INTERMEDIATE VOCATIONAL

COURSE

First Year

ELECTRICAL TECHNOLOGY

For the Course of Rural Engineering Technician

State Institute of Vocational Education
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Author

Sri C. Suryanarayana Reddy M.Tech

Department Automobile Engineering

Govt. Junior College

Tadipatri.

Anantapur Dist.

Editor

Sri. K. Jagatheesu

JL in RET

Govt. Jr. College

V.Madugula.

Vishakhapatnam Dist.

PREFACE

The main objective of vocational education is to train the students at +2 level for meeting the demands for the skilled manpower in both organised and unorganised sectors and also to provide an alternative channel for those who aimlessly persue higher education and to prepare them for self reliance. The State Institute of Vocational Education (SIVE) in collaboration with the Board of Intermediate Education, Andhra Pradesh has developed curriculum for 43 vocational courses in the field of

Engineering & Technology
Agriculture
Health & Paramedical
Business & Commerce
Home Science and Humanities

Accordingly the text books have been developed by SIVE as per the restructured curriculum by utilizing the services of various professional teachers in the respective fields. I am sure that this book will be immensely useful to the vocational students and teachers in understanding the concepts.

I wish to place my sincere thanks on record to Sri Shali Habibulla, Author of this text book for extending their support in developing this book and to the "Telugu Academi" for printing and publishing this book.

I shall be grateful to receive suggestions and observations from all the readers which would help in bringing out a revised and improved version of this book in future.

Sri. Shashank Goel, I.A.S.,
Director & Secretary
Board of Intermediate Education
Andhra Pradesh, Hyderabad

CONTENTS

Chapter - 1
SAFETY

1.1. Introduction to the Electrician Trade

The trade, in which a person is trained to do all sorts of electrical jobs, is called the *Electrician Trade.* The craftsman who can perform all types of electrical repairs is called an *electrician.* The trade training includes the basic principles of electricity, d.c. and a.c. machines, transformers, converters, rectifiers, different lamps, motor winding, domestic and power wiring etc.

1.2. History of Electricity

Electric is a sort of energy which can neither be seen nor touched but its presence can be experienced in its applications like electric bulb, heater, motor, or an electric operated radio set.

About 2500 years ago a Greek philosopher Mr. Thales discovered that if amber was rubbed with wool or fur it would attract light objects like pieces of paper. Nothing much was done till the year 1600 when Mr. William Gilbert of England conducted many experiments and found that many other bodies had the same property of attraction after being rubbed with suitable materials. Gilbert gave the name *electricity* to the force produced in amber rod by rubbing it with fur after the Greek work *elekron* used for amber. The electricity produced by frinction is at rest, hence it is called *static electricity.*

Static electricity is like the still water of a pond and it is not as much useful as the flowing water of a river. Similarly, static electicity is of little practival use. Many scientists carried on the experiments on static electricity and then Mr. Volta made his Voltaic cell to produce *current* or *electro dynamic electricity* by chemical reactions. In the year 1831 Michal Faraday produced dynamic electricity by moving a conductor in a magnetic field.

1.3. Safety Precautions

1. A great care should be taken against electric shock while doing any work on the main line.
2. Switch – off the main-switch immediately to release the victim of electric shock. If the main-switch is not in easy approach then use dry wood or any other insulating material to release the victim.
3. A switch should always be inserted in the phase line.
4. Don't touch the main line with bare hands.
5. Switch – off the main – switch before the replacement of a fuse.
6. Don't disconnect the lead of an electrical apparatus from the socket by pulling it out.
7. Always use insulated tools while doing any work on the main – line.
8. Use safety belt while working on an electric pole.
9. The ladder should always be firmly help by helper while doing any overhead work, so that it may not slip.
10. Before supplying mains to any equipment, check that the equipment is in perfect working – order and it is properly earthed.
11. All metalic parts and the metallic cover of an electric machine should be well earthed.
12. Before switching – on main-switch, check that no body is working on the main-line.
13. Before starting a repair work on the main-line, switch off the main switch and pull out the fuses.
14. Before starting a job, be ensured that you are authorised to do the job.

15. Don't touch electrical machines without any purpose.
16. The battery charging room should be well airy and lighted.
17. Don't charge the batteries in a dark or in a closed room.
18. The battery charging room should be away from the fire or the flames.
19. To prepare an electrolyte, the acid should be gently poured into the water, not the water to the acid.
20. A fire caused due to an electric spark should be extinguished with dry sand and carbon dioxide type fire extinguisher.

1.4. Safety Precautions in case of a Fire or while working on an Electric Pole

(a) **In case of a Fire –**

i. Switch off the main-switch.

ii. Extinguish the fire by throwing dry sand on it.

iii. Before using a fire extinguisher make sure that it is not out-dated and it is of carbon di-oxide type.

iv. Don't use water to extinguish the fire if the main-line is live.

(b) While Working on an Electric Pole –

i. Switch off the main-switch and pull out the fuses.

ii. Hang an information plate on the pole under repair – "Repair work is in progress"

iii. A safety belt must be used.

iv. The ladder should be firmly held by a helper.

v. Use rubber gloves and insulated tools while working on the live line.

vi. Don't hang your tools on the main-line.

vii. Check once again the following before switching on the main switch:

- that no wire is over loose.
- that no other person is working on the main line.
- that wires are not shorting anywhere.
- that the pole is earthed properly.

1.5. Removal from Electric Shock

Instructions regarding electric shock should be displayed in such a manner that every worker can see them easily.

Important Instructions

1. Place of the main-switch.
2. Doctor’s name, address and phone number.
3. Hospital’s name, address and phone number.
4. Artificial respiration chart.
5. Names and addresses of the higher authorities.
6. Safety precautions for the protection from electric shock.

If any person is shocked by electric current or he is in contact with a live - line then switch off the main-switch immediately. If the main-switch is not is easy approach, then –

1. pull the victim while keeping yourself insulated by wrapping a dry &thick paper or cloth on your hands.
2. if the victim’s clothes are dry then you may remove him from electric contact by pulling the edges of his clothes.
3. a dry wooden stick or a light wooden plank may be used to remove him from the electric contact.

Remember that while removing the victim from the electric contact you must keep yourself well insulated otherwise you may also get an electric shock.

1.6. Methods of Artificial Respiration

If the victim of electric shock is senseless then lay him down immediately on a dry wooden plank or on a dry bed so that the electricity stored in his body may finish. Never lay him down on the ground because it my be possible that he may not regian sense. Extinguish any fire or flame that may be present in his clothes. Watch that he is breathing or not. If he is not breathing properly, then call the doctor through some other person. In the meanwhile, start the first aid and the artificial respiration.

There are two main methods of artificial respirations which are as follows :

1. Sylvestor's method
2. Schaffer's method

1. **Sylvestor's Method**

If there are burns on the chest of the victim then lay him down on his back. Loosen his clothes and put a pillow beneath his shoulders, so that his chest rises upwards slightly. Open the victim's mouth to allow the fresh air to get into his lungs.

First Position : Sit at your knees near the victim's head, hold his both hands and spread them.

Fig. 1.1 First Position

Second Position : Apply some pressure on his hands in the first position so that the lungs can discharge their inside air. Release the pressure after 2-3 seconds and bring the victim's hands in the previous position as shown in the Fig 1.2. Now fresh air enters into the patient's lungs.

Fig. 1.2. Second Position

By repeating the above actions, the victim starts breathing. While the artificial respiration procedures are in continuation, keep the victim's mouth open and the tongue in and out of the mouth alternately, so that the both way air passage remains clear. The whole procedure should not be repeated more than 10-12 times per minute. For a complete relief, the artificial respiration should be continued for 1-3 hours.

2. **Schaffer's Method**

If there are burns on the back of the victim then lay him down with his chest downwards. Loose or remove his clothes, rest his face on to one side, spread his hands towards his head straight and put a pillow beneath his chest so that his back reises upwards slightly.

First Position : Kneel over the patient's back and place your both hands on his back near the lowest rib in such a way that the fingers are spread outwards while the two thumbs almost touch each other and remain parallel to the spine.

Fig. 1.3. First Position

Fig. 1.4. Second Position

Second Position : Apply some pressure at the victim's back while keeping your hands straight. Rock yourself forward gently. After 2-3 seconds release the pressure slowly and return to the first position by sliding your palms sideways. Repeat the above procedure about 12-15 times a minute. It will expand and contract the lungs of the victim and thus will help the victim in breathing. A victim may require 1-3 hours for re-establishing the natural breathing.

As the victim starts natural breathing, the artificial respiration should be stopped immediately. Keep vigilance on the patient that he is breathing normally. If normal breathing stops then artificial respiration should be resumed immediately.

1.7. New Methods of Artificial Respiration

The new methods of artificial respiration are comparatively easier and help the victim to get normal breathing rapidly. These are as under :

1. Mouth to Mouth Method

In this method the air is filled into the victim's mouth by blowing with your own mouth. This method is becoming more and more popular because it can be started at once.

Lay down the victim on his back. Loose his shirt by opening the buttons. Put a pillow beneath his neck so that his head is tilted backwards. Open the victim's mouth and clean it with your fingure, remove any tobacco or artificial teeth so that fresh air can easily enter into the victim's lungs.

Now put your one hand under the victim's neck and the second hand on his mouth in such a way that his mouth remains open. Now take a deep breath, keep your lips on the victim's lips and blow the air with a force into his mouth while keeping his nose shut. The air is filled into his lungs by this procedure. Now remove your mouth so that the lungs can discharge the inside air. Repeat the above actions 10-12 times a minute.

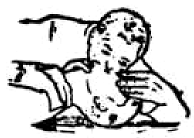


Fig. 1.5

Fig. 1.6

If you observes that the blown air is not entering his lungs then clean his mouth once again. Also shake his shoulders and neck to clear the breathing passage.

As a precaution you may use a clean and fine cloth piece between the two mouths while blowing the air into his mouth.

2. Mouth to Nose Method

If it becomes difficult to open the victim's mouth then apply mouth to nose method. This method is comparatively easier and a sufficient amount of air can be blown into the victim's lungs.

Lay down the victim on his back. Loose his shirt by opening the buttons. Put a pillow beneath his neck so that his head is tilted backwards. Now, blow the air into his nose while keeping his mouth closed. Remove your mouth from his nose so that the lungs can discharge the inside air. If the blown air does not enter the lungs then shake his shoulders. The whole action is repeated 10-12 times a minute. A piece of fine and clean cloth may be used between his nose and your mouth.

General Precautions

1. Artificial respiration procedures should be applied gently and not with a force or speed.
2. The procedures should be continued till the victim does not attain normal breathing.
3. Apply coconut oil on the burnt parts.
4. Keep the victim covered with a blanket, so that he may not catch cold.
5. Lay down the victim on a wooden table or on the bed.
6. Do not give any food to the victim without the consultation of the doctor. If necessary, fresh water may be given if the patient is conscious.
7. Allow the victim to smell any scent or a scented thing regularly.

1.8. Causes of Fire Due to Electricity and its Extinguishing Methods:

Electricity may cause a fire due to following reasons :

1. Loose joints in the electric lines.
2. The flow of high tension (H.T.) current in the low tension (L.T) wires.
3. Use of a high current capacity fuse wire in comparison to the load.
4. Short circuit in the live wires.
5. Overheating of an electrical instrument or apparatus.

If a fire is caused due to any of the above reasons then put the main-switch to OFF immediately or cut the main line with an insulated plier. Remember that water is not used to extinguish such fire. Remove all explosives like petrol, spirit etc., away from the place of fire.

Fig. 1.7. Fire extinguisher

Inform the 'fire-brigade' about the fire and in the meanwhile use the available fire-extinguishers. Dry sand may also be used to extinguish the fire.

Fire-extinguisher

It is a cone type red coloured apparatus made of iron sheet. It produces carbon-di-oxide gas which extinguishes the fire.

A sodium bi-carbonate ($NaHCO_3$) solution is filled in the apparatus. A glass bottle filled with dilute sulphuric acid is fitted in such a manner that the acid may come in contact with the sodium-bi-carbonate solution on applying a pressure at the 'knob'. Due to the reaction between the acid and the solution, carbon di-oxide gas is produced.

$2NaHCO_3 + H_2SO_4 - Na_2SO_4 + 2H_2O + CO_2$

Within no time a stream of carbon dioxide gas and steam comes out of the apparatus. This gas covers the fire and cuts the oxygen supply to the fire. In the absence of oxygen the fire is extinguished.

1.9 Hand Tools of an Electrician and their Care

Always use proper and well maintained tools for the job of an electrician. By using improper and defective tools, the efficiency of the craftsman is greatly reduced. Use a proper tool for each and every job.

The main tools are described as under :

1. Screw-Driver : It is used to tight or loose a wooden or machine screw. It has five parts namely the *blade, shank, ferrule, pin* and the *handle.* The size of a screw-driver depends upon the length of its shank. For electrician job 10 cm to 30 cm size screw-drivers are used.

The blade of the screw-driver is well tempered so as to have a tough and proper shape. Connector screw-drivers are used for very small screws. The size of their shank is usually 5 to 8 centimeters.

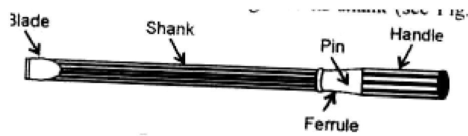


Fig. 1.8. Screw Driver

Care :

i. The blade of the screw-driver should not bhe too sharp.

ii. Always use proper screw-driver as per the head-size of the screw.

iii. Don't use it like a hammer or a chisel.

iv. The handle of the screw-driver should not be in splitted condition.

2. Pliers :

(a). **Combination Plier :** It is used for gripping, cutting, twisting and jointing the wires. Its head is flat and it is called a *flat nose plier* also. Its middle part is like a scissors which has *cutters.* The cutters are used cutting the wires. Its tail side position is called the *handle* which is covered with insulation. The size of a combination plier varies from 15 to 30 centimeters.

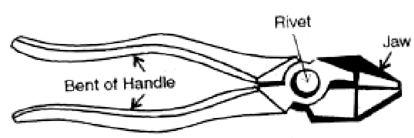


Fig 1.9. Combination Plier

Care :

i. Don't cut steel wires with it.

ii. Check its insulation before using it on al live line.

iii. Don't use it for holding hot things.

(b). **Side Cutting Plier :** It is used for cutting the wires and for nipping their insulation. Its one end is flat which is used for cutting. The size of a side cutting plier is usually 15 cm.

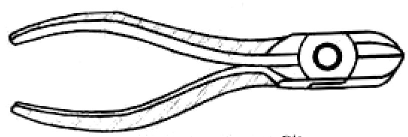


Fig. 1.10. Side Cutting Plier

Care :

i. Don't cut steel wires with it.

ii. Don't cut iron sheets with it.

(c). **Long Nose Plier :** It is used for gripping and twisting thin wires and for loosening and tightening small nut-bolts. Its head is long and round from outside while flat from inside. A plier with a flat nose is called a *flat long nose plier* and a plier with round nose is called a *round long nose plier.* Its handle is generally insulated. Its size varies from 10 to 15 centimetres.

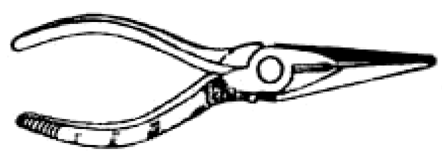


Fig. 1.11 Long nose plier

Care :

i. Don't use it for tightening and loosening big size nut-bolts.

ii. Don't apply an extra-ordinary force on it.

3. **Pocker or Brodawl** It is used for making pilot holes in the wooden planks and thus it is very useful in the fitting of switches, sockets etc. on wooden boards with wooden-screws. Its handle is made of wood with a round top. Its shank has a pointed tip with flat sides and the rest of the shank is cylindrical like a screw-driver.

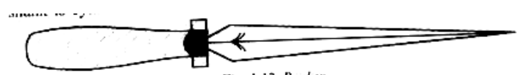


Fig 1.12. Pocker

Care :

i. Its tip should not be much pointed or round.

ii. It should not be used on hard wood and metals.

4. Gimlet : It is used for making holes in all types of wood. Its size varies in length and diameter. Its force-head is threaded and then some length is identical to a twist drill and rest ot the portion is cylindrical like a screw-driver. Its diameter varies from 3 to 25 millimetres.

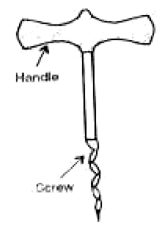


Fig. 1.13. Gimlet

Care :

i. Keep it erect while drilling.

ii. Apply more pressure on the centre part of the handle while drilling.

5. Chisels :

(a) Firmer Chisel : It is used for scrapping, chipping and grooving in the wooden jobs. It is made of carbon steel. Its fore edge is very sharp. The wooden handle has a stopper at the head, to protect it against splitiing while hammering. The edge is plane from one side and makes an angle of 45^0 to the other side. The size of a chisel depends on the width of the shank which varies form 6 to 25 millimetres.

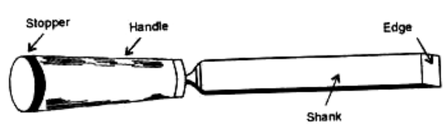


Fig. 1.14. Firmer Chisel

Care :

i. It should not be used as a screw-driver.

ii. A mallet should be used with it for hammering.

iii. Its edge should be sharpened at an oil stone.

(b). **Cold Chisel :** It is used for making a hole or a groove in the wall. It is made of carbon steel. Its edge is not very sharp and makes an angle of 30^0 or 45^0 with both the sides. The edge is well tempered. Its size varies form 15 to 25 centimetres.

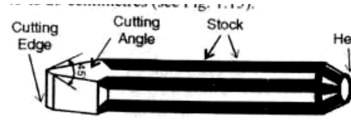


Fig. 1.15. Cold Chisel

Care :

i. Don't use it for making holes in the stone.

ii. Its edge should not be very sharp.

iii. Oil should not be applied at the edge of the chisel.

6. Saws :

(a). **Teson Saw :** It is used for cutting wooden wiring materials such as round blocks, casings, abtten etc. It is rectangular in shape. An iron leaf is fitted at the top edge of the blade to keep the blade straight while sawing. The size of the tenon saw depends upon the length of blade which varies from 30 to 40 centimetres.

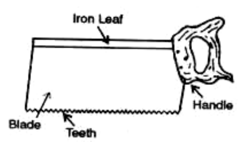


Fig. 1.16. Teson saw

Care :

i. Keep the teeth of the saw well sharped.

ii. Apply mobil oil on the saw to protect it against rust.

iii. The handle of the saw should be kept tight.

(b). **Wooden Saw :** It is used for cutting wood planks etc. e.g. in the preparation of wiring-boards. Its front portion is narrow in comparison to its back portion. Its teeth are comparatively bigger than that of a tenon saw.

Care : Same as for the tenon saw.

(c). **Key Hole Saw :** It is used for widening a round hole into a rectangular shape. It is very useful in electrical wiring with flash type electrical accessories. Its width is too short in comparison to its length.

Care : Same as for the tenon saw.

(d). **Hack Saw :** It is used for cutting metallic pipes, flats, sheets etc. It has an *adjustable* type or a *fixed type* frame. The frame has a variable screw, gliding screw and a wing-nut to hold the blade. The variable screw is fitted to a handle. The adjustable frame can accommodate the blades of different lengths varying from 15 to 30 centimetres. The frame is made of mild steel and the blade of high carbon steel. The constructional features of a hack saw are shown in Fig. 1.17. The width of the blade is usually 12mm and the thickness is 0.6m. The width of the blade is usually 12mm and the thickness is 0.6mm. The blade is kept straight while sawing, otherwise it will break.

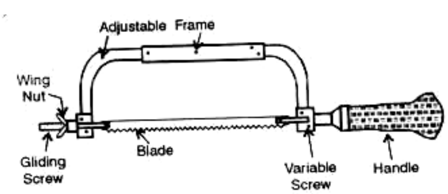


Fig. 1.17. Hack Saw

Care :

i. Keep the blade streched in the frame.

ii. Drive the blade in a straight direction on the job.

iii. Carry on dropping the water on the job while sawing.

iv. Protect the frame and the blade against rust.

7. **Hammer :** It is used in riveting, chipping etc. The various types of hammers are as folows :

   (a). Ball pane hammer.

   (b). Cross pane hammer.

   (c). Straight pane hammer.

   (d). Riveters hammer.

   (e). Carpenter's claw hammer.

   (f). Extra type hammer.

Out of the above six types of hammers, only ball pane hammer is mostly used for electrical jobs. It is made of cast steel. It has face, post, handle, pane, eye hole. Out of these parts the face and the pane are tempered but post part is kept soft. The size of a hammer varies according to its weight ranging from 100 grams to 1 kilogram. Three different types of hammers are shown in Fig 1.18, 1.19 and 1.20.

The eye hole of the hammer is made in egg shape so that its handle may not slip. Further, the fore-head of the handle is splitted into two parts and a *wedge* is fitted in the slot. In this way the hammer holds the handle firmly.

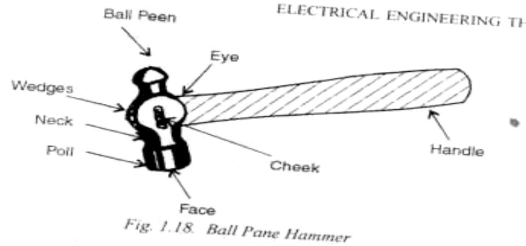


Fig. 1.18 Ball Pane Hammer

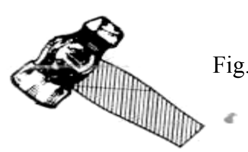


Fig. 1.20 Straight Pane Hammer

Fig. 1.19 Cross Pane Hammer

Care :

i. The handle should be tough and well fitted.

ii. No part of the hammer should be greasy.

iii. Drive the hammer by holding it at its end.

iv. Don't work with loose handled hammer.

8. Mallet : It is a wooden hammer. It is used for straightening the wires and the sheets of different metals. Its face is usually round or square.

Care :

i. A mallet should not be used for fixing the nails.

ii. The wood used for making a mallet should be sufficiently tough.

9. Electrician Knife : It is used for removing the insulation from the wire ends. It has a steel blade which can be folded inside the handle. The size of its blade is generally 10 centimetres.

Care :

i. The knife should have a sharp edged blade.

ii. Don't use it for cutting the wires.

10. Hand Drilling Machine : It is used for making holes in the wooden and mild-steel jobs. It has a geared wheel, wheel handle, machine handle and a drill-chuck. A twist drill bit is fitted in the drill-chuck whose diameter may vary from 1mm to 12mm.

Fig. 1.21. Hand Drill Machine

Care :

i. Keep it straight while drilling.

ii. Lubricate its gears from time to time with grease.

iii. The drill bit should be firmly held by the jaws of the drill chuck.

11. Ratchet Brace : It is used for making holes of large diameters in wood. An auger bit is used in it. It is a low spped machine. It is driven with a handle.

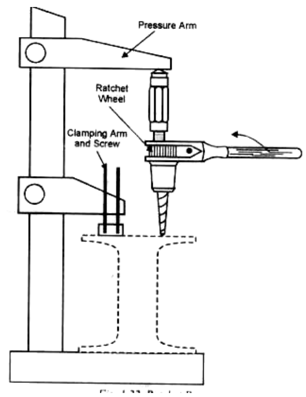


Fig. 1.22. Ratchet Brace

Care :

i. Keep it erect while drilling.

ii. The auger bit used should be clean.

12. Electric Drill Machine : It is an electric operated drill machine. It is operated with 220 to 250 volts A.C. supply. It may be portable or stand type. The twist drill bit is fitted in the drillchuck with the help of a chuck-key. The diameter of the drill bit varies from 1 mm to 25mm.

Care :

i. Keep it straight while drilling.

ii. Carry on dropping the water on the job while drilling.

13. Files : It is used for grinding the conduit pipe edges or the wooden jobs. It is made of high carbon steel duly hardened and tempered. Its main parts are tang, heel, face, edge, tip and the wooden handle. The size of files varies in accordance with length, shape, grade and cut. The main types of files are as follows :

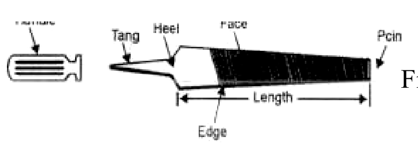


Fig. 1.23. Parts of file

(a). **Flat File :** It is flat on both the sides and it has a rectangular cross-sectio. It is used to grind the surplus metal or wood from the job.

(b). **Round File :** It has a round cross-section and its diameter reduced form the heel to tip. It si used for widening a rounded hole.

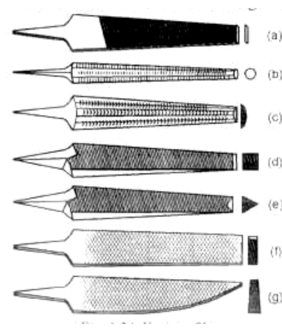


Fig. 1.24 Various files

(c). **Half – round File :** It is flat on one side and 1/3 curved on the other side. The amount of convexity never equals a semi-circle. Double cut dents are cut on it and like a round file it is also tapered. With this file the damaged hole can be set in order again.

(d). **Square File :** It has a square coss-section. It is used for widening a square or a rectangular hole. It is of double cut type.

(e). **Triangular File :** It has a triangular cross-section. It is used for sharpening the teeth of a saw.

(f). **Hand File :** It is rectangular in shape and in cross-section.

(g). **Rasp File :** It is a file for the use of carpenters. It has projected teeth. It has a half round cross-section.

Care :

i. Don't use a file without a handle or with a splitted type handle.

ii. A file should always be cleaned with a metallic wire brush.

iii. Use an acid for the cleaning of the files.

14. Stock and Die : It is used for making threads on the conduit and G.I. pipes. The stock is made of cast iron and the die is made of high carbon steel. For electrical jobs, the size of die varies from 12mm to 38 mm.

Care :

i. Don't cut the threads to the full depth of the job at a time.

ii. Tight up the die between the threading operations as and when required.

iii. Apply equal pressure on both the handles.

15. Rawal Plug Tool : It is used for making a hole in a concrete or a stone wall. Its bit is made of high carbon steel. The size of the general purpose tool varies from 6 to 10 SWG. numbers. A fibre plug is used in the hole made by rawal plug tool.

Care :

i. Rotate the tool gently after each hammering.

ii. The size of the rawal plug and the tool should be the same.

iii. It should not be used on metallic jobs.

16. Vice : It is *holding* tool used for holding the jobs. Different types of vices are used for different works. The main types of vices are as follow

(a). **Bench Vice :** It is also known as a *parallel jaw vice.* It has two main parts, namely the fixed jaw and the *movable jaw.* Its body is made of cast iron while its jaw-plates are made of tool steel. Jaw-plates are fitted to the body with machine screws. In order to increase the holding capacity of the jaws, the jaw-plates have *knurlings* on their faces. The movable jaw has a spindle, spring and a handle. The fixed jaw has a base with two holes for fixing it on the bench with bolts. The size of the vice is the length of its jaw-plates which varies from 6.5 to 20 centimetres.

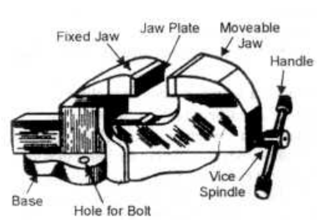


Fig. 1.25 Bench vice

Fig. 1.26 Pipe vice

(b). **Pipe Vice :** It is used for gripping the pipes while cutting or threading on them. It is made of cast iron. It has a *fixed-jaw* with two or three holes in its base for fixing it on the bench with bolts. The *movable jaw* moves vertically on its threaded spindle with the help of handle. The jaws of this vice are of 'V' shape.

(c). **Hand Vice :** It is used for gripping small jobs. It can't be fitted on a bench and it is used for hand work only, that is why it is called a hand-vice. It has two jaws, a long bolt and a wing nut.

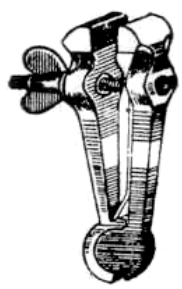


Fig. 1.27. Hand vice

(d). **Line Vice :** It is used for holding the cables in the over head wiring work. It has hooks or holes for the attachment of a tope in it.

17. Steel Scale : A measuring scale of hard and tempered steel is called a steel scale. Its length is usually 15, 30 or 60 centimetres.

18. Try Square : It is used in electrical wiring to set the casing or battern at right angles as and where required. It has a cast iron stock and a steel *blade*. The blade is marked in centimetres and its length is usually 15 or 30 centimetres.

19. Wrench : It is used for loosening or tightening the bolts and nuts. The different types of wrenches (or spanners) are as follows :

(a). **Double Ended Wrench :** It has open sockets on both of its ends, that is why it is called a double ended wrench. A set of wrenches consists of 6 to 13 pieces of different sizes.

(b). **Adjustable Open Ended Wrench :** The socket size of an adjustable wrench can be adjusted by a ring nut which can move on a bolt fitted in the head of the wrench. Its size depends on its length which varies from 15 to 30 centimetres.

(c). **Pipe Wrench :** It is also an adjustable wrench which has a fixed and an adjustable jaw sliding over the fixed-jaw. Its size depends on its length which varies from 20 to 60 centimetres.

Care :

i. It should not be used as a hammer.

ii. A proper wrench should be used as per size of the nut, bolt or a pipe.

iii. Care should be taken that your hand does not slip from the wrench while opening a nut or a bolt.

20. Scissors : It is a domestic tool used for cutting cotton cloth, tape etc.

21. Soldering Iron : It is a hand tool used for soldering the joints of wires. It consists of an heating element fitted in a case. A copper bit is attached to the element and a wooden handle is fitted at the other end of the case. Wires for electrical connections passes through the wooden handle. Its *wattage* varies from 25 to 250 watts for general purposes.

Care :

i. Clean the bit before soldering.

ii. The soldering iron should not be allowed to be overheated.

iii. Soldering flux should be used in soldering work.

22. Wire Gauge : It is used for measuring the diameters of metallic wires. It is made of steel. It has *slots* of different sizes on its circumference. The diameter of each slot is marked in millimetre and in SWG (standard wire gauge). The SWG system has numbers ranging from 0 to 36.

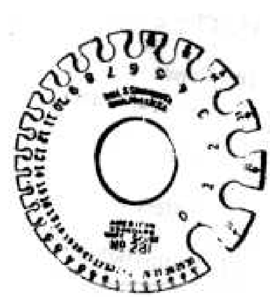


Fig. 1.28. Wire gauge

Care :

i. The slots of the wire gauge should be kept clean.

ii. Protect it against rust.

iii. The wire under measurement should not pass very tightly, through the slot.

1.10 Care and Maintenance of Tools :

i. Use a proper tool for each job.

ii. Protect the tools against rust.

iii. A tool, without handle or with a splitted handle, should not be used.

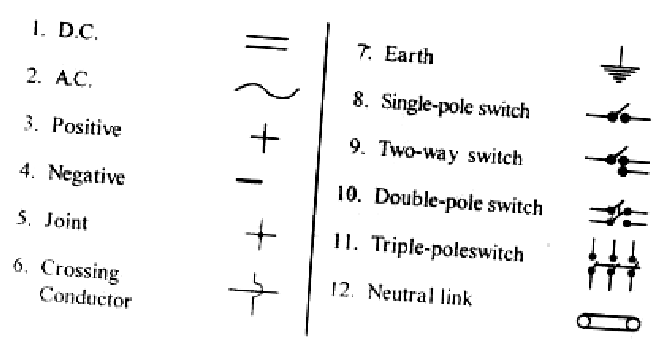
iv. Protect the pointed tips and blades of the tools.

v. Tools should not be placed in a haphazared way.

vi. Drilling tools should be driven straight.

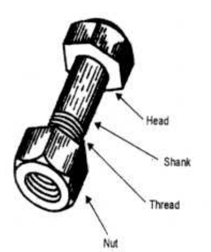
1.11 Identification and Specification of Bolts, Nuts and Screws :

Screws and bolts are used for joining two pieces of wood or metal. Both have threads. The shape of a screw is tapered but the shape of a bolt is cylindrical except the head. Nuts are used for tighting the bolts. Nut-bolts are used in motors, generators, transformers etc. Their size vary in length and diameter. A small bolt is known as a *machine screw* also.



13. Fuse cutout	31. Auto transformer
14. Coil	32. Wattmeter
15. Choke	33. Star
16. Condenser (Capacitor)	34. Delta
17. Cell	35. Circuit breaker
18. Battery	36. Horn
19. Lamp (bulb)	37. Siren
20. Lamp code	38. Fan point
21. Resistance	39. Fan regulator
22. Variable resistance	40. Earth plate
23. Intermediate switch	41. Socket
24. Ceiling rose	42. Socket with switch
25. Bell push	43. Multipush
26. D.C. Machine	44. Tubular heater
27. A.C. Machine	45. Water heater
28. Voltmeter	46. Bell
29. Ammeter	47. Buzzer
30. Transformer	48. Ring

Screws or wooden screws are used in wood work. They are made of iron or brass and vary in length and diameter. Generally 2/3 part of a screw is threaded. The length of the screw used for fixing round blocks, boards, casings, batten etc, should be thrice the thickness of the wooden fixture. The length of the screws used in general work varies from 12 mm to 75 mm.



GLOSORY

1. Instructions regarding electric shock should be displayed in such a manner that every worker can see them easily in industries.
2. There are two main methods of artificial respirations
   a. Sylvestors method
   b. Schaffers method
3. There are two new methods of artificial respirations
   a. Mouth to mouth method
   b. Mouth to nose method

SHORT QUESTIONS

1. What are the important instructions regarding electric shock should be displayed in industries ?
2. What will you do if any person is shocked by electric current or he is in contact with a live-line ?
3. Write a short note on ‘Electric Shock’ ?
4. What is artificial respiration ?
5. Mention the two methods of artificial respiration ?
6. Mentionn the new methods of artificial respiration ?
7. Mention the hand tools of an Electrician ?
8. What are the main types of files ?
9. Write a short note on care and maintenance of tools ?

ESSAY QUESTIONS

1. What safety precautions would you observe to avoid electrical accidents ?
2. What precautions wil you observe while working on an electrical machine ?
3. Explain about ‘Removal of Electric Shock’ ?
4. Explain the different methods of artificial respiration ?
5. Describe main hand tools of an Electrician ?

Chapter – 2

Basic Electricity

2.1 Introduction :

The theory of electricity has emerged from the basic structure of atom. Atom is the smallest particle which cannot be further subdivided. An atom consists of protons, neutrons and electrons. An atom is electrically neutral i.e., positive charge of protons is equal to the negative charge of electrons.

If the electrons are detached from a neutral body, it no longer remains neutral, but attains positive charge because of the deficit of electron.

If neutral body is supplied with electrons, it no longer remains neutral, but attains negative charge because of the excess electrons.

Therefore a body is said to be charged if it has either excess or deficit of electrons from its normal number.

2.2. Electric Potential :

"The capacity of a charged body to do work is called electric potential".

Every charged body has the capacity to do work by moving another charged body either by attraction or repulsion. The unit of electric potential is 'Volt'.

The electric potential at a point due to a charge is one volt if, one joule of work is done in bringing a unit charge from infinity to that point.

Electric Potential (v) = Work done (W) / Charge (Q)

1 volt = 1 joule / 1 Coulomb

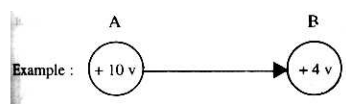
2.3. Potential Difference :

The difference in the electric potentials of two charged bodies is known as potential difference.

From the above example we can see that the potential difference between the two charged bodies A and B is = 8 – 3 = 5 Volts.

2.4. Current :

The flow of electrons is known as current. If two bodies of different electric potentials are joined through a conductor the electrons will flow from a body of higher potential to a body of lower potential.



From the above example it can be seen that electrons will from the body. A which is at a higher potential i.e. 10 v to the body B which is a lower potential i.e. 4 v.

When the two bodies attain same potential, the flow of current stops. Therefore, the current can also be defined as the rate of flow of **electric** charge, in electric circuits.

The unit of current is 'Ampere'.

Current (I) = (Charge (Q) / Time (t))

1 Ampere = (1 Coulomb / 1 Second)

2.5. Ohm's Law :

"Temperature remaining constant, the current passing through a given conductor is directly proportional to the voltage applied to the conductor".

From Ohm's law, Current α Voltage.

$1 \alpha V$

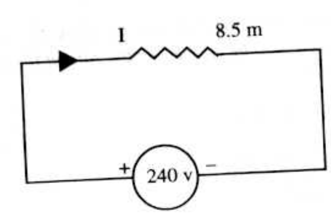
V/I = R(Constant)

V = IR

The constant R, which is equal to V/I is known as resistance of that conductor. The unit of resistance is 'ohm' denoted by ' '.

2.6. Problems on Ohm's Law :

1. An accidental short circuit to a 240 V supply is caused by the connection of a component of 8.5 mΩ across the supply terminals. What will be the short circuit current.



From Ohm's law V = IR

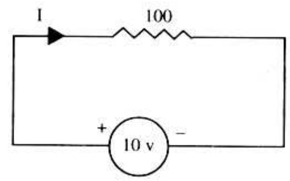
$I = V/R = 240/8.5 \times 10^{-3}$

$= 28.23 \times 10^{3}$ Ampere's.

∴ Short circuit current is 28.23 Kilo-amperes. Ans.

2. A current in a circuit due to a potential differences of 10V applied to a resistor of resistance 100Ω. What resistance would permit the same current to flow if the supply voltage were 100V.

Solutions:

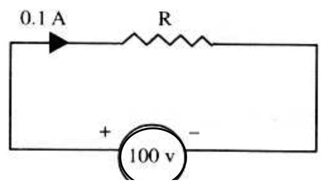


According to Ohm's law V = IR

I = V/R = 10/100.

= 0.1 Ampere's

The resistance to permit the same current at 100V supply voltage is given by



V = IR

R = V/I = 100/0.1

= 1000 = 1kΩ. Ans.

2.7. Laws of resistance and specific resistance :

Laws of resistance can be obtained from the factors upon which resistance depends :

1. The resistance (R) of a conductor is directly proportional to its length (l).

$$R \propto l$$

2. The resistance of a conductor is inversely proportional to its cross sectional area 'a'.

$$R \propto \frac{l}{a}$$

3. The resistance of a conductor depends upon the nature of the material used.
4. The resistance depends on the temperature.

From these laws, we have

$$R \alpha \frac{l}{a} \quad ; \qquad R = \frac{l}{a}$$

Where ρ (rho), is a proportionality constant known as resistivity or specific resistance. Its value depends on the nature of the material.

Specific resistance = Ra / l

$= (\text{ohm x } m^2) / m$

= ohm – m.

Therefore the unit of specific resistance is ohm – meter (or ohm-cm).

2.8. Problems on resistance and specific resistance :

1. Find the resistance of 100 meters of copper wire 0.05 cm in diameter. Take specific resistance of copper is 1.7µ -cm.

Solution :

Length of the wire l = 100m = 100 x 100 = 10,000 cm,

Diameter of the wire d = 0.05cm.

Cross sectional area, $a = \Pi d^2/4$

$= \frac{22}{7} x(0.05)^2/4$

$= 1.96 \times 10^{-3} \text{ cm}^2$

Resistivity, ρ $= 1.7\mu\Omega\text{-cm.} = 1.7 \times 10^{-6}\Omega\text{-cm.}$

From, R = l/a $= (1.7 \times 10^{-6}) \times 10{,}000/1.96 \times 10^{-3}$

$= 8.67\Omega$

Therefore resistance of the wire, R = 8.67 ohm. Ans.

2. A length of wire has a resistance of 4.5 ohm. Find the resistance of another wire of the same material three times long and twice the cross sectional area.

Solution : From the equation

$$R = \frac{l}{a}$$

Let length of the wire = l_1

Cross sectional area = a_1

Resistivity = ρ

Resistance, R = 45 ohm.

From the equation,

$$R = \frac{\rho l}{a}$$

$$4.5 = \frac{\rho l_1}{a_1} \quad \text{----------- (1)}$$

Another wire is of same material, therefore resistivity is same i.e. ρ. But it is given that the length of

Area of another wire $a_2 = 2a_1$.

Resistance $R = \rho l_2/a_2$

$= \rho 3l_1/2a_1$

$= 1.5 \times pl_1/a_1$

= 1.5 x 4.5 = 6.75Ω Ans.

Therefore the resistance of another wire of same material which is 3 times long and twice the cross section area is 6.75 ohm.

Exercise Problems

1.Determine the resistance of a 564m length of aluminum conductor whose rectangular cross section is 4cm x 2cm

Take = 2.826×10^{-8} -m [Ans : 0.02 Ω]

2. The resistance of a manganin wire of 10mm long is 50Ω. If its cross sectional area is 0.1 mm2, calculate its specific resistance in Ω - m. If the wire is stretched to four times its original length, by how many times would you except its resistance to be increased?

[Ans : 50×10^{-6} Ω-m; 16 times]

2.9. Effect Of Temperature On Resistance :

The resistance of the material changes with the change in temperature.

In some materials, resistance increases with the increase in temperature. Such materirals are said to have positive temperature coefficient of resistance. E.g. : Copper, Aluminum etc.

In some materials, resistance decreases with the increase in temperature. Such materials are said to have negative temperature coefficient of resistance. E.g. : Mica, Germanium. Rubber etc.

2.10 Temperature co-efficient of Resistance :

Consider a conductor having resistance of R_0 at 0^0C and R_t at t^0c. If we change the temperature from 0^0C to t^0C, its resistance increases from R_0 to R_t.

1. The change in resistance $(R_t – R_0)$ is directly proportional to its initial Resistance R_0.
2. The change in resistance $(R_t – R_0)$ is directly proportional to the rise in Temperature. $(t-0=t^0C)$.
3. The change is resistance depends on the nature of the material.

$$R_t – R_0 \propto R_0 t$$

$$R_t – R_0 = \alpha_0 R_0 t. \qquad \text{------(1)}$$

Where α_0 is the proportionality constant known as temperature co-efficient of resistance at 0^0C. Its value depends on the nature of the material and temperature.

From equation (1)

$R_t = R_0 (1 + \alpha_0) t$ ------(2)

$\alpha_0 = \frac{R_{\backslash T} - R_o}{R_{oT}}$ ------(3)

The unit of temperature co-efficient of resistance is '$/^0$c' (per degree centigrade).

If the temperature co-efficient of resistance α is positive, then the resistance increases with the increase in temperature.

If α is negative, then the resistance decreases with the increase in temperature.

Let R_1 be the resistance at t_1 ^{0}C.

R_2 be the resistance at t_2 ^{0}C.

$R_1 = R_0 (1+\alpha_0 t_1)$ -----(1)

$R_2 = R_0 (1+\alpha_0 t_2)$ -----(2)

Dividing equation (2) by equation (1)

$R_2 = R_1 [1+\alpha_0(t_2-t_1)]$

$\frac{R_2}{R_1} = \frac{(1+\alpha_o t_2)}{(1+\alpha_o t_1)}$ $= \frac{R_2}{R_1} = 1 + \alpha_o (t_2 - t_1)$

2.11. Resistance in Series :

Let,

R_1, R_2, R_3 ---- R_n be the individual resistance which are connected in series,

V be the applied voltage and,

I be the current passing in the circuit as shown in the fig. Below

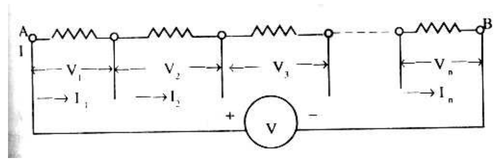


Fig. 2.1 Resistances in Series

It can be seen from the circuit diagram same current 'I' flows through all resistors i.e. $I = I_1 = I_2 = I_3 = \text{-----} = I_n$. The total voltage 'V' is distributed among all resistance as shown in Fig.1.10(a).

Let, V_1 be the voltage across R_1, V_2 be the voltage across R_2, and so on.

By applying Ohm's law,

$$V_1 = IR_1$$

$$V_2 = IR_2$$

$$V_3 = IR_3$$

$$V_n = IR_n$$

The total voltage is equal to V

$V = V_1 + V_2 + V_3 + \text{---------} + V_n$

$= IR_1 + IR_2 + IR_3 + \text{-----} + IR_n$

$= I\,(R_1 + R_2 + R_3 + \text{------} + R_n)$

$= V/I = (R_1 + R_2 + R_3 + \text{------} + R_n)$

But V/I is the total resistance R_T between A and B

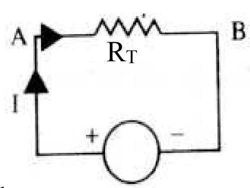


Fig. 2.2 Equivalent circuit

R_T is called total resistance or equivalent resistance of all resistances.

$R_T = R_1 + R_2 + R_3 + \text{-----------} + R_n$

Hence when a number of resistance are connected in series, total resistance is equal to sum of individual resistances.

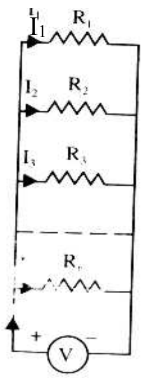
2.12. Resistances in Parallel :

Let,

R_1, R_2, R_3 ---- R_n be the individual resistances connected in parallel,

V be the applied voltage and,

I be the current passing through the circuit.



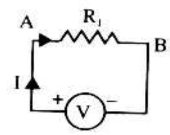


Fig. 2.3. Resistances in parallel

When the resistors are connected in parallel, the voltage across each resistor is same, but currents are different. The total current I is divided into I_1, I_2, I_3 ---- I_n and if R_T is the resultant equivalent resistance of the circuit as shown in fig(b) above then,

$= V/R_T = I$ -----(1)

$I = I_1 + I_2 + I_3 + \text{---------} + I_n$ ------ (2)

But $I_1 = V/R_1$

$I_2 = V/R_2, I_3 = V/R_3 \ldots\ldots\ldots\ldots I_n = V/R_n$

Substituting the values of I_1, I_2, I_3 ---- I_n in equations 1 & 2.

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

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \ldots\ldots + 1/R_n$$

If only two resistors are connected in parallel, then

$1/R_T = 1/R_1 + 1/R_2$

$$RT = (R_1 R_2) / (R_1+R_2)$$

2.13. Resistance in series and parallel combination :

Some times the circuits may be neither pure series nor pure parallel, but a combination of series and parallel, may come across as shown in Fig 2.4(a) below.

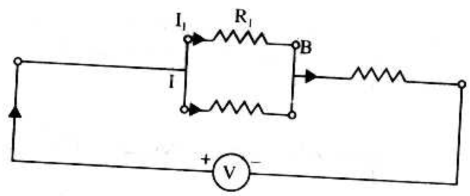


Fig. 2.4a. Resistances in series and parallel

For such circuits, first the parallel combination of resistances R_1 and R_2 should be solved for finding its total equivalent resistance.

$1/R_e = 1/R_1 + 1/R_2$

$Re = (R_1 R_2) / (R_1+R_2)$

Then the equivalent resistance R_e and R_3 are in series as shown in Fig. 2.4 (b) below.

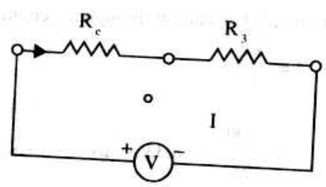


Fig. 2.4b. Equivalent circuit diagram

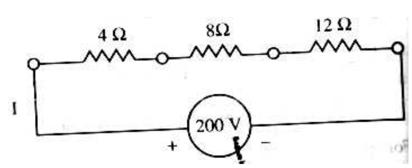
Thus the total resistance of the series parallel circuit is the sum of R_e and R_3.

$$R_T = R_e + R_3$$

2.14 Solved Problems

1. Three resistances 4, 8 and 12 ohms are connected in series across a generator, which maintains a potential of 200V. What is the resistance of the circuit? What is the value of current?

Solution

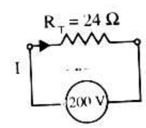


In series circuit, $R_T = R_1 + R_2 + R_3$

= 4+8+12

= 24Ω

Equivalent circuit :



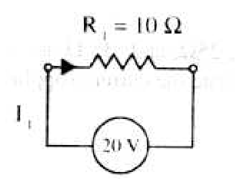
According to ohm's law current through the circuit

I = V/RT

= 200 / 24 = 8.33 Amps……ANS.

2. A circuit has 200V battery across resistance R_1 = 10Ω. How much current will flow in the circuit? How much resistance 'R_2' should be added in series with R_1 to reduce the current to one fourth?

Solution :

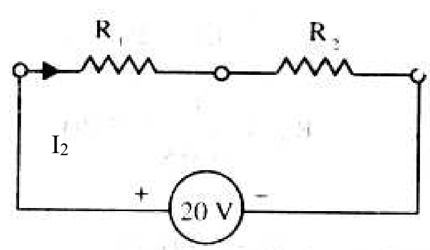


Current through resistance R_1 is given by

$I_1 = V/R_1$

= 20 / 10

I_1 = 2 Amps



By adding R_2 resistance in series current value reduces to one fourth.

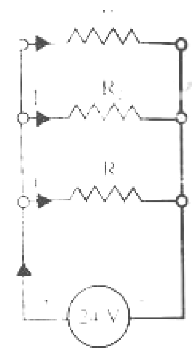
$I_2 – I_1/4 = 2/4 = 0.5$ Amps.

$I_2 (R_1 + R_2) = V$

$R_1+R_2 = V/I_2 = 20/0.5 = 40\Omega$

$R_2 = 40 - R_1 =40 – 10 = 30\Omega$. Ans.

3. Three resistances of 15Ω, 25Ω, and 35Ω are connected in parallel across a 24V battery. Calculate the current supplied by the battery.



Solution :

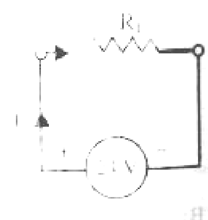
Given $R_1= 15$, $R_2=25$, $R_3 = 35$

In parallel circuit,

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

$$\frac{1}{RT} = \frac{1}{15} + \frac{1}{25} + \frac{1}{35} = \frac{1}{50}$$

$R_T = 1/0.315 = 7.394$

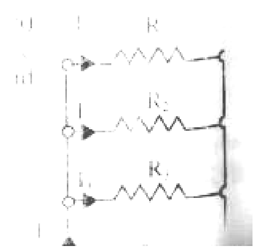


Equivalent resistance $R_T = 7.394\Omega$

Current through the circuit,

$I = V/R_T = 24 / 7.394 = 3.246$ Amps. ANS

Parallel circuit has three branch resistances of 20 and 5Ω. The current through 20Ω resistance . Find the voltage across each resistor and current flowing through other two resistors.



Solution :

Given $R_1 = 20$

$R_2 = 10$

$R_3 = 5$

$I_1 = 1A$

In a parallel circuit,

$I_1 = V/R_1$

$V = I_1 R_1 = 20V$. ANS

The voltage across each resistor in parallel circuit is same i.e.,

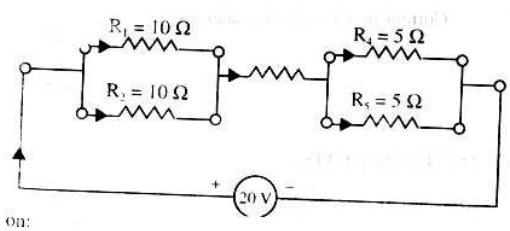
$V = V_1 = V_2 = V_3 = 20V$.

Curren flowing through other two resistors is given by

$I_2 = V/R_2 = 20/10 = 2A$. ANS.

$I_3 = V/R_3 = 20/5 = 4A$. ANS.

4. Find the equivalent resistance and current supplied by the battery of the given circuit.



Solution :

Given $R_1 = 10\Omega$ $R_2 = 10\Omega$

$R_3 = 2.5\Omega$ $R_4 = 5\Omega$

$R_5 = 5\Omega$

Resistance R_1 and R_2 are in parallel, therfore their equivalent resistance is given by,

$R_{e1} = R_1 R_2 / R_1 + R_2$

$= 10 \times 10 / 10 + 10 = 5\ \Omega$

Similarly resistance R_4 and R_5 are in parallel, therefore their equivalent resistances are given by,

$R_{e2} = R_4 R_5 / R_4 + R_5$

$= 5 \times 5 / 5 + 5 = 2.5\ \Omega$

Now the resistances R_{e1}, R3, and R_{e2} are in series.

Therefore, total resistance of the circuit

$R_T = R_{e1} + R_3 + R_{e2}$

= 5 + 2.5 + 2.5

R_T = 10 ANS

Current supplied by the battery $I = V/R_T = 20/10$

I = 2A Ans

Exercise Problems

1. Two resistances 40 and 20 Ω are connected in series across a 240 supply. Find the current flowing in and the voltage across each of the resistances. [Ans. 4A, 160V, 80V]

2. A circuit has 12 V applied across 5Ω resistance R_P How much is the current in the circuit? How much resistance R2 must be added in series with R1 to reduce the current by one-half? [Ans. 2.4A, 5ohms]

3.What is the combined resistance of a circuit that has resistances 20,10,40 and 80 Ohms all connected in parallel. [Ans. 8.33 ohms]

4. Find I_1, I_3, R_2 and R_3 of the circuit shown in Fig. below. The total resistance R_T is 90 ohms. [Ans. I_1=0.6667, I_3=0.1443A,]
[R_2 = 333.33 ohms, R_3=693 ohms]

5. A resistance of 30 ohms is connected in parallel with a resistance of 60 ohms. In series with the parallel combination is 20 ohms resistor. What is the resistance of the entire circuit. [Ans. 40 ohms]

6. The combined resistance of two conductors is 9 ohms when the are connected in series and 2 ohms when they are connected in parallel. Find the resistance of each conductor. [Ans. 6 ohms, 3 ohms]

2.15 TERMINOLOGY

1. **Circuit :** A circuit is a conducting path through which either an electric current flow is intended to flow. Circuits are of two types namely,

a. Active circuit b. Passive circuit.

2. **Electric Network :** A combination of various electric elements connected in any manner whatever, is known as electric network. A circuit may be a network or a part of the network.
3. **Electric elements or circuit elements or network elements :** These are the components with which a circuit or network is formed. These electric elements are of two types namely,

a. Active elements b. Passive elements.

4. **Active elements :** The sources may be voltage / current sources which supply energy to a circuit / network are known as active elements. E.g. : Generators, batteries etc.
5. **Passive elements or circuit parameters :** The various elements like resistance, inductance, capacitance are called passive elements or circuit parameters. The parameter may be lumped or distributed.
6. **Linear circuit :** A linear circuit is one whose parameters are constant i.e. they do not change with voltage or current.
7. **Non-linear circuit :** A circuit in which the parameters change with voltage or current is known as non-linear circuit.
8. **Unilateral circuit :** A circuit whose properties or characteristics change with the change of direction of its operating current is known as unilateral circuit. E.g. Rectifier.
9. **Bilateral circuit :** A circuit whose properties or characteristics are same in either direction is known as bilateral circuit. E.g. Transmission line.
10. **Active circuit :** A closed electric circuit in which active elements like voltage or current sources are found along with passive elements is known as active circuit.
11. **Passive circuit :** A closed electric circuit in which only passive elements are present is known as passive circuit.

12. Junction or Node : In a network or circuit a point at which two or more elements are connected and where division of current takes place is known as junction node. Junctions are represented by thick dots.

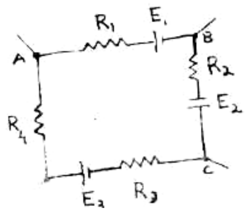


Fig. 2.5a. Active Circuit

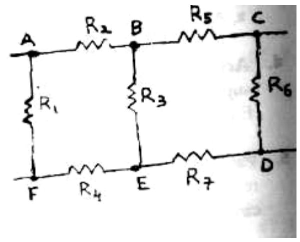


Fig. 2.5b. Passive Circuit

13. Branch : A part of the network or circuit connected between two junctions is called a branch.

14. Loop or Mesh : A loop is a closed path and may contain active or passive elements or both. A loop may be a part of a circuit or network.

2.16. KIRCHOFF'S LAWS

When a D.C network is complicate and cannot be reduced to a simple series or parallel arrangement then Kirchoff's laws are used. There are two laws, which are nothing but extension of Ohm's law.

Kirchoff's first law :

It is also known as Kirchoff's current law (KCL) or point law. It states that,

"The algebraic sum of the currents meeting at an electric junction in a network is equal to zero"

Or

In an electric network, the sum of current flowing towards an electric junction is equal to the sum of the currents flowing away from the junction".

In fig 2.6 shown below, at junction A the current towards the junction is I and away from the junction are I_1, I_2, I_3.

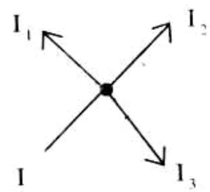


Fig. 2.6

Assuming the currents flowing towards the junction be positive and the currents flowing away the junction be negative, according to Kirchoff's law, the algebraic sum of currents at junction A is,

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

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

Therefore, Sum of incoming currents = Sum of outgoing currents.

Kirchoff's second law :

It is also known as Kirchoff's voltage law (KVL) or mesh law. It states that,

"In any closed mesh or path, the algebraic sum of the products of current and resistance in each of the conductor plus the algebraic sum of the emf's in that path is equal to zero".

Or

"The sum of all emf's and resistive drops with their proper signs in a closed mesh or path is equal to zero".

We assign positive sign to a voltage rise i.e., if we start from negative terminal of a battery to its positive terminal.

We assign negative sign to a voltage drop, i.e., if we start from the positive terminal of the battery to its negative terminal.

Consider a closed mesh ABCDA as shown in fig.2.7 below.

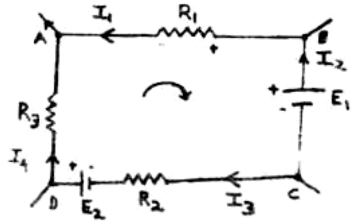


Fig. 2.7

Starting from point A and travelling through B to C to D to A, signs or different voltage sources and voltage drops are as follows.

Let,

I_1, I_2, I_3, and I_4 are the assumed directions through A-B, B-C, C-D and D-A.

I_1R_1 is a rise in voltage, so positive.

I_3R_2 is a voltage drop, so negative.

I_4R_3 is a voltage drop, so negative.

E_1 is a decrease in potential so negative.

E_2 is a rise in potential so positive.

Now apply KVL to mesh ABCDA,

$I_1R_1 – E_1 - I_3R_2 + E_2 - I_4R_3 = 0$

Or $I_1R_1 - I_3R_2 - I_4R_3 = E_1 – E_2$

2.17 APPLICATION OF KIRCHOFF'S LAWS TO THE WHEATSTONE BRIDGE

The Wheatstone bridge network consists of four resistances P,Q,R,S and B and a galvanometer 'G' as shown in fig. 2.2. Vertical resistance indicates the galvanometer. It is mostly used in electric measurements to determine the value of unknown resistance.

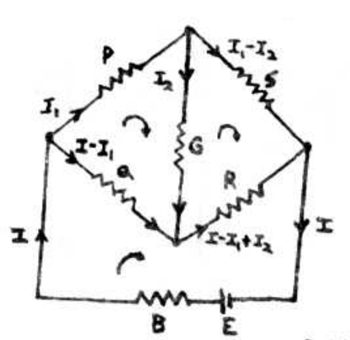


Fig. 2.8. Wheat stone bridge

B is the internal resistance of cell, E is the voltage of the cell E. G is the internal resistance of galvanometer.

Taking the mesh (a) BQRB according to KVL,

$E = IB + (I-I_1) Q + (I -I_1+I_2)R$ --------------(1)

For the mesh (b) PGQP according to KVL,

$0 = I_1P + I_2G – (I – I_1)Q$ ----------------(2)

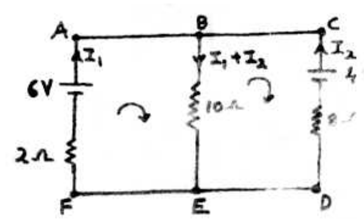
For the mesh (c) SRGS according to KVL,

$0 = (I_1 – I_2)S – (I – I_1+I_2)R – I_2G$ -------------(3)

Solving equations (1), (2) and (3), currents I_1, I_2, and I_3 can be detemined.

2.18. PROBLEMS

1. Using Kirchoff's law calculate the current in each branch of the circuit shown in fi. 2.9 below.



Solution :

Fig. 2.9.

Let the current distribution in each branch be as shown in fig.2.3.1

Applying KVL to mesh ABEFA,

$-10(I_1 + I_2) –2I + 6 =0$

$-10 I_1 – 10 I_2 – 2 I_1 + 6 = 0$

$12 I_1 + 10 I_2 = 6$

or $6 I_1 +5 I_2 = 3$ -----------------------(1)

Applying KVL to mesh BCDEB,

$-4 + 8 I_2 + 10(I_1 + I_2) = 0$

$-4 + 8 I_2 + 10I_1 + 10I_2 = 0$

$10I_1 + 18I_2 = 4$

or $5I_1 + 9I_2 = 2$ -------------------(2)

Multiplying equation (1) by 5,

$30\ I_1 + 25\ I_2 = 15$ -------------------(3)

Multiplying equation (2) by 6,

$30\ I_1 + 54\ I_2 = 12$ -----------------(4)

then subtracting equation (4) from equation (3)

$30\ I_1 + 25\ I_2 = 15$ --------------------(3)

$30\ I_1 + 54\ I_2 = 12$ ---------------------(4)

$-29\ I_2 = 3$

$I_2 = -0.10345A$ Ans.

Substituting the value of I_2 in equation (1) we get,

$6\ I_1 + 5(-0.10345) = 3$

$$I_1 = \frac{3 + 5\,(0.10345)}{6}$$

$I_1 = 0.5862$ A. Ans

Since I_2 is negative, its actual direction of flow is opposite to that shown in fig 2.3.1. It is a charging current where as I_1 is discharging current.

2. Calculate the current through the galvanometer in the following Wheatstone bridge network below.

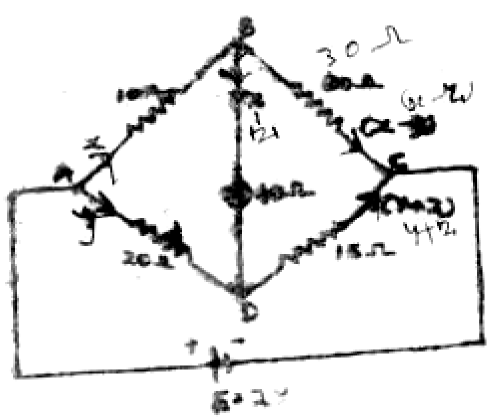


Fig. 2.10

Solution :

Let the current through the galvanometer be 'z' as shown in fig. 2.10

Applying KVL to mesh ABDA.

$-10x - 40z + 20y = 0$

$-x - 4z + 2y = 0$ ------------------- (1)

Applying KVL to mesh BCDB,

$-30(x-z) + 15(y+z) + 40z = 0$

$-30x - 30z + 15y + 15z + 40z = 0$

$-30x + 15y + 85z = 0$

or $-6x + 3y + 17z = 0$ -----------------(2)

Now applying KVL to mesh ADCEA,

$-20y - 15(y+z) + 2 = 0$

$-20y - 15y - 15z = -2$

$35y + 15z = 2$ ------------------ (3)

Multiplying equation (1) by 6 and subtracting equation (2) from equation (1),

$-6x + 12y - 24z = 0$

$-6x + 3y + 17z = 0$

____

$9y - 41z = 0$ ------------------------(4)

Multiplying equation (3) by 9 and equation (4) by 35 then, subtract equation (4) from equation (3), we get

$315y + 135z = 18$

$315y - 1435z = 0$

____

$1570z = 18$

$z = 0.011465A$

$z = 11.465mA$ Ans.

Therefore, current through the galvanometer is 11.465mA.

3. Find the current in each branch of the given network shown in fig.2.11 below.

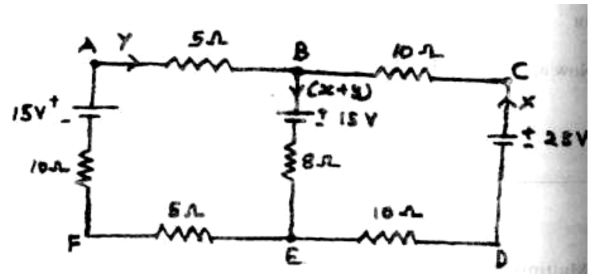


Fig. 2.11

Solution :

Let the currents in each branch are shown in fig.2.3.3

Applying KVL to mesh ABEFA,

$5y - 15 - 8(x+y) - 5y - 10y + 15 = 0$

$-8x + 28y = 0$

or $2x + 7y = 0$ ----------------------(1)

Applying KVL to mesh BCDEB,

$10x - 25 + 10x + 8(x+y) + 15 = 0$

$28x + 8y = 10$

or $14x + 4y = 5$ ----------------------(2)

Multiply equation (1) by 7 then subtract equation (2) from Equation (1) we get,

$14x + 49y = 0$

$14x + 4y = 5$

$45y = -5$

$y = -0.1111A.$ Ans.

Negative sign indicates the battery in branch AF is charging.

Substituting value of y in equation (1), we get

$2x + 7(-0.1111) = 0$

$x = 0.3889A.$ Ans.

Current through branch BE is,

X + y = 0.3889 – 0.1111 = 0.2778A. Ans.

Exercise Problems

1. Find the current in branch BE of the network shown in fig. Below.

2. Solve the bridge given in fig. below for the current through 4 ohms Resistor.

3. Determine the current in each branch of the network shown in fig. below.

GLOSSARY

1. The capacity of a charged body to do work is called electric potential. Its unit is volt.
2. The flow of electrons is known as Current. It is measured in amperes.
3. Ohms law states, "Temperature remaining constant, the current passing through a given conductor is directly proportional to the voltage applied to the conductor".

   $V = IR$
4. According to laws of resistance.

Where ρ is specific resistance

5. Effect of temperature on resist.

   $R_t = R_0 (1 + \ )t$

   Where α is temperature coefficient of distance measured in $/^0C$.
6. $R_2 = R_1 [1 + \alpha_0(t_2 - t_1)]$
7. Resistances in series, $R_T = R_1 + R_2 + R_3 +$ -------------------- $+ R_n$
8. Resistances in parallel,
9. In a network, where the division of current takes place is known as a junction or node.

10. A part of the network connected between two junctions is called a branch.
11. A loop is a closed path in a circuit.
12. Kirchoff's current law or first law states that the algebraic sum of the currents meeting at an electric junction in a network is equal to zero.
13. Kirchoff's voltage law or second law states that the sum of all emf's and resistive drops with their proper sign in a closed mesh or path is equal to zero.

SHORT QUESTIONS

1. What is Electric Potential ? Give units?
2. Define potential difference and state units ?
3. Define (i). Current

   (ii). EMF
4. What is Resistance ? Give units.
5. State Ohm's law.
6. Define resistivity and state units.
7. Define temperature coefficient of resistance.
8. Define a network.
9. Define loop and junction.
10. State Kirchoff's current law.
11. State Kirchoff's voltage law.

ESSAY QUESTIONS

1. Derive an expression for an equivalent resistance, when three resistances are connected in series ?
2. Derive an expression for an equivalent resistance, when three resistances are connected in parallel.
3. State and explain Kirchoff' Laws of electric current.

Chapter – III

Work, Power and Energy

3.1. Work and its Units

'If a body is displaced by the appliacation of a force on it then a work is said to be done.' If the body is under-rest and it remains under-rest even on the application of a force on it, then no work is done. If the body is raised up a certain height or it is displaced upto a certain distance then the work is said to be done. In this way the work depends on two factors – the force and the distance.

∴ Work = Force x Distance

Or W = F x d

Unit of Work. The unit of work is a derived unit. Therefore it depends on the units of the force and the distance, e.g., s

1 kilogram x 1 meter= 1 Kg.m

1 pound x 1 foot = 1 Foot pound

1 Newton x 1meter = 1 joule

The C.G.S. unit of work is erg. It is the amount of work done in displacing a body upto a distance of one centimetre with application of one dyne of force. The M.K.S. unit of work is joule. It is the amount of work done in displacing a body upto a distance of one metre with the application of one newton of force. The F.P.S. unit of work is *foot – pound.* It is the amount of work done in displacing a body upto a distance of one foot with the application of one pound of force.

Therefore, 1 dyne x 1cm = 1 erg

1 newton x 1m = 1 joule

1 pound x 1 ft = 1 ft.lb (foot.pound)

3.2. Power and its Units

Power is the rate of doing work. In C.G.S. system its unit is Erg/second. In M.K.S. system its unit joules/second. In S.I. system of units, the unit power is watt.

3.3. Energy and its Units

Energy is the capacity for doing the work and is measured by the work which the body can do. There are various types of energies i.e., Electrical Energy. Mechanical Energy, Heat Energy etc.

In electrical engineering the unit of energy is joule. The practical unit of energy is kilowatt hour. It is also known as one unit of Electrical Energy, or Board of trade unit.

1 joule = 1 watt second

1 Kilowatt hour = 1 unit of electricity

= 1 B.O.T. unit.

3.4.Joule's Law

Dr. Joule during the year 1841 has discovered that whenever current flows through a conductor, heat is produced. Hence according to Joule's law, Heat produced in a current carrying conductor is

i) directly proportional to the square of the conductor

ii) directly proportional to the resistance and

iii) directly proprotional to the time for which the current flows

Let H = Heat produced in calories.

Electrical energy expended = I^2 R.t joules

Note: 1joule = 1 watt x 1 second

1 kilo calorie = 4180 joules

1 calorie = 4.18 joules

Hence Heat produced in calories H= $\frac{I^2 RT}{J}$

Where J = Joule constant

= 4.18 joules per calorie

3.5. Applications of Heating Effect of Electric Current

There are various useful practical applications of the heating effect of electic current. The following are teh examples in which it is practically applicable:

i) Electric Kettle and cooker

ii) Electric iron and heater

iii) Metal filament lamps and arc lamps

iv) Electrical ovens and stoves

v) Electrical thermostats and fuses

vi) Electrical arc welding

vii) Electric water heating and space heating

viii) Electrical furnaces meant for Heat treatment and melting of metals.

3.6. Heating Effect of Electric Current

When an electric current flows through a conductror, electrical energy is expended in overcoming the frictional resistance between electrons and molecules of the wire. This electrical expended will be converted into heat energy. The phenomenon of convention of electrical energy into heat energy is known as *Heating Effect of Electric Current.*

The following information is very useful while evaluating relative problems on heating effect.

i) Quantity of heat required = m.s.t calories

Where, m = Mass in grams

S = Specific heat

T = Rise in temperature in ^0C

Note. Specific heat of water = 1

Mass of 1 litre water = 1 kg.

ii)

Where R = Resistance of heating element

V = Applied voltage

W = Wattage of Kettle

I = Current in amperes

iii).Efficiency of Kettle =

iv) Electrical energy in joules = Wattage x Time in seconds

∴ Wattage of Kettle =

∴ Time in seconds =

v) 1 Kilo calorie = 4180 joules

1 joule = 1 watt second

Density of water = 1 gram / c.c.

Example 3.1. Define joule's equivalent of heat and calculate the time taken to raise the temperature of 2.5 liters of water at 15^0C to boiling temperature by means of a heater also. The efficiency of heater is 80%.

Solution.

Boiling temperature of water = 100^0C (Assumed)

Specific heat of water S = 1(Assumed)

Mass of water m = 2.5 kg

Wattage of Kettle w = 1500 watts

Applied voltage V = 230 volts

∴ Rise in temparature t = 100-15 = 85^0 C

∴ Quantity of heat required = m.s.t calories

= 2.5 x 1 x 85

= 212.5 kilo calorie

Input required =

=

= 265.625 kilo calories

= 265.625 x 4180 joules

= 1110312.5 joules

∴ 1kilocarie = 4180 joules

1 joules = 1 watt second

= 1110312.5 watt seconds

∴ Time required =

=

= 740.21 seconds

= 12 minutes 20.21 seconds

= say 12 minutes 20 seconds Ans.

= 35.27 ohms Ans.

∴ Time required = 12 minutes 20 seconds

∴ Resistance of heating element = 35.27 ohms

Example 3.2. An electric kettle rated 500 watts raises the temperature of one liter of water from 25^0 C to 100^0 C in 15 minutes. What percentage of electrical energy is utilised in heating water?

Solution.

Mass of water m = 1 kg

∴ 1 liter water weighs 1 kg

Specific heat of water S=1

Rise in temperature = 100 – 25 = 75^0 C

∴ Quantity of heat required = m.s.t calories

= 1 x 1 x 75

= 75 kilo calories

= 75 x 4180 joules

∴ kilo calorie = 4180 joules

∴ Energy output = 75 x 4180 joules

Energy input in joules

= Input power in watts x Time in seconds

= 500 x (15x60)

= 500 x 15 x 60 joules

∴ Efficiency of Kettle =

=

=

= say 69.7%

∴ Percentage of electrical energy utilised = 69.7% Ans.

3.7. Electrical Power

Power of any machine is the rate of doing work. In Electrical Engineering unit of power is joule per second or watt. The product of voltage and current is also known as Electrical Power. 1 kilowatt is equal to 1000 watts. In general, the power of electrical machines is expressed in H.P. (Horse Power). Horse Power is the practical unit of power and in metric system, its value is equal to 735.5 watts.

∴ 1 watt = 1 joule per second

1 watt = 1 volt x 1 ampere

1 kilowatt = 1000 watts

1 H.P. = 735.5 watts or 0.7355 KW

let W = Power in watts

V = Voltage in volts

I = Current in amperes

R = Resistance in ohms

We know, Wattage = Voltage x Current

$W = V.I$

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

$= \frac{V^2}{R}$

Again $W = V.I$

$= (I.R).I \qquad = I^2. R$

Hence W $\frac{V^2}{R}$ or $I^2. R$

From above expression it is clear for up to extract values of V.I and R.

Example 3.3. A 100 W bulb normally takes 0.833 A and 200 W bulb takes 1.666 A from the 120 V power line. If these two bulbs were connected in series across a 240 V power line, prove that teh current would be 1.111A in both bulbs, assuming the resistance remain constant.

Solution.

In the circuit diagram, it is shown that, the two bulbs are connected in series.

We know : Resistance = Voltage^2 / Wattage

$\therefore$ At normal conditions:

Resistance of 100 W bulb

$= 120 \times 120 / 100 = 144\Omega$

Resistance of 200 W bulb

$= 120 \times 120 / 200 = 72\Omega$

$\therefore$ Total resistance in the circuit = $144 + 72 = 216\Omega$

$\therefore$ Current in the circuit = Voltage applied / Total resistance

240 / 216 = 1.111 amperes.

$\therefore$ Current in the circut = 1.111 amperes

Hence proved Ans.

3.8. Electrical Energy

Energy of a body is the capacity for doing work and is measured by the work which the body can do. Hence units of work and energy are same. Electrical energy is generally expressed in joules and kilowatt hours. Kilowatt hour is a practical unit of electrical energy and is generally termed as 1 unit of electrical energy.

∴ Joule = Power in watts x Time in seconds

Kilowatt hour(KWh) = Power in KW x Time in hour

= 1000 watt hours

= 1 unit of electrical energy.

Example 3.4: Following is the connected load in a factory:

a) 2 Motors of ratings 5 H.P., 3ϕ, 440 V and 0.8 p.f.
b) 8 Tube lights of 40 watts each.
c) 2 lamps of 100 watts each
d) 4 ceo;omg fams of 80 watts each.

Assuming that each equipment runs on average for 4 hours a day and the factory works for 25 days in a month. Calculate the monthly electricity bill of the factory, if the electricity rate is Re.1 per unit.

Solution. It is given in the problem, that each equipment runs on average for 4 hours a day and the factory works for 25 days in a month.

∴ Total No. of hours used in a month

= 4 hours / day x 25 days in a month

= 4 x 25 = 100 hours

a) Motors:	2 x 5 x 735.5 x 100 =	735500 watt hours
b) Tube lights:	8 x 40x 100 =	32000 watt hours
c) Lamps:	2 x 100 x100 =	20000 watt hours
d) Fans:	4 x 80 x 100 =	32000 watt hours

∴Total energy consumed in a month = 819500 watt hours

∴ Total energy consumed in the month

= 819500 watt hours

= 819.5 kilowatt hours

= 819.5 units

Cost of energy = Re 1 per unit

∴ Total cost of energy in a month = Rs. 819.5 x 1

Rs = 819.50 Ans.

Example 3.5. An electric installaiton consists of the following:

a) 10 lamps of 200 watts working 6 hours per day.

b) A 1500 watts heater working 6 hours per day.

c) 2 H.P. motor of effciency 85% working 4 hours per day.

Calculate the total number of units consumed during 30 days.

Solution: In item (c) it is given, output of motor is 2 H.P.

∴ Output of motor = 2 H.P.

= 2 x 735.5 watts

∴ Input of motor $= \frac{Output}{Efficiency}$

$= \frac{2x735.5}{85\%}$

$= \frac{2x735.5x100}{85\%}$ watts

Now, finding below energy consumption:

a) Lamps : 10 x 200 x 6 = 12000 watt hours

b) Heater : 1500 x 6 = 9000 watt hours

c) Motor : 2x735.5 x 100/85 x 4 = 6922.35 watt hours

∴ Daily energy consumption = 27922.35 watt hours

∴ Energy consumed for 30 days

= 27922.35 x 30 watt hours

= 837670.5 watt hours

= 837.6705 kilowatt hours (KWh)

= 837.6705 units

∴ No. of units consumed in 30 days = 837. 6705 units Ans.

Example 3.6. An electric installation consists of the following:

i) 10 lamps 100 W each working 8 hours per day.

ii) 8 ceiling fans 75 W each working 10 hours per day.

iii) One electric heater 1500 W working 3 hours per day.

iv) One 1.5 H.P. motor working 4 hours per day.

Calculate the total units consumed in a month of 30 days and cost of energy at the following rate:

First 200 units @ Rs. 1.50 per unit

Second 200 units @ Rs. 2.00 unit

Rest @ Rs. 2.50 per unit.

Solution.

Lamps : 10 x 100 x 8 = 8000 watt hours
Fans : 8 x 75 x 10 = 6000 watt hours
Heater: 1 x 1500 x 3 = 4500 watt hours
Motor : 1 x (1.5 x 735.5)x4 = 4413 watt hours
1.H.P. = 735.5 watts

∴ Energy consumed per day = 22913 watt hours

∴Energy consumed in 30 days

= 30 x 22193 watt hours

= 687390 watt hours

= 687.39 kilo watt hours

= 687.39 K W h = 687.39 units.

∴1 KWh = 1 unit

∴Energy consumed in 30 days = 687.39 units Ans.

Bill Calculations:

For first 200 units = Rs. 1.50 x 200 = Rs.300.00
For next 200 units = Rs. 2.00 x 200 = Rs. 400.00
For rest of 287.39 units = Rs.2.50 x 287.39= Rs. 718.475

∴ Total bill for 30 days= Rs.1418.475

∴Total bill for 30 days = Rs. 1418.475 = Say Rs. 1418.50 Ans.

∴ Energy consumed for 30 days = 687.39 units

∴ Cost of energy for 30 days = Rs. 1418.50

EXERCISE PROBLEMS

1. Three lamps of rating 230V, and 100W, 200W, and 500W are connected in parallel across 200V supply. Calculate the power dissipation of each mp at 200V supply. Also calculate resistance of each lamp.
2. Calculate the monthly electricity bill at 50 paise per unit for residential building with the following load. Meter rent per month is Rs. 2.

i. 6 No.s 60 watt lamps used for 3 hrs per day.
ii. 2 No.s 80 watt fans used for 6 hrs per day.
iii. 1 No. 500 watt refrigerator working at 80% efficiency for 4 hrs per day.
iv. 1 No. ¾ H.P motor working at 80% efficiency fo 1.5 hours per day. [Ans. Rs 85.61/-]

3. Calculate the bill of electricity charges for the following load fitted in electrical installations.

i. 20 lamps 100 watt each working 6 hours a day.
ii. 10 ceiling fans 120 watt each working 12 hours a day.
iii. 2kW heater working 3 hours a day.
iv. 2 H.P motor (n = 85%) working 4 hours a day.
Rate of charges for light and fans 50 paise per unit and heater and motor is 65 paise per unit. [Ans. Rs 21.60/-]

4. A consumer has the following loads.

i. 10 lamps of 60W each working for 10 hours a day.
ii. 2 fans of 75W each working for 12 hours a day.
iii. 1 heater of 1.5kW working 2 hours a day.

If the unit charge is 70 paise find the electricity bill for the month of November 1991. Meter rent is Rs.5 per month. [Ans. Rs 231.80/-]

5. A residential house has the following load.
1. Ten lamps of 60 watts each running 5 hours per day.
2. Five 75W fans running 12 hrs/day.
3. One 750W electric iron running 2 hrs/day.
4. One 1/6 H.P refrigerator of efficiency 80% running 18 hrs/day.
5. One ½ H.P pump set of efficiency 85% running 2 hrs/day.

Calculate monthly bill at 80 paise per unit. [Ans. Rs 303/-]

GLOSSARY

1. Both work and energy are measured in joules
2. One unit of Electrical Energy is called B.O.T (Board of Trade Unit)
3. Electric Power is measured in watts (w)

   $W = VI$ or $W = I^2R$ or $P = V^2/R$
4. Heat produced in calories $H = I^2Rt / J$
5. Efficiency = Output / Input
6. Out put = Input – losses.

SHORT QUESTIONS

1. Define Work. Give units.
2. Define Power. Give units
3. Define Energy. Give units
4. What is Electric Power ? Give units
5. What is electrical energy ? Give units.

ESSAY QUESTIONS

1. Write short notes on

   (i). Work

   (ii). Power

   (iii). Energy

2. Explain (i). Electric Power

   (ii). Electrical Energy

Chapter – IV

Conductors and Insulators

4.1. Conductors, Insulators and Semi-conductors

(/) Conductors. Substances through which a flow of current, *i.e.,* a flow of free electrons can be set up easily are called conductors. The number of free electrons present in the substances decides its conductivity. Most of the metals are good conductors.

I. Properties of Conductors

i) They should have a low specific resistance.

ii) They should be mechanically rigid.

iii) They should be easily available and should not be much costly.

iv) If the conductor is a metalthen it should be ductile,

v) The resistance of most of the conductors (except carbon) increase with an increase in their temperature.

vi) A conduction path for the flow of current can be prepared by connecting conducting wires or strips.

II.Uses of Conductors

S. No.	*Name of Conductor*	*Uses*
1.	Silver	In sensitive measuring instruments, tiny capacitors, C.B. points etc. ,
2.	Copper	In electric wires and cables, winding wire, transformer choke, motor$_r$ generator etc.
3.	Brass	In electrical accessories
4.	Aluminium	In electrical wires and cables, winding wire, capacitors, shielding etc.
5.	Iron	In telephone wire, chassis and body of equipments.
6.	Lead	In underground cables, solder.

7.	Tin	In solder and anti-corrosive plating on various metals.
8.	Zinc	In Lechlanche and dry cells and in galvanizing iron sheets, wires etc.
9.	Eureka	In resistors.
10.	Nichrome	In heating elements.
11.	Tungsten	In bulbs, thermionic tubes etc.
12.	Carbon	In resistors, brushes of electric machine, electrodes etc.

III. Note. Out of the above-mentioned metals brass, eureka and nichrome are alloys. The percentage of their constituent metals may vary in accordance with their applications. Generally their composition is as follows :

i. Brass-Copper 67%, Zinc 33%

ii. Eureka-Nickel 60%, Copper 40% ;

iii. Nichrome-Nickel 80%, Chromium 20%

1. **Insulators** Substances, through which- a flow of current or liberation and diversion in any direction of free electrons is not easy, are called *insulators.* Some insulators have 4 and some other have 8 electrons in their outermost shell. Substances having 8 electrons in their outermost Shell are very good insulators. In chemistry, such elements are called *inert elements* and they do not combine with any other element.

2. **Properties of Insulators**. Good insulators should have the following properties :

i. **Permanent**. An insulator should have a permanent nature and its property should not finish by a change in physical conditions.

ii. High Break-down Voltage. An insulator should have a high value of break-down voltage.

"The magnitude of voltage for a substance at which a flow of current can be set up through one mm thick sheet of the substance is called its break down voltage." It is also known as *dielectric strength.* It is measured in kilovolts/mm.

iii. Mechanical Strength. An insulator should be capable to bear mechanical pressure and vibrations.

iv. Temperature Tolerance. An insulator should be capable to bear variations in atmospheric temperature, humidity etc. Further, it should be capable to bear high temperature without any change in its physical of chemical structure.

v. Least Electric Absorbent. The electric absorption capability of an insulator should be least so that no unwanted consumption of electricity may result.

vi. Dielectric Constant. The dielectric constant of an insulator should be high enough.

Dielectric strength of some principal insulators is shown in the following table

S.No.	Name of the Instructor	Dielectric-Strength KV/mm. 50Hz
1	Dry wood	0.4 to 0.6
2	Slate	1 to 2
3	Paper	1 to 10
4	Marble	2 to 6
5	Shellac	3
6	Cotton	3 to 4
7	Asbestos	3 to 4.5
8	Fibre	5
9	Glass	5 to 12
10	Paraffin was	8
11	Porcelain	8 to 12

12	Transformer oil	10 to 16
13	Empire cloth	10 to 20
14	Rubber	10 to 25
15	Resin	12
16	Bitumen	14
17	Bakelite	17 to 21
18	Mica	20 to 40
19	Ebonite	30 to 40
20	Vulcanized rubber	30 to 50

4.2. Use of Conductors in Wires

Silver is a very good conductor and it has a low specific resistance tool; even though it is not used as a conductor, because it is a costly metal. The copper is next to silver in the order of conductivity. It is used in the manufacture of wires. The gold is next to copper but it is also a very costly metal; therefore, it is not used for electrical purposes. Next metal is aluminium which is a cheap metal and that it is why now a days it is widely used in the manufacture of wires etc. Steel has a high specific resistance; therefore, it is not used as a conductor but it is used in metal-alloys to increase their mechanical strength.

The following conductors are used for electrical purposes :

1. Silver
2. Copper
3. Aluminium
4. Lead
5. Tin
6. Nichrome
7. Tungsten
8. Eureka
9. Acid solution
10. Carbon

1. **Silver**
   i. It is a white coloured, soft, ductile and malleable metal.
   ii. It is used in heavy duty contact-points and sensitive meters because of its high conductivity.

2. **Copper**
   i. It is obtained from copper oxide, sulphide or sulphate.
   ii. It is red in colour,

iii. It becomes ductile and malleable on heating.
iv. It softens on cooling it quickly, but it becomes brittle on cooling it slowly after being heated up.
v. It is least affected by atmosphere and air.
vi. It is used for making the bits of soldering irons, water heaters, pipes, sheets etc, due to its high thermal conductivity.
vii. It is used for making wires and jajjles due to its high conductivity.

3. Aluminium

i. It is white in colour and light in weight.
ii. It does not get rusted.
iii. It has a low mechanical strength but it is soft, ductile and malleable.
iv. Its specific resistance is higher than copper,
v. Its conductivity is lesser than copper.
vi. It is used for making wires, pipes, sheets, bus-bodies, radio-chassis, small parts of light weight etc. Its power is used in aluminum paints.

4. Lead

i. It is obtained from galena, carbonate of lead or sulphate of lead.
ii. It is a soft and heavy metal.
iii. It is least affected by acid and water.
iv. It is used for making battery plates and terminals solder and in covering the pipes and cables.

5. Tin

i. It is obtained from cassiterite
ii. It is a lusterous white metal.
iii. It is a very soft metal therefore it is converted into sheets, by rolling and hammering.
iv. It is used for tin-plating tin other metals.
v. It is used for making different types of solders.

6. Nichrome

i. It is an alloy having 80% nickel and 20% chromium.
ii. It has a high specific resistance.
iii. It has a good Tieatirl effect
iv. It has a good mechanical strength.
v. It is used for making heating elements of heaters, irons, kettles etc.

7. Tungsten

i. It is silvery white metal.
ii. It has a good tensile strength.
iii. It has a high melting point.
iv. It is used for making filaments of lamps and fluorescent tubes.

8. Eureka

i. It is an alloy having 40% nickel and 60% copper.
ii. It has a high specific resistance.
iii. It is used for making resistors, resistive loads, starters, field regulators, wire wound resistors etc.

9. Acid solution

i. It is a solution of sulphuric acid and distilled water mixed in a ratio of l :3.
ii. It has a quick effect on metals.
iii. It causes burns on human skin.
iv. It is used in batteries.

10. Carbon

i. It is a black coloured material.
ii. It is brittle and easily convertible into powder.
iii. It has a high specific resistance,
iv. It is used for making brushes of D.C. machines and carbon resistors.

Properties of Conductors

	Conductor	Melting Point °C	Density g/cm^2	Specific Heat cal/gm	Thermal Conducti vity cal/cm/ sed°C	Specific Resistance micro-ohm cm	Tempera ture Coefficient per°C
1.	Silver	960	10.5	0.056	0.992	1.63	0.004
2.	Copper	1083	8.96	0.093	0.918	1.72	0,0041
3.	Gold	1063	19.3	0.316	0.707	2.42	0.0034
4.	Aluminium	657	2.7	0.216	0.480	2.65	0.0038
5.	Carbon	3500	2.23	0.17	0.012	13.75	0.00056
6.	Lead	327	11.34	0.03	0.083	20.6	0.0043
7.	Manganin	—'	8.5	0.096	0.052	44.5	0.00001
8.	Nickel	1453	8.8	0.109	0.142	7.8	0.0060
9.	Platinum	1773	21.25	0.032	0.165	11.0	0.0035
10.	Tin	232	7.3	0.054	0.155	11.5	0.0051
11.	Mercury	356	13.6	0.033	0.019	95.8	0.0009
12.	Water	100	0.99	1.0	0.0014	—	_
13.	Sulphuric Acid (20%) solution	105	1.14	0.84	0.0013		

4.3 Use of Wire-Gauge

A wire gauge is used to measure the thickness of a wire or a sheet It is made of steel. Its shape is circular or rectangular. Slots of different sizes are cut on its circumference, (see Fig. 1.28) The size of each slot is marked, in millimeter on one side of the gauge and in SWG numbers on the other side of the gauge. The wire or sheet, whose thickness is to be measured, is tried in different slots and the number of the fittest slot is taken as the thickness of the wire or the sheet.

Following types of wire-gauges *we* in use :

1. American or Brown and Sharp Standard Wire Gauge.
2. Birmingham or Stubs Iron Wire Gauge.
3. American S and W Go. Wire Gauge.
4. Imperial Standard Wire Gauge.
5. U.S. Standard Gauge.

(Note. The wire gauge at S. No. 4 is called SWG and it is in common use.)

4.4. **Insulators**

The substances which can not pass a current through them under normal conditions are termed as insulators. The resistance of an insulator is usually high. The resistance of *dry-air* is high enough and that is why it is a good insulator. The resistances of glass, mica, abonite etc. are lesser than the resistance of air. Following are the common insulators :

1. Dry air	9. Porcelain
2. Asbestos	10. Cotton
3. Bakelite	11. Rubber
4. Glass	12. Plastic
5. Mica	13. Varnish
6. Paper	14. Mineral oil
7. Wax	15. Dry wood
8. Slate	16. Ebonite

4.5. Properties of Good Insulators .

A good insulator should have the following properties :

i. It should have a high specific resistance.
ii. It should have a high *dielectric strength.*

[The voltage bearing capacity of a dielectric is called its dielectric strength. It is measured in kilo volts per millimetre. It is also known as *Break down voltage*.]

iii. It should have an ability to bear high temperatures.
iv. It should have a good mechanical strength.
v. It should be moisture and water proof.
vi. It should have a permanent nature.

Common Insulators and their Electrical **uses** :

S. No.	Name of Insulator	Its Electrical Uses
1.	Bakelite	In switches, holders, sockets, ceiling roses etc.
2.	Procelain	In pipes, fuse cut-outs, neutral links etc.
3.	Mica	In heating elements winding.
4.	Rubber	In hand gloves, rubber mattings, covering of conducting wires.
5.	Fibre	In formers of transformer windings.
6.	Varnish	To insulate a winding.
7.	Glass	In Insulators of over head wiring.
8.	Wood	In Boards, round blocks, casing-capings, battens, gatties etc.
9.	Leatheroid paper	In motor winding.
10.	Cotton tape	For covering a winding.
11.	P.V.C.	Covering of wires
12.	Oil	In oil circuit breakers, transformers.

4.6. Classification of Insulators

Insulators may be classified into following three main classes

1. Solid Insulators— These are usually hard and heavy in weight,

e.g., Bakelite, porcelain, slate, glass etc.

2. Soft Insulators— These are usually flexible and light in weight,

e.g., paper, cotton, rubber, P.V.C, mica etc.

3. Liquid Insulators— These are usually fluids and therefore these

are kept in containers, *e.g.,* oil, varnish etc.

1. Solid Insulators

(a) Bakelite

i. It is a synthetic substance which is made of different resins.
ii. It is water-proof.
iii. It is used for making switches, lamp holders, sockets, plugtops, switch boards etc.

(b) Porcelain

i. It can be moulded into required shapes.
ii. It is fire-proof.
iii. Polished porcelain is water-proof.
iv. It is used for making fuse cut-outs, pipes, insulating formers etc.

(c) Marble

i. It is a white stone which is dug from mines.
ii. It is incombustible, therefore it is used in the appliances which work at high temperatures.
iii. It is used in the appliances which work up to 30 amperes of current.
iv. It should be hard and well polished.
v. It is used for switch boards, fuse boards and distribution boards.

(d) Ebonite or Vulcanite

i. It is made by heating India-rubber with sulpher at a temperature of 150°C.
ii. It is a good insulator.
iii. It may be polished also.
iv. It can't be used in the appliances which work above a temperature of 70°C.
v. It can be shaped as per requirement, on a lathe machine.
vi. Water has no effect on it.
vii. It is used for making containers of lead-acid battery and meter's cases.

(e) Glass

i. Water has no effect on it.
ii. In the form of fibre-glass, it is used for insulating the wires used in aeroplanes.
iii. It is used in making the insulators of overhead wiring.

(f) Asbestos

i. It is a cheap and light material which can have different shapes as required.
ii. It is fire-proof-and it is used in the appliances which work at high temperature.
iii. Its insulation properties are increased at high temperature or when dipped in oils,
iv. Acid has no effect on it.
v. It is used for making formers of wire-wound resistors etc.

(g) Mica

i. It is dug from mines in the form of thick-layed sheets.
ii. It can easily be subdivided into thin layers.
iii. It is water-proof and fire-proof
iv. It is used for making washers, heating elements etc.
v. It is used for bushing and isolating commutator segments.

2. Soft Insulators

(a) Rubber

i. It softens on heating.
ii. Its resistance reduces on heating.
iii. It is used for making vulcanized rubber.

(b) Vulcanized India Rubber (V.I.R.)

i. It is made by heating India-rubber with sulpher at a temperature of 150^oC.
ii. Water has no effect on it but it is badly affected by oil or grease.
iii. Sulpher has *s* bad effect on metals, therefore, metallic wires are coated with tin before VJ.R. coating.
iv. V.LR. cables are used upto 11,000 volts.

(c) Poly-Vinyle-Chloridc (P.V.C. or Plastic)

i. It is combustible but water-proof.
ii. It can be made thin and flexible or hard.
iii. It is soluble in petrol.
iv. It is used for covering the conducting wires.
v. P.V.C. pipes are used in underground electrical wiring.

(d) Bitumen

i. It is used for filling in the joint boxes of cables.
ii. It is water proof upto certain state.
iii. It softens on heating.

(e) Cotton

i. It is combustible and water absorbent.
ii. It is used for covering the windings.
iii. It is used in black-tape.

(f) Silk

i. It is used for covering thin conducting wires such as telephone wires etc.
ii. It is moisture absorbent but it can't bear high temperatures.

(g) Paper

i. An oiled paper does not absorb moisture.
ii. It is used as insulation covering of low voltage conducting wires.
iii. It is used for making leatheroid paper which is used in the winding of motors and generators. Leatheroid paper is bluish grey, flexible, thick and hard in structure.

(h) Micanite

i. It is made of mica coated paper or cloth.
ii. It is flexible.
iii. It softens on heating and hardens on cooling.
iv. It is used in the winding of motors and generators etc.

(i) Presspahn

i. It is yellow or grey in colour.
ii. It is smooth and well polished.
iii. It is used in the winding of motors and generators.

3. Liquid Insulators

(a) Oil

i. It is a light and fluid material.
ii. It is also known as mineral oil.
iii. It is used in circuit breakers, transformers and joint boxes.

(b) Shellac

i. It is soluble in methyl spirit.
ii. It is used for making varnish.
iii. It is used for making moisture-proof paper, wood, slate etc.
iv. It breaks into layers at high temperatures.

Dielectric Strength

Insulating Material	Dielectric Strength kilo volt / mm	Insulating Material	Dielectric Strength kilo volt / mm
Marble	2-4	Paper	1-7
Mica	20-40	Leatheroid paper	12-17
Bakelite	17-21	Vulcanised rubber	30-50
Micanite	20-40	Shellac	2-3
Dry wood	0.4-0.6	Oil (insulating)	10-16
Ebonite	30-40	Procelain	8-12
Glass (crown)	8-12	Slate	1-2
Asbestos	4-6	Resin	12

4.7. Use of Insulators in Domestic Electrical Wiring

1. Dry wood —For board, round block, batten, gatti etc.
2. V.I.R. — For covering conducting wires.
3. Bakelite — For switch, holder, socket, ceiling rose etc.
4. Porcelain — For pipes, fuse cut-out, neutral link, round cleat etc.

Insulators used in conducting wires and cables

1. V.I.R., 2. P.V.C., 3. Presspahn, 4. Empire cloth, 5. Cotton tape.

Insulators used in motor winding

1. Fibre, 2. Leatheroid paper, 3. Empire cloth. 4. Cotton tape, 5. Mica, 6. Varnish,

7. Micanite 8. Presspahn.

4.8. Classification of Cables according to the Insulator used

The cables may be classified as follows according to the type of insulators used for covering:

(1). **V.I.R. Wire.** Its full name is Vulcanised-India-Rubber wire. It has a V.I.R. covering and a cotton covering over V.I.R. covering.

(2). **P.V.C. Wire.** Its full name is Poly-Vinyle-Chloride wire. It has a P.V.C. covering.

(3). **Flexible Wire.** It has a number of thin wires together covered with P.V.C. or V.I.R. insulation.

(4). **Enamelled Wire.** It has an enamel varnish coating over a copper wire.

(5). **Cotton Covered Cover.** It has a cotton covering over a copper wire.

4.9. Grading of Conducting Wires

The conducting wires may be graded into following three main classes :

(1). Low Voltage Grade Wire. This type of wire has single braided covering and it is capable to work upto 250 volts.

(2). Medium Voltage Grade Wire. This type of wire has double braided covering and it is capable to work upto 650 volts.

(3). **High Voltage Grade Wire** - This type of wire has two or three coverings of different insulators. It can work above 650 volts and upto 11000 volts. It can be single core or a multi core type. Common high voltage grade cables are as follows :

i. Paper insulated lead covered cable (PILC)

ii. Paper insulated lead covered single tape armoured cable (PILCSTA).

iii. Paper insulated lead covered double steel taped armoured cable (PILCDSTA).

There are so many other types of cables having multilayers of P.V.C. leatheroid paper, empire cloth and lead covering.

GLOSSARY

1. The number of free electrons present is the substances decides its conductivity.
2. Insulators are classified into (i). Solid Insulators
   (ii). Soft Insulators
   (iii). Liquid Insulators
3. The conducting wires may be graded into following three main classes,
   (i). LVG wire
   (ii). MVG wire
   (iii). HVG wire.

SHORT QUESTIONS

1. Define conductor. Give examples.
2. Define Insulator. Give examples
3. Define Semiconductor. Give examples

ESSAY QUESTIONS

1. What are conductors ? Give the proporties of conductors.
2. What are Insulators ? Give the properties of Insulators.
3. Explain 'Grading of Conducting wires'.

Chapter – V

Electrical Accessories

5.1. Electrical Accessories and their Uses

"The items used in domestic and industrial electrical wiring are called electrical accessories, *e.g.,* switch, holder, socket, plug-top, ceiling rose, fuse cut-out etc. A switch is used to make a circuit ON and OFF. A holder is used with a lamp, a ceiling rose is used with a ceiling fan, tube light or a pandent lamp. A socket is used to provide main supply to a portable appliance, such as, table fan, table lamp, electric iron, radio, T.V. etc. A fuse cut-out is used to stop an excess flow of current in a circuit.

The common electrical accessories are made of *bakelite* which is a good insulating material and which is least affected by moisture and oil etc.

5.2. Switches and their Types

A switch is used to make a circuit ON and OFF. A perfect switch should take a minimum time in closing or opening a circuit so that a minimum spark is produced at the switch.

A switch may be operated by hand or by an electromagnet The later one is called an automatic switch. Hand operated switches are of two main types—*main switch* and *branch switch. A* main switch is used to control a current of 20 amperes or more than 20 amperes and a branch switch is used to control a current of less than 20 amperes. The types of switches are as follows :

1. Tumbler switch
2. Flush switch
3. Knife switch
4. I.C. main switch.

1. Tumbler Switch. It is a 5 ampere current rating switch which is used in domestic electrical wiring. It is also known as a *surface switch.* It can be fitted on a wooden board or a round block. It is made of bakelite in various shapes and designs. While selecting a switch one should check the time taken by it in closing or opening a circuit, position of terminals, size of terminals, space for connecting wires, insulation and the function of contact points. The types of tumbler switches are as follows :

i. *Single Way Switch.* It is a two terminal switch which is used to control a single circuit *(i.e.,* a lamp, fan, tube-light etc.)- It may be round or rectangular in shape (see Fig. 5.1).

ii. *Two Way Switch.* It is a four terminal switch which is used in stair case or godown wiring.

iii. *Intermediate Switch.* It is used alongwith a two way switch to control a lamp etc. from more than two places.

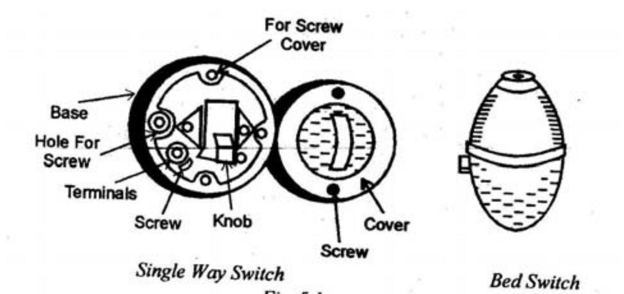


Fig. 5.1.

iv. *Bed Switch.* It is a hanging type single way switch which is used with bed lamps.

v. *Grid Switch.* It is used in machines such as an electric drilling machine.

vi. *Duplex Switch.* It is also used in machines.

vii. *Bell Push Switch.* It is spring type single way switch which is used with an electric bell to make the circuit ON for a very short time.

2.Flush Switch. These are generally 5 or 15 amperes current rating switches. The main part of the switch remains withiirthe board and only 'ON-OFF part remains visible. In this way, these switches remain safe from dust etc. and their contact points remain clean. These types of switches take a little time in closing or opening a circuit. These may be of a single way type, two way type, bed switch type or a bell push type.

[Note. Flush type switches were introduced by 'Anchor' company for the first time, therefore these are also known as Anchor-type switches.]

3.Knife Switch. It is a coverless switch, therefore, it can be used in workshops, sub-stations and distribution stations etc. It should be fitted in such a way that it may remain beyond the approach of the general public and dust or water. It may be of a *single throw* or of a *double throw* type. A single-throw switch can 'ON OFF' a single line, whereas, a double-throw switch can close one line in one direction; and it can open the first line and close the second line in the other direction simultaneously. It has a bakelite handle. Both the above types of switches are shown in Fig. 5.2 *(a)* and 5.2 *(b).* Knife switches for a single phase line and for a three phase line are built separately. These switches can control a circuit having 30 to 1000 amperes of current.

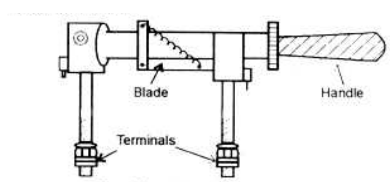


Fig. 5.2. (a) Single Throw Knife Switch

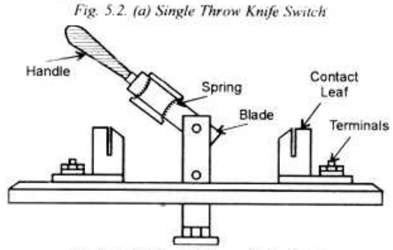
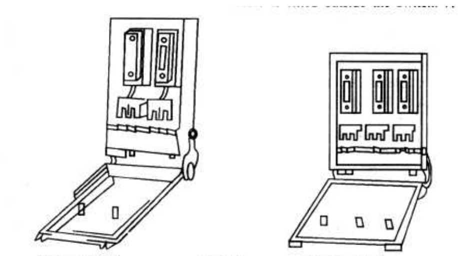


Fig. 5.2. (b) Double Throw Knife Switch

4. I.C. Main Switch. An IC main switch has a case of cast iron and that is why it called an iron clad main switch. Porcelain fuse cut-outs are fitted inside the switch and a handle is fitted outside the switch. A square shaped bakelite rod is attached to the handle. U-shaped clips are fitted on the square shaped bakelite rod. When the handle is moved upwards then the U-shaped clips make the circuit ON by joining the contact points when the handle is moved downwards then the switch makes the circuit OFF. Line wires are usually fitted to the bottom side and the load wires to the top side of the switch.



I.C.D.P. Switch *Fig 5.3* *I.C.T.P. Switch*

These switches are of following two types

i. C.D.P. switch (Iron clad double pole main switch)

ii. I.C.T.P. switch (Iron clad triple pole main switch)

Both types of switches are made in different sizes to control the circuit currents from 15 to 300 amperes. An I.C.D.P. switch is used in a single phase line and an I.C.T.P. switch in a three-phase line. Later type has a neutral link and an earthing terminal also, (see Fig. 5.3).

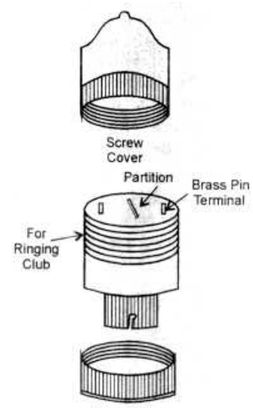
5.3. Lamp Holders and their Types

A lamp holder is used for connecting a lamp (or a bulb) to the electric line. There are following two main types of lamp holders :

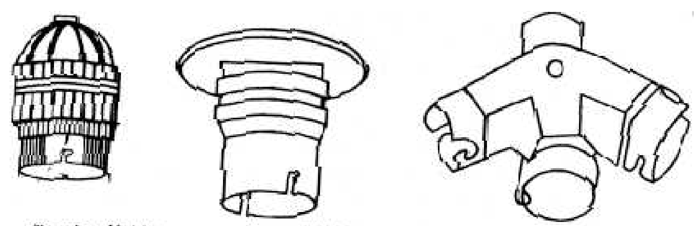
i. Bayonet cap type.

ii. Edison screw type.

i. Bayonet Cap Type. As shown in Fig. 5.4 it has two L-shaped slots for holding the lamp. The base of the lamp has two project pins. When the bulb is gently pushed into the holder and turned slightly in the clock-wise direction then the pins of the lamp get entangled in the slots. The holder has two spring controlled plungers for making contact with the filament terminals of the lamp. Spring controlled plungers are screwed into two brass terminals; And, the supply wires are fitted on these brass terminals with small screws. The holder has a screw-cover and a clamping ring also.



Bayonet Cap Holder
Fig. 5.4.


Pandent Holder *Batten Holder* *3- Way Holder*
Fig. 5.5

A bayonet cap type holder is used for lamps upto 200 watts. There are six main types of holders which are as follows :

(a) Pandent holder

(b) Batten holder

(c) Bracket holder

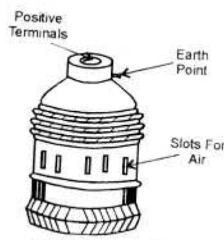
(d) Two way holder

(e) Three way holder

(f) Holder with switch

Pandent, batten and three way holders are shown in fig. 5.5.

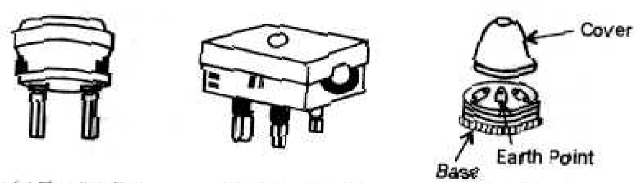
ii. **Edison Screw Type Holder**. As shown in figure 5.6, it has threads inside its body. The lamp to be fitted in this holder also has threads. Therefore, the lamp is screwed in the clock-wise direction for fitting it in the holder. The lamp has one filament terminal at its cap and the other at its threads. Similarly, the holder has one connecting leaf at the top and the other at the threads. This holder is used for lamps above 200 watts. This type of holders are also used in torches which are known as miniature screw type lamp holder. See Fig. 5.6.



Edison screw type holder
Fig. 5.6

5.4. Ceiling Rose, Pin Plug, Socket and Adapter

1. Ceiling Rose. It is used for connecting a ceiling fan, fluorescent tube, exhaust fan or a pandent lamp. It is made of bakelite or porcelain. It has two or three pins for connections, third pin is connected to earth line. It is designed to work at 250 volts and 5 amperes. See Fig. 5.7 (c).



(a) Two Pin Top *(b) Three Pin Top* *(c) Ceiling Rose*
Fig. 5.7

2. Pin Plug. It is used for connecting a portable appliance, eg. Table fan, table lamp, electric iron, radio, T.V. etc. to a socket. It may be two or three pin type. A two pin plug is used at 5 or 15 amperes. The third pin is the earth line pin and it is thicker than the two other pins. It is also made of bakelite. See Fig. 5.7 (A) A pin-plug is also known as a *plug-top.*

3. Socket It is used for taking the supply for a portable electrical appliance in conjunction with a plug-top. It has two or three hollow brass pins. There is a small screw at the bottom of each pin for tighting the wire to the pin (see Fig. 5.8). According to pin numbers there are two types of sockets—(a) *two pin socket, (b) three pin socket.* A two pin socket is used at 5 amperes and a 3 pin socket is used at 5 or 15 amperes. The third pin is usually larger and thicker than the two other pins and it is used for earth line. A socket may be of *switch and socket combined unit* type also.

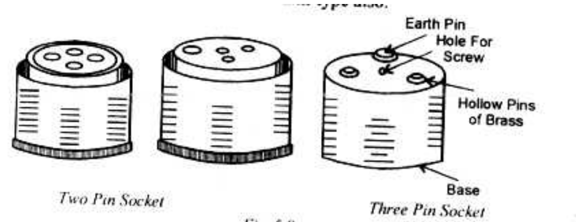


Fig. 5.8

4. Adapter. The electrical accessory used for taking additional connections from a socket or a holder is known as adapter. The types of adapters are as follows:

i. Single Adapter. It is used with a lamp holder for taking an additional connection. Some times, it is called a *lamp holder adapter,* (see Fig. 5.9)

ii. Socket Adapter. It is used with a socket. A lamp holder is built on its other end. (see Fig. 5.9)

iii. Parallel Adapter. It is used with a lamp holder. One holder and two sockets are built on its body in three different sides, (see Fig. 5.9)

iv. Multi-plug Adapter. It is used with a socket. Three sockets are built on its body in three different sides, (see Fig. 5.9)

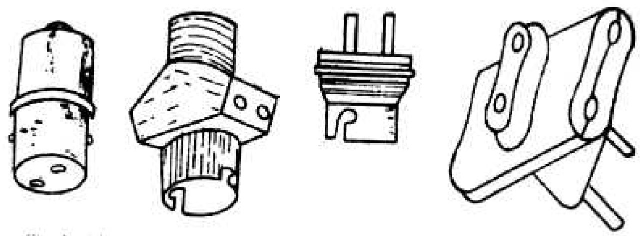


Fig. 5.9

5.5. Fuse Cut-outs and their Types

The electrical accessory used for connecting a fuse wire is called a fuse cut-out. A fuse is a small piece of wire of a specified current rating. The fuse wire is made of 63% copper and 37% tin. If a circuit having a fuse is over loaded or short circuited, then a heavy current flows in the circuit, which burns the fuse and the circuit becomes open. There are following three types of fuse cut-outs :

i. Kit-kat Fuse Cut-out. It is divided into two parts—a fuse-base and a fuse-carrier. The fuse-base is fixed on the board and the fuse-carrier has a fuse wire tied in it (see Fig. 3.10). If a fuse is burnt out then the fuse-carrier is pulled out and a new fuse wire is replaced. It is not necessary to switch off the main switch for the replacement of a fuse.

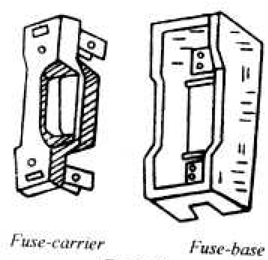


Fig. 5.10.

Fuse cut-outs are made of porcelain. In domestic electrical wiring, each branch circuit is wired through a 5 or a 15 amperes fuse as per requirements. In the workshops, the range of fuse varies from 15 to 300 amperes.

ii. Cartridge Fuse Cut-out In a cartridge fuse, the fuse wire is placed inside a porcelain or a glass container. The rest of the portion of the hollow container is filled with an insulating power, e.g., dry sand, paris-plaster etc. The terminals of fuse wire are joined to two L-shaped leaves. Fig. 5.11 shows the assembly of a cartridge fuse.

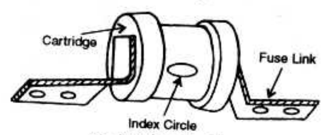


Fig. 5.11. Cartridge Fuse

This type of fuse is unrepairable and a burnt fuse is always replaced with a new one. Porcelain container type fuses have a index circle. There is a piece of paper fitted inside the index-circle. This piece of paper becomes black in case the fuse wire is burnt; Therefore, a burnt fuse can be identified easily.

The main advantage of a cartrigde fuse is this, that the sparking in the events of melting a fuse wire is eliminated.

***iii.* High Rupturing Capacity Fuse (H.R.C., fuse).** H.R.C. fuse is similar is construction to a cartridge fuse. The cartrigde or a H.R.C. fuse is perfectly air-tight so that the oxygen of the air can not cause the oxidation of fuse wire to make it week, (see Fig. 5.12). This type of fuse has a capability of bearing 1½ times excess amount of current for a few seconds caused due to a momentry short- circuiting or an over loading.

These fuses are made for 30, 60, 100, 200, 300 and 500 amperes current ratings and are used widely in power lines.

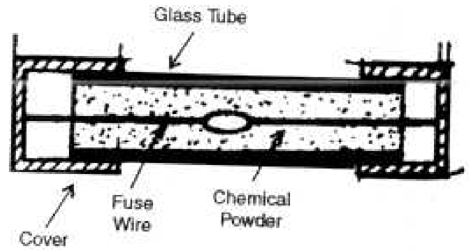


Fig. 5.12. H.R.C. Fuse

5.6. Precautions for using Aluminium Cables

Following precautions should be observed while using aluminium cables :

1. It should not be bent repeatedly at any point because being some what brittle, it can break.
2. It should not be loaded with heavy weights, because it has a low mechanical strength.
3. While soldering on an aluminium conductor joint an acid or an alkali should not be used as a flux.
4. A joint should be made gently and it should be soldered if possible conveniently.
5. It should not be allowed to carry any excess amount of current than its rated value.
6. It should be protected against a short-circuit because it can break easily.
7. It can't bear much tensile-force, therefore it should be kept slightly loose.

5.7. Difference between Insulated Wires and Cables

The conductors used for carrying electric currents are generally in the shape of wires. These are made of copper or aluminium and may be classified as follows:

1. **Bare Wire.** A conducting wire without any insulation covering is called a *bare wire.* If it is made of copper then it is called a *bare copper wire* (b.c. wire), and if it is made of aluminium then it is called a *bare aluminium wire* (b.a. wire). A bare wire can only be ased in over-head wiring.

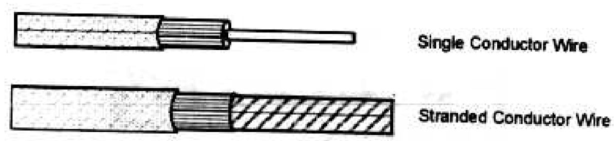


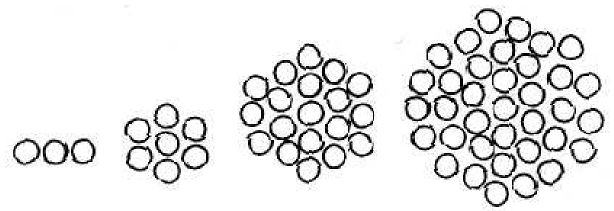
Fig. 5.13

2. Insulated Wire. An insulation covered wire used in domestic wiring is called an insulated wire. It may be a *single conductor wire* (in case of aluminium conductors) or a *stranded conductor wire* (in case of copper conductors) as shown in Fig. 5.13.

Advantages of Stranded Conductor Wires

i. It is more flexible in comparison to a single conductor wire:
ii. It has more current carrying capacity.
iii. It has more tensile-strength.
iv. It has a long life.

3. **Cables.** Single cored or multi-cored insulated wires, having high current carrying capacities, are called cables. Each core of a cable may have 3, 7, 19, 37 or 61 wires as shown in Fig. 5.14. The wires are arranged in the following arrangements:



3 7 19 37

Fig. 5.14. Cross-sectional views of cables

i. A 17 conductor cable has one conductor in the centre and six conductors around it in the second layer.

ii. A 19 conductor cable has one conductor in the centre, 6 in second round and 12 conductors in the third round layer.

Table for Measurement of Different Wires

S.No	No. and dia of wire		No. of Standed wire and gauge no	Cross sectional area of wire		Current in Amperes	Voltage drop per 50- feet	Maximum load at 250 volts A.C
	Inches	mm		$Inch^2$	mm2		Volts	Watts
1	1/0.044	1/1.20	1/18	0.0015	1.9	5	2.7	1250
2	3/0.029	3/0.70	3/22	0.002	2.54	5	2.2	1270
3	3/0.036	3/0.91	3/20	0.003	3.81	10	2.9	2500
4	7/0.029	7/0.70	7/22	0.0045	5.72	15	2.95	3760
5	7/0.036	7/0.91	7/20	0.007	8.91	24	3.5	7250
6	7/0.044	7/1.20	7/18	0.01	12.76	31	3.2	9500
7	7/0.052	7/1.41	7/17	0.0145	18.46	37	2.8	11250
8	7/0.064	7/1.62	7/16	0.0225	28.66	45	2.2	14000
9	19/0.044	19/1.20	19/18	-	-	53	-	-
10	19/0052	19/1.41	19/17	-	-	65	-	-
11	19/0.064	19/1.62	19/16	-	-	70	-	-

iii. A 37 conductor cable has one conductor in the centre, 6 in second, 12 in third and 18 conductors in the fourth layer.

iv. A 61 conductor cable has one conductor in the centre, 6 in second, 12 in third, 18 in fourth and 24 conductors in the fifth round layer.

Each core of a cable, having any number of wires, is insulated and then all the cores are again insulated together with V.I.R.C.T.S. or P.V.C. insulation.

5.8. Measurement of Wires

A wire gauge is used for the measurement of the diameter of a wire. In India, Standard Wire Gauge (S.W.G.) and Metric Wire Gauges are used. A wire gauge has a different slot for each diameter. A metric wire gauge measures the diameter of the wire directly in millimeters; *e.g.* 0.70 mm, 1.20 mm etc.

A S.W.G. measures the diameter of a wire in S.W.G. number. If a wire has 3 conductors of 22 number, then it is called a 3/22 wire. If a wire has 7 conductors of 20 number, then it is called a 7/20 wire and so on. In metric system, if a wire has 3 conductors of 0.70 mm diameter then it is called a 3/.70 wire

A cable is measured as per its cross-sectional area; .*e.g.* 1.5 mm^2, 2.5 mm^2 etc.

5.9. Types of Wires

The types of wires used in electrical wiring are as follows :

(A)**According to Core**

i. Single core wire.
ii. Two core wire.
iii. Three core wire
iv. Four core wire.

(B) **According to Insulation**

i. V.I.R. wire.
ii. CT.S. or T.R.S.wire.
iii. P.V.C. wire
iv. Flexible wire,
v. Lead covered wire.
vi. Weather proof wire.
vii. Enamelled wire.
viii. C.C. or S.C. wire.
ix. Fire resisting wire.

(C) **According to Metal**

i. Bare copper wire.
ii. A.C.S.R.wire
iii. Fuse wire.
iv. Eureka wire
v. Nichrome wire.

(A) According to Core

i. *Single Core Wire.* It has a single conductor and is generally used in domestic wiring (see Fig. 5.15).

ii. *Two Core Wire.* It has two separately insulated cores within one insulation cover. One core is used for phase-line and the other for neutral line (see Fig. 5.15).

iii. *Three Core Wire.* It has three separately insulated cores within one insulation cover. One core is used for phase-line, second for neutral-line and third for earth-line. It may be used for 3 phase wiring alongwith a separate neutral-line, (see Fig. 5.15).

iv. *Four Core Wire.* It has four separately insulated cores within one insulation cover. Three cores are used for 3'phases and the fourth core for the neutral line.

(B) According to Insulation

i. *V.l.R. Wire.* A tinned copper wire covered with *vulcanized India rubber* is called a V.l.R. wire. Further it has a cotton thread woven covering dipped in a bitumen compound. It is used in domestic casing-caping wiring.

ii. *C. T.S. or R. T.S. Wire.* It is a *cab tyre sheathed or a tough rubber sheathed* wire. It has a tinned copper wire which is covered with a layer of vulcanized India rubber and then with a layer of hard rubber.

C.T.S. wire has the following advantages :

(a) It is a weather proof and water proof wire.
(b) It can directly be fitted in a wall or a floor.

(c) It can be repaired by vulcanization.
(d) It can bear a mechanical strain.

iii. *P. V.C. Wire.* A tinned copper wire covered with P.V.C. insulation is called a P.V.C. wire. A single cored wire is round in shape and a two or three cored wire may be round or flat in shape. It is used for domestic and temporary wiring.

iv. *Flexible Wire.* It is quite flexible double cored ware which is used for temporary wiring. Each core has 14,23,40 or 70 fine bare copper wires. The gauge number of a fine bare copper wire is usually 36.1tcan be used for««c«its having a current rating of 15 amperes or less.

Older types of flexible wires were made of tinned fine copper wires covered with V.I.R. insulation and then with a silken or cotton-woven covering.

There are three cored wires also in which the third wire is used for earth-line. In this wire, each core is covered with V.I.R. or P.V.C. insulation and then with cotton-thread woven covering. It is also known as a *workshop-cable or a telephone Cable.* It is used as a *connecting-lead* for a room heater, electric iron, electric cooker, cooler or a freeze. The wires used in heating appliances are as follows :

(A) For appliances working below 65°C of temperature—a V.I.R. or P.V.C. insulated flexible wire.

(B) For appliances working above 65°C.

(a) Heat resisting rubber, asbestos and cotton woven covered wire.

(b) Asbestos arid varnished cotton woven covered wire.

(c) Cambric varnished cotton woven and asbestos woven covered wire.

v. *Lead Covered Wire.* These wires have a V.I.R. or a P.V.C. covering and then finally a lead covering. It has sufficient mechanical strength but it has following disadvantages:

1. If the wire is bent 2-3 times at any point then its lead cover may crack and the insulation of the wire may be damaged. Water can also enter the cable from the cracked points.

2. Lead can change its shape due to mechanical vibrations or a sudden change in temperature.

3. If insulation is damaged then the current may leak into- lead cover, therefore, the lead cover should be earthed properly.

vi. *Weather Proof Wire.* It is a two or three cored wire with a C.T.S. or P.V.C. outer covering, while each core is separately covered with V.I.R. or P.V:C. covering. It is used for service line connection.

vii. *Enamelled Wire.* It is a copper or aluminium wire covered with an insulating varnish. It is used for winding the coils of a motor, generator, transformer, choke or any other electrical equipment.

viii. *C.C. orS.C. Wire. A cotton coveredor* a *silk covered v/ire* is called a C.C. or S.C. wire. It is a copper wire covered with cotton or silken thread woven covering. It is used in telephones, small dynamos and ether low voltage-low current instruments.

ix. *Fire Resisting Wire.* It has a cotton thread woven covering dipped in asbestos and finally it is painted with a fire-proof chemical paint. It is used for electrical wiring in workshops and industries where high temperature can develop quite usually.

Lead, tin, zinc, copper, silver and aluminium metals are used in making fuse wires. The fiising capacity of each metal is different and is given in the following table:

Table for Fuse Wire Metals

S. No.	**Name of Metal**	**Specific Resistance micro-ohm-cm**	**Approximate Melting Temperature**
1.	Silver	1.56	960.5
2.	Copper	1.7	1083
3.	Aluminium	2.8	658
4.	Zinc	6	419
5.	Tin	11	232
6.	Lead	22	' "327""

Table for Fuse Rating

Fusing Current in Amp.	**Fuse Rating in Amp.**	**Tinned Copper Wire Gauge No.**	**Aluminium Gauge No.**	**Alloy (63% tin, 37% lead) Gauge No.**
—	1.8	—	—	27
4.76	3	38	38	23
8	5	35	34	21
14.15	8.5	30	30	—
15.5	10	29	29	—
29	15	25	25	—
33.5	17	24	24	—
38	20	23	23	—
48	24	22	22	—
58.6	30	21	21	—
81.6	37	19	19	—
107.7	46	18	18	—
132.5	60	17	17	—
198	83	15	15	—
232	100	14	—	—

Generally a tinned copper wire is used as a fuse. It may have a single wire or 3-4 wires standed together. Tow standard wires can with stand a current of 1 2/3 times, three standard wires 2 ¼ times and four standard wires 2 ¾ times greater than its rated value.

Table for Tinned Copper Fuse Wire

Gauge No	Diameter in mm	Current rating	Approx. Fusing current	Gauge No.	Diameter No	Current rating	Approx. Fusing current
40	0.12	1.5	3	26	0.45	15	28
39	0.13	2.5	4	25	0.5	17	30
38	0.15	3	5	24	0.55	20	33
37	0.17	3.5	6	23	0.6	24	38
36	0.19	4.5	7	22	0.71	29	48
35	0.21	5.5	8	21	0.81	34	58
34	0.23	6	9	20	0.91	38	70
33	0.25	7	10	19	1.01	43	81
32	0.27	8	11	18	1.21	45	106

31	0.29	9	12	17	1.42	65	135
30	0.31	10	13	16	1.62	73	166
29	0.34	12	16	15	1.82	78	197
28	0.37	13	18	14	2.03	102	230
27	0.41	14	23	13	2.23	130	295

iv. Eureka Wire. It is an alloy metal wire in which nickel and copper are mixed in the percentages of 40 and 60 respectively. It is used for making variable resistances and rheostats. It has a high specific resistance.

v. Nichrome Wire. It is an alloy metal wire in which nickel and chromium are mixed in the percentages of 80 and 20. It is used for making heating elements of heaters, electric irons, electric cookers etc. It has a high specific resistance.

5.10. Types of Cables

There are following types of cables

1. Vulcanized India-rubber insulated cables and PVC cables – These are weather proof cables and these are used in domestic service lines and open air lines in building etc.
2. Impregnated paper insulatted cables.
3. Impregnated jute insulated cables.
4. Lead covered vamished cambric cables.
5. Minral insulated copper sheathed cables.

5.11. Grades of cables According to Voltage

The cables are graded according to their working voltages as follows.

1. Upto 1000 volts – Law voltage grade.
2. Upto 11000 volts – High voltage grade.
3. From 33 to 66 KV – Extra high voltage grade.
4. From 66 to 132 KV – Oil or gas presured cables.

SHORT QUESTIONS

1. What are electrical accessories ? Mention their uses.
2. What are the types of switches ?
3. Mention the types of Lamp holders.
4. What is ceiling rose ?
5. What is Pin Plug ?
6. What is socket ? Mention the types.
7. What is adaptor ? Mention the types.
8. What is fuse cut – out ? Mention the types.
9. Mention the types of cables.

ESSAY QUESTIONS

1. What are the types of switches and explain.
2. What are the types of lamp holders and explain.
3. Write short notes on (i). Ceiling Rose
   (ii). Pin Plug
   (iii). Socket and Adapter
4. Explain different types of wires used in electrical wiring.

Chapter – 6

Magnetism and Electromagnetism

6.1. Definitions

1. Magnetic field :

The space surrounding magnet in which its influence is felt is called magnetic field.

The intensity of this field decreases as the distance from the magnet increases. Magnetic field can be mapped in the form of lines or force.

2. Magnetic Poles :

The magnetism of a bar magnet is consentrated at the end points of the bar magnet and are known as magnetic poles. They are (i). North Pole. (ii). South Pole. "Like poles repell each other and unlike poles attract each other". This is called law of magnetic poles.

3. Magnetic lines of force :

A line offorce in a magnetic field is a line or curve along which an isolated free north pole would move when placed at a point in it.

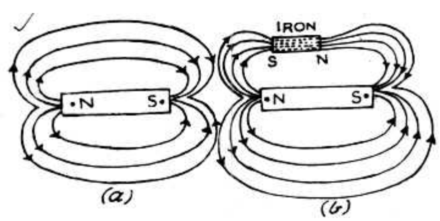


Fig. 6.1

The magnetic line of force do not exist really but they are useful devices in explaining different magnetic phenomena. The lines of force diverge from the north pole and converge at the south pole of magnet. But they never intersect.

4. Magnetic flux :

The total number of lines of induction passing perpendicular to the cross section of the substance is called magnetic flux and is denoted by ϕ. It is measured in weber.

5. Flux Density :

The number of lines of induction passing through unit area normal to the lines of induction is called flux density or magnetic induction field strength.

$\therefore$ B = Flux density = ϕ / A

Where A is the area normal to the lines of induction

$\therefore$ ϕ = BA.

6. Magnetic Circuit :

It may be defined as the route or path which is followed by magnetic flux. The laws of magnetic circuit are quite similar to those of the electric circuit.

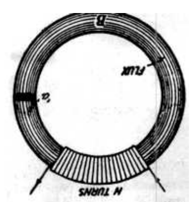


Fig. 6.2

Consider a solenoid or a toro idal iron ring having a magnetic path of 1 metre, area of cross – section Am^2 and a coil of N turns carrying I amperes wound any where on it as in Fig – 6.2.

Field strength inside the solenoid is

H = NI / Λ AT / m

Now $B = \mu_o\mu_r H$

$\therefore B = \mu_o\mu_r NI / \Lambda$ wb/m^2

$\varphi = B \times A = \mu_o\mu_r ANI / \Lambda$ wb

$\varphi = NI / \Lambda\mu_o\mu_r A = NI / S$

The numerator NI which produces magnetisation in the magnetic circuit is known as magnetomotive force obvuiously its unit is ampere – turn.

It is analogous to e.m.f. in an electric circuit.

7. Magneto motive force :

It drives or trends to drive flux through a magnetic circuit and corresponds to electromotive force in an electric circuit. It is given by the product NI.

M.M.F is equal to the work done in joules in carrying a unit magnetic pole once through the entire magnetic circuit. It is measured in amper – turns.

8. Reluctance :

It is the name given to that property of a material which opposes the certain of magnetic flux in it. It infact measures the resistance offered to the passage of magnetic flux through a material and is analogous to resistance in an electric circuit even inform its unit is AT / wb.

Reluctance = $l / \mu_o\mu_r A$ or $l / \mu A$

Resistance = $P\ l/A = l/A$

6.2. Magnetic field around current carrying conductor :

Danish scientist versted in the year 1826 discovered that the conductor carrying current produces magnetic field arround it. This effect gives the relation between electric current and magnetic field. If the flow of current is stopped the magnetic field produced arround is disappears. Hence the moving charge in a conductor produces a magnetic field. In absence of electric current the elecrons in a conductor are in rondom motion. Due to this random motion of electrons the resultant magnetic field becomes zero in the space surrounding the conductors.

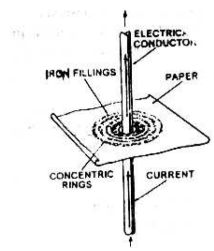


Fig. 6.3. Magnetic field around current carrying conductor

The direction of magnetic field produced by an electric current can be obtained by the following rules.

(i). Ampere's Swimming rule :

Suppose a man is swimming with stretched hands along the direction of the current flowing through a conductor then the north pole of the needle kept beneath him, deflects towards his left hand.

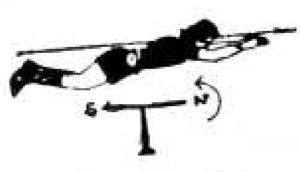


Fig. 6.3

(ii). Ampere's right hand rule :

If a conductor carrying current is grasped in the right hand with extended thumb in the direction of the current then the remaining figures that encircle the conductor. Show the direction of the magnetic field.

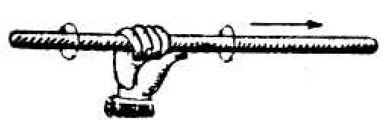
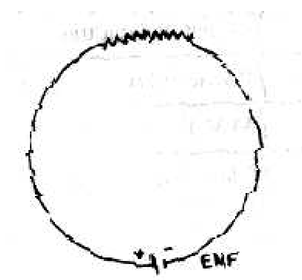
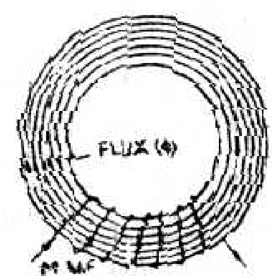


Fig. 6.4

6.3. Comparision between Electric Circuit and Magnetic Circuit

Magnetic Circuit	**Electric Circuit**
1. Flux = M.M.F./reluctance	1. Current = e.m.f/resistance
2. M.M.F. (ampere – turn)	2. E.M.F. (in volts)
3. Flux (in webers)	3. Current I (inamperes)
4. Flux density B (in wb/m^2)	4. Current density (A/m^2)
5. Reluctance	5. Resistance
$S = l/\mu A = l/\mu_o\mu_r A$	R = P l/A = l/σA
6. Permeance (=1/reluctance)	6. Conductance (=1/resistance)
7. Reluctivity	7. Resistivity
8. Permeability (=1/reluctivity)	8. Conductivity (=1/resistivity





6.4. Care and Maintenance of Magnets :

For the care and maintenance of magnets the following precautions should be observed.

1. A magnet should not be heated at all.
2. A magnet should not be hammered or dropped from a height on a hard surface.
3. Two magnets should always be stored in such a manner that their opposite poles remain together.
4. Keepers should always be used with a pair of magnets.

5. A magnet should always be used for any purpose in accordance with it's capacity.
6. A magnet should not be handled roughly.

GLOSSARY

1. Magnetism : It is the property of a substance due to which it attracts iron pieces.
2. The points of maximum attraction are called magnetic poles.
3. Flux Density B = ϕ/A Terla.
4. The force experienced by a current carrying conductor F = Bil. Newtons.
5. Magnetic flux = M.M.F./Reluctance.

SHORT QUESTIONS

1. Define Magnetic Poles.
2. Define Magnetic axis.
3. Define Magnetic lines of force.
4. Define Magnetic field.
5. Define Magnetic flux.
6. Define Flux density.
7. Define Magneto – motive force.
8. Define Reluctance.
9. What is Magnetic Circuit ?

ESSAY QUESTIONS

1. Write short notes on

   (i). Flux Density

   (ii). Magneto motive force

   (iii). Reluctance.
2. Give the detailed comparision between Electric Circuit and Magnetic Circuit.
3. Explain about care and maintenance of magnets.

Chapter VII

Electro Magnetic Induction

7.0 Introduction

The transfer of electric energy from one circuit to another without any electrical connections is called induction. When electric energy is transferred by means of a magnetic field it is called electromagnetic induction.

Electromagnetic induction occurs whenever there is a relative movement between a conductor and a magnetic field. This phenomenon is idscovered by Michael Faraday. He formulated two laws of electromagnetic induction.

7.1 Faraday's Laws of Electromagnetic Induction

7.1.1 First law:

Whenever a conductor cuts (or is being cut by) the magnetic flux an E.M., is inudced in the conductor.

7.1.2 Second law:

The magnetic of the induced emf is equal to the rate of change of flux linkages.

Let e = induced emf (V)

N = Number of turns in the coil.

ϕ_1 = Intial flux linkages (wb)

ϕ_2 = Final flux linkages (wb)

t = time taken to change the flux from ϕ_1 to ϕ_2 (second)

Initial flux linkages = $N\phi_1$

Final flux linkages = $N\phi_2$

Change in flux linkages = $N\phi_2 - N\phi_1 = N(\phi_2 - \phi_1)$ wb – turns.

According to Faraday's second law,

$$\text{Induced emf, } e = \frac{\text{Change of flux linkages}}{\text{Time}}$$

$$= \frac{N(\phi_2 - \phi_1)}{t} Volt$$

Putting the above equation in differential form, we get

$$e = \frac{d(N\phi)}{dt} = N = \frac{d\phi}{dt} Volt$$

$$\boxed{e = -N \frac{d\phi}{dt} Volt}$$

The minus sign is due to Lenz's law, which indicates that the voltage induced opposes the change in flux that produced it.

7.2 Direction of Induced E.M.F and Current

The direction of induced emf and hence current in a conductor can be determined by

1. Lenz's law Or
2. Flemings right hand rule.

7.2.1 Lenz's law:

It states that,

"An induced current always flows in such a direction that its field opposes any change in the existing field"

Or

"An induced current always flows in such a direction, that it opposes every cause producing it".

7.2.2 Fleming's right hand rule:

It states that,

"Place the fore finger. middle finger and thumb of the right hand mutually perpendicular to each other such that, fore finger points the direction of the magnetic field, thumb points the direction of motion of the conductor, then the middle finger gives the direction of induced current flowing through it".

7.3 Problems

1. A coil of 360 turns is linked by a flux of 100 μ - wb. If the flux is reversed in 0.01 second, find the emf induced in the coil.

Solution:

$N = 360$

$\phi_1 = 100 \text{ x } 10^{-6}$ wb

$\phi_2 = -100 \text{ x } 10^{-6}$wb

$dt = 0.01$ sec.

$d\phi = \phi_1 - \phi_2 = 100 \text{ x } 10^{-6} - (-100 \text{ x } 10^{-6})$

$= 200 \text{ x } 10^{-6}$ wb

$= 7.2$ V Ans.

2. A dc motor field pole is wound with 400 turns and carries 25 m-wb when excited. The exciting current is then switched off and the flux is reduced to 0.6 mwb in 0.03 sec. Calculate the average emf induced in the coil.

Solution:

$N = 400$

$\phi_1 = 25 \text{ x } 10^{-3}$ wb

$\phi_2 = 0.6 \text{ x } 10^{-3}$wb

$t = 0.03$ sec.

$d\phi = \phi_1 - \phi_2 = 25 \text{ x } 10^{-3} - 0.6 \text{ x } 10^{-3}$

$= 24.4 \text{ x } 10^{-3}$ wb

$= 325.333$ V Ans.

Exercise Problems

1. A coil of 200 turns is linked by a flux of 0.65 mwb. If teh flux is reversed in 0.012 second, find the emf induced in the coil.

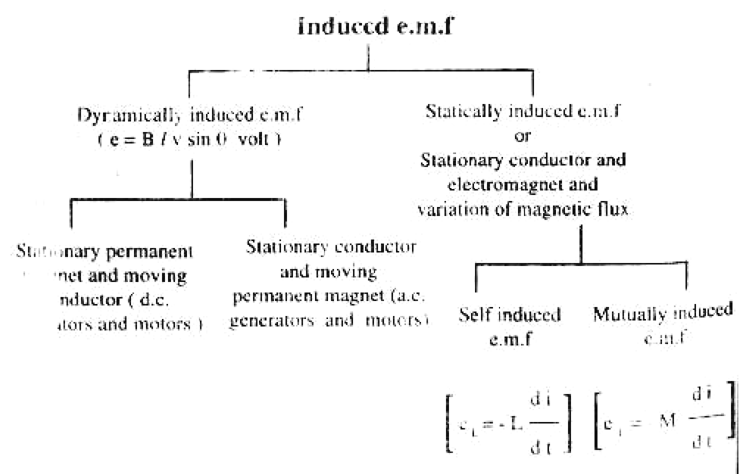
   [Ans: 21.67V]

3. The field coils of a 4 pole generator each having 400 turns, are connected in series. When the field is excited, there is a magnetic flux of 0.015 wb/pole. If the field circuit is opened in 0.01 second and the residual magnetism is 0.001 wb/pole, calculate the average voltage which is induced across the armature terminals.

   [Ans: 8960 V]

7.4 Classification of Induced E.M.F

The emf induced by electromagnetic induction may be classified as Follows:



7.5 Dynamically Induced E.M.F

The emf induced in a conductor due to motion (either conductor or electromagnet) is called dynamically induced emf.

Consider a single conductor of length ‘l’ meters moving at right angles to a uniform magnetic field of B wb / m^2 with a velocity of v m/s as shown in Fig.7.5 below.

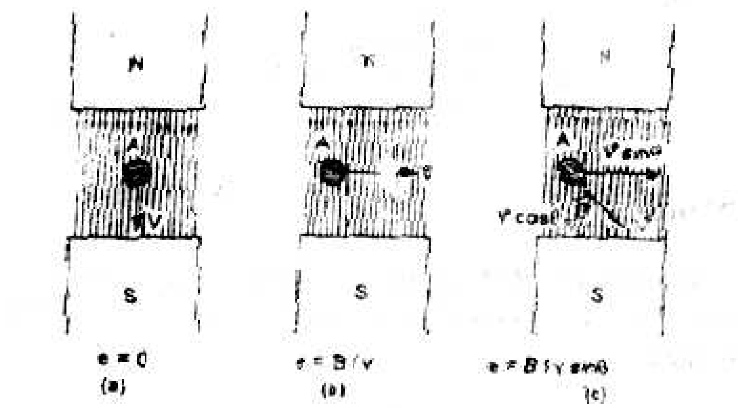


Fig. 7.5.

Suppose the conductor moves through a small distance of ‘dx’ in ‘dt’ seconds.

The area swept by the conductor, dA = l dx

Flux cut, dϕ = flux desity x area swept = B l dx

According to Faraday’s laws of electromagnetic induction, emf induced n the conductor is given by,

$$e= N \frac{d\phi}{dt}$$

$$\frac{d\phi}{dt} \text{(Since N=1)}$$

$$\frac{Bldx}{dt}$$

$$e= Blv \text{ volts} \quad \left[Since \ \frac{dx}{dt} = v \right]$$

If the conductor moves through an angleθ to the magnetic filed as shown in Fig. 6.5 (b) then the velocity at which the conductor moves across the field is V sinθ.

$$\boxed{e= Blv \sin \theta \text{ volts}}$$

7.6 Problems

1. A stright conductor of 10 m long is moved at right angles to uniform flux density of 1 T, at a speed of 50 cm / sec. Calculate the emf induced in the conductor.

Solution:

l = 10m

B = l T

v = 50cm / sec. = 50 x 10^{-2}m / sec. = 0.5 m/sec.

e = Bl V

= 10x 1 x 0.5 = 5 volts Ans.

2. A conductor of active length 30 cm and carrying current of 100A moves at an angle of 30^0 with the direction of an uniform magnetic field of dinsity 0.4 wb/m^2. Find the emf induced in it, if teh velocity of the conductor is 0.5 m/sec.

Solution:

l = 30cm = 0.3m

I = 100 A

$\theta = 30^0$

B = 0.4 wb/m^2

V = 0.5 m/sec.

Induced emf, e= B l v sinθ = 0.4 x 0.3 x 0.5 x sin 30^0

= 0.03 volts. Ans.

EXERCISE PROBLEMS

1. A wire of length 50 cm moves at right angles to its length at 40 m/s in a uniform magnetic field of density 1 wb/m^2. Calculate the emf induced in the conductor when the direction of motion is,

i) Perpendicular to the field and

ii) Inclined at an angle of 30^0 to the direction of field. [Ans: 20V, 10V]

2. Calculate the emf induced in a conductor placed in a magnetic field of 0.02 wb is established by 150 sq. cm poles. The active length of the conductor is 0.12 m and is moved at a speed of 10m/sec. Calculate the emf induced in the conductor. [Ans: 1.6 V]

7.7 Statically Induced E.M.F

The emf induced by variation of flux in a stationary conductor and magnet is known as statically induced emf. It can further divided into, a) Self induced emf b) Mutually induced emf.

7.7.1 Self induced e.m.f

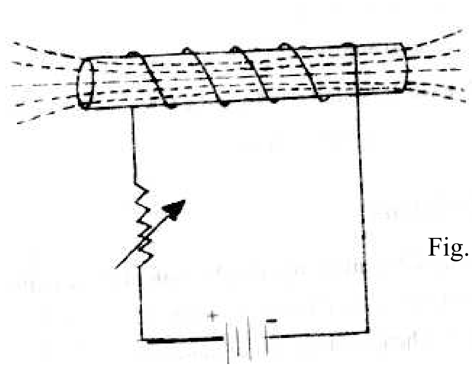


Fig. 7.7.1 Self induced EMF

The self induced emf exists as long as the current in thecoil changes. By Lenz's law, this induced emf will oppose the applied voltage and hence known as 'back emf' or 'counter emf'.

induced emf, $e = N\frac{d\phi}{dt} = \frac{d(N\phi)}{dt}$

Since flux is due to current in the same coil, so flux linkages (=ϕ N) will be proportional to I.

$e = \frac{d(N\phi)}{dt} \quad \therefore e \ \alpha \ \frac{dI}{dt}$

$= \text{constant x } \frac{dI}{dt}$

$= \boxed{e_L = L \text{ x } \frac{dI}{dt}}$

Where L is the proportionally constant called self inductance or inducta.ce of the coil. Tg% + unit of inductance is henry.

7.7.2 Mutually Induced e.m.f:

The emf induced in a coil due to flux changing in the neighboring coil is called mutually induced emf.

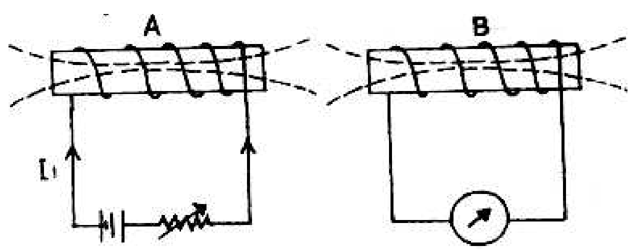


Fig. 7.7.2. Mutually induced EMF

The mutually induced emf in a coil 'B' exists as long as the current in coil A is changing.

The mutually induced emf in coil B is directly proportional to the rate of change of current in coil A.

$e_m \,\alpha\, \frac{dI_1}{dt}$

$\boxed{e_m = M \frac{dI_1}{dt}}$

Where M is a constant, known as mutual inductance between two coils. The unit of mutual inductance is henry.

Self Inductance

When a current is passed through a coil, then a magnetic flux is produced around it. Now, if the direciton of current is changed, then the direction of magnetic flux is also changed. If an alternating current is passed through the coil, then the magnetic field produced will also be alternating. In this way, 'An alternating flux produced an induced e.m.f. in the coil'. The property of a coil of inducing an e.m.f. in itself when placed in an alternating magnetic field is known as self induction or self inductance. It is denoted by letter L. Its units is henry which is denoted by letter H. See Fig. 7.8

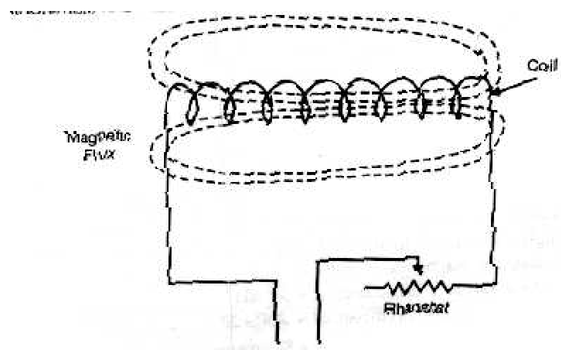


Fig. 7.8

If a current of l amperes is passed through a coil of N turns and the produced magnetic field is ϕ webers, then—

$$L = \frac{N\phi}{l} \ \ Henry$$

Mutual Inductance

When two coils A and B are wound on the same core and an alternating current is passed through A, then an alternating magnetic flux is produced around the coil A. But, the coil B is also placed in the alternating magnetic flux of coil A, hence an e.m.f. is induced in it which is called mutually induced e.m.f. and the property of the coils is called the mutual inductance. It is denoted by letter M. Its unit is henry which is denoted by letter H. It depends on the number of turns, thickness of conductor, area of a turn, length of the coil and distance between the coils.

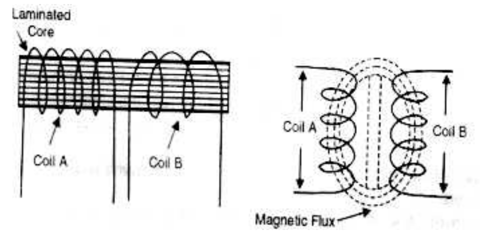


Fig. 7.9

If an alternating current of one coil which is changing at the rate of one ampere per second induces an e.m.f. of one volt in the second coil, then the two coils will have a mutual inductance of one henry.

∴ Induced e.m.f = mutual inductance x rate of change of current

Or $e = - M \frac{di}{dt}$

Where, e = induced e.m.f., volts

M = mutual inductance, henrys

di = change in current, amps

di = time taken by dt, seconds

sign (-) = it indicates that the direction of induced e.m.f. is opposite to that of applied e.m.f.

GLOSSARY

1. Faraday's laws of electromagnetic induction:

   First Law: Whenever a conductor cuts the magnetic flux, an emf is induced in the conductor.

   Second Law: The magnitude of induced emf is induced in the conductor.

2. The direction of induced emf and hence current in a conductor can be determined by i) Lenz's Law ii) Flemings Right Hand Rule.

3.Induced emf, $e = N\, d\varphi \,/\, dt$ volt

4. Dynamically induced emf e = BIV since volt.

5. Coefficient of self Industance, $L = N\varphi \,/\, I$ henry

SHORT QUESTIONS

1. State Faraday's first Law of electromagnetic Induction.
2. State Faraday's second Law of electromagnetic Induction.
3. State Lenz's Law.
4. State Flemings Right Hand Rule.

ESSAY QUESTIONS

1. State and explain Faraday's Law of electromagnetic induction.
2. Write short notes on i) Self Induction ii) Mutual Induction.

Chapter VIII

Electrical Machines

8.1 Generator

An electrical generator is a machine which converts mechanical energy into electrical energy.

Principle of working: AD.C generator works according to the Faraday's laws of electromagnetic induction. According to first law of electromagnetic induction.

"Whenever a conductor cuts the magnetic field, an emf is induced in the conductor".

The operation of a D.C. generator can be explained by a simple loop generator as shown in Fig. 8. below.

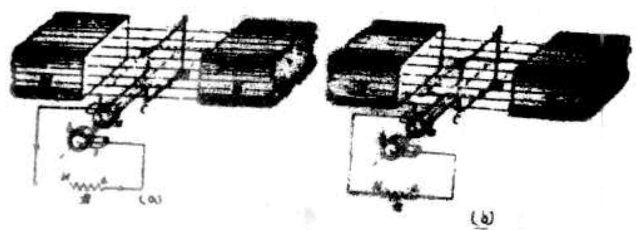


Fig. 8.1. Simple open loop generator

Consider a single turn copper coil ABCD is placed in the magnetic field produced by two permanent magnets. The ends of the coil are connected to two slip rings which are insulated from each other and also shaft. Two carbon bushes are pressed against the slip rings to collect current. These burshes are stationary and they are connected to the external load.

If we rotate teh conductor, say in clockwise direction, some emf is induced the conductor. The direction of the induced emf is found by applying Flemming's right hand rule. The direction of the current in the conductor under N-pole is inwards (say positive) and the current direction in the conductor under S-pole is outwards (i.e. negative). Therefore, we find that the current in a simple generator reverses for every half cycle i.e. when it changes from N-pole to S-pole, i.e. alternating current.

For making the flow of current uni-directional in the external circut, the slip rings are replaced by split rings as shown in Fig. 8.2 below.

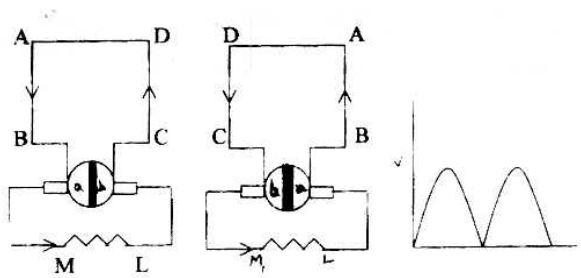


Fig. 8.2. Split rings

The split rings are made out of conducting cylinder which is cut into two halves or segments insulated from each other by a thin mica sheet.

8.2 Practical Generator

Simple loop generator is considered to undustand operating principle. Whereas the practical generator is as shown in Fig. 8.2 below.

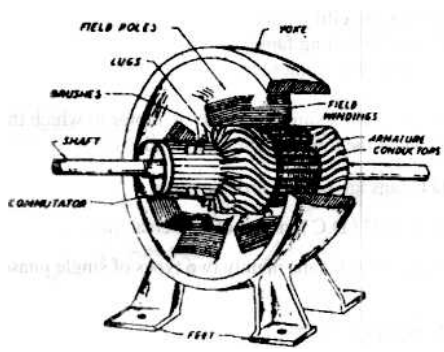


Fig. 8.3. Practical generator

Parts:

1. **Frame or Yoke:** The outer frame of a D.C generator is known as Yoke. It should have good mechanical strength and good permeability. E.g. Cast steel, rolled steel etc.
2. **Field magnets or poles:** Magnetic flux is obtained by electromagenets. They carry field winding and produce flux.
3. **Armature:** The rotating part of a D.C generator is known as armature. It carries armature conductors in slots and are connected in the form of a winding.
4. **Commutator:** The ends of the coils of the armature winding are soldered to commutator segments, which are insulated from each other by a thin mica sheet. Commutator convers A.C to D.C.
5. **Brushes:** Corbon brushes are stationary and they are pressed against the commutator segment to collect current from it.

8.3. D.C. Motor: An electic motor is a machine which converts electric energy into machanical energy. Its action is based on the principle that when a current – carrying conductors is placed in a magnetic field, it experinces a mechanical force whose direction is given by Fleming's Left – hand rule and whose magnitude is given by F = BIT newton.

Principle of working:

Its action is based on the principle that when a current – carrying conductro is placed in a magnetic field, it experiences a machanical force whose direction is given by Fleming's Left – hand rule and whose magnitude is given by F = BIZ newton.

When its field magnets are excited and its armature conductors are supplied with current from the supply mains, they experience a force tending to rotate the armature. Armature conductors under N-role are assumed to carry current down wards (crosses) and those under S-poles, to carry current upwards (dots). By applying Fleming's Left – hand Rule, the direction of the force on each conductor can be found. It is shown by small arrows placed above each conductor. It will be seen that each conductor experinces a force F which tends to rotate the armature in anticlock wise direction. These forces collectively produce a driving torqued which sets the armature rotating.

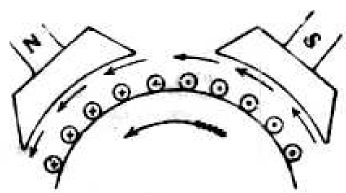


Fig. 8.4. D.C. Motor

8.4. Fleming's Left – hand Rule:

If the first three fingers of the left hand are stretched mutually perpendicular to each other, with the fore finger in the direction of the current, then the thumb indicates teh direction of motion of the conductor (or the force).

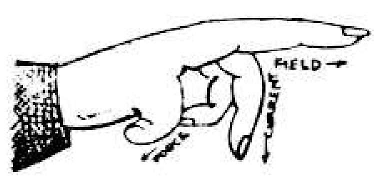


Fig. 8.5. Flemings left hand rule

8.5. Fleming's Right – hand Rule:

Hold out the right hand with the first finger, second finger and thumb at right angles to each other.

If fore finger represents the direction of the lines of Flux, the thumb points in the direction of motion, then second finger points in the direction of the induced current.

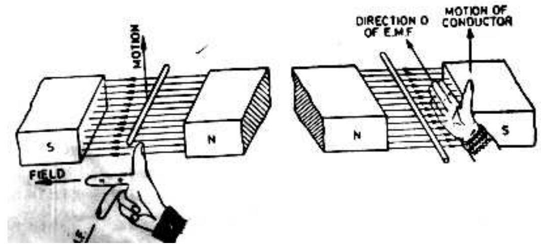


Fig. 8.6. Flemings right hand rule

a. A Motor Fails to Start. The possible reasons are as follows :

i The supply is off

ii The brushes are not making good contact with the commutator

iii The connecting cable is broken or the connection are open.

iv The starter coil is open-circuited.

v The armature or field windings are open-circuited

b. **As the Motor is started, the fuse burns out.**

i The capacity of the fuse is small as compared to the load.

ii The motor is over loaded

iii The cable is short -circuited or earthed.

iv The starting resistance is short-circuited

c. Heavy Sparking at the commutator

i The brushes are not in the neutral axis

ii The polarities of the interpoles are wrong

iii Armature wires are broken

iv There are small pits on the commutator segments

v The connections of armature windings at the commutator are loose

vi The commutator is dirty

vii the brushes are loose

viii The motor is over loaded

ix The pressure at the brushes is not proper

GLOSSARY

1. An electrical generator convers mechanical energy into electrical energy.
2. A. D.C. generator works according to Faraday's law of electromagnetic induction.
3. A D.C. motion convers electrical energy into mechanical energy.
4. "A current carrying conductor, which is placed in a magnetic field, tends to move at right angle to the field". It is the principle of D.C.Motor.

SHORT QUESTIONS

1. What is D.C. Generator?
2. What is the working principle of D.C. Generator?
3. Mention the parts of D.C. Generator.
4. What is D.C.Motor?
5. What is the working principle of D.C. Motor?
6. State Fleming's Left hand rule.
7. State Fleming's Right hand rule.

ESSAY QUESTIONS

1. Explain the working principle of D.C. Generator with neat sketch.
2. Explain the working principle of D.C. Motor with neat sketch.
3. Describe the parts of a pratical generator.
4. Explain Trouble shooting in an electric motor.

Chapter – IX

Electrical Appliances

9.1. Introduction

A number of appliances have been made by utilising the heating effect of electric current. These appliences are being used in every field of life such as domestic, agriculture, industry, medical etc. An electrician should have a general knowledge of these appliances so as to enable him to repair them.

Appliances based on heating effect of electric current usually employ an element made of Nichrome. The shape and wattage of the element depends on the requirements of the particular appliance. Nichrome is an alloy and it usually consists of 80% nickel and 20% chromium, but the percentage of constituent metals may be altered by 1-2% or some other metal can be mixed in the alloy upto 1-2% so as to obtain a high quality wire. Actually speaking, the ratio of constituent metals in an alloy is a 'trade secret' which is based on the long experience of industrialists.

9.2. Immersion Rod

1. **Construction.**

   It consists of an element which is fitted in a thin brass or copper pipe (upto one centimetre external dia.) with the help of an insulating powder in such a way that the element remains isolated from the pipe. Now, the pipe is bend into a shape which is shown in Fig.9.1 The ends of the pipe are terminated into a bakelite case and the terminals of the element are joined with a main lead.

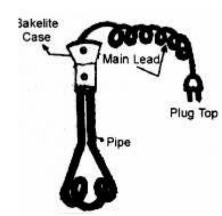


Fig. 9.1 Immersion Rod

2. Specifications.

The wattage of an immersion rod varies from 500 to 2000 watts and according to wattage, 1 to 50 liters of water can be heated up with it.

3. Uses.

Small immersion rods are used for heating water for shaving purpose while large size rods are used for heating water for bathing ect. Large tanks fitted with a number of rods of 2000 watts are used for heating water in industries.

4. Repairs.

If an element gets burst then it is quite difficult and expensive to repaire it, therefore, it is unrepairable. If main leads terminals become loose or open, they can be repaired up.

5.Precaution.

Always keep most of the immersion rod well dipped in the water except 3-4 centimeters portion just below the case. The portion of the rod left outside the water may burst and cause holes in the pipe thus rendering the rod useless.

9.3. Electric Iron

1. Construction.

In an electric iron, an element is well tighten between an iron base plate and iron pressure plate of the shape shown in Fig. 9.2 The element and pressure plate etc. are covered by a cover. A bakelite handle and a socket for electrical connections are mounted on the cover. The other surfaces of the base plate and the cover are chrome polished.

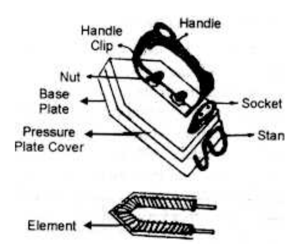


Fig. 9.2 Electric Iron

2. **Specifications.**

   The wattage of element of an electric iron varies from 400 to 1000 watts in accordance with the weight of the iron. The weight of a domestic iron is kept upto 3 kilograms and of a commercial iron is kept upto 6 kilograms.

3. **Uses.**

   It is used for ironing on all types of garments by housewives, washerman and drycleaners.

9.4. Electric Stove

1. **Construction.** The construction of an electic stove is shown in Fig. 9.3. it consists of porcelain plate fitted a spring shaped element. A wooden or bakelite handle is fitted to the stove for its easy handling. A socket is mounted at one side of its base for electrical connections. The construction of porcelain plate the element are shown separately in the same figure.

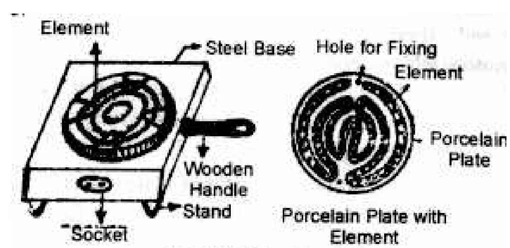


Fig. 9.3. Electric stove

2. **Specifications.** It is usually made in the range of 1000, 1500 or 2000 watts. Its base may be given a round, rectangular or coal type oven.
3. **Uses.** It is used for cooking food, tea etc. In industries also it is used as an stove or oven.
4. **Repairs.** If its element becomes defective then it is replaced with a new one having the same wattage- For this, remove the old element by loosening it form nut bolts and clean the porcelain plate properly.

Now, tighten the terminals of the element with nut-bolts and set the spring shaped element in the groove of the procelain plate. Ensure that the distribution of turns of the element is uniform throughout the length of the groove. The turns should not be crowded or over shaped anywhere. The element would spoil very soon in such cases.

9.5. Water Heater

During winters, warm water is required for bathing etc. For this purpose, an immersion rod is also suitable but in big families it proves to be in-sufficient, thus storage water heater were developed to meet the requirements. Water heaters are mainly of following two types.

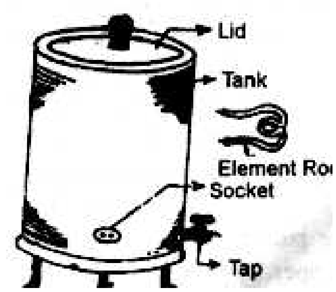


Fig. 9.4. Tank type water heater

1. Tank type water- heater.
2. Geyser water- heater.

1. **Tank type Water-heater.** Its construction is shown in Fig.9.4. It consists of a cylindrical tank of 20 to 50 liters capacity. The top of the tank is kept open and it can be covered with a circular lid. The tank is installed on a stand. An outlet top is fitted near bottom and a socket is provided for electrical connections. The tank is fitted with water, covered with the lid and then connected to the main supply. Approximately with in half an hour the water becomes warm for bathing etc.

There is an immersion rod fitted inside the tank for heating the water, itswattage ranges from 1500 to 2000 watts. The appliance is used in cities and villages where tap-water facility is not available. It is also known as non-pressure type water-heater. It is replaced with a new one. If the tap becomes defective then first try to repair by replacing a new washer in it and even if it does not work then replace the tap with a new one.

2. **Geyser Water Heater.** It consists of a cylindrical tank of 10 to 50 liters capacity. The tank is kept closed completely from all sides except inlet and outlet. It can only be used in such houses, hotels etc. where tap-water facility is available. The inlet is directly coupled to the water pipe line and the outlet is coupled to a tap or shower or both. A geyser is generally installed on the bathroom wall, see Fig. 9.5 A resonable water-pressure always exists in the tank, hence it is also known as pressure type water heater. As the warm water is drained of through the outlet, cold water replaces it in equal volume through the inlet. Its wattage ranges from 1000 to 2500 watts. A vertically installed immersion rod is used in it which is equal in length to the length of the tank. In some small size geysers, electric kettle type elements may also be used but they should be fitted at the outer surfaces of its top and bottom.

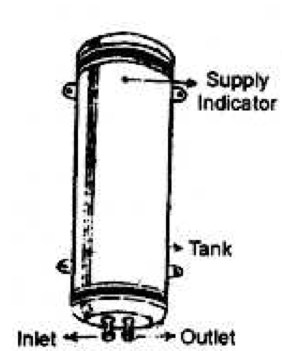


Fig. 9.5 Geyser

Being straight in shape, the immersion rod of a geyser is repairable and its element can be replaced a new one.

9.6. Ceiling Fan

The Ceiling Fan is a simplest form of fan. It consists of an ac split phase capacitor start and run indication motor. The main parts of Ceiling fans are the starter, rotator, body and fan blades. The motor is rotating part of the fan (outer part) and the stator part is the (inner part) stationary parts of the fan.

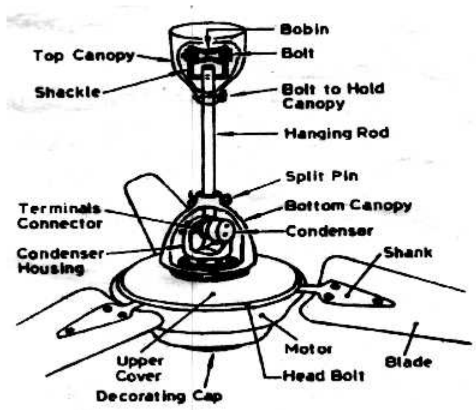


Fig. 9.6. Ceiling fan

The startor is made up of high silicon stampings, which are rivited together to form a solid starter body. These is stampings (lamination) are thin sheets, insulated from one another with varnish. The laminated core minimises eddy current losses. The thickness of core is known as stack height. For Ceiling fans, number of poles are equal to number of slots. If stack height is more, flux will be more and greater the effiecency.

To achieve design symetry, more flux and to place more conductions, rectangular slots are preferred. There is a centre hole in a startor to fix the spindle (hollow spindle)

There are symmetrically placed circular holes in the stator for ventilation purpose and circulate air for cooling. Also these ducts reduce the weight of the stator. The main / running winding is placed in slots which are near to rotor and auxilary winding / starting winding is placed in the inner slots and made by super enamitted coated Cu wire of 34 SWG is used. The winding in the slots is done in one direction while in the next slot in opposite direction, in order to get alternate south and north poles.

After making winding in inner and outer slots and giving proper insulation, three terminals, are brought out from main and auxilary winding. Starting terminal of main winding and end terminal of auxilary winding are connected together and brought out as common terminal (yellow), the second wire is brought from end terminal of main winding (red). And third wire is brought from starting terminal of auxilary winding (blue). The spindle is fixed in centre hole.

Ceiling fan rotor is made of silicon stampings with end rings of Alluminium. Rotor slots are filled with alluminium alloy. A capacitor of 2.00 to 2.2 MFD is connected in series with Auxilary winding and both main winding and auxilary winding are connected in parellel with the supply terminals. The introduction of capacitor and phase displacement between auxilary and main winding, will cause rotating magnetic field and for developing the starting torque. The starter and rotor are assemble with Alluminium enclosure. The rotor is filled with bush bearing or bush bal bearings or ball bearings on both ends.

Ceiling fans blades are manufactured from alluminium alloy sheet. Cantour, angles, curvatures are designed to have optimum air displacement. The speed of ceiling fan can be controlled Rheostatic regulator or electronic regulator.

GLOSSARY

1. Electrical Appliances utilise the healing effect of electric current.
2. Electrical Appliances usually employ an element made of Nichrome.
3. Immerson rod, Electric Iron, Electric stove, Geyser, water heater are some of electrical appliances.

QUESTIONS

1. Explain the working principle of Immersion Rod with neat sketch.
2. Explain the working principle of Electirc Iron with help of neat sketch.
3. Explain the working principle of Electric stove with help of neat sketch.
4. Explain the working principle of water heater with help of neat sketch.
5. Explain the working principle of a ceiling fan with help of neat sketch.

CHAPTER – 10

BATTERIES

10.1.The Battery

The battery is the main part of teh electrical system in an automobile. Without the battery, the engine cannot be started with the starting motor. The battery supplies current for operation of the starting motor and ingition system when the engine is being cranked for starting. It also supplies current for light, radio, heater and several other accessory units when the generator is not operating fast enough to handle the electrical load.

The batteries are the following types:

1. Lead – acid battery.
2. Alkaline – iron battery.
   a) Nickel – iron type.
   b) Nickel – cadmium type
3. Zinc – air battery.

   Within scope of the book lead – acid battery will be described here in details.

10.2. Cell

The word 'cell' means one unit or a combination of materials for converting chemical energy into electrical energy. A 'battery' means a combanation of the cells. Essentially cell consists of two dissimilar conducting electrodes (Cathode and Anode) immersed in a liquid called electrolyte. By using the energy released by chemical action, electrons are shifted from one electrode to another there by creating potential difference between the electrodes.

10.3 Lead – acid Battery construction

A lead acid cell consists of the following components:-

1. Container 2. Plates 3. Separators 4. Cell covers 5. Electrolyte.

1. Container

The container is a single piece construction and is made of hard rubber or a bituminous material. It is divided into compartments by partitions for different cells. Bridges are formed at the bottom of each compartment on which the battery plates rest. The spaces between the bridge ribs are provided to collect sediment.

2. Plates

In a cell several similar plates are properly spaced and welded or lead – burned to a strap to form plate group. The plates consists of perforated grids into which lead or lead peroside has been pressed. The grids are made of an alloy of lead and antimony, which makes them resistant to electrochemical corrosion, and gives them strength and rigidity. There are two types of plates groups in each cell – positive plate group and negative plate group. The plate group connected to the positive terminal of the cell consists of grids filled with a paste of lead peroxide brown in colour. The plate group connected to the negative terminal on the cell consists of grids filled with metalic lead. It is ipongy and dull gray in colour. Each group of plates is held together by a post strap to which each individual plate is welded. These straps extended up through the cell cover to provide the cell terminals to cannot one cell to the other. The plate groups are arranged in the cell so that the positive and negative plates alternate.

3. Separators

Separators are placed between the negative and positive plates to keep them separate with each other. The separators are designed to hold the plates apart so that they do not touch and same time they must be porous enough to permit liquid to circulate between the plates. Separatory are usually made of specially treated wood, hard rubber, rexin impregnted fibre alone or in combination with rubber or meats of glass fibers. Some cells have separators made of polycinal chloride or polyethytene saturated cellulose.

4. Cell Cover

Each cell is sealed by a cover of hard rubber through which the positive and terminals project. Adjacent negative and positive terminals are connected by connector straps. Each cover has an opening through which liquied can be added. A filler cap is serewed on this opening. The filter cap has an air vent for the escape of gas. In many late model cells one – piece cover is provided that covers all the cells.

5.Electrolyte

The electolyte used in the lead acid cells is the solution of suplhuric acid. It consists of 40% sulphuric acid and 60% distilled water.

10.4 Applications of Lead – Acid Cells

Storage cells are these days used for a great variety and range of purpose some of which are summarised below:

i) In central stations for supplying the whole load during light load periods also asist the generating plantduring speak load periods for providing reserve emergency supply during periods of plant breakdown and funally to store energy at times when load is light for use at times when is at its peak value.

ii) In private generating plants both for industrial and domestic use, for much the same purpose as in central stations.

iii) In sub-stations, they assist in mantaining the decleared voltage by meeting a part of the demand and so reducing the load on and the voltage drop in feeder during peak – load periods.

iv) As a power source for industrial and mining cell locomotives and for road vehicles, like cars and trucks.

v) As a power source for submarines when submerged.

vi) For petrol motor car starting and ignition etc.

vii) As a low – voltage supply for operating purpose in many different ways such as high – tension surtchgear, automatic telephone exchange and repeater stations, broadcasting stations and for wireless receiving sets.

10.5 Care and Maintenance of Cells

The cells of vehicle cells must be inspected periodically, say every week. The following points may be taken careof .

1. The cell terminals should be clean and tight. The electolyte may escape from the battery due to overfilling and cause the corrosion of the terminals. A loose connection at the terminals will result in a faulty starting and discharged cell.
2. Remove vent plugs taking care that no flame is brought near the vents because the gas inside is highly inflammabel.
3. In case the electrolyte level in the cell is not sufficient, top up with distilled water. If distilled water is not available sometime clean water may also be used.
4. Never let the cell remain in discharged condition, otherwise the plates will become sulphated.

5. Cell electrolyte being corrosive, avoid its contact with eyes, skin and clothes. In case it goes into the eyes accidentally wash the eyes with clean water and consult your doctor.

6. Do not bring any flame near the cell a the highely explosive vapours coming out of the cell may get ignited accidentally.

7. To avoid accidental arcing always remove the negative ground cable first while disconnecting and cannot the same last while assembling.

8. Use proper protective clothing i.e. apron gloves and face shield while handling cells.

9. While marking cell connections take special care to observe proper polarities so that correct connections are made.

10. Jump start cells only if permitted by the cell manufacturer. Some manufacturers specially prohibit jump start.

10.6 charging and discharging of Batteries

Following chemical changes take place during the charging and discharging of a lead – acid cell.

Discharging

When the cell is fully charged its possitive plate or anode is pbo_2 (dark chocolate brown) and the negative plate or cathode is pb (Slate grey). When the cell discharges i.e. it sends current through the external load, then H_2 SO_4 is dissociated into positive H_2 ions and negative SO_4 ions. As the current within the cell is following from cothode to anode. H_2 ions move to anode and SO_4 ions move to the cathode.

At anode (pbo_2) H_2 combines with the oxygen of pbo_2 and H_2 SO_4 attacks lead to form $pbso_4$.

$Pbo_2 + H_2 + H_2\,SO_4 \rightarrow pbso_4 + 2H_2O$

At the cathode (pb), SO_4 combines with it to form $pbso_4$

$pbso_4 \rightarrow pbso_4$

It will be noted that during discharging

i) Both anode and cathode become $pbso_4$ which is some what witish in colour.

ii) Due to formation of water specific gravity of the acid decreases.

iii) Voltage of the cell decreasess.

iv) The cell gives out energy.

Charging

When the cell is re-charged H_2 ions move to cathode and SO_4 ions go to anode and the following changes take place.

At cathode, $PbSO_4 + H_2 \rightarrow pb + H_2\,SO_4$

At anode, $pbso_4 + SO_4 + 2H_2O \rightarrow Pbo_2 + 2H_2\,SO_4$

Hence, the anode and cathode again become Pbo_2 and pb respectively.

It will be noticed that during charging: -

i) The anode becomes dark chocolate brown in colour (Pbo_2) and cathode becames grey metallic lead (pb).

ii) Due to consumption of water specific gravity of $H_2\,SO_4$ is increased.

iii) There is a rise in voltage.

iv) Energy is absorbed by the cell.

The charging and discharging of the cell can be respresented by a single reversible equation given below:

POS . plate	Neg.Plate discharge	Pos. Plate	Neg. Plate
$Pbo_2 + 2H\,SO_4 + pb$	Charge	$PbSO_4 + 2H_2O +$ pbSO	

For discharge the equation should be read from left to right and for charge from right to left.

GLOSSARY

1. A cell is a source of emf in which chemical energy is converted into electrical energy.
2. A battery ia a group of cells.
3. Lead acid cell occupies prominent place because of its application in automative field.
4. The cell is which chemical action is not reversible are called primary cells.
5. The cells is which chemical action is reversible are called secondary cells.

SHORT QUESTIONS

1. Distingvish between cell and battery.
2. What are the types of batteries?
3. Mention the parts of Lead acid cell.
4. What is the purpose of separators in the cell?
5. What is the electrolyte used in Lead acid battery? Give the composition.

ESSAY QUESTIONS

1. Descibe Lead – Acid cell construction with neat sketch.
2. What are the applications of Lead – Acid cell?
3. Explain about care and Maintenance of Cell?
4. Explain charging and discharging of batteries with chemical reactions.