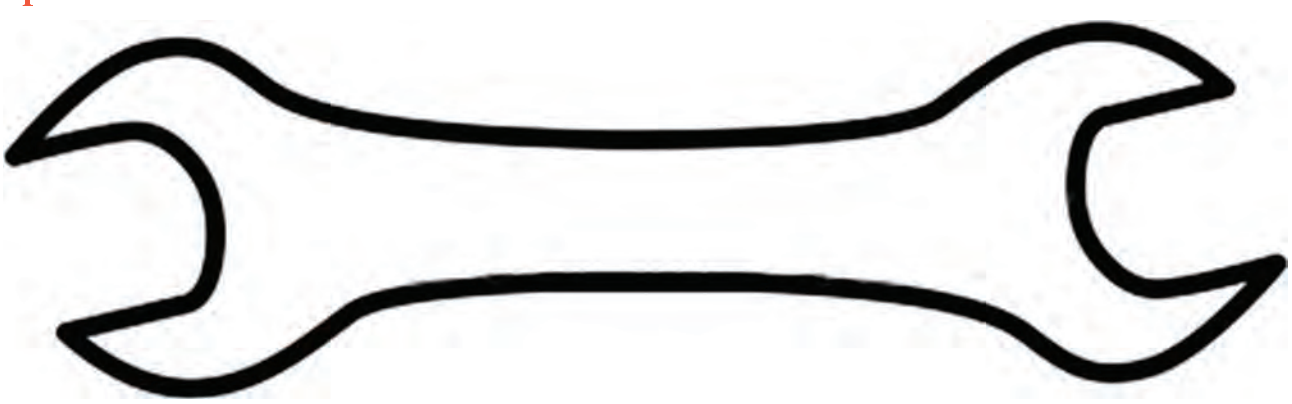
It has a wooden handle and a cast steel blade of 150mm length. It's size is measured according to the width of the blade, e.g: 6 mm, 12 mm, 18 mm or 25 mm. It is used for chipping, scrapping and grooving in wood.

Poker

Uses

It is a long sharp tool used for making pilot holes on wooden articles to fix screws.

Spanner - Double Ended



Uses

The size of a spanner is indicated so as to fit on the nuts. They are available in many sizes and sharps.

The sizes indicated in double- ended spanners are

10 – 11 mm

12 – 13 mm

14 – 15 mm

16 – 17 mm

18 – 19 mm

20 – 21 mm

Spanner sets are used for loosening and tightening of nuts and bolts. It is made of cast steel. They are available in many sizes and may have single or double ends.

Ring Spanner

Uses

The ring spanner is used in place where the space is restricted.

Centre Punch

Uses

The size of the centre punch is given by its length and diameter of body, e.g: 100×8 mm. The angle of tip of the centre punch is 90°.It is used for making and punching pilot holes on metals. It is made of steel and the ends are hardened and tempered.

Hand Drill

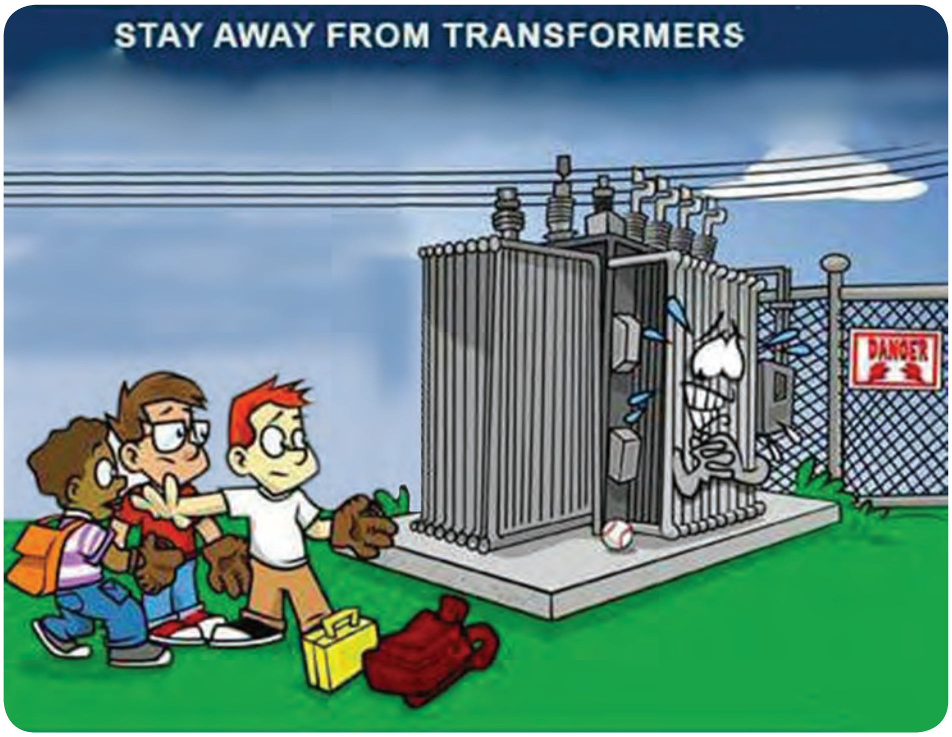
Uses

A hand drill machine is used for making holes in thin metal sheets or wooden articles.

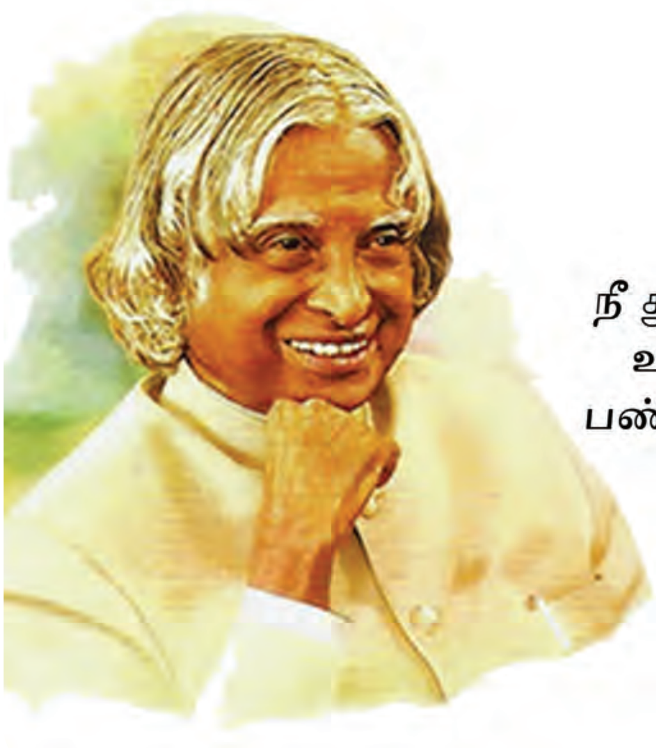
Electric Drill

Uses

When power is available, power drilling machine is more convenient and an accurate tool for drilling holes on wooden and metal articles.


STAY AWAY FROM TRANSFORMERS
DANGER

2 HOUSE WIRING AND ELECTRICAL SAFETY RULES



கனவு காணுங்கள்.
ஆனால்,
கனவு என்பது
நீ தூக்கத்தில் காண்பது அல்ல.
உன்னைத் தூங்கவிடாமல்
பண்ணுவது எதுவோ, அதுவே
இலட்சிய கனவு.

– அப்துல் கலாம்

Aim

To study the basic components of house wiring, safety devices, house wiring rules as per ISI-specification and safety measures of electrical wiring.

Components of Basic Electrical Wiring

Besides safety precautions and regulations, the main thing want to familiarise the design of house wiring. It consists of three basic components:

- **Service Entry**

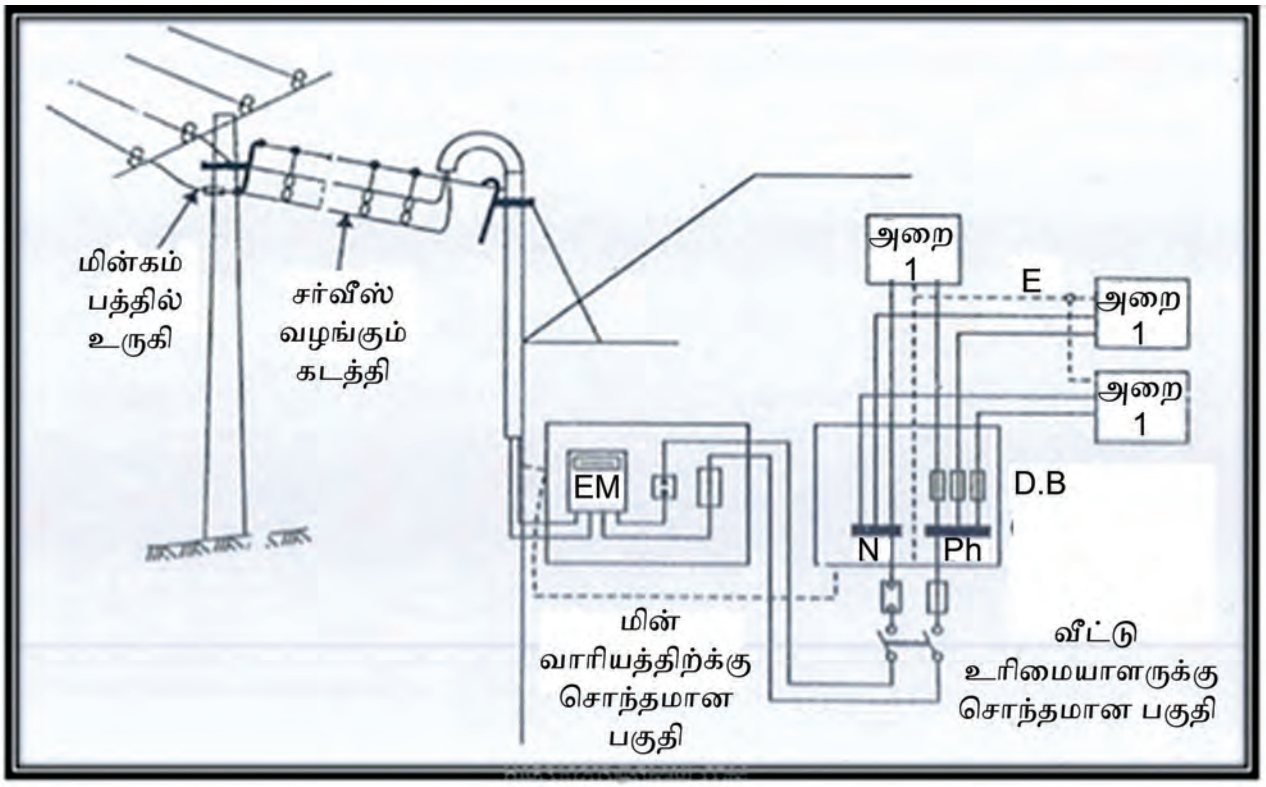
This refers to service wire (which brings power supply) from the main grid or pole to house and the Energy meter. The service entry is critical and there are a few things to keep in mind. First of all, make sure all service line are at least 10 feet above the ground, inaccessible from windows, and free of obstructions such as tree limbs. Besides that, make sure your service entry is properly installed so that no water can penetrate the access point or meter. Any changes or fault rectification in this area must be done by the service provider i.e, T.N.E.B.

- **Panel Board**

Panel board is the control centre for electrical wiring. It consists of Main switch and Distribution fuse board. Now-a-days new safety devices Double Pole MCB instead of Main Switch and Single Pole MCB instead of distribution fuse were used. While installing an Air conditioner, Heater, Washing machine or running wiring to a new addition, ensure electricity is switched off before starting the work, and where you install new breakers.

- **Branch Circuits**

Calculate total load of various electric points used in house, and the wiring should be carried out on distribution systems with branch circuits. Each branch circuit must have light circuits not exceeding 10 points or 800 watts, if power wiring circuit not more than 2 points and AC 1 point. This refers to isolate the areas of house from panel board. For instance, you cut power to your kitchen while the rest of the house is in operation.



Line Diagram of Service Line to Main Switch Connection

Safety Devices

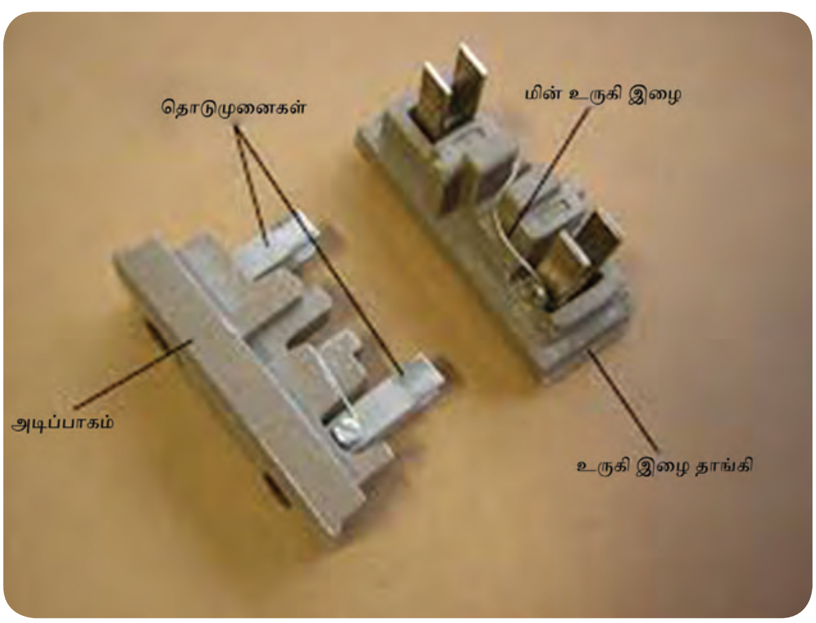
Fuse

Fuse and circuit breaker prevent overheating of wires and protect all electrical equipments. If the current through fuse is greater than its specified rating, it gets fused. This breaks the circuit and stops the current, making the equipment safe.

Safety points regarding fuse are:

- Always use the correct rating of fuse. For example, if the circuit is of 10 Amp capacity, the fuse rating must be 150% i.e. 15 amp.
- Always use the correct size of fuse, keep the old one to check.
- Never replace the fuse with bare wire.It will not be safe.
- Do not increase the fuse capacity for preventing or eliminating frequent fuse blow-ups. Instead it is essential to locate the causes and eliminate the same.
- Circuit Breakers are fuses that have buttons or switches for reset.Thus they do not normally need replacing.

Wiring of the Distribution Board with RCD (Single Phase Consumer Unit)
(From Energy Meter to the Main Distribution Board)



Miniature Circuit Breakers (MCB)

Miniature Circuit Breakers are gaining increasing prominence in household, labs and distribution wiring in shops & commercial establishments. MCB is an electromagnetic device that embodies complete enclosure in a moulded insulating material. MCB works as circuit breaker in case of overload/short circuit. It has an advantage since no replacement is required and it can be reset on elimination of fault and switched ON again. The main function of an MCB is to switch the circuit, i.e., to open the circuit (which has been connected to it) automatically when the current passing through MCB exceeds the value for which it is set. It can be manually switched ON and OFF as similar to normal switch if necessary. MCBs are of time delay tripping devices, to which the magnitude of over current controls the operating time. This means, these get operated whenever overload exist long enough to create a danger to the circuit being protected. Therefore, MCBs doesn't respond to transient loads and motor starting currents. Generally, these are designed to operate within 2.5 milli seconds during short circuit faults and 2 seconds to 2 minutes in case of overloads (depending on the level of current). MCBs characteristics are:

- Rated current up to 100 A
- Trip characteristics are not normally adjustable
- Thermal or Thermal-Magnetic operation

MCB Type	Minimum Trip Current	Maximum Trip Current
Type B	3 Ir	5 Ir
Type C	5 Ir	10 Ir
Type D	10 Ir	20 Ir

MCCBs

Moulded Case Circuit Breakers are used for commercial purposes. Its characteristics are:

- Rated current up to 1000 A
- Trip current may be adjustable
- Thermal or Thermal-Magnetic operation

ELCBs

Earth Leakage Circuit Breaker works as a circuit breaker in case of only earth leakage.

- Phase (Line), Neutral and Earth wire are connected through ELCB
- ELCB is working based on earth leakage current.

RCD/RCCB

Residual Current Device (RCD)/Residual Current Circuit Breaker(RCCB) which works as a circuit breaker in case of an earth leakage, over load or short circuit. It is used for protection against electric shocks.

It's Characteristics:

- Phase (Line) and Neutral both wires are connected through RCD.
- It trips the circuit when an earth fault occurs.
- The amount of current flowing through the phase should return through neutral.Any mismatch between two currents flowing through phase and neutral is detected by RCD and trips the circuit within 30 milliseconds.
- RCDs are an extremely effective form of shock protection.

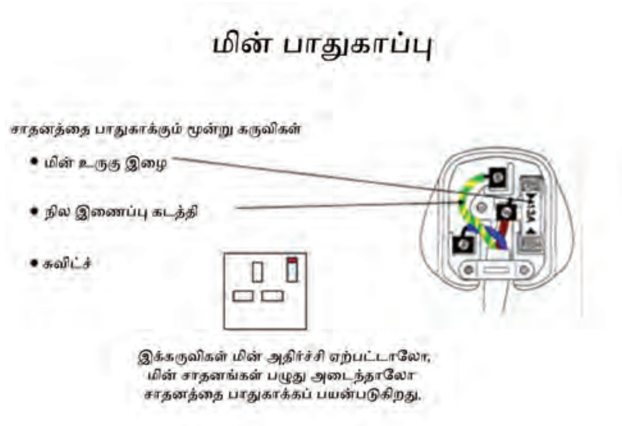
House Wiring Rules as Per ISI Specification

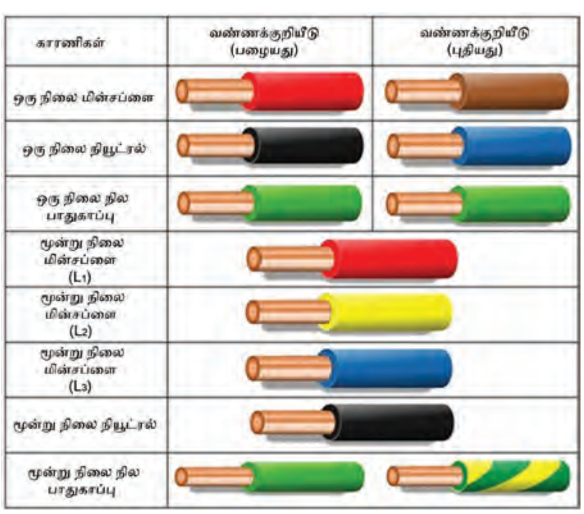
In construction of a house, the owner should focus on electric works, which need a lot of attention while laying wiring as well as quality of wiring, specification of electric appliances and cables/wires. Always plan to work exactly where the outlets, switches and fixtures are going to be placed. This also allows to check the appropriate tools and materials are in sufficient quality. Calculate the total load from various items that would be used in the house and select the proper conductor that is capable of withholding the total load and distribute accordingly.

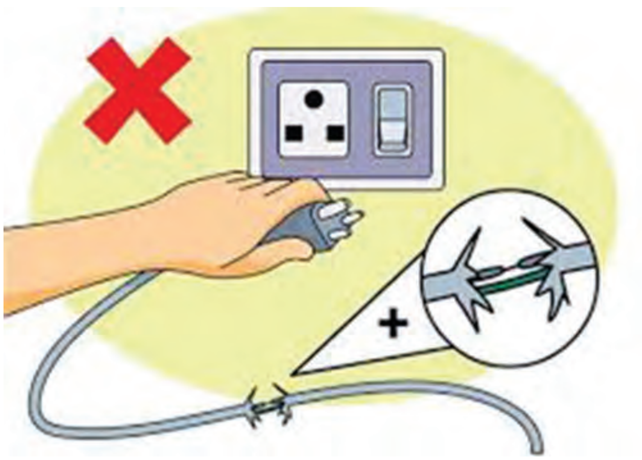
Care should be taken while fitting pipes, junction boxes, fan hook boxes in RCC slab and walls. If any fault happens, it may cause any incident and may require dismantling of the defective portion. So take proper care to avoid dismantling which is very costly in comparison to get them fixed properly earlier. To avoid an electric shock, the following precautions must be kept in mind.Therefore the following rules laid down by the Indian Standard Institution should be followed. Few of them are listed below for your guidance.

- The wiring should be carried out on distribution systems with main and branch distribution boards.
- All conductors should run along walls and ceiling, so that they are easily accessible and capable of being thoroughly inspected. In any case, wiring should not be run above ceiling.
- Horizontal run of wiring should be at a height of 3 metre.Switch Boards should be fitted at a height of 1.5 metre.
- Fuse wire should be connected with phase only. Connect all switches with phase wire. Connect the neutral link in neutral wire.
- One circuit means, one connection from electrical meter or main fuse board.The number of points in light circuit should not exceed 10 (or) total load on circuit should not exceed 800 Watts.
- All conductors should be made of copper and should be stranded. They should have a cross section less than 0.002 square inches, nominal area (3/0.029 inches).
- For Power wiring circuit, the size of wire should be 1.5 mm square for copper and 2 mm square for aluminium.[One power circuit = (three 5 amp socket) or (two 15 amp socket) or (one 15 amp socket + two 5 amp socket) or (one Alternating current circuit)]
- Never use damaged insulation, for wiring. It avoid short circuit and overloading, with the use of MCB and save the electrical appliances.
- Burnt element, cut/broken wiring, loose/open connection should be avoided.
- Earthing means to connect electrical system to general mass of earth to ensure immediate discharge of electrical energy without danger. Provide earth connection to enhance voltage and protect human beings from sudden electric shock.Earth wire should be 14 SWG in case of copper and 4 mm square in case of Aluminium.

- All materials used in electrical fitting should be of approved quality of make and from a reputed manufacturer as per ISI specification.
- For low power operations 5 Ampere small size sockets, and for heavy power operations 15 ampere large size sockets should be used. Multi-plug adaptors are used for temporary usage only i.e., for a short period of time. No socket or extension box should be overloaded.
- Most of the imported equipments function in two different settings 110-120V and 220-240V. These equipments have switch for setting the input supply voltage. Hence, make sure that the switch in equipment is in 220-240V position.
- The wiring of a plug is colour coded to help guard against electrical accidents. The colour codes in India as per Indian Electricity Rules are: Phase (Line) is Red, Blue or Yellow, Neutral is Black and Earth (Ground) Green or Green with Yellow lines.
- If there are only two wires in the power cable, no earth connection is required. If there are three conductors then the equipment needs to be earthed properly.
- Always make sure that the earth wire is longer than the other two so that if the cable is accidently pulled out of the plug, the earth wire is the last wire to become disconnected.







Safe Work Practices

While operating the electrical circuits and handling the hand tools, the following safety measures should be taken.

1. **Avoid** contact with energized electrical circuits.
2. **Disconnect** the power source before servicing or repairing electrical equipment. Leave a note that you are working. Tape the circuit breaker in OFF position (or) Pull the fuse carrier, while working.
3. Use **Tester** to make sure of electrical connection is live or not. Even though fuse is pulled there may be supply from U.P.S or Auto Generator. So ensure it carefully.
4. Use **tools** and equipment only with insulated handles when working on electrical devices. Make sure that all the tools are provided before commencing the wiring. Example are Tester, Cutting plier, Screw driver, Hammer, Jumper, Electric Drill, Colour insulation tapes, Wire Stripper etc.,
5. Never use metallic pencils or rulers, or wear rings or metal watchbands when doing work with electrical equipment.

6. When it is necessary to handle equipment that is plugged in, be sure hands are dry and when possible wear non conductive **gloves & shoes** with rubber soles.
7. If it is safe to do so, work with only **one hand**, keeping the other hand at your side or in your pocket, away from all conductive material.
8. Equipment producing a **"tingle"** should be disconnected and reported promptly for repair.
9. **Drain capacitors** before working near them and keep the short circuit on the terminals during the work to avoid electrical shock.
10. When it is necessary to touch electrical equipment (*for example, when checking for overheated motors*), use the back of the hand. Thus, if accidental shock were to cause muscular contraction, you would not "freeze" to the conductor.
11. Do not rely on grounding to mask a defective circuit nor attempt to correct a fault by inserting another fuse or circuit breaker, particularly one of a larger capacity. Before replacing a fuse or circuit breaker, **check the problem** that caused earlier was rectified.
12. **Insulate** all electric contacts and conductors. Never splice wires together and conceal them within a wall without a junction box. An accessible junction box should always be used to join wires.
13. Never use an aluminium or steel ladder while working on any receptacle at height in your home. An electrical surge will ground and the whole electric current will pass through the body. Use only bamboo, wooden or a fibre glass ladder for electrification work.
14. Do not store **highly flammable liquids** near electric supply.
15. Minimize the use of electrical equipment in cold rooms or other areas where condensation is likely.
16. Keep the length of **extension cords** to restricted length.
17. **Unplug** cords by gripping the plug and, do not by pulling the cord.
18. **Do not wear** loosed clothing or ties near electrical equipment.
19. If a person was affected by an electric shock, immediately disconnect the power source of the circuit breaker or pull out the plug using a leather belt.
20. Never work on **live** equipment.
21. **De-energize** open experimental circuits and equipment to be left unattended.
22. Never use equipment with frayed cords, damaged insulation or broken plugs.
23. Be aware that interlocks on equipment disconnect the high voltage source when a cabinet door is open, but the power for control circuits may remain ON.
24. Try to cover the live wire with cap while working on circuit panels. The cap acts as an insulation and helps to prevent electric shock.

3 VERIFICATION OF OHM'S LAW

> நேரம்
> எப்போதும்
> உனக்காக
> காத்திருக்காது.

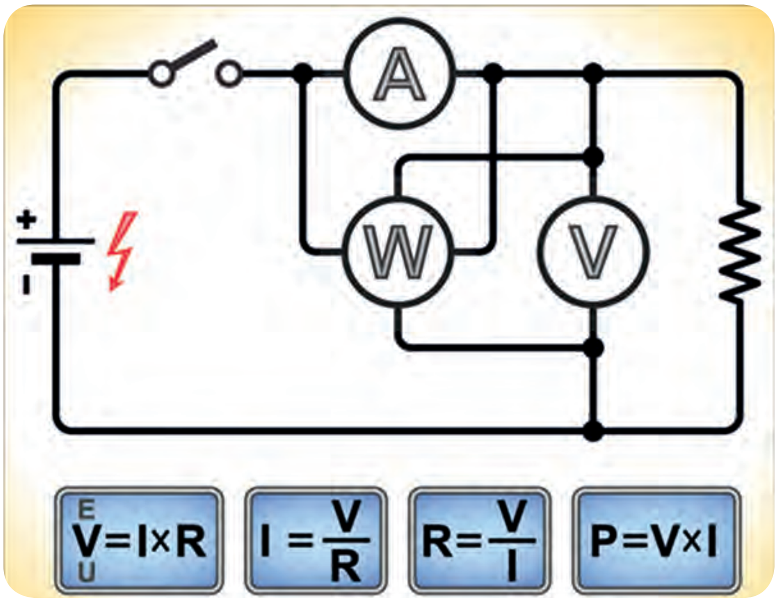
Aim

To determine the resistance value of two given coils of wire by using Ohm's Law.

Apparatus Required

S No	Name	Quantity
1	Battery -12V	1
2	Plug Key	1
3	Rheostat	1
4	Resistances	2
5	Voltmeter - 0-10V	1
6	Ammeter - 0-1A	1
7	Connecting Wires or Cord	As Required

Connection Diagram



Ohm's Law

At constant temperature, the current flowing through the conductor is directly proportional to the voltage across it and inversely proportional to the resistance of the conductor.

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

$$V = I \times R$$

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

Where

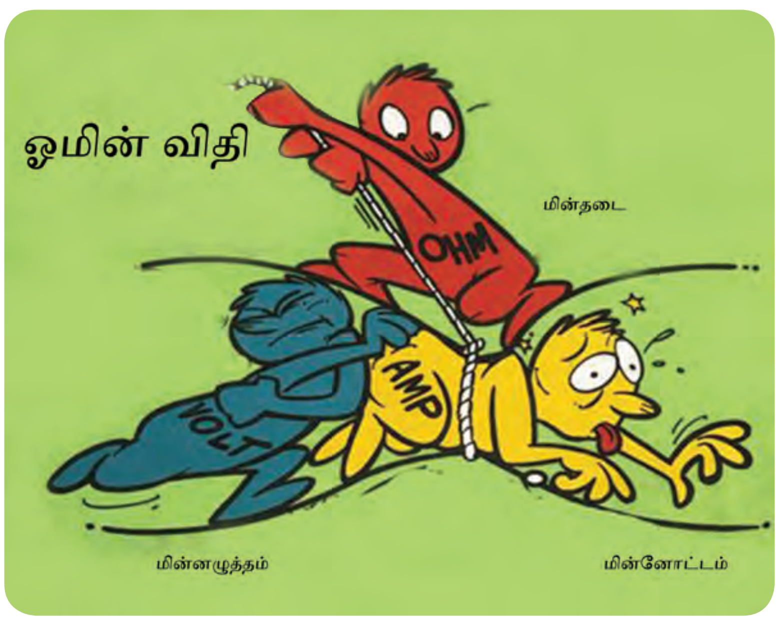
V= Voltage in volts

I = Current in amps

R = Resistance in ohms

Procedure

- The first coil R_1 is connected as shown in the circuit diagram.
- After checking the connection, close the plug key.
- Adjust the rheostat.
- The corresponding voltmeter and ammeter readings are noted and are tabulated.
- By using the formula $R_1 = \frac{V}{I}$, the value of resistance is determined.
- Similarly, the second coil R_2 is connected as shown in the circuit diagram.
- After checking the connection, close the plug key.
- Adjust the rheostat.
- The corresponding voltmeter and ammeter readings are noted and are tabulated.
- By using the formula $R_2 = \frac{V}{I}$, the value of resistance is determined.



To Find R_1

S No	Ammeter reading 'I' in ampere	Voltmeter reading in 'V' volts	Resistance $R_1 = \frac{V}{I}$ Ohms
1.			
2.			
3.			
4.			
5.			

Mean R_1 = _______________

To Find R_2

S No	Ammeter Reading 'I' in ampere	Voltmeter reading in 'V' volts	Resistance $R_2 = \frac{V}{I}$ Ohms
1.			
2.			
3.			
4.			
5.			

Mean R_2= _______________

Result

The resistance of two coils of wire R_1 = ____________________Ohm

R_2 = ____________________Ohm

4

PREPARATION OF APPLIANCES TEST BOARD

நீ எப்பொழுதும்
நல்லதையே செய்.
எதை நீ
விதைக்கிறாயோ,
அதையே பின்பு
அறுவடை செய்வாய்.

Aim

To learn and to prepare an appliances test board and also know, how to test domestic appliances using it.

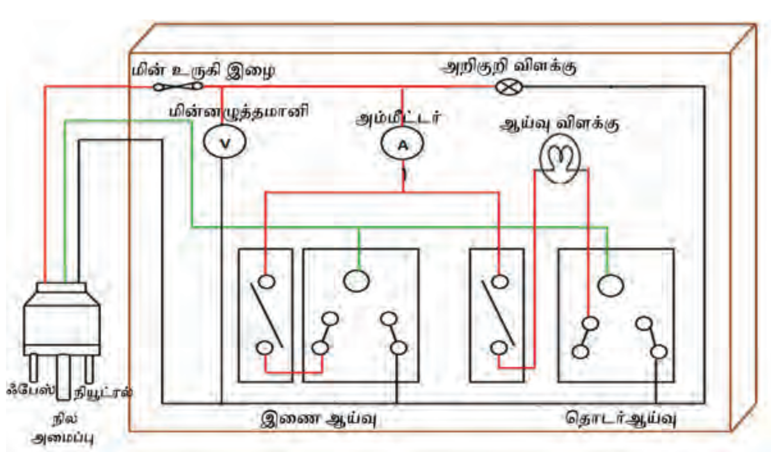
Tools Required

S.No	Name	Quantity
1	Screw Driver	1
2	Cutting Plier	1
3	Tester	1
4	Electrician Knife	1
5	Poker	1
6	Drilling Machine	1
7	Ball Peen Hammer	1
8	Hacksaw Frame	1

Materials Required

S.No	Name	Quantity
1	Wooden Board -12" × 18"	1
2	Fuse Unit - 16A, 240V	1
3	Ammeter - 0-5A	1
4	Voltmeter - 0-300V	1
5	Lamp - 200W	1
6	Three Core Power Cord	5 metre
7	1/18 Copper Wire	3 metre
8	Indicating Lamp	1
9	Lamp Holder	1
10	One Way Switch	2
11	Five Pin Socket	2
12	Three Pin Plug 16A, 240V	1

Connection Diagram



Test Board

Connection Procedure

1. Provide holes in the wooden board at the required places wherever necessary.
2. Fix the switches, socket, fuse indicator, ammeter and voltmeter properly.
3. Give connection to all accessories as per the connection diagram.
4. Connect the power cord properly.

Testing Procedure

1. Connect the given appliances to the test lamp by series.
2. Lamp lighting and faults

S No	Lamp Lighting	Fault
1	Glows Dimly	No fault. Appliance "Good".
2	Glows Brightly	Short circuit fault
3	If not Glow	Open circuit fault

3. After rectifying all the faults, connect the appliance parallel to the supply and find out the value of current and voltage

   1 Current = ___________

   2 Voltage = ___________

Result

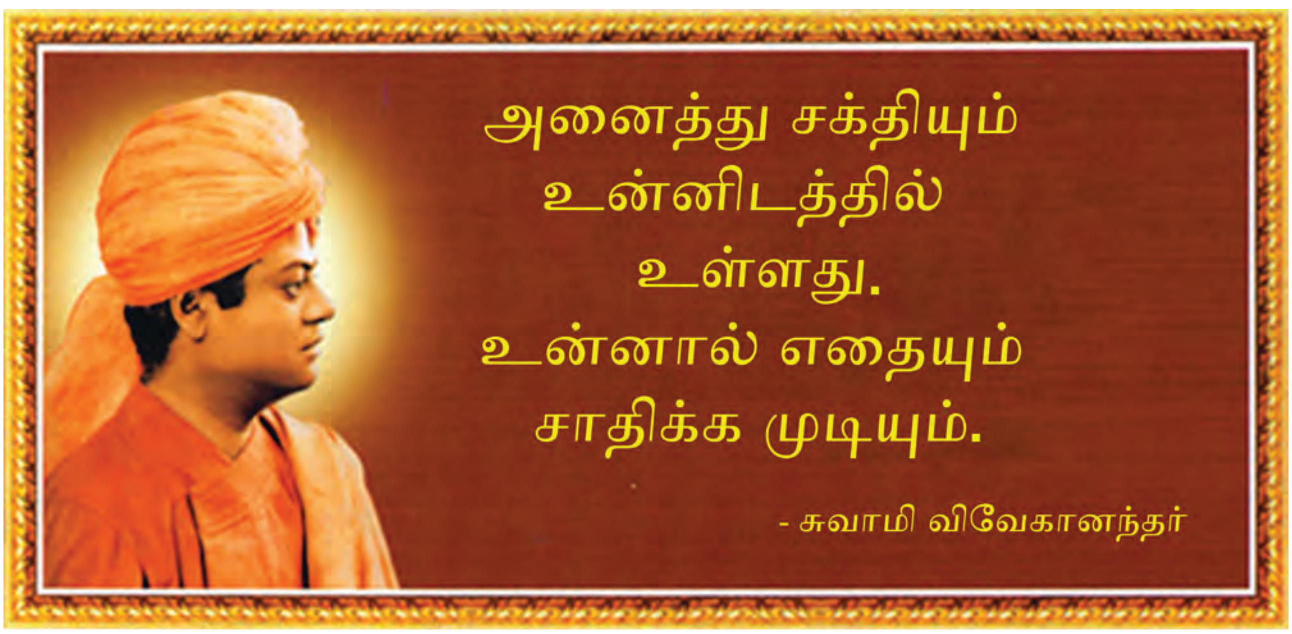
I have known the method of preparing an appliances test board and also known the method of testing all the appliances by using test appliance board.

And also I have measured the value of current and voltage by ammeter and voltmeter respectively. The value of

1. Current = ___________
2. Voltage = ___________

5

ONE LAMP CONTROLLED BY A REGULATOR



Aim

To learn about one lamp controlled by one regulator in various position.

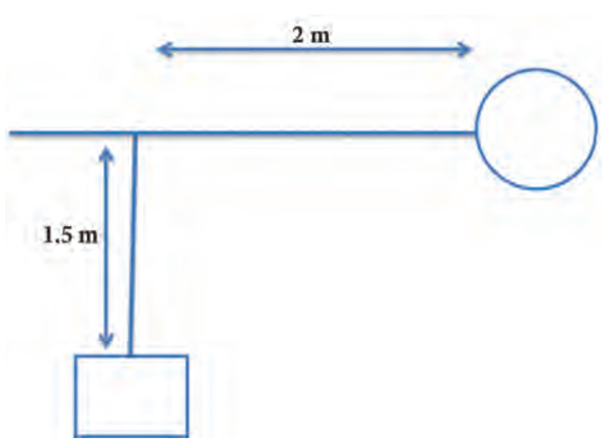
Tools Required

S No	Name	Quantity
1	Screw Driver	1
2	Cutting Plier	1
3	Tester	1
4	Electrician Knife	1
5	Poker	1
6	Drilling Machine	1
7	Ball Peen Hammer	1
8	Hacksaw Frame	1
9	Measurement Tape	1
10	Try Square	1

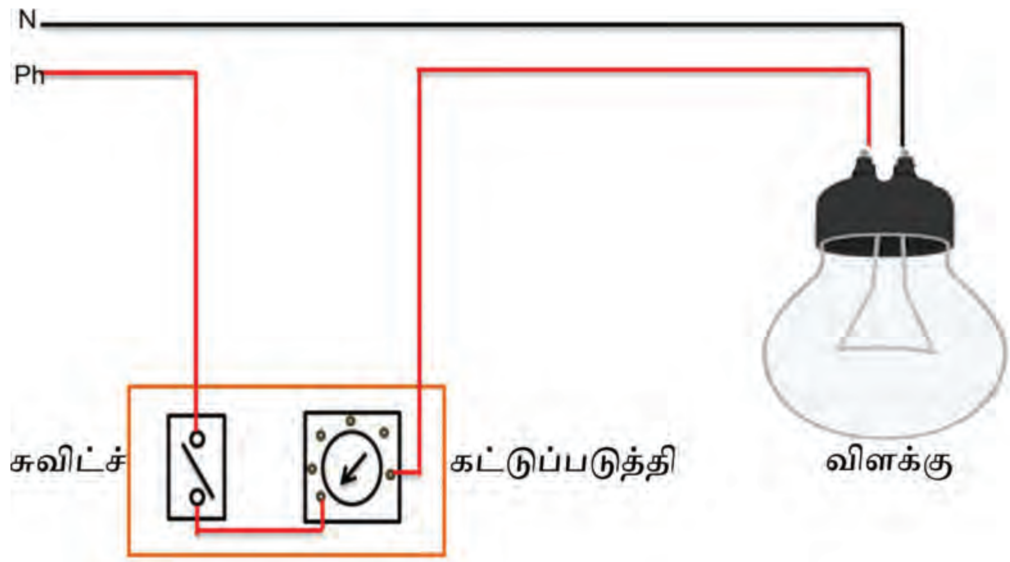
Materials Required

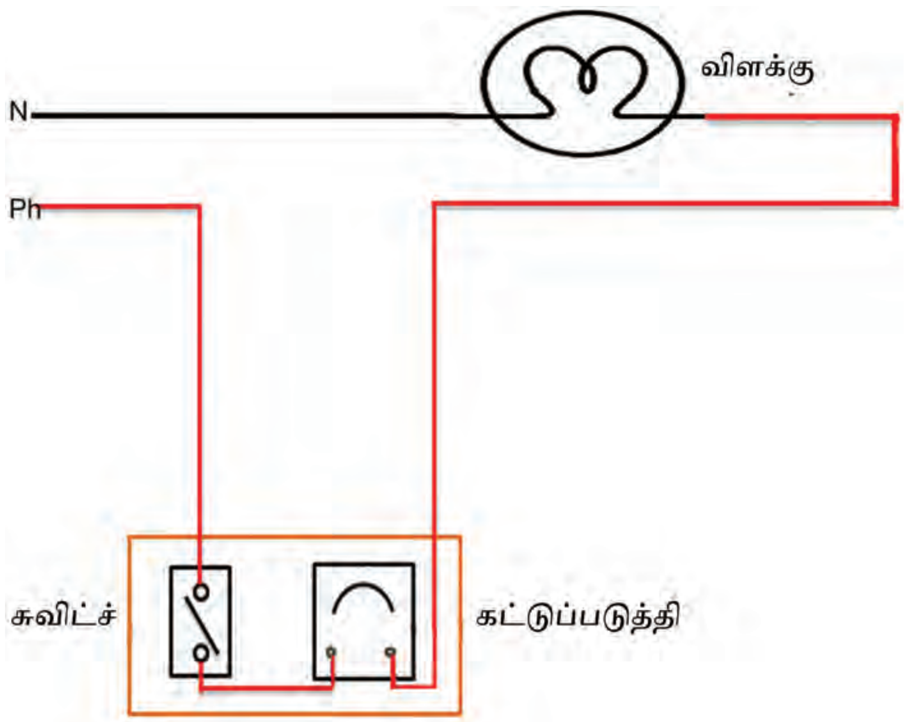
S No	Name	Quantity
1	Wooden Board - 3" × 4"	1
2	3/4" P.V.C Pipe	1 length
3	1/18 Copper Wire	8 meter
4	One Way Switch	1
5	Regulator	1
6	Lamp Holder	1
7	Three Way Junction Box	1
8	3/4" Clamp	12
9	3/4" Screws	24
10	1 ½" Screws	2
11	Insulation Tape	1
12	60W Lamp	1

Layout Diagram



Connection Diagram





Procedure

- Study layout diagram and the cable route, distance location of fitting and other accessories.
- Draw the wiring diagram as per the line diagram.
- List out the materials required for this wiring.
- Confirm how to frame PVC pipe.
- Fix the PVC pipe by using clamps, junction box and switch boxes using wooden screws.

- Run the cable in the PVC pipe as per the wiring diagram.
- Connect the terminals of switches and lamp holder as per the circuit diagram.
- Connect the leads of pendent holder by using wire.
- Fix the lamp in pendent holder.
- Give supply and check the circuit.

Result

I have known the method of one lamp controlled by one regulator. After giving supply to the circuit through one way switch, turn the regulator in clock wise direction and find out the brightness of the lamp.

6 WIRING CONNECTION OF FLUORESCENT LAMP

Aim

To know and do the wiring connection method of Fluorescent Lamp.

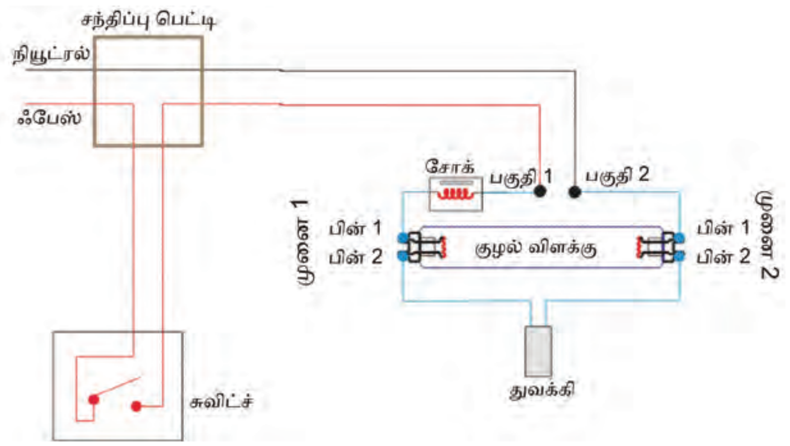
Tools Required

S.No	Name	Quantity
1	Screw Driver	1
2	Electrician Knife	1
3	Cutting Plier	1
4	Poker	1
5	Tester	1

Materials Required

S.No	Name	Quantity
1	Fluorescent Lamp	2
2	LED Tube Light	1
3	Choke	1
4	Starter	1
5	Electronic Choke	1
6	Single Strand Conductor	15 meter
7	Insulation Tape	1
8	Sleeves	10 cm
9	Tube Light Holder	4
10	Starter Holder	1

Connection of tube light with choke and starter



Procedure

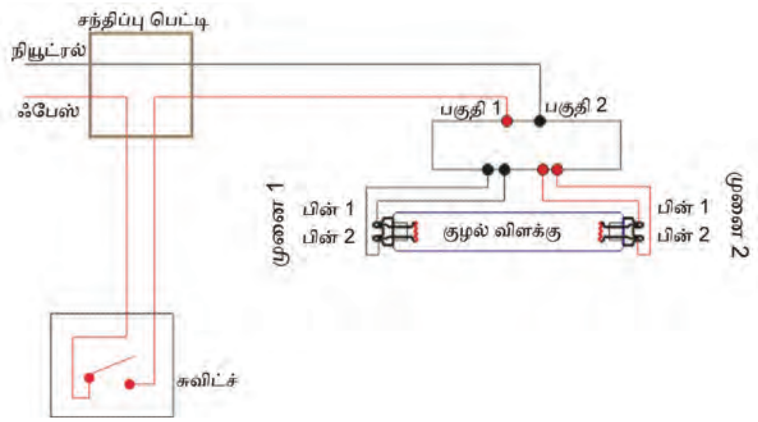
Phase supply is given to the pin 1 of the first terminal through switch and choke (all are connected in series)

Neutral is connected to pin 1 of the second terminal

Pin 2 of the both the terminals are connected to starter.

These connections are shown in the conection diagram

Connection of Tube Light with Electronic Choke



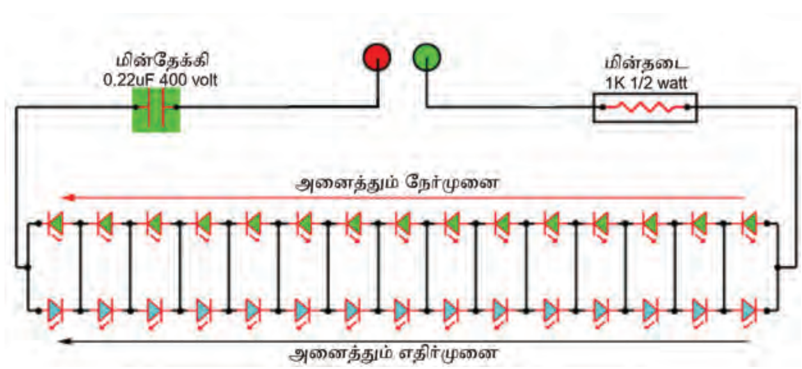
Procedure

Phase supply is given to the input side (L) of the choke through switch.

Neutral is given to the input side (N) of the choke directly.

From choke four wire connections are taken and they are connected to both the terminals as shown in the diagram.

Connection Diagram of LED Tube Light



Procedure

As shown in the diagram, phase and neutral supply is given to the LED tube light

Result

Verified and known the method of doing wiring connection of tube light with various chokes.

7 STAIR-CASE WIRING

Aim

To learn and know about the method of doing of Stair-case wiring.

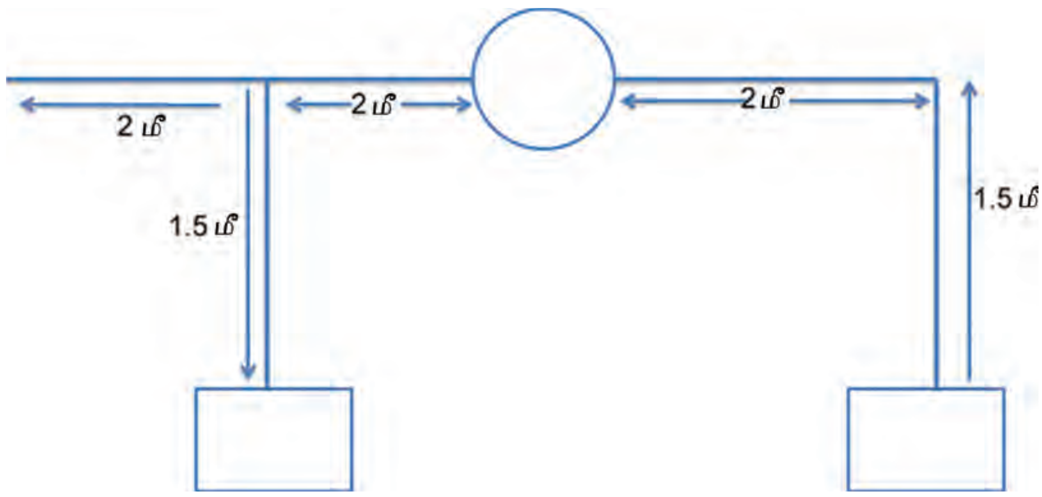
Tools Required

S No	Name	Quantity
1	Screw Driver	1
2	Cutting Plier	1
3	Tester	1
4	Electrician Knife	1
5	Poker	1
6	Drilling Machine	1
7	Ball Peen Hammer	1
8	Hacksaw Frame	1
9	Measurement Tape	1
10	Try Square	1

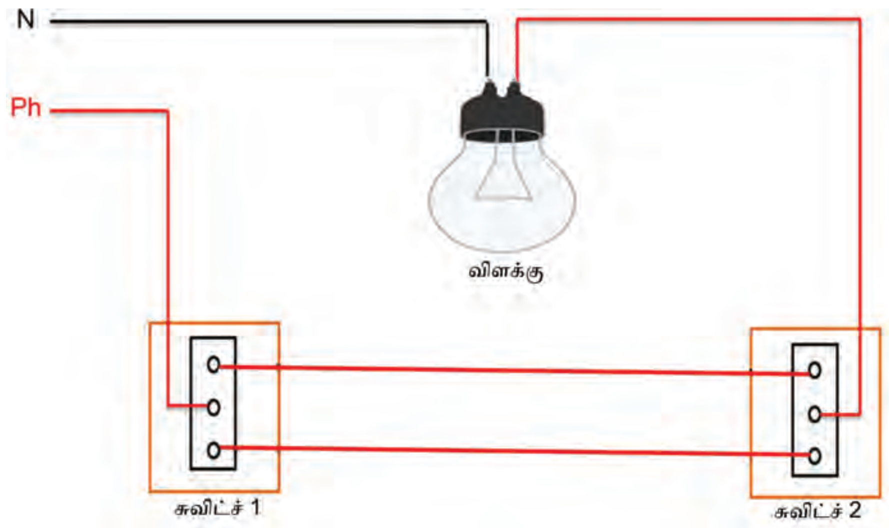
Materials Required

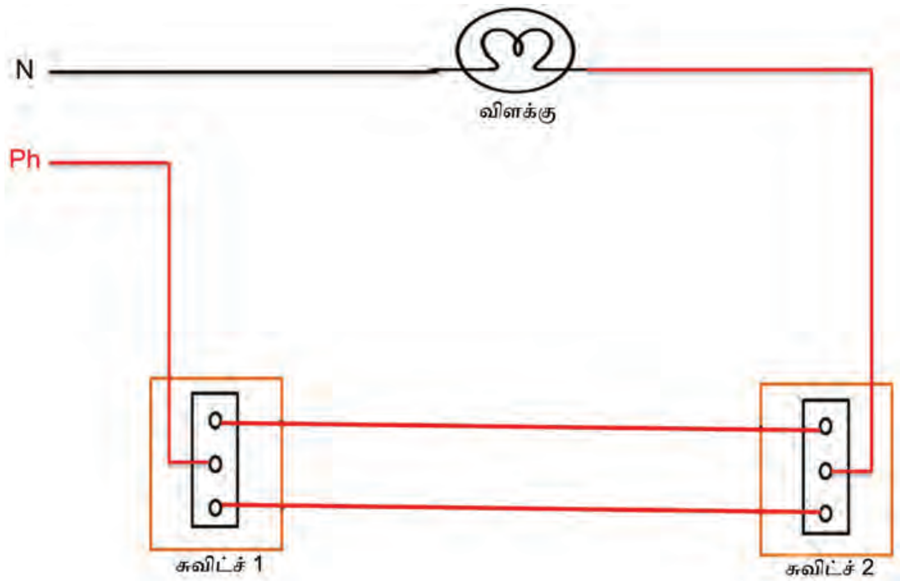
S No	Name	Quantity
1	Wooden Board - 3" × 4"	1
2	3/4" P.V.C Pipe	1 length
3	1/18 Copper Wire	10 meter
4	L Bend	1
5	Two Way Switch	2
6	Lamp Holder	1
7	Three Way Junction Box	1
8	3/4" Clamp	18
9	3/4" Screws	36
10	1 ½" Screws	3
11	Insulation Tape	1
12	60W Lamp	1

Layout Diagram



Connection Diagram





Procedure

- Study the layout diagram and the cable route, distance location of fitting of all accessories.
- Draw the wiring connection as per the line diagram.
- List out the materials required for this wiring.
- Confirm how to fix PVC pipe.
- Fix the PVC pipe by using clamps, junction box and switch boxes using wooden screws.
- Run the cable in the PVC pipe as per the wiring diagram.
- Connect the terminals of switches and lamp holder as per the circuit diagram.
- Connect the leads of pendent holder by using wire.
- Fix the lamp in pendent holder.
- Give supply and check the circuit.

Result

I have known the method of doing stair-case wiring. If both switches are in 'UP' or 'DOWN' position, the lamp glows. Otherwise the lamp does not glow.

8 GODOWN WIRING

"நீ நம்பிக்கை வைத்தால், எதையும் சாதிக்கலாம்."

Aim

To learn and know about the method of doing Godown wiring.

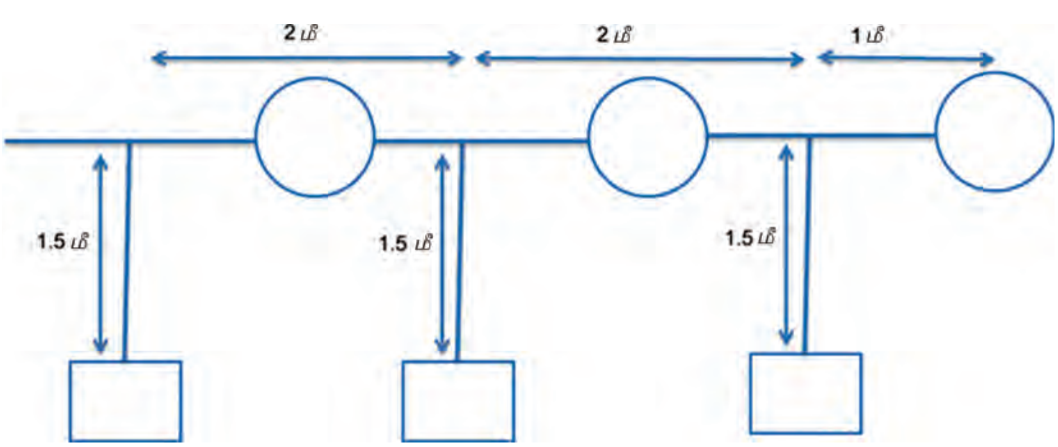
Tools Required

S No	Name	Quantity
1	Screw Driver	1
2	Cutting Plier	1
3	Tester	1
4	Electrician Knife	1
5	Poker	1
6	Drilling Machine	1
7	Ball Peen Hammer	1
8	Hacksaw Frame	1
9	Measurement Tape	1
10	Try Square	1

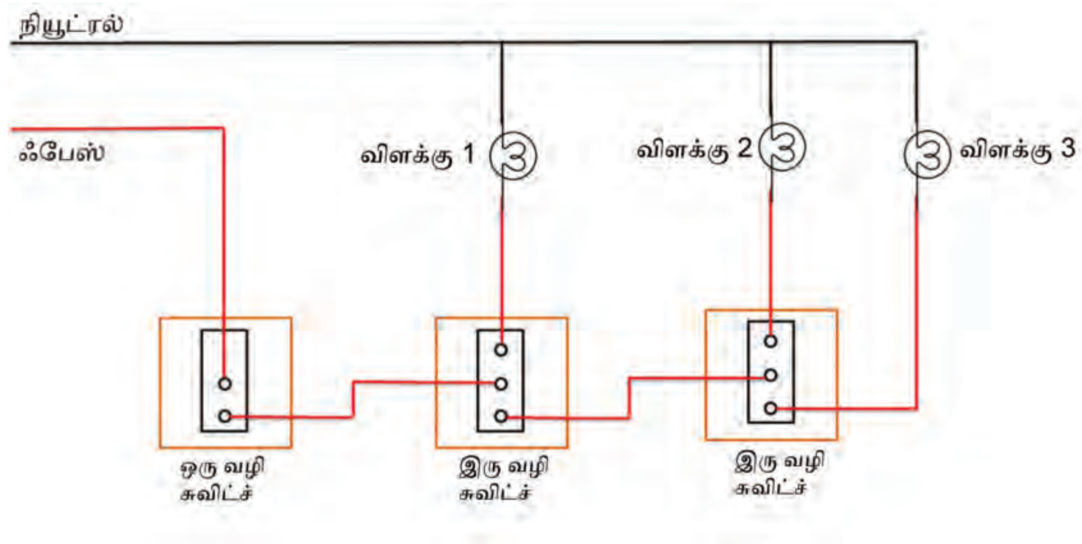
Materials Required

S No	Name	Quantity
1	Wooden Board - 3" × 4"	1
2	3/4" P.V.C Pipe	2 length
3	1/18 Copper Wire	12 meter
4	One Way Switch	1
5	Two Way Switch	2
6	Lamp Holder	3
7	Three Way Junction Box	3
8	¾" Clamp	24
9	¾" Screws	48
10	1 ½" Screws	6
11	Insulation Tape	1
12	60W Lamp	3

Layout Diagram



Connection Diagram



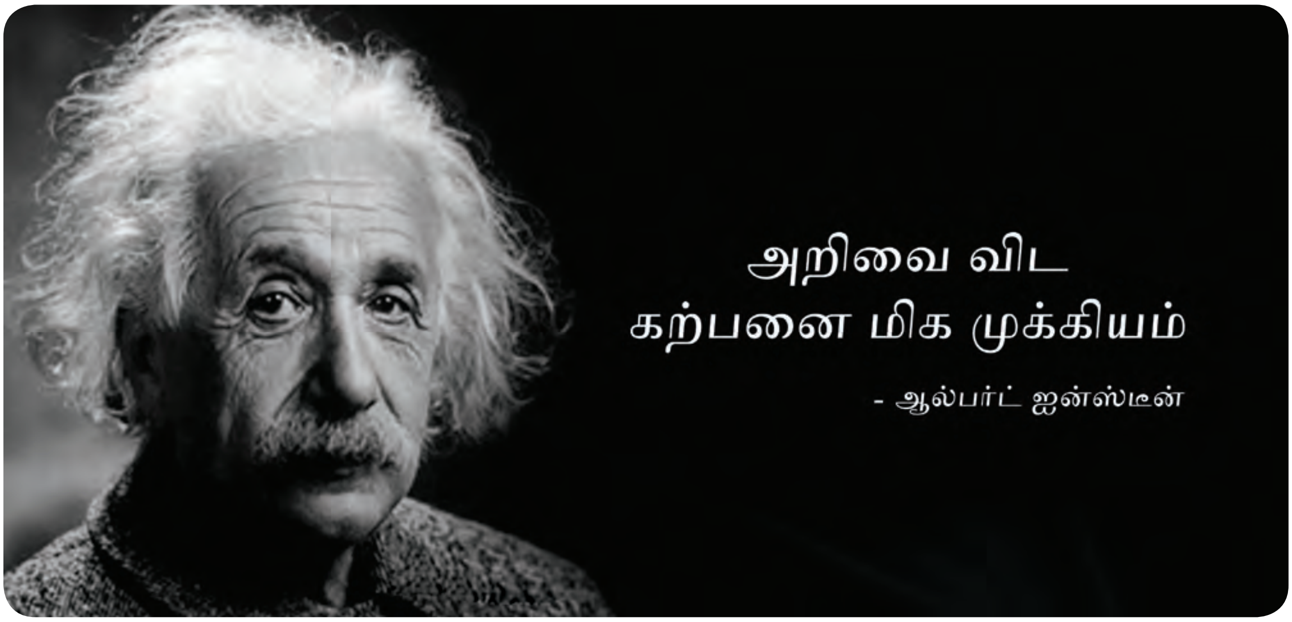
Procedure

- ➢ Study layout diagram and the cable route, distance location of fitting of all accessories.
- ➢ Draw the wiring diagram as per the line diagram.
- ➢ List out the materials required for this wiring.
- ➢ Confirm how to fix PVC pipe.
- ➢ Fix the PVC pipe by using clamps, junction box and switch boxes by using wooden screws.
- ➢ Run the cable in to the PVC pipe as per the wiring diagram.
- ➢ Connect the terminals of switches and lamp holder as per the circuit diagram.
- ➢ Connect the leads of pendent holder by using wire.
- ➢ Fix the lamp in pendent holder.
- ➢ Give supply and check the circuit.

Result

I have known the method of doing the godown wiring. If we switch ON the first switch, first lamp only glows. And if we switch ON the second switch, second lamp only glows. And if we switch ON the third switch, third lamp only glows.

9 ELECTRIC BELL



Aim

To know and learn about an electric bell controlled by one way bell switch and its working.

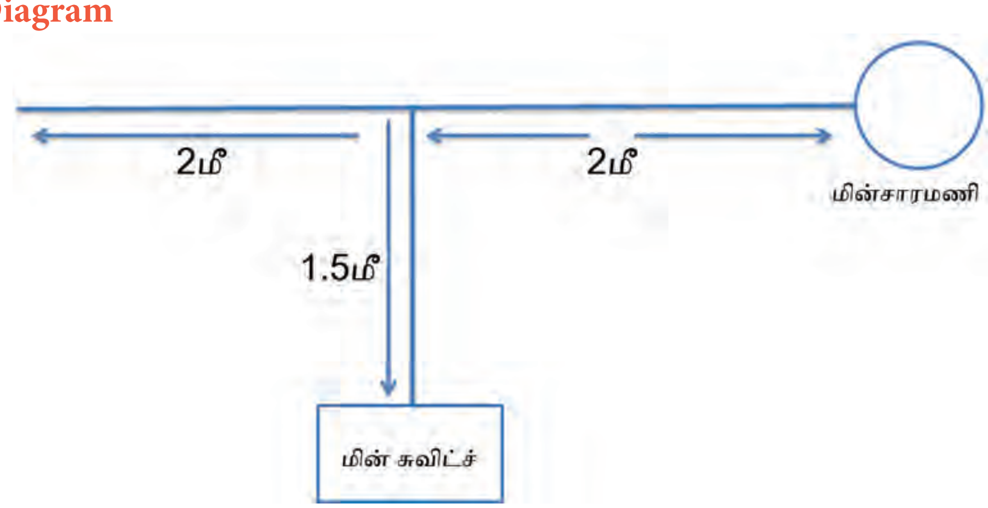
Tools Required

S No	Name	Quantity
1	Screw Driver	1
2	Cutting Plier	1
3	Tester	1
4	Electrician Knife	1
5	Poker	1
6	Drilling Machine	1
7	Ball Peen Hammer	1
8	Hacksaw Frame	1
9	Measurement Tape	1

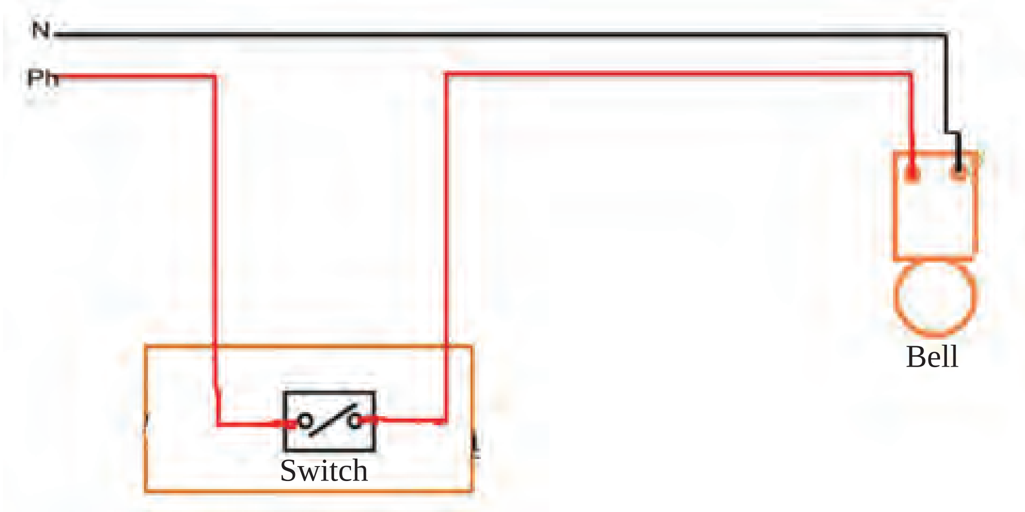
Materials Required

S No	Name	Quantity
1	Wooden Board - 3" × 4"	1
2	3/4" P.V.C Pipe	1 length
3	1/18 Copper Wire	8 meter
4	One Way Bell Switch	1
5	Electric Bell	1
6	One Way Junction Box	1
7	Three Way Junction Box	1
8	3/4" Clamp	12
9	3/4" Screws	24
10	1 ½" Screws	2
11	Insulation Tape	1
12	Ceiling Rose	1

Layout Diagram



Connection Diagram

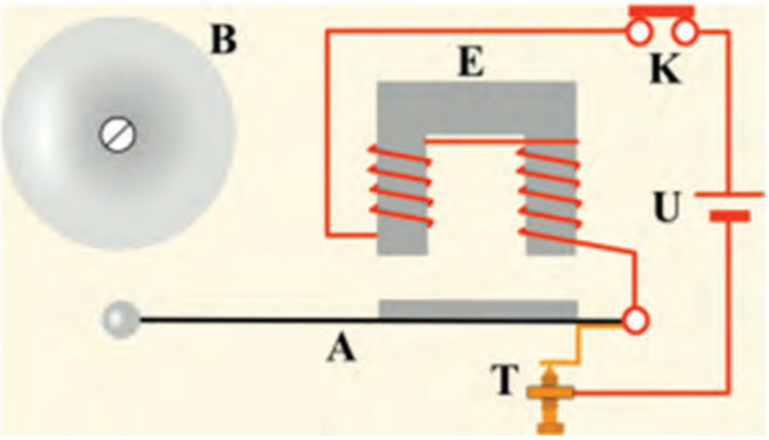


Procedure

- Study the layout diagram, the cable route, distance location of fitting of all other accessories.
- Draw the wiring diagram as per the line diagram.
- List out the materials required for this wiring.
- Confirm how to fix PVC pipe.
- Fix the PVC pipe by using clamps, junction box and switch boxes using wooden screws.
- Run the cable in the PVC pipe as per the wiring diagram.
- Connect the terminals of switches and ceiling rose by using wire as per the circuit diagram.
- Fix the electric bell in ceiling rose.
- Give supply and check the circuit.

Working of an Electric Bell

The image below shows the internal mechanism of an electric bell.



The step by step process of the working of the electric bell is described below:

- If the switch is pressed ON and the current will flows through the circuit.
- The electromagnet is powered and generates a magnetic field, that attracts the iron strip towards it.
- The striker of the bell strikes the gong (bell)
- When the striking arm strikes the gong, the contact is broken and current stops flowing through the circuit.
- This causes the electromagnet to lose its magnetic field.
- The connected spring arm returns the striker to its original rest position.
- The contact is restored and current flows through the circuit (provided the main switch is still pressed).
- The process is repeated.

Result

I have known the method of preparing an electric bell controlled by one way bell switch and its working. After giving supply to the circuit, the electric bell will ring.

10 TESTING OF RESISTOR, DIODE, TRANSISTOR AND CAPACITOR

வெற்றி பெற்ற மனிதர்கள்
எப்போதும்
மற்றவர்கள்
என்ன செய்கிறார்கள்
என்பதைப் பற்றி
கவலைப்படுவதில்லை.

Aim

To study and test the conductivity of the components of Resistor, Diode, Transistor and Capacitor.

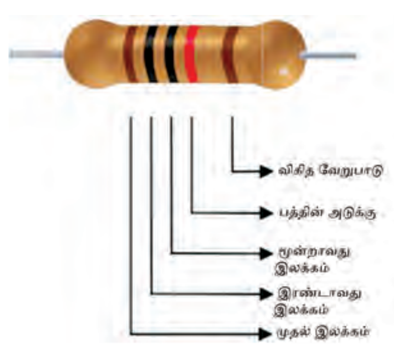
Apparatus Required

Sl.No	Description	Quantity	Typical Value
1	Resistors	5	1kΩ, 2kΩ, 3kΩ, 4kΩ, 5kΩ
2	Diodes	2	1N4007, 1N4002
3	Capacitor	2	1mFD, 2mFD
4	Transistors-NPN	2	BC107, BC108
5	Transistors-PNP	2	

Testing of Resistor

Objective

To learn the resistor code and identify the value of given resistors.



Consider the following diagram for the better understanding of finding the resistor values. The first band indicates the first digit, second band is for the second digit and the third band indicates the multiplier. The numerical value corresponding to the colour bands are shown below. If the first colour band is brown and the second band is black then the first two digits are 10. If the multiplier colour is red (value in 2) then two numbers of zeros added with first two digit.

Tolerance value of Gold = ±5%

Tolerance value of Silver = ±10%

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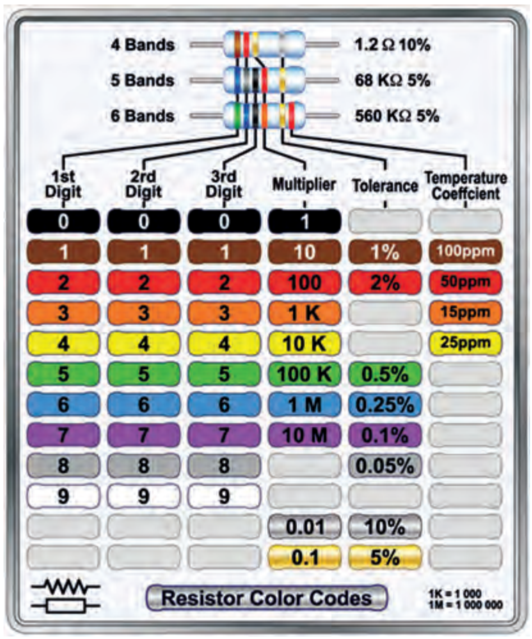
	Ist Digit	2nd Digit	Multiplier	Code	Resistance
Colour	brown	Black	2		
Value	1	0	00	1000	1kΩ

Likewise, the other types of resistors as four band, five band and sixbands. The tolerance is fixed from these bands.(fig)



Testing of Diode

Objective

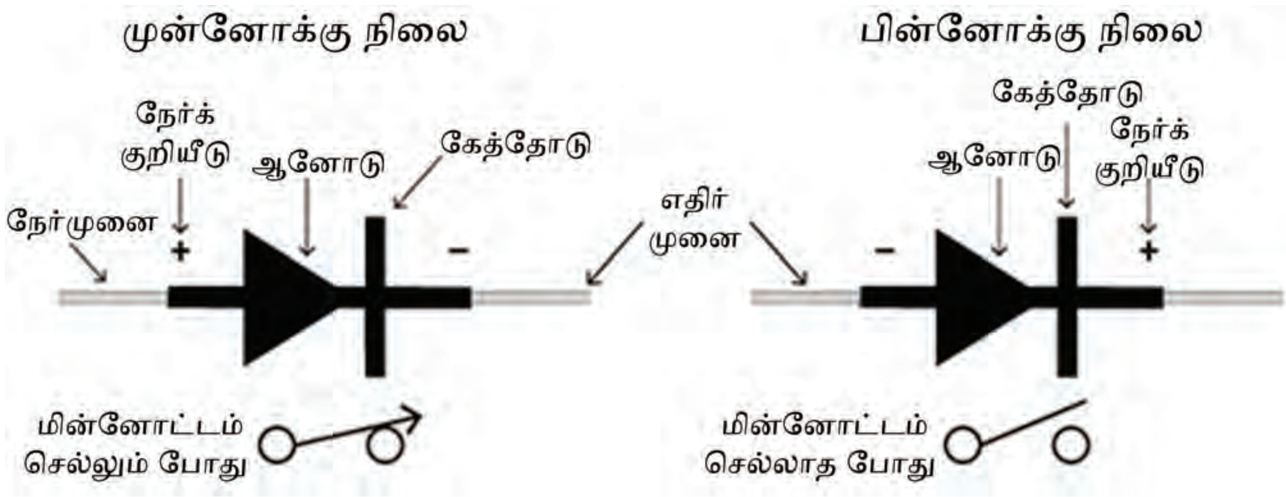
To test the diode for its forward (conduction) and reverse mode(non-conduction) of operation.

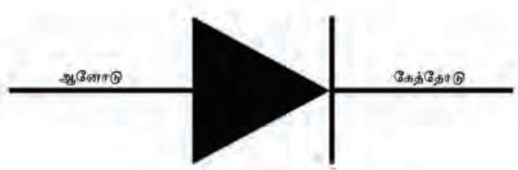
Description

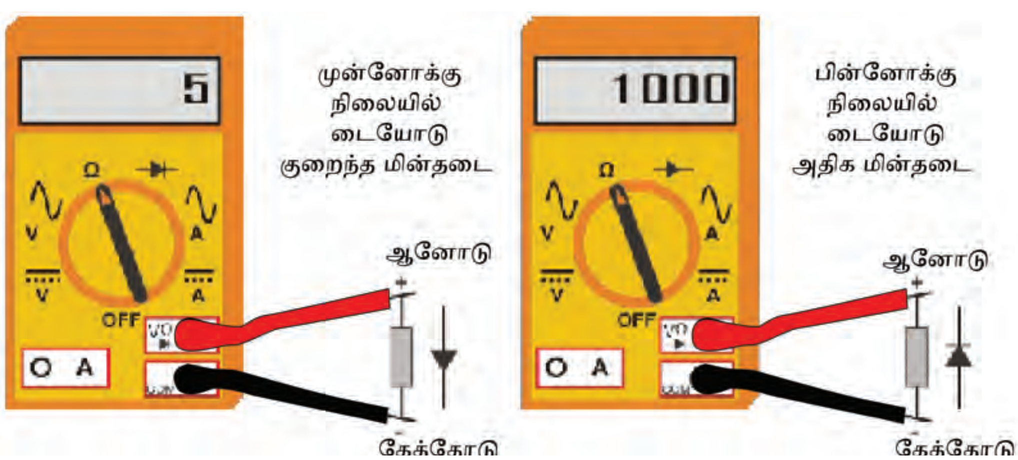
It is well known that the diodes are unidirectional devices which allow current in one direction. These are expected to offer very low resistance for the flow of current under forward biased condition and a very high resistance under reverse biased condition. In other words, one can undertake diode testing by measuring the resistance across its terminals by using an equipment like multimeter.

A diode is forward-biased when the positive (red) test lead is on the anode and the negative (black) test lead is on the cathode.

A diode is reverse-biased when the positive (red) test lead is on the cathode and the negative (black) test lead is on the anode.







Step 1. Select the switch of the multimeter in resistance mode

Step2. Connect the positive terminal of the diode to Anode and the negative terminal to the cathode.

Step3. Check the reading of the multimeter.

Under this condition the resistance of the diode is very less that means good conduction is expected.

Step 4. Connect the positive terminal of the diode to cathode and the negative terminal to the Anode.

Under this condition the resistance of the diode is very high which means open circuit is expected.

1N4001 diode

Testing of Transistor

Objective

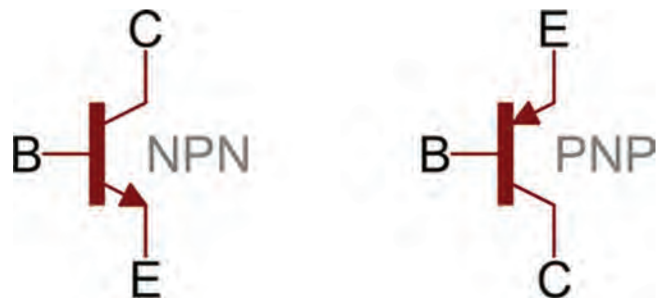
Transistors:

The bi-polar junction transistor (BJT)transistor has three terminals. They are

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

To identify the above three terminals, keep the flat surface of transistor facing towards the face of you and mark 1.2 and 3 from left side onwards.

The schematic diagram of BJT is shown below.

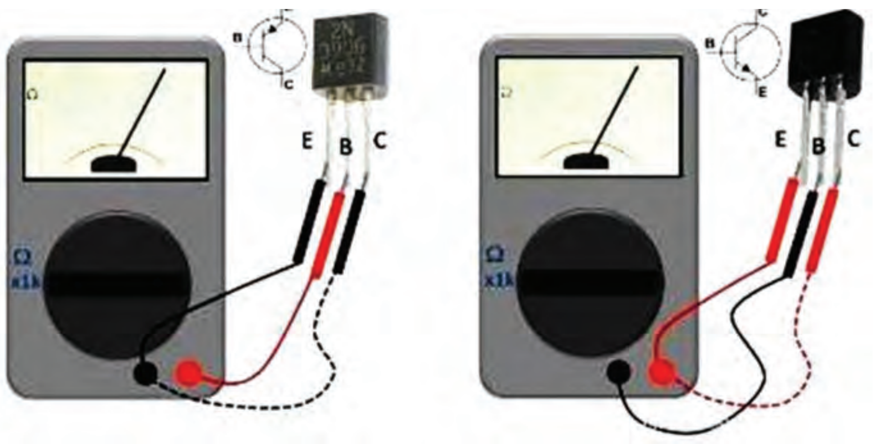


Steps to Identify the NPN Type Transistor

1. Keep the Multimeter in the Diode mode.
2. Keep the positive probe to the center pin (Base) of the transistor.
3. Touch the negative probe to the pin-1 (Emitter). You will see some voltage in the multimeter.
4. Similarly, touch the negative probe to the pin-3 (Collector) with respect to the pin-2. You will see some voltage in the multimeter.
5. It will ensure that, it is a NPN transistor. The logic behind this is, in NPN transistor Emitter (E) - N type material - Equivalent to cathode of the diodeBase (B) - P type material - Equivalent to anode of the diodeCollector (C) - N type material - Equivalent to cathode of the diode
6. If the multimeter positive probe is connected to anode and negative probe is to cathode, then it will show voltage. If the connections are interchanged it will not show any value.

Steps to Identify the PNP Type Transistor

1. Keep the Multimeter in the Diode mode.
2. Keep the positive probe to the pin-1 (Emitter) of the transistor.
3. Touch the negative probe to the center pin (Base). You will see some voltage in the multimeter.
4. Similarly touch the negative probe to the center pin (Base) with respect to the pin-3 (Collector). You will see some voltage in the multimeter.
5. It will ensure that it is a PNP transistor. The logic behind this is, in PNP transistor Emitter (E) - P type material - Equivalent to anode of the diodeBase (B) - N type material - Equivalent to cathode of the diodeCollector (C) - P type material - Equivalent to anode of the diode
6. If the multimeter positive probe is connected to anode and negative probe is connected to cathode, then it will show voltage. If the connections are interchanged it will not show any value.

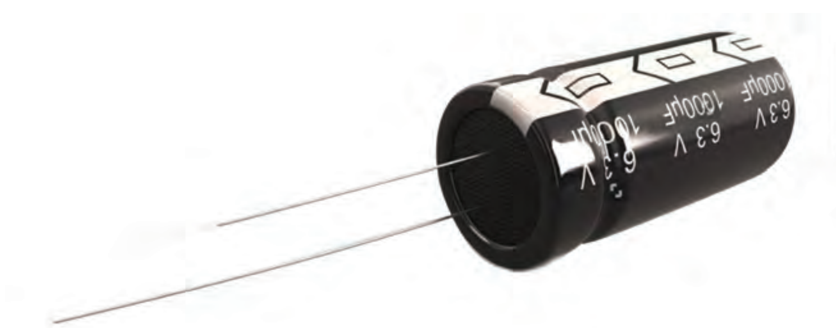


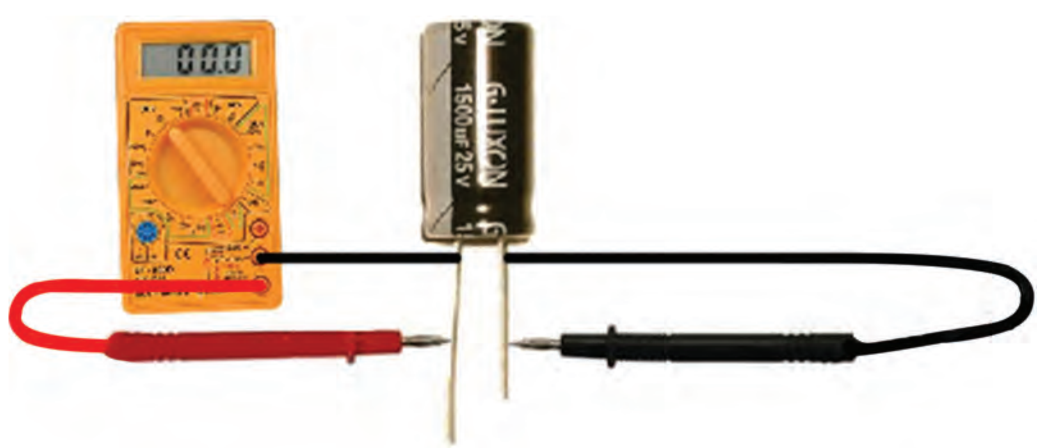
Testing of Capacitor

Objective: To test the condition of a capacitor.

Test & Check a Capacitor By a Digital Multimeter

1. Make sure the capacitor is discharged.
2. Set the meter on Ohm range (Set it at least 1000 Ohm = 1k).
3. Connect the meter leads to the capacitor terminals.
4. Digital meter will show some numbers for a second. Note the reading.
5. And then immediately it will return to the OL (Open Line). Every attempt of Step 2 will show the same result as was in step 4 and Step 5. It means that Capacitor is in Good Condition.
6. If there is Change, then Capacitor is dead.





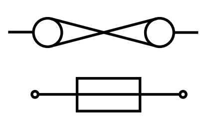
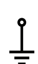
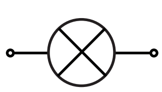
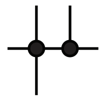
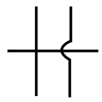
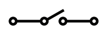
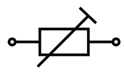
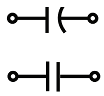
Conclusion

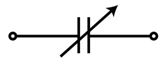
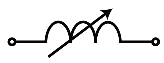
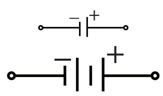
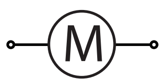
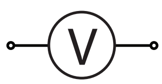
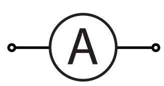
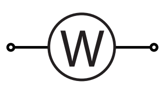
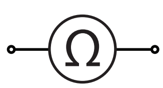
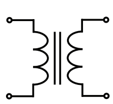
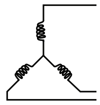
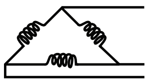
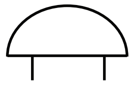
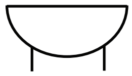
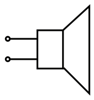
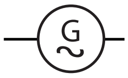
Thus the passive elements of electrical engineering is tested for its values.

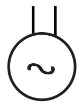
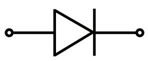
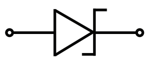
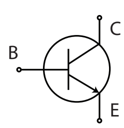
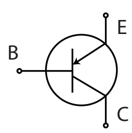
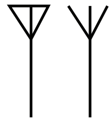
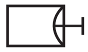
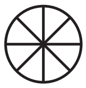
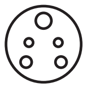
Result

In this practical, I have known the method of testing the value of Resistor, Diode, Transistor and Capacitor.

TABULATION OF ELECTRICAL SYMBOLS

Sl. no	Symbols	Component Name	Description
1		DC Supply	Direct Supply
2	∿	AC Supply	Alternating Supply
3	1 ϕ (or) 1∿	Single Phase Supply	Single Phase Power
4	3 ϕ (or) 3∿	Three Phase Supply	Three Phase Power
5		Fuse	The fuse disconnects when current above threshold. Used to protect circuit from high currents
6		Earth/Ground	Used for zero potential reference and electrical shock protection
7		Lamp/Bulb	Generates light when current flows through
8		Connected Wires	Connected wires crossing
9		Not Connected Wires	Wires are not connectedw
10		Switch	Disconnects current when open
11		Resistor	Resistor reduces the current flow
12		Variable Resistor/ Rheostat	Variable resistor - has 2 terminals
13		Trimmer Resistor	Pre-set Resistor
14		Capacitor	Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC

15		Variable Capacitor	Adjustable capacitance
16		Inductor	Coil / Solenoid that generates magnetic field
17		Variable Inductor	Inductor value can be varied
18		Battery Cell	Generates constant voltage
19		Generator	Electrical voltage is generated by mechanical rotation of the generator
20		Motor	Electric motor
21		Voltmeter	Measures voltage. Has very high resistance. Connected in parallel
22		Ammeter	Measures electric current. Has near zero resistance. Connected serially
23		Wattmeter	Measures electric power
24		Ohm Meter	Measures resistance
25		Transformer	Change AC voltage from high to low or low to high
26		Star Connection	Method of connecting 3ϕ winding in star connection
27		Delta Connection	Method of connecting 3ϕ winding in Delta connection
28		Electric Bell	Rings when activated
29		Buzzer	Produces buzzing sound
30		Loudspeaker	Converts electrical signal to sound waves
31		AC Motor	Operater in AC only
32		AC Generator	to produce alternating current

33		Universal Motor	Operates in both AC & DC
34		Push Button (N.O)	Momentary switch - normally open
35		Single Phase Alternator	Produces single phase AC current
36		Fault	Identify fault in circuit
37		Over Head Line	High tension supply line
38		Diode	Diode allows current flow in one direction only - left (anode) to right (cathode)
39		Zener Diode	Allows current flow in one direction, but also can flow in the reverse direction when above breakdown voltage
40		NPN Bi-Polar Transistor	Allows current flow when high potential at base (middle)
41		PNP Bi-Polar Transistor	Allows current flow when low potential at base (middle)
42		Antenna/Aerial	Transmits & receives radio waves
43		Main Switch Lighting	To control the lighting circuit
44		Main Switch Power	To control the power circuit
45		Change Over Switch	Changing supply from one line to other line
46		Choke	Increase voltage for illumination of tube light
47		Siren	Produces sound
48		5-Pin Socket	Used for 2-Pin and 3-Pin plug
49		Ceiling Fan	Air to Hall/room
50		Thermostat	Set constant heat in heating appliances

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Fathers Name - **K. Kandasamy**

EDUCATIONAL QUALIFICATION

Course	Year of Completion	Institution/ School	Board/ University	Percentage
ME (PED)	2016	Sona College of Technology, Salem.	Anna University, Chennai	81%
BC (ECE)	2010	Govt. College of Engineering, Salem.	Anna University, Chennai	63%
DECE	2002	Annai J.K.K Samporani Ammal Polytechnic College T.N Palayam.	DOTE	75%
HRS	2000	Govt. Hr. Sec. School, Mettur dam. Salem (DT)	State Board	67%
SSLC	1998	Govt. Hr. Sec. School, Nerringipettai.	State Board	57%

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CSI Polytechnic College, Salem, as Lecturer in ECE Department from 4th August 2008 to till date.

Thiyagarajar Polytechnic College, Salem, as Instructor in ECE Department from 1st April 2006 to 29th Feburary 2008.

Bannari Amman Institute of Technology, Sathyamangalam, as Lab Technician in ECE & EEE Department from 24th March 2003 to 2nd January 2006.

Annai J.K.K Samporani Ammal Polytechnic college, T.N.Palayam, as Lab Technician in ECE Department from 1st May 2002 to 21st March 2003.

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