CHAPTER 5: PERFORMING ELECTRICAL INSTALLATION

Unit of learning code ENG/CU/EI/CR/01/4

Related Unit of Competency in Occupational Standard: Perform Electrical Installation

5.1 Introduction

This unit describes the competencies required to enable trainee be able to exhibit competency in the application of health, safety and environmental standards, preparation of working drawings, Assembly of tools, equipment, materials and drawing instruments, and performing electrical installation

5.2 Summary of Learning Outcomes

1. Apply health, safety and environmental standards
2. Prepare working drawings
3. Assemble tools, equipment, materials and drawing instruments
4. Perform electrical installation

5.2.1 Learning Outcome 1: Apply and Adhere to Safety Procedures

5.2.1.1 Introduction

To apply and adhere to safety successfully, one requires the ability to understand causes of accidents and sources of danger, apply good housekeeping and apply first aid where necessary.

5.2.1.2 Performance Standard.

5.2.1.3 Information Sheet

Non-statutory regulations

Statutory laws and regulations are written in a legal framework, some don't actually tell us how to comply with the laws at an everyday level. Non-statutory regulations and codes of practice interpret the statutory regulations telling us how we can comply with the law. They have been written for every specific section of industry, commerce and situation, to enable everyone to comply with, or obey the written laws. When the Electricity at Work Regulations (EWR) tell us to 'ensure that all systems are constructed so as to prevent danger' they do not tell us how to actually do this in a specific situation. However, the IEE Regulations tell us precisely how to carry out our electro technical work safely in order to meet the statutory requirements of the EWR. In Part 1 of the IEE Regulations, at 114, it states 'the Regulations are non-statutory. They may, however, be used in a court of law in evidence to claim compliance with a statutory requirement'. If your electro technical work meets the requirements of the IEE Regulations, you will also meet the requirements of EWR.

The IEE Wiring Regulations requirements for electrical installations

The Institution of Electrical Engineers Requirements for Electrical Installations (the IEE Regulations) are non-statutory regulations. They relate principally to the design, selection, erection, inspection and testing of electrical installations, whether permanent or temporary, in and about buildings generally and to agricultural and horticultural premises, construction sites and caravans and their sites.

PPE

PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing. Under the Health and Safety at Work Act, employers must provide free of charge any PPE and employees must make full and proper use of it.

<u>Safety and work habits</u>

Safety is the behavior undertaken to prevent injury to people and damage to machines and equipment. Many people are injured or killed in electrical accidents due to ignorance or carelessness. There are various safety/protective wear that needs to be used in a work environment

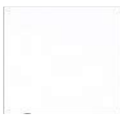


Figure 1 Protective wear

1. Safety helmet-Protects head from falling objects
2. Goggles-protects eyes from flying objects and excessive light
3. Ear muffles-Protects ears from excessive sound.
4. Dust coat/Overall- Protects personal clothing from dirt
5. Hand gloves- Protects hands from injury.
6. Safety boots- Protects feet from falling objects.

Safe working habits

1. **Handling of tools and equipment**

   All tools and equipment should be handled with care. They should be handled individually. They should NEVER be stacked as a pile.

2. **Handling of heavy loads**

   Always ask for assistance. Carry heavy loads with the back upright.

Figure 2 Handling of heavy loads

If the load is too heavy use a crane or other mechanical assistance.

3. Movement of sharp items

Sharp items should be moved pointing downwards and away from the body. The movement should be slowly.

Never run when carrying sharp items.

ALWAYS warn other people when carrying sharp and/or long objects.

4. Working environment

The working area should be well ventilated and well lit. The floor should be free from oil spillage or any slippery substance. Always wipe any liquid that is on the floor.

Care and maintenance of tools

Tools which are not properly taken care of can cause injuries, therefore:

1. Tools should be stored in their racks or kits.
2. After use the tools should be cleaned.
3. Wipe them to be free from dust and oil or grease.
4. Use cotton waste for cleaning.

5. Cutting tools should be sharpened from time to time.
6. Tools that require oiling should be oiled as planned.

Safety rules and regulations

1. Do not run in the workshop, always walk.
2. Work from marked work places.
3. Do not work on live circuits.
4. Always ensure the circuit is checked for correct functioning before connecting it to power.
5. Do not entertain horse play in the working area.
6. Clean the work area after the job is done.
7. All slippery floors should be cleaned/wiped.
8. Conceal all bare conductors.
9. When working with a ladder ensure it is properly supported.
10. Clear all pathways of any obstructions.

<u>Dangers of electricity</u>

1. Electric Shock

Electric shock is the passage of electricity in the human body. This can be due to getting in contact with live wires. When a person gets into contact with a live wire and gets an electric shock, the following steps should be followed to save the victim:

i. Use a dry insulator to remove the victim from electrical contact.
ii. Take the victim away from the place where the shock occurred.
iii. If the victim has stopped breathing lay he/she flat on the ground then apply first aid by KISS OF LIFE method of artificial respiration as follows.
iv. Call for medical help

Figure 3 Kiss of life position

Steps of Kiss of life

1. Place a support below the neck and loosen the clothing.
2. Clear all air passages.
3. Pinch the nose and breathe into victim's mouth until the chest rises.
4. Release the nose and let the air rush out.
5. Continue with this process until the victim breathes normally.
6. Take the victim to hospital for further medical checkup.

2. Electrical fire

Electrical fires can be caused by short circuits or loose connections. These fires cannot be put off by water because water is a good conductor of electricity. The fire extinguisher used in case of electrical fires include: carbon dioxide, dry sand, fire blanket, foam and dry powder. In the event of the fire, raise alarm, switch OFF the circuit and use the correct fire extinguisher to put it off. In case the fire is out of control use a designated exit route and escape. Always know the position of fire extinguishers in the workshop. Read the instruction on how they are operated and use them on the appropriate fires. Always know the position of emergency switches and use them in case of any danger in the workshop.

Classes of Fire

1. **Class A**: Fires that involve solid flammables and dusts, such as wood, plastics, paper and cardboard, fabric and textiles, and dusts such as grain dust and flour.
2. **Class B**: Fires that involve flammable liquids, such as gasoline, petroleum oil, paint, or diesel.
3. **Class C**: Fires that involve flammable gases, such as propane, butane, or methane.
4. **Class D:** Fires that involve combustible metals, such as magnesium, lithium, sodium, potassium, titanium, or Aluminium.
5. **Class F**: Fires that involve cooking oils and fats, such as vegetable oil, sunflower oil, olive oil, maize oil, lard, or butter (typically those used for deep-fat fryers).
6. **Class E**: These are electrical fires that involve live equipment and electrical sources

Types of fire extinguishers

1. Water Extinguishers

Water extinguishers are only suitable for **class A** fires, which means they can fight fires that involve wood, cardboard, paper, plastics, fabric and textiles, and other solid materials. Do not use water extinguishers on burning fat and oil fires and electrical appliances.

2. Dry water mist

These types of fire extinguishers will be solid red and will have the words ‘water mist’ printed within a white rectangle. Dry water mist extinguishers are unique in that they can extinguish almost **all types** of fires

3. Foam Extinguishers

Foam extinguishers are identifiable by the word ‘foam’ printed within a cream rectangle on their bodies. They are primarily water based but contain a foaming agent, which has rapid flame knock-down and a blanketing effect. It smothers the flames and seals vapour so that re-ignition cannot occur. They are suitable for fighting **class A and B** fires**. Warning:** these should not be used on any other fire classes, especially electrical fires.

4. Carbon Dioxide (CO_2) Extinguishers

These types of extinguishers can be identified by the text ‘carbon dioxide’ or ‘CO_2‘printed in white on a black rectangle. They also have a distinct type of hose. Carbon dioxide extinguishers are used for fighting **class B and electrical fires** – they suffocate the fire by displacing oxygen in the air. They must never be used on hot cooking oil and fat (class F) fires.

5. **Wet Chemical Extinguishers**

These types of fire extinguishers are identifiable by the words 'wet chemical' printed across a yellow rectangle. It also has an extended hose that you can hold and point at a given direction, which is useful when fighting fires on a kitchen top. Wet chemical extinguishers are used for fighting **class F** fires

First aid kit

First aid is the first treatment given to an accident victim before regular medical treatment is obtained. It is important for one to familiarize oneself with basic first aid skills. The ***first aid kit*** is a collection of supplies and equipment. The basic contents of the first aid kit includes; a pair of scissors, pain killers, surgical spirits, eye drops, cotton wool, adhesive plasters, roller bandages, petroleum jelly and sterilized dressings for use in giving first aid. All workshops should have a first aid kit. It can be used to address cuts, burns and even breakage of bones.

Figure 4 First aid box

Holger-Nielsen method

Steps

1. Lay the casualty in a prone position on a flat surface.
2. Place the casualty's hands one over the other under his forehead
3. The hand must be turned slightly on one side.
4. Nose and mouth must be unobstructed.
5. Place one knee with its inner side in line with the casualty's cheek, a few inches from the top of his head.
6. Place the other foot with the heel in line with the casualty's elbow.
7. Place your hands on the casualty's back on the lower part of the shoulders back, fingers pointing at casualty's feet.
8. Keeping the arms straight, rock forward gently until arms are vertical. The movement takes seconds counting "one, two". This pressure causes **expiration**
9. Then rock back counting, "three" for one second, and slide your hand past the casualty's shoulder until you can grab his upper arms near the elbows.
10. Rise and pull the arms until tension is felt for two seconds counting "four, five".
11. Do not raise chest from ground. This movement causes **inspiration**.
12. Your hands should remain straight, count "six" for one second

Safety signs

Safety signs must be displayed in appropriate places where they are easily seen. Examples of safety signs which MUST be clearly displayed and strictly observed are

5.2.1.4 Learning activities

Field/Visit to Kenya Red Cross Office

Visit Objective/Aim	Indicators	Special Instruction
To establish first aid methods	- Methods used for resuscitation - First aid kits contents	-Observe keenly methods of resuscitation -Observe keenly contents of first aid kit -Take notes

Practical assignment

Visit Objective/Aim	Indicators	Special Instruction
To establish firefighting techniques	- Fire extinguishers types - Types of fire	Participate in safety drills

5.2.1.5 Self-Assessment

1. What are the dangers of electricity?
2. Explain the steps to be followed when rescuing a non-conscious victim of an electric shock
3. Name ANY FOUR types of fire extinguishers.
4. Explain why it is important to wear the following protective clothing in a work environment:
   i. Helmet
   ii. Gloves
   iii. Goggles
   iv. Safety boots
   v. Dust coat

5.2.1.6 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company
ii. A functional Safety department.
iii. Computers
iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector

viii. Drawing equipment
ix. Workshop
x. Protective clothing

5.2.1.7 References

Donnely. (1980). *Electrical Installation theory and practice.*

Hyde. (1994). *Electrical Installation Principles and practice.*

ngari, c. k. (2019). *electrical installations for artisan level 2.* kenya literature bureau.

John Bird, (2007). *Electrical and Electronic Principles and Technology*,

https://www.osha.gov/sites/default/files/2019-03/electrical_safety_manual.pdf

https://safetyculture.com/topics/electrical-hazards/

5.2.2 Learning Outcome 2: Prepare Working Drawings

5.2.2.1 Introduction

To prepare working drawings successfully, one requires the ability to read and interpret drawings correctly to determine job requirements.

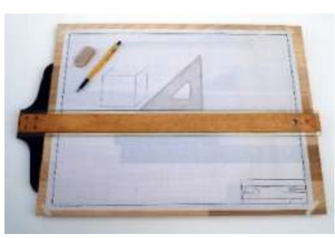
5.2.2.2 Performance Standard.

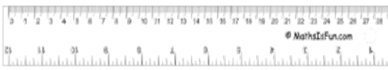
5.2.2.3 Information Sheet

Drawing Equipment and Materials

1. **Equipment**

S/N	Types drawing equipment	Application	Recommended care
1.	T-squares 	1. T-squares are used to draw straight horizontal lines. 2. The head of the square, the cross member, is placed along the left edge or the top of the drafting table, while the square's blade is laid across the table's top, over the drawing paper. 3. The drafter slides the square up, down or across on the table top, as required by a design, always keeping the flat side of the square flush with the table top's edge. This action keeps the square's blade parallel to the table top's edges.	1. Clean regularly 2. Tighten screws at joint to avoid non-parallel lines 3. Keep free from wet areas or any other liquids

2.	Set squares 	1. There are 30/60, 45/90, & adjustable set squares for drawing perpendicular and angled lines 2. The adjustable set square enables you to set the angle on the set square to anywhere between 0 ° and 90 °. 3. If you have an adjustable set square you can manage without the other two.	4. Clean regularly 5. Tighten screws at joints to avoid wrong angles (for adjustable set squares) 6. Keep free from wet areas or any other liquids
3.	Drawing sets/ compass 	Compasses are drawing instruments that are primarily used to perform the following tasks in geometry: i. To draw a circle around a point. ii. To transfer distances precisely.	1. Clean regularly 2. Tighten screws at joints to avoid inaccuracies 3. Keep free from wet areas or any other liquids to avoid corrosion
4.	Drawing boards 	1. They are used to draw parallel lines easily and precisely 2. The rulers/ Tee squares are used to precisely determine straight lines and angles and are individually adjustable. 3. Technical drawing boards are available in A4, A3, A2, A1 and A0 size which are designed for the corresponding paper formats.	1. Clean regularly 2. Keep free from wet areas or any other liquids to avoid corrosion

5.	Ruler 	It's used to measure dimensions and draw straight lines	Clean regularly
6.	Rulers and scale rules 	1. A scale rule is a scaled, three-edged ruler which has six different scales marked to its sides. A typical combination for building details is 1:20, 1:50, 1:100, 1:25, 1:75 and 1:125. 2. Today scale rulers are made of plastic, formerly they were made of hardwood.	Clean regularly

2. Materials

S/N	Drawing materials	Uses and care	Recommended care
1.	Pencils 	**A pencil** is an implement for writing or drawing, Most pencil cores are made of graphite powder mixed with a clay binder. Graphite pencils (traditionally known as 'lead pencils') produce grey or black marks that are easily erased. **B** grade means the core has more graphite, and will make a bolder,	1. Sharpen regularly. 2. Keep away from moist.

		darker line, and also be a little smudgier than a light pencil. **H** grade means the core has more clay, and will make a lighter, finer line, and will be less smudgy than a dark pencil. You will need a selection of pencils. A hard leaded pencil (3H) can be used for light lines, a softer pencil (H) for the outlines and an even softer pencil (HB) for printing. (More than one pencil of each grade will save you from frequent re-sharpening.)	
2.	Erasers 	They are used to erase pencil marks and lines. They assist in error correction and maintaining neat work**.** Choose a good quality rubber, one that does not smudge. 1. Clean regularly 2. Keep free from wet areas	Keep clean
3.	Sharpeners 	1. Sharpening of lead of pencils 2. Keep free from wet areas	1. Avoid breakage 2. Keep clean

<table>
<tr>
<td>4.</td>
<td>Drawing Paper
<table><tr><th>Designation</th><th>Size (mm)</th><th>Area cm²</th></tr><tr><td>A0</td><td>841 × 1189</td><td>1 m²</td></tr><tr><td>A1</td><td>594 × 841</td><td>5000</td></tr><tr><td>A2</td><td>420 × 594</td><td>2500</td></tr><tr><td>A3</td><td>297 × 420</td><td>1250</td></tr><tr><td>A4</td><td>210 × 297</td><td>625</td></tr></table></td>
<td>Drawing paper sizes

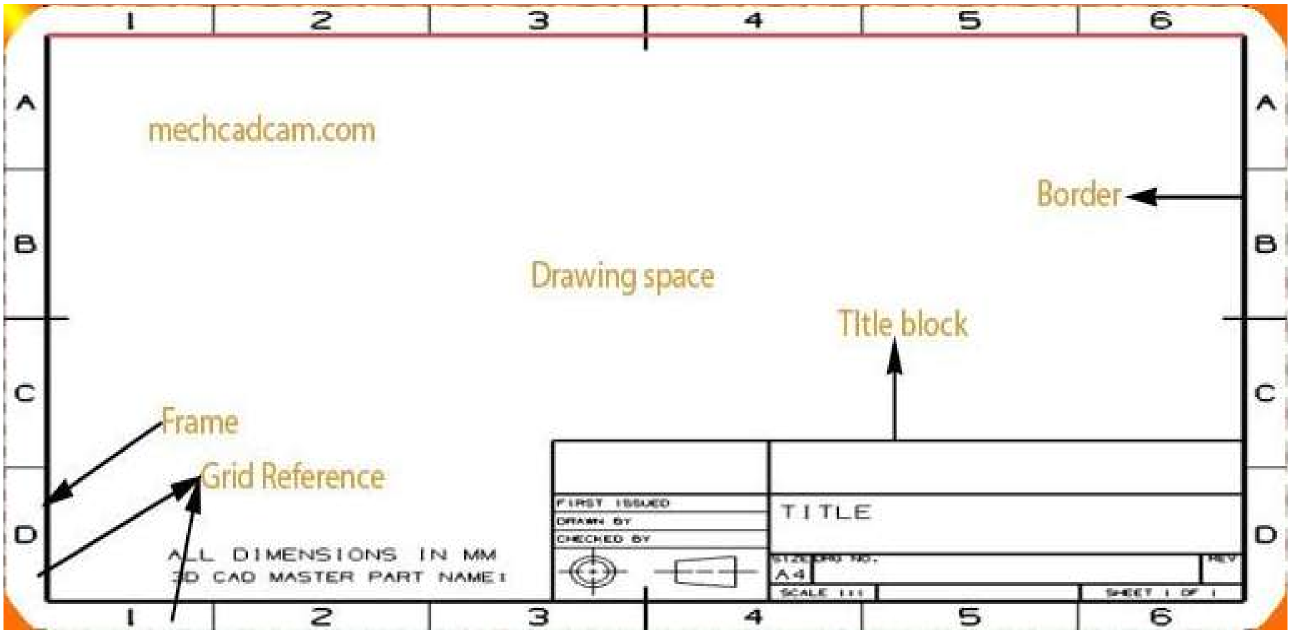
The British Standard BS8888 recommends that for normal practical purposes the area of the largest sheet is one square meter and the sides are in the ratio of 1:√2. The dimensions of the sheet are 841 mm × 1189 mm.</td>
<td>1. Keep free from wet areas
2. Package paper in enclosed covers to protect them from direct sunlight
3. Keep clean</td>
</tr>
<tr>
<td>5.</td>
<td>
Masking tape</td>
<td>The best tape to use to hold paper on the drawing board is masking tape but metal drawing board clips are easier to use.</td>
<td>Keep away from moist</td>
</tr>
</table>

Title block

The title block of a drawing, usually located on the bottom or lower right-hand corner, contains all the information necessary to identify the drawing and to verify its validity. A title block is divided into several areas as illustrated below.

The title block should lie within the drawing space such that, the location of it, containing the identification of the drawing, is at the bottom right hand corner. This must be followed, both for sheets positioned horizontally or vertically

The direction of viewing of the title block should correspond in general with that of the drawing. The title block can have a maximum length of 170 mm although this may vary from type of drawing to another



__**Types of electrical drawings**__

1. **Architectural drawings**

   These are drawings showing the building layout during its construction, the drawings consists of

   i. Floor plan
   ii. End and Front elevations
   iii. Structural

   The floor plans greatly assists the electrician to design the wiring systems. The legend and additional information in the plans will also aid the electrician in knowing other useful information like the floor finish, height and type of the ceiling e.t.c

2. **Layout diagram**

   This is a diagram of a system showing the actual placement components including dimensions from one component to the other.

3. **Circuit diagram**

   This is a simplified conventional graphical representation of an electrical circuit. In a circuit diagram, the arrangement of the components interconnections on the diagram does not correspond to their physical locations in the finished device

4. **Line diagram**

This is a one-line diagram or single-line diagram is a simplified notation for representing an electrical system. The one-line diagram is similar to a block diagram except that electrical elements such as switches, circuit breakers, transformers, and capacitors are shown by standardized schematic symbols.

5. **Pictorial diagram**

   This is a diagram that represents the elements of a system using abstract, graphic drawings or realistic pictures.

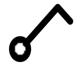
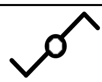
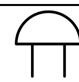
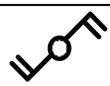
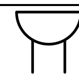
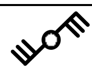
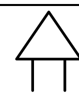
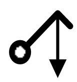
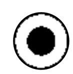
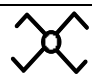
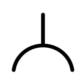
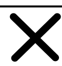
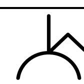
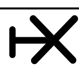
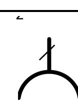
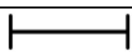
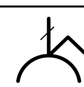
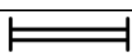
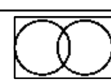
6. **Schematic diagram**

   This is a diagram that uses lines to represent the wires and symbols to represent components. It is used to show how the circuit functions.

7. **Wiring diagram (or pictorial)**

   This is a simplified conventional pictorial representation of an electrical circuit. It shows the components of the circuit as simplified shapes, and how to make the connections between the devices. A wiring diagram usually gives more information about the relative position and arrangement of devices and terminals on the devices.

Electrical Symbols

S/N	Symbol	Description	S/N	Symbol	Description
1.		One way, 1 gang switch	**13.**		Consumer control unit
2.		One way, 2 gang switch	**14.**		Distribution board
3.		One way, 3 gang switch	**15.**		Indicator board
4.		Two way, 1 gang switch	**16.**		Electric bell
5.		Two way, 2 gang switch	**17.**		Buzzer
6.		Two way, 3 gang switch	**18.**		Siren
7.		Cord operated switch	**19.**		Bell push
8.		Intermediate switch	**20.**		Unswitched single socket outlet
9.		Lighting switch	**21.**		Switched single socket outlet
10.		Wall mounted switch	**22.**		Unswitched Twin socket outlet
11.		Single Fluorescent fitting	**23.**		Switched Twin socket outlet
12.		Twin Fluorescent fitting	**24.**		Bell transformer

8. **Architectural Floor plan**

The electrician uses the plan to come up with the following drawings:

i. Lighting scheme and its switching arrangement
ii. Power points and circuiting including call and alarms circuits
iii. Conduit runs, trunking systems and number of cables
iv. Single line diagram showing the system protection devices and load balance

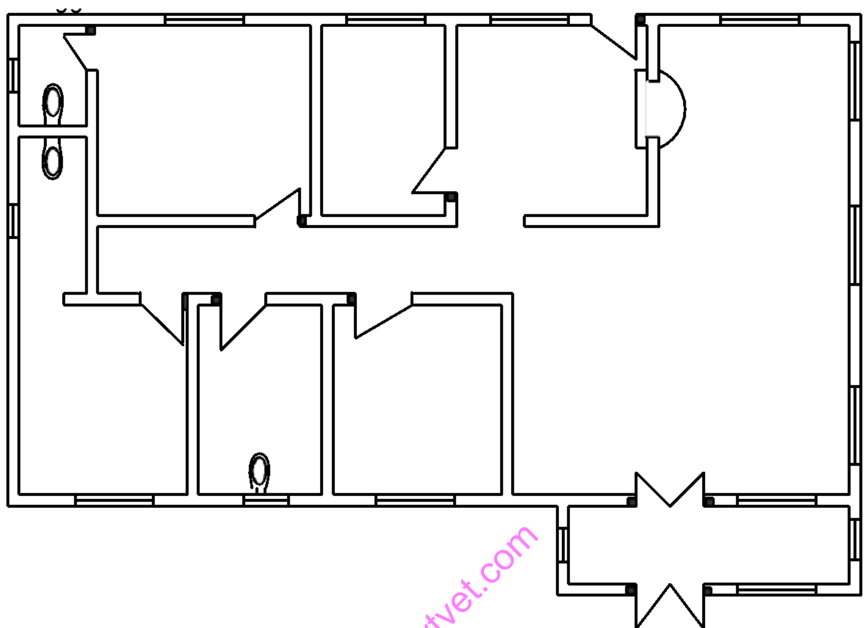


Figure 5 Floor plan of a residential building

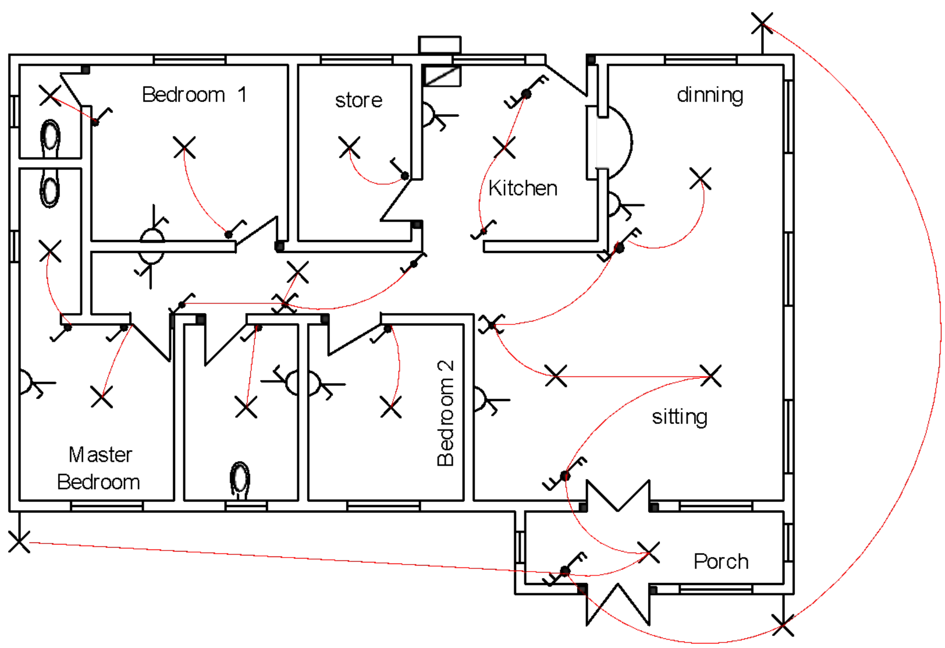


Figure 6 Lighting and power circuit of the plan

Layout diagram

This shows the exact position of components including measurements from one component to the other. The drawing uses BS 3939 symbols.

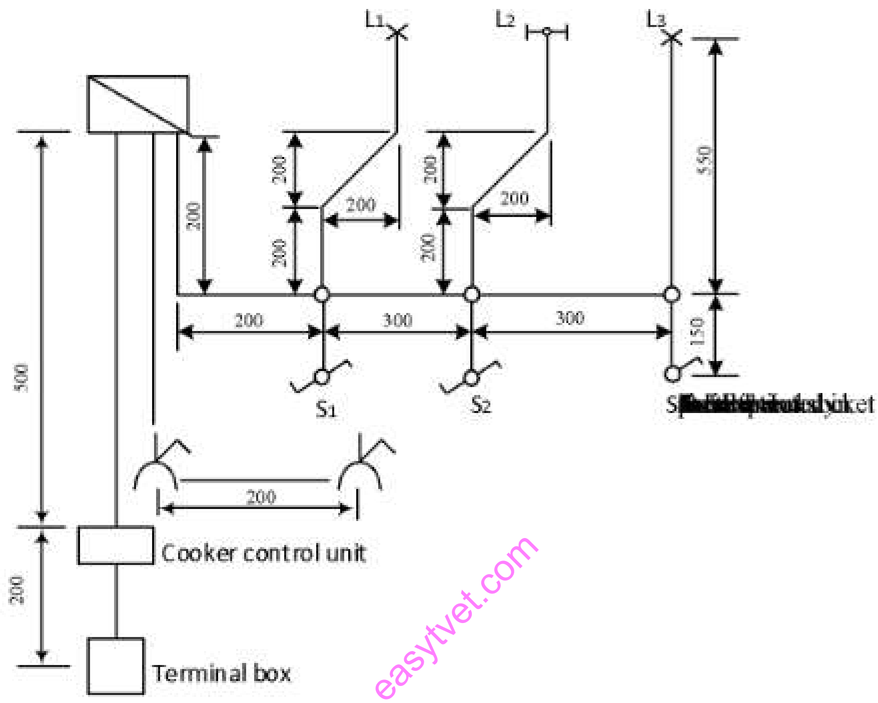


Figure 7. An electrical installation layout diagram.

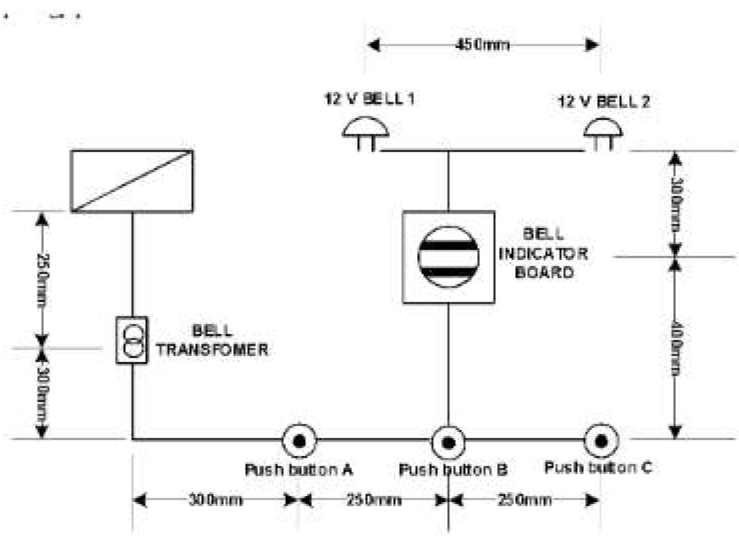


Figure 8 Call and alarm circuit layout diagram

Wiring diagram

This shows the exact cable runs for the electrical installation work to be carried out. It is an interpretation of the layout diagram. Figure 9 is a wiring diagram of layout diagram of figure 7.

Note the interpretation of the various symbols.

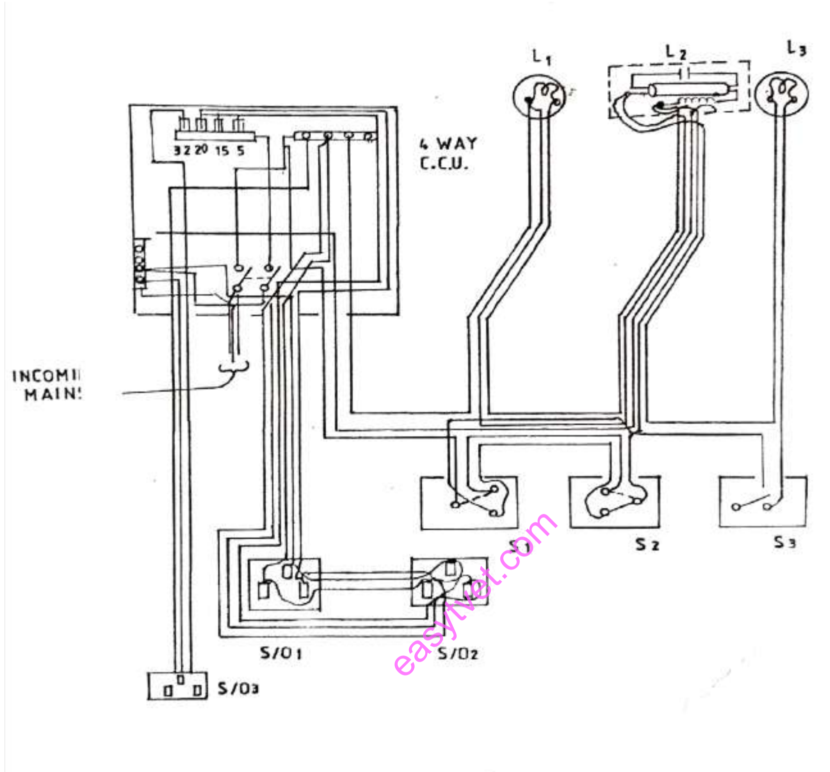


Figure 9 Wiring diagram of figure 7

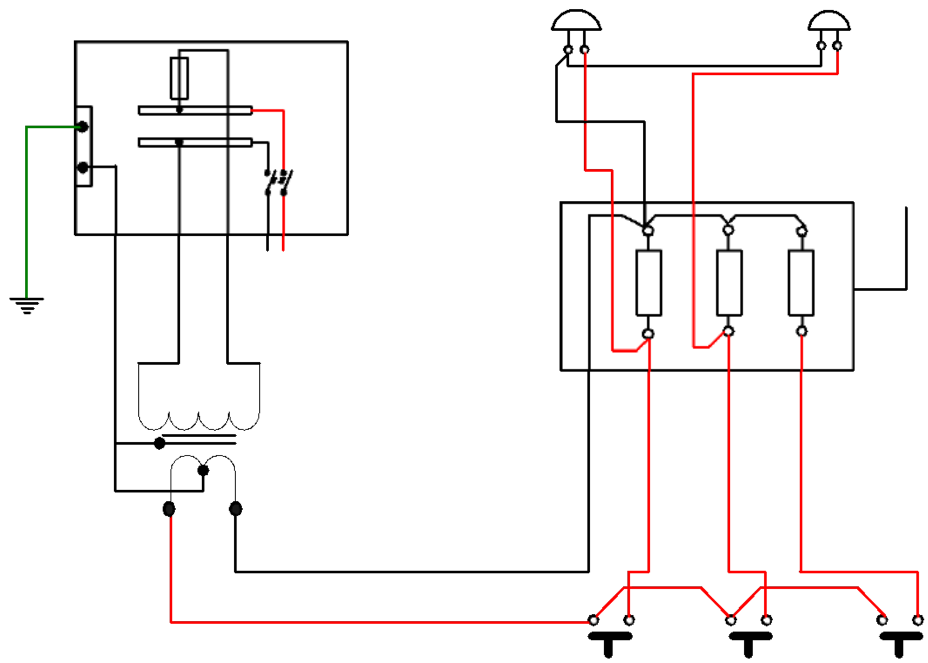


Figure 10 Wiring diagram for figure 8

5.2.2.4 Learning activities

Field/Visit to an electrical installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish correct preparation of working drawings	- Drawing instruments types - Types of electrical drawings	-Observe keenly types of instruments - Observe keenly types of drawings used. -take notes

Practical assignment

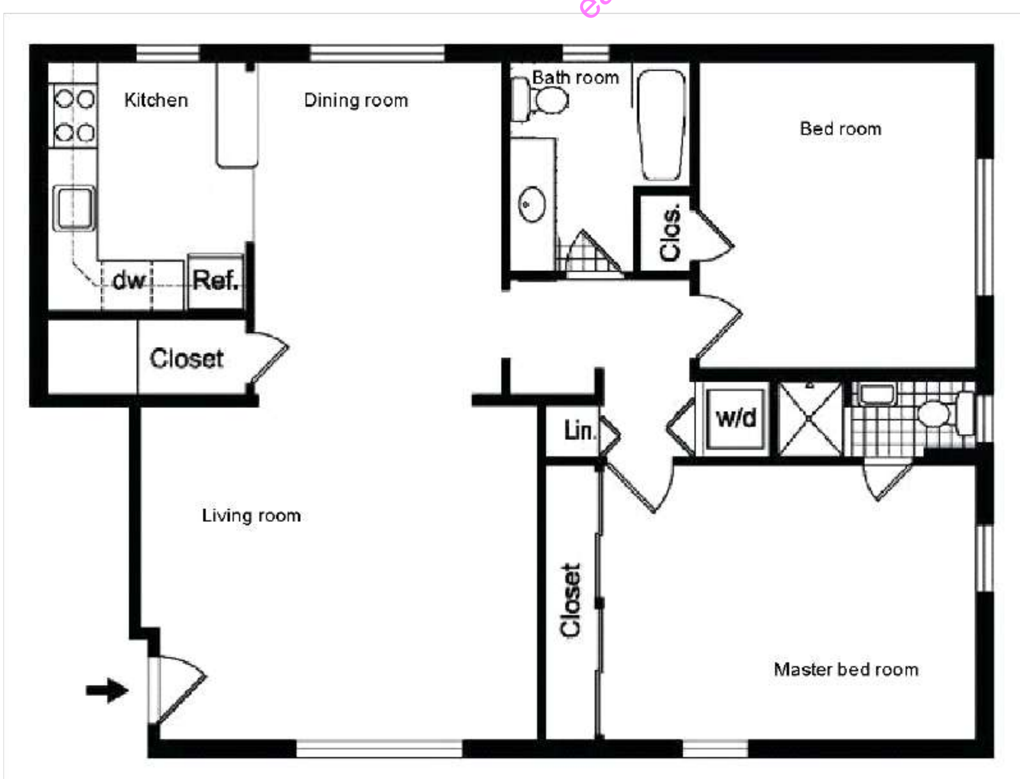
Visit Objective/Aim	Indicators	Special Instruction

To establish correct preparation of working drawings	- Drawing instruments types - Types of electrical drawings	To participate in working drawings preparation

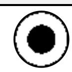
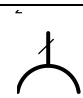
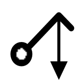
5.2.2.5 Self-Assessment

1. What is the difference between a layout and wiring diagram?
2. Name any two grading of drawing pencils
3. Sketch a combination pliers using free hand
4. Which of the following is not used in preparation of electrical working drawings?
   A. Pliers
   B. Pencil
   C. Ruler
   D. T-square

5. Given the floor plan of a residential building, design the lighting scheme and its switching arrangement.



5. Fill in the following table below

S/N	Symbol	Description
1.		
2.		Siren
3.		
4.		Two way, 2 gang switch
5.		Buzzer
6.		
7.		Intermediate switch
8.		
9.		Consumer control unit
10.		Twin Fluorescent fitting

5.2.2.6 Tools, Equipment, Supplies and Materials

The following resources are provided

i. An electrical installation company

ii. A functional Safety department.

iii. Computers

iv. Stationery
v. Lecture room
vi. Workshop
vii. Projector
viii. Drawing equipment
ix. Drawing room

5.2.2.7 References

Donnely. (1980). *Electrical Installation theory and practice.*

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https://www.osha.gov/sites/default/files/2019-03/electrical_safety_manual.pdf

https://safetyculture.com/topics/electrical-hazards/

5.2.3 Learning outcome 3: Prepare Tools, Equipment & Materials

5.2.3.1 Introduction

To prepare tools, equipment and materials successfully, one requires to have knowledge in electrical installation tools, equipment and materials, calibration of instruments, care and maintenance of instruments.

5.2.3.2 Performance Standard

5.2.3.3 Information Sheet

Electrical installation tools, equipment and their use

Hammers

These are tools used in driving or pounding out nails they are made of hard steel, wood, plastic or rubber.

Bending spring

This is a tool used for bending PVC conduits

Stock and die

This is a tool used for making threads on metallic conduits

Side cutter

This is a tool used for medium and big cables.

Combination Pliers

These are made of metal with insulated handles. They are used for cutting, twisting, bending, holding and gripping wires and cables

Screw driver

It slot has a cross/flat tip and is used to drive screws with cross/straight heads.

Long nose pliers

This is used for cutting and holding wires. It made to reach tight space and or small opening where other pliers cannot reach. It is also used in making terminal loops of copper wires.

Wire stripper

A tool used for removing insulation from insulated cables.

Hacksaw

This is a tool used to cut metal conduit and armoured cable

Measuring tools

To   measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape

Soldering equipment

In  doing electric wiring, splices and taps (connections made to wire) should be soldered, unless you use solderless connectors.

Drilling equipment

 Drilling equipment is needed to make holes in building structure passages of conduit sand wires

Ladders

The term ladder is generally taken to include step ladders and trestles. The use of ladders for working above ground level is only acceptable for access and work of short duration. It is advisable to inspect the ladder before climbing it. It should be straight and firm. All rungs and tie rods should be in position and there should be no cracks in the stiles. The ladder should not be painted since the paint may be hiding defects. Extension ladders should be erected in the closed position and extended one section at a time. Each section should overlap by at least the number of rungs indicated below:

1. Ladders of up to 4.8 m length – 2 rungs overlap
2. Ladders of up to 6.0 m length – 3 rungs overlap

3. Ladder over 6.0 m length – 4 rungs overlap

Draw wire/Fish tape

This is a tool used for drawing cables in conduits

Electrical instrument checking and calibration

A digital Multimeter is used to measure voltage, current and resistance and can be used to measure electrical continuity in a circuit. There are two types of Multimeter: digital and analogue. Multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

Calibration of Multimeter

Electrical calibration refers to the process of verifying the performance of, or adjusting, any instrument that measures or tests electrical parameters to maintain their accuracy. Electrical calibration involves the use of precise devices that evaluate the performance of key properties for other devices called units under test (UUTs).

Equipment that are not calibrated can result in the wrong decision being made which has the potential for further damage to what the instrument was to be used for.

The fragile electronics within Multimeter are protected by a hard casing, which means they can usually be stored in a toolbox. Multimeter do not require any deep cleaning - just wipe them down with a damp (not wet) cloth, every now and then. Ensure your devices are fully functioning before each use. Change batteries and fuses when necessary and consider removing the batteries if the meter will not be used for an extended period of time.Many people do a field comparison check of two meters, and call them "calibrated" if they give the same reading. This isn't calibration. It's simply a field check. It can show you if there's a problem, but it can't show you which meter is right. If both meters are out of calibration by the same amount and in the same direction, it won't show you anything. Calibration typically requires a standard that has at least 10 times the accuracy of the instrument under test. Calibration, in its purest sense, is the comparison of an instrument to a known standard.

Two instruments, A and B, measure 100 V within 1 %. At 480 V, both are within tolerance. At 100 V input, A reads 99.1 V and B reads 100.9 V. But if you use B as your standard, A will appear to be out of tolerance. However, if B is accurate to 0.1 %, then the most B will read at 100 V is 100.1 V. Now if you compare A to B, A is in tolerance. You can also see that A is at the low end of the tolerance range. Modifying A to bring that reading up will presumably keep A from giving a false reading as it experiences normal drift between calibrations.

Why Multimeter is calibrated

A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time, environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter.

A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

How to calibrate a digital multimeter

1. Set the multimeter to the highest resistance range by turning the dial to the highest "ohm" setting.
2. Touch the test probes of your digital multimeter together.
3. Press the calibration knob until the display reads "0" on the digital multimeter if you don't see "0 ohms" initially**.**

Calibration may be required for the following reasons:

a) a new instrument
b) after an instrument has been repaired or modified
c) when a specified time period has elapsed
d) when a specified usage (operating hours) has elapsed
e) before and/or after a critical measurement
f) after an event, for example:

i. after an instrument has been exposed to a shock, vibration, or physical damage, which might potentially have compromised the integrity of its calibration

ii. sudden changes in weather

g) whenever observations appear questionable or instrument indications do not match the output of surrogate instruments

h) As specified by a requirement, e.g., customer specification, instrument manufacturer recommendation.

How to take care of your tools

Good tools can be quite an investment but only if you take good care of them, they'll return the favour. Keeping your tools properly stored, cleaned, and maintained will save you time and money and make your DIY endeavours that much more rewarding.

In keeping the tools and equipment, you need to work with the space you have. Maybe you hang them on pegboards, maybe you store them in boxes, bags, or chests, or maybe you keep them in drawers or on shelves in your shop. Whatever works for you is best.

Toolboxes also make for great tool storage, offering the primary advantage of portability. While some people opt to store all their tools in toolboxes, for most, the toolbox is a way of carrying around your most-used tools while leaving the bulk safely stored on pegboards, shelves, or drawers.

Basic maintenance of electric tools

To ensure that your **electric tools** work properly, you must take proper care of them. A good regimen of maintenance for your tools is one thing that you can do to make sure that the tool you need is working when you need it.

a) **Clean out the dust:** To make sure that your electric tools are ready for use, keep them clean and free of dust. The housing intake on your electric tools and the exhaust are especially important areas to keep clean. Take some time to clean out the dust every once in a while on your tools while they are sitting in storage.

b) **Check the cords:** Look for wear and tear on the power cords on your electric tools. There can be damage to the insulation and you should keep an eye out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Wipe the cords down to keep them from becoming damaged from oil and grease. The prongs on the cords should be examined as well. Make sure that the casing is intact and the prongs are not loose.

c) **Oil some electric tools**: The electric tools in your toolbox that have a cutting surface should be lightly oiled to prevent rust. Examine the cutting surface for rust to make sure that your tools are kept in good condition.

d) **Storing your tools:** Keep your electric tools stored in their original cases and containers. This will keep them free of dust and dirt while they are not being used.

PROPER STORAGE OF TOOLS AND EQUIPMENT

The proper care and storage of tools and equipment are not only the concern of the management but of the workers who use the equipment.

Importance of proper storage of tools and equipment

1. It is an important factor for safety and health as well as good business.
2. Improves appearance of general-shop and construction areas.
3. Reduces overall tool cost through maintenance.
4. This also ensures that tools are in good repair at hand.
5. Teaches workers principles of (tool) accountability.

Pointers to follow in storing tools and equipment:

1. Have a designated place for each kind of tools.
2. Label the storage cabinet or place correctly for immediate finding.
3. Store them near the point of use.
4. Wash and dry properly before storing.
5. Store knives properly when not in use with sharp edge down.
6. Put frequently used items in conveniently accessible locations.
7. Gather and secure electrical cords to prevent entanglement or snagging.
8. Cutting boards should be stored vertically to avoid moisture collection.
9. Metal equipment can be stacked on one another after drying such as storage dishes and bowls.

10. Make sure the areas where you are storing the equipment are clean, dry and not overcrowded.

Tool Box for Storing Tools

For keeping tools safe, secure, and organized one can use portable and stationary toolboxes, rolling toolboxes, truck-mounted tool chests, and workbench/toolbox hybrids.

1. Rolling Toolboxes

Rolling toolboxes are larger for storing more tools, but they aren't portable outside of your work area. These are usually tall, upright storage containers with wheels on the bottom. They'll have large drawers for large tools, and smaller drawers on top for smaller tools.

2. Portable Toolboxes

Portable toolboxes are what most people think of when they think of tool storage. These boxes are rectangular, open with a metal clasp or lock, and have a handle for carrying from one job to another job. Most are made of heavy-duty plastic, metal, or canvas and have various compartments tucked inside for storing the most common tools. They're ideal for storing and transporting small, hand-held tools like pliers, hammers, pliers, and screwdrivers.

3. Truck-Mounted Toolboxes

For large tools which are needed to be taken to job sites or projects, a truck-mounted toolbox is the right storage. These are usually made of steel or some other type of indestructible metal, and are mounted and bolted to the bed of a truck. The lid will lock so the tools remain secure. This type of toolbox is best for storing and transporting large tools ladders

4. Stationary Toolboxes

Stationary toolboxes can hold a lot of tools, help keep them dry and secure, and organize your work area. These will usually have wheels, but they're only meant for initial placement of the tool chest.

5. Toolbox/Workbench Hybrids

This type features a rolling toolbox that has a big work surface attached. It comes in all kinds of widths and materials and makes a perfect portable workstation for lots of jobs.

5.2.3.3 Learning activities

Field/Visit to an electrical Installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish tools used in Electrical installation works	- Types of tools - Tools storage	-Take notes -Observe keenly types of tools -Observe keenly types of tools

Practical Assignment

Visit Objective/Aim	Indicators	Special Instruction
To experience usage and storage of Electrical tools	- Tools used - Proper use of tools	Participate in an exercise of tools, equipment and material preparation

5.2.3.4 Self-Assessment

1. Name any four tools used in electrical installation work
2. Describe calibration of Multimeter
3. Why is calibration of multimeter important?
4. As an Electrical Installation Technician, what test do you perform to find an open circuit?
   A. Resistance test
   B. Continuity test
   C. Voltage check
   D. Ohm test

5. One of the following is the most accurate instrument used for testing insulation resistance, which one is it?
   A. Growler
   B. Megohmmeter
   C. Ohmmeter
   D. Tachometer
6. List any four tools used in break down maintenance

5.2.3.5 Tools, Equipment, Supplies and Materials

5.2.3.6 References

Donnely. (1980). *Electrical Installation theory and practice.*

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https://safetyculture.com/topics/electrical-hazards/

5.2.4 Learning outcome 4: Perform Electrical Installation

5.2.4.1 Introduction

To apply and adhere to safety successfully, one requires the ability to understand causes of accidents and sources of danger, apply good housekeeping and apply first aid where necessary.

5.2.4.2 Performance Standard

5.2.4.3 Information Sheet

Meaning of terms

Circuit- an electric circuit is an arrangement of electrical conductors and associated devices for the purpose of carrying electricity.

Live conductor- It is that conductor which carry current towards the appliance from the source.

Live- means that under working condition a difference in voltage exists between the conductor and earth.

Neutral conductor- The conductor which carries current from the appliances to the source.

Earth- This is the conductive mass of the earth whose electric potential at any point is electrically taken to be zero.

Earth conductor- The conductor that has the same potential with the earth.

*Phase conductor-*A conductor of an AC system for the transmission of electrical energy other than a neutral.

Potential- The level of electric pressure.

Dead- At or about earth potential zero and disconnected from any live system.

Fuse- A device for opening a circuit by means of a fuse element designed to melt when excess current flows.

Insulation- suitable non-conducting material enclosing or surrounding or supporting a conductor.

Switch- A mechanical device for making and breaking non-automatically a circuit carrying current.

*Consumer intake point***-**This is the point where the electricity power supplier terminates the service line to the consumer's premises. It is commonly known as a meter box or power house.

Conductor

A conductor is a material which offers a low resistance to a flow of electric current.

Conductors for everyday use must

a) Have low electrical resistance
b) Be mechanically strong and flexible
c) Be relatively cheap.

Silver is a better conductor than copper but it is too expensive for practical purposes. Other examples of conductors are aluminium, brass, and iron.

Types of Conductors

The most common electrical conductors used are copper and aluminium. Copper conductors are formed from a block of copper which is cold-drawn through a set of dies until the desired cross-sectional area is obtained. Aluminium wire is also drawn from a solid block

Characteristics of Aluminium and Copper as Conductors

Aluminium	**Copper**
Smaller weight for similar resistance and current-carrying capacity	Can easily be drawn into wires
Easier to machine	Has better electrical and thermal conductivity
Greater current density because of larger surface	Has greater mechanical strength
High resistivity (2.845μΩ-cm)	Is corrosion resistant
Light in weight	Has high scrap value
	Easy to joint
	Lower resistivity (1.78 μΩ-cm)

The determining factor in the use of one type of metal for conductors is usually that of cost. Aluminium cables are used where weight is a factor like for overhead transmission.

Stranding of Conductors.

Stranding of conductors is done to make the completed cable more flexible. A set number of strands are used in cables: 1, 3, 7, 19, 37, 61, 91, and 127. Each layer of strands is spiraled on to the cable in opposite direction to the previous layer. This system increases the flexibility of the completed cable and also minimizes the danger of **'bird caging'**, or the opening-up of the strands under a bending or twisting force.

Size of Stranded Conductors

The size of a stranded conductor is determined by the number of strands and the diameter of the individual strands. For example, a 7/0.85 mm cable consists of seven strands of wire, each strand having a diameter of 0.85 mm.

The cross-sectional area will be $= 7\times\frac{\pi D^2}{4} = 3.142\times7\times\frac{0.85^2}{4} = 4.0 \text{ mm}^2$

Figure 11 Stranded conductor

Cable

A cable is defined in the I.E.E. Regulations as: "A length of insulated single conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall covering for mechanical protection." A cable consists of two basic parts:

(a) The conductor (b) The insulator.

Construction of Cables

A cable derives its name from the type of insulation used.

Polyvinyl Chloride (P.V.C.) Cable.

This is also known as 'thermo-plastic' cable since the insulation is made from a synthetic resin which softens when heated. The process of manufacture is as follows:

Multi-core Cable.

This is cable which is made up of two or more insulated conductors. Multi-core cable is sheathed in a protective covering— for example, tough rubber for tough rubber-sheathed cables (t.r.s.) and p.v.c. for plastic cables.

Tough-Rubber-Sheathed (t.r.s.) Cable.

This is made of specially toughened rubber which is resistant to acids and alkalies.

Polychloroprene (p.c.p. or neoprene) Cable.

Uses an insulation somewhat similar to that of t.r.s. but capable of withstanding most weather conditions and particularly direct sunlight.

Heat-resisting, Oil-resisting and Flame-retardant (h.o.f.r.) Cables.

These cables are used in conditions damaging to P.V.C. cables such as high temperature and oil. The resistant qualities are developed by a vulcansing (or curing) process which forms an elastomer capable of withstanding tough conditions and still retaining its flexibility.

COMPARISON OF T.R.S. AND P.V.C. CABLE

t.r.s. Cable	*p.v.c. Cable*
Affected by oil and water	Largely unaffected by oil, water, and corrosive chemicals
More flexible	Hardens at low temperatures and softens at high
	temperatures
Must be protected against direct sunlight	Does not support combustion

The maximum operating temperature for both rubber PVC insulated cables is 45°C.

Flexible cable

The I.E.E. Regulations define a flexible cable as: "A cable consisting of one or more cores, each containing a group of wires, the diameters of the wires and the construction of the cable being such as to afford flexibility."

Flexible cord

A flexible cord is defined as: "A flexible cable in which the cross-sectional area of each conductor does not exceed 4 mm^2".

Twisted Twin Flex Cable

This is made up of a multi-strand tinned-copper conductor with silicon rubber insulation. *Application:* lighting flex.

Figure 12 Twisted twin flex.

Circular Flex. The rubber-insulated cores are formed into a circular section with cotton worming and contained in a cotton braiding.

Applications: connections to household appliances (iron boxes, kettles, etc.)

Circular Flex, Rubber Sheathed

This flex is also packed with jute or cotton to form a circular cross-section but an outer sheath of rubber replaces the cotton braiding.

Applications: vacuum cleaner and portable drill leads (3-core).

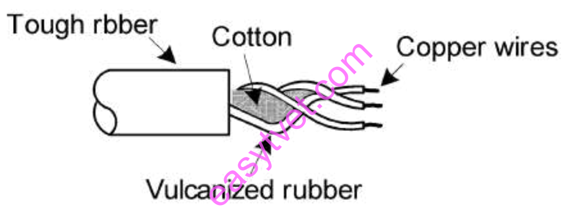


Figure 13 Circular flex, rubber sheathed.

Workshop (or Industrial) Flex

This flex is similar in construction to the above, but has the addition of a compounded braiding. *Application:* connections to industrial lighting.

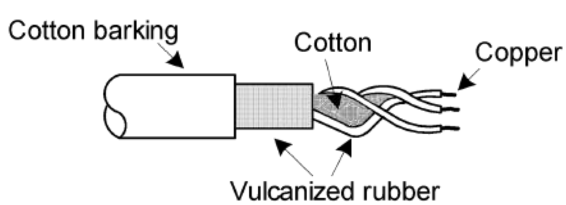


Figure 14 Workshop (or industrial) flex.

Permissible Voltage Drop in Cable.

Voltage drop is an essential feature in the calculation of cable size. Low voltage at the consumer's equipment leads to the inefficient operation of lighting, power equipment, and heating appliances.

The maximum voltage drop allowed between the consumer's terminals and any point in the installation is 2-5 per cent of the voltage supplied by the Electricity Supply Authority, including motor circuits.

Voltage Drop and the I.E.E. **Tables.**

The I.E.E. tables state the voltage drop across a section of cable when maximum current is flowing through it. If the current is halved, the voltage drop will also be halved. For example a 4 mm^2 twin-core cable has a current rating of 24A and a-voltage drop 10 mV per ampere per meter. If the current is halved (to 12 A) the voltage drop will be halved to 5 mV per ampere per meter.

Cable Sizes: Use of I.E.E. Tables

The **I**.E.E. Regulations contain comprehensive information regarding the current-carrying capacity of cables under certain conditions.

These tables supply:

(a) Cross-sectional area, number, and diameter of conductors;

(b) Type of insulation;

(c) Length of run for 1V drop;

(d) Current rating (a.c. and d.c.), for either single or bunched.

The following terms are used in the I.E.E. tables:

(a) Ambient temperature

(b) Rating factor.

Ambient Temperature. This is the temperature of the air surrounding the conductor. The current rating of a cable is decreased as the temperature of the surrounding air increases, and this changed current-carrying capacity can be calculated by using the relevant rating factor.

Rating Factor.

This is a number, without units, which is multiplied with the current to find the new current-carrying capacity as the operating conditions of the cable change. For example, a twin-core 10 mm^2 (7/1.35 mm) PVC cable will carry a maximum current of 40 A at an ambient temperature of 25 °C, but if the ambient temperature is increased to 65 °C the maximum current allowed will now be:

$$40A \times 0.44 \text{ (rating factor)} = 17.6A$$

The rating factor is also dependent on the type of excess current protection. If cables are bunched together, their current-carrying capacity will decrease; a rating factor is therefore supplied for the bunching, or grouping, of cables.

Current Density and Cable Size.

The current density of a conductor is the amount of current which the conductor can safely carry without undue heating per unit cross-sectional area. For example, if a copper conductor has a current density of 300 A/cm^2 a copper conductor of cross-sectional 0.5 cm^2 will be capable of carrying one half of 300 A, that is, 150 A.

To calculate the current-carrying capacity of a cable (given cross-sectional area (cm^2) and current density (A/cm^2):

Current-carrying capacity = current density x cross-sectional area

Example.

Calculate the current-carrying capacity of a 0.1 cm^2 conductor if the current density of the conductor is 400 A/cm^2.

$$\text{Current-carrying capacity} = 400A/cm^2 \times 0.1cm^2 = 40\ A$$

Terminating and Jointing P.V.C. Cables

Stripping P.V.C. Cables.

A single-core PVC. cable should be stripped by holding the cutting knife at an angle to the cable and cutting away from the hand holding the cable. Multi-core cable is stripped by running the cutting knife along the center of the cable and then nicking the end of the cable to give two finger grips. This allows the sheathing to be pulled down the cable with the thumb and forefinger of each hand. The sheath is then folded on top of the cable and cut by drawing the knife between the sheathing and the cable.

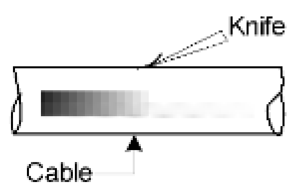


Figure 15 Stripping cable.

There are two basic methods of joining electrical conductors: (a) mechanical joints; and (b) soldered joints.

Mechanical Jointing.

This is done by using connector blocks. These consist of one-way or multi-way brass terminal blocks enshrouded with porcelain or plastic insulation. The connector must be capable of containing all the strands of the conductor.

Another method, usually used with larger cables, is **mechanical crimping**. This is done by placing a sleeve over the conductors to be jointed and crimping (squeezing) the connection with a manual or hydraulically operated crimping jack.

Soldered Joints.

Materials required: pliers, sharp knife, soldering bit, flux, blowlamp (or butane gas cylinder), solder, PVC. tape and black insulating tape.

Soldering Bit. Every joint which is made by twisting strands together must be soldered. Where a lot of single-core jointing is being carried out, it is often convenient to use a heavy bit which has a slot filed in it to take cables. The soldering bit should be heated until a green flame appears and must always be kept clean. Always' tin' the bit with flux and solder before using. *Flux.* The purpose of the flux is to remove the oxide film from the surface of the conductor and prevent it from re-forming.

Blowlamp. This should be operated as follows:

1. The lamp should not be more than two-thirds full.
2. Leave the valve open when starting.
3. Start lamp with small rag dipped in methylated spirits.
4. When the lamp is hot, the valve should be closed and the pump operated.
5. The pump forces the paraffin through the heated vaporizing tube and out of the nozzle where it is ignited under pressure.
6. The blowlamp should be played against an asbestos sheet until the flame is fully established.

Solder. Two basic types of solder are used in electrical work: fine solder (tinman's solder), which is **60** parts tin and **40** parts lead, and plumber's metal, which is **30** parts tin and **70** parts lead. Fine solder melts more easily, as tin has a lower melting point than lead, and so it is commonly used for electrical joints. Plumber's metal is used for 'plumbing' joints in armoured cables, as it remains in a plastic state, allowing it to be shaped, longer than fine solder.

Methods of Soldering.

There are three methods used for soldering conductors:

(a) Soldering bit,

(b) 'Stick' method

(c) (Metal) pot and ladle method.

Soldering Bit. The conductors to be jointed are first smeared with a resinous flux. The tinned bit is then applied under the joint until the heat penetrates it. The stick of solder is then applied to the joint until the solder flows freely through it.

'Stick' Method. In this method, the joint is first heated with a blowlamp, flux being applied. The solder is then applied by pressing the stick of solder against the heated joint until it penetrates the joint. Care should be taken to protect the insulation against the blowlamp flame.

Pot and Ladle Method. This method is commonly used by jointers when jointing heavy conductors. A solder pot is heated until the solder is running freely. The solder should not be overheated as this will burn the tin and a dross will form on the surface of the solder. When the solder has reached working temperature it is taken from the pot with a ladle. The solder is then poured over the prepared joint and is caught by another ladle placed under the joint. This action is repeated until the solder penetrates the joint.

Soldering Aluminium.

The following special points should be noted when soldering aluminium:

i. All surfaces must be scrupulously clean.
ii. When making a joint between stranded conductors ' step' the strands to increase the surface area.
iii. The surface must be heated *before* the flux is applied as the flux will only take when the temperature is high enough.
iv. Apply aluminum solder until the complete surface is bright.
v. Joints in aluminum should be protected from contact with the atmosphere. This can be done by painting, taping, or compounding.

Soldering a Socket (or Lug). The method used is as follows

1. Strip insulation back about 5 cm.
2. Tin the socket.
3. Smear both the socket and the bared conductor with flux.
4. Fit the socket to the conductor. The socket should be a hammer fit.

*If the socket is too large, the conductor can be enlarged with a tinned- wire binding or. Better still, by pressing a strand of cable into the centers of the conductor***.**

5 Play the blowlamp in the top of the socket until the heat has penetrated the conductor, and then apply a stick of solder to the lip of the socket. The completed connection should have a rim of solder showing round the lip the socket; this can be done by applying plumber's metal as the joint is cooling

6 When the termination is cooled, cut back damaged insulation and apply pvc or cambric tape

7 Tape is used to replace insulation which has been removed prior to jointing

Do not attempt to cool a soldered joint by pouring water over it. This can lead to an effect joint known as a dry joint. Never smooth the joint with a file but use a dry cloth before it sets.

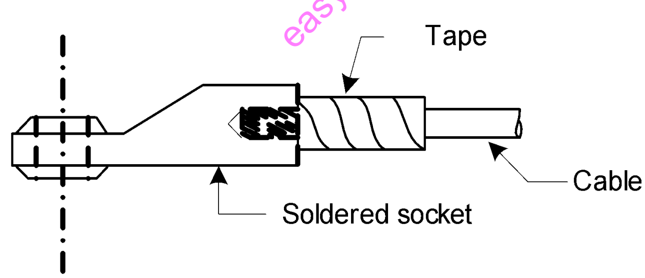


Figure 16 Section through soldered socket

Through joint

This joint is made by using mechanical connectors, compressor ferrules or grip-type (weak back) soldered sleeves.

The completed joint is wrapped with PVC tap. The joint can further be protected by the use of a cold pouring of resin compound to fill the protection box.

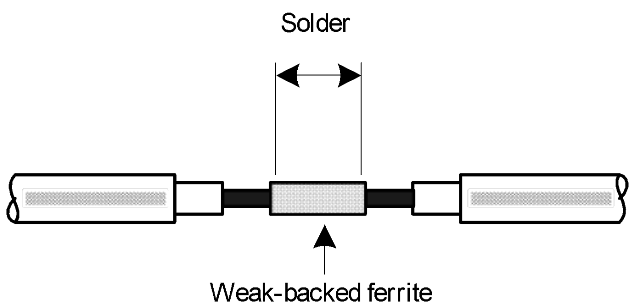


Figure 17 Straight-through joint using weak-backed ferrule

Straight-through joint using weak-backed ferrule

A weak-backed ferrule is a tubular piece of tinned-copper opened along the top and weakened at the bottom thus allowing it to be closed or opened easily.

Procedure of making the joint

1. Strip insulation back from both conductors.
2. Clean and tin ferrule
3. Place ferrule on cable. Butt cables together before tightening the ferrule
4. Wind small pieces of cloth at each end of the ferrule to contain the molten metal
5. Solder the connection
6. Remove damaged insulation and apply tape.

Tee (breeches) Joint

This joint is used to tee-off a service from an armoured cable. The weak-backed ferrule is often used. Mechanical connectors or compression ferrule can also be used

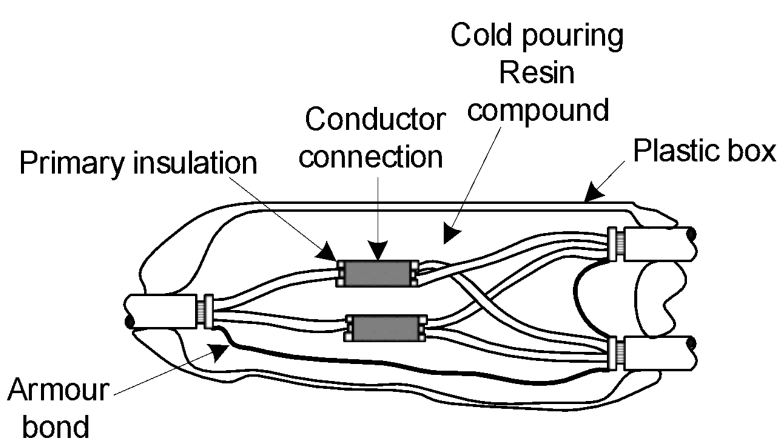


Figure 18 Tee (breeches) joint

Armoured cable

This cable is used where there is a likelihood of the insulation or conductor being subjected to mechanical damage. This can occur when the cable is run underground.

There are two main types of armoured cables:

a) Paper insulated lead covered steel wire or steel tape armoured cables, abbreviated as P.I.L.C.S.W.A. and P.I.L.C.S.T.A cables respectively
b) P.V.C.armoured cable

P.I.L.C.S.W.A.

The cable has the following parts

(a) An inner core of jute used to keep the cable circular.
(b) Copper or aluminium conductors insulated with mineral oil-impregnated paper.
(c) A lead sheath which contains the insulation and is also used as an earth continuity conductor
(d) Jute bedding tape impregnated with bitumen that protects the lead from armoring
(e) Galvanized steel wire (one layer) or steel tape (two layers).
(f) Bitumen impregnated jute serving

Termination of P.I.L.C.S.W.A. cable

1. Place binder 1m from end of cable
2. Remove serving to this point
3. Bend steel wire armoring back until it is clear to lead sheath
4. Remove about 13cm of lead sheath and clean the remainder
5. Place brass gland on cable, leaving approximately 10cm of lead sheath showing. Wedge gland with wood to keep it central on cable
6. Use plumber's metal to plumb the joint
7. Clean galvanized wire paraffin rag and shape the wire over the plumb
8. Clamp wires on the gland and bolt the gland on sealing chamber
9. Cut back paper insulation on conductors and make through-joint to V.R.I conductors, using weak-back ferrule
10. Assemble sealing chamber and pour in hot bitumen to seal oil-impregnated paper against moisture

P.V.C. Armoured Cable

This is made up of p.v.c insulated cores packed with p.v.c. to give a circular cross section. An outer p.v.c. sheath covers the galvanized steel wire.

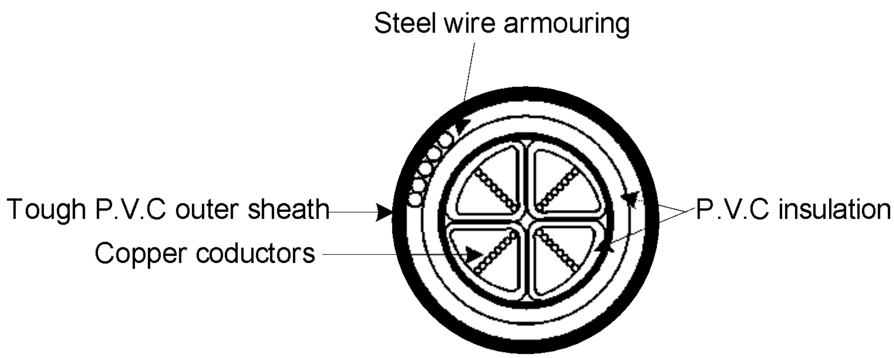


Figure 19 P.V.C Armoured cable

Termination of P.V.C. armoured cable

The following must be taken into consideration when terminating

(a) P.V.C. must be protected from heat

(b) P.V.C. tapes must be used for insulating the conductors

(c) Care must be taken when clamping and cleaning the galvanized wire so that it is not broken as it is the sole earth continuity conductor

(d) The temperature of the hot pouring compound should not melt the p.v.c. insulation of conductors. Dip a piece of scrap p.v.c. into the compound before pouring to test the temperature.

Mineral Insulated Metal Sheathed (M.I.M.S.) Cable

This cable consists of three parts. These are:

Copper or aluminium conductors

Each core consists of a single copper conductor. Common core numbers are 1,2,3,4 and 7

Insulation

The insulation between the cores is magnesium oxide. It can withstand high temperatures but is absorbent to moisture

Outer sheath

Is a seamless copper or aluminium tube

ADVANTAGES AND DISADVANTAGES OF M.I.M.S. CABLE

Advantages	Disadvantages
Heat resistant. Can withstand temperatures up to 250^0C	Expensive
The sheath provides an excellent earth continuity conductor	Termination takes time
Is mechanically strong must be protected against shape edges	Has greater voltage drop per metre at the same current rating
High current density	
Does not deteriorate with age	

WIRING SYSTEM

As defined in level one, a wiring system is a system of cables, accessories and protective devices that make a complete electrical system is premises (domestic, commercial or industrial).

Conduit installations

A conduit is a tube, channel or pipe in which insulated conductors are contained. The conduit, in effect, replaces the PVC outer sheath of a cable, providing mechanical protection for the insulated conductors. A conduit installation can be rewired easily or altered at any time, and this flexibility, coupled with mechanical protection, makes conduit installations popular for commercial and industrial applications. There are three types of conduit used in electrical installation work: steel, PVC and flexible.

Steel Conduit Wiring System

Steel conduits are made to a specification defined by BS 4568 and are either heavy gauge welded or solid drawn. Heavy gauge is made from a sheet of steel welded along the seam to form a tube and is used for most electrical installation work. Solid drawn conduit is a seamless tube which is much more expensive and only used for special gas-tight, explosion-proof or flameproof installations. Conduit is supplied in 3.75 m lengths. Steel conduit system offers the highest mechanical protection of all the wiring systems. They are available in the diameters of 16mm, 20mm, 25mm, and 32mm. The most commonly used is 20mm. Steel conduits come in varieties. These include; welded, solid drawn, black enamel and galvanized. Welded conduit has a welded seam along its entire length. This seam is almost invisible as the whole conduit is usually painted. It is the cheapest type of steel conduit. Solid drawn conduit is seamless and is used in situations where the installation is required to be gas tight and flame proof, for instance at petrol stations. Black enamel is a paint that is applied in most conduits. Galvanised steel conduits are used where dampness or steam is present. Conduit boxes make a major part of the system. They are made of steel with knock-outs for conduit entry. The boxes accommodate switches, socket outlets and other accessories. Metal conduits are threaded with stocks and dies and bent using special bending machines. The metal conduit is also utilized as the CPC and, therefore, all connections must be screwed up tightly and all burrs removed so that cables will not be damaged as they are drawn into the conduit. Metal conduits containing a.c. circuits must contain phase and neutral conductors in the same conduit to prevent eddy currents fl owing, which would result in the metal conduit becoming hot (Regulations 521.5.2, 522.8.1 and 522.8.11).

Tools

Apart from the electrician's ordinary tools such as rule, hacksaw, hammer, screwdrivers and pliers, it is necessary to have stocks and dies, file or reamer, bending machine and a pipe vice. For 16mm and 20mm conduit, the small stocks are available, but for 25mm and 32mm the medium stocks should be used. Stocks and dies for threading conduits should be clean, sharp and well lubricated, and should be rotated with a firm and steady movement. To get the best results stocks and dies should be of the self-clearing pattern to prevent soft swarf from clogging the chasers. Worn out dies and guides should always be replaced when showing signs of wear, otherwise the workmanship will suffer as a result of bad threads. Ratchet operated stocks and dies are available which are useful for the larger thread sizes and there are also powered conduit threading machines which offer certain advantages on a conduit installation where considerable amount of large conduit is being installed.

Conduit Bending

Regulations require that the minimum radius of a bend should be 2.5 times the outside diameter of the conduit. A pipe bender machine or a wooden block is used for bending. Before installation, all ends of conduits threaded conduits have to be fully installed before cables are drawn into them. Running couplers are used to join two conduits together

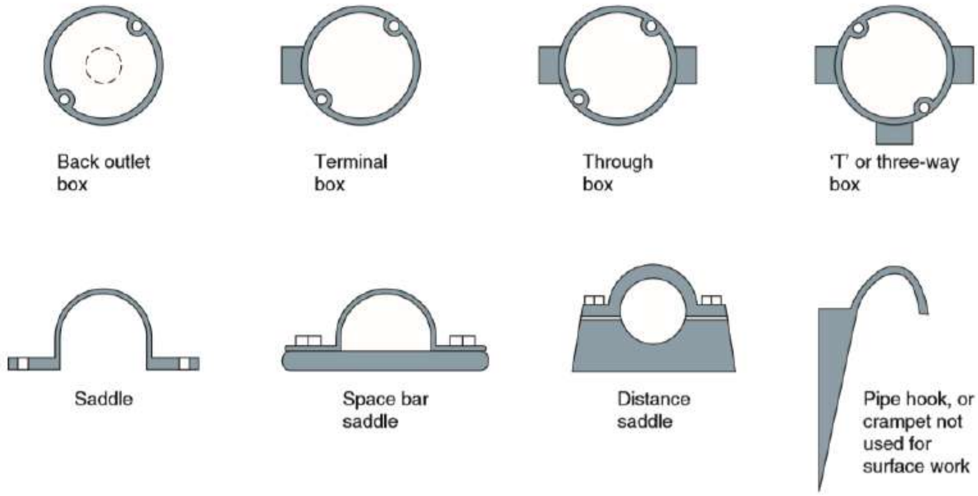
Conduit cutting

Conduit should be cut with a hacksaw. The ends of all conduits must be carefully reamed inside the bore with a file, or reamer to be certain that no sharp edges are left which might cause damage to the conductors when they are being drawn in. The reaming should be carried out after the threading has been completed.

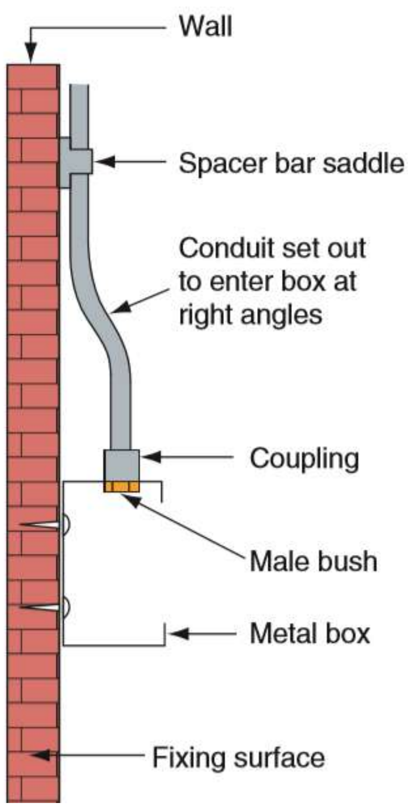
Checking Conduits for obstructions

When the length of conduit has been removed from the pipe vice, it is advisable to look through the bore to ensure that there are no obstructions. Some foreign objects such as stones may have entered the conduit during storage. If such obstructions are not detected before installation of the conduit considerable difficulty may be experienced when the conductors are being drawn in.

Fixing Conduits on Masonry or Wooden Surfaces



The method employed for fixing a conduit depends upon what the conduit has to be fixed on to. Some of the methods include



1) Distance Saddles

Distance saddles are most commonly used and are fixed by means of screwing into the wall or other surfaces. They are designed to space conduits approximately 10mm from the wall or ceiling. Distance saddles are generally made of malleable cast iron.

2) Spacer Bar Saddles

These are ordinary saddles mounted on a spacing plate. The spacing plate is approximately of the same thickness as the switches, sockets and other conduit fittings and therefore, serves to keep the conduit straight where it leaves these fittings. The purpose of the spacer bar saddle is to prevent the conduit from making contact with the plaster and cement walls and ceilings which could result in corrosion of the conduit.

3) Ordinary Saddles

These saddles are not extensively used. Fixing is by means of two screws. They provide a secure fixing and should be spaced not more than 1.3m apart.

4) Multiple Saddles

These are used where two or more conduits follow the same route. The proper method is for the conduits to be spaced so that when they enter conduit fittings there is no need to set the conduit. An alternative means of running two or more conduits together is to stagger the saddle positions, allowing the conduits to be placed closer together.

PVC Conduit

PVC conduit used on typical electrical installations is heavy gauge standard impact tube manufactured to BS 4607. The conduit size and range of fittings are the same as those available for metal conduit. PVC conduit is most often joined by placing the end of the conduit into the appropriate fitting and fixing with a PVC solvent adhesive. PVC conduit can be bent by hand using a bending spring of the same diameter as the inside of the conduit. The spring is pushed into the conduit to the point of the intended bend and the conduit then bent over the knee. The spring ensures that the conduit keeps its circular shape. In cold weather, a little warmth applied to the point of the intended bend often helps to achieve a more successful bend.

The advantages of a PVC conduit system are that it may be installed much more quickly than steel conduit and is non-corrosive, but it does not have the mechanical strength of steel conduit. Since PVC conduit is an insulator it cannot be used as the CPC and a separate earth conductor must be run to every outlet. It is not suitable for installations subjected to temperatures below 25°C or above 60°C. Where luminaires are suspended from PVC conduit boxes, precautions must be taken to ensure that the lamp does not raise the box temperature or that the mass of the luminaire supported by each box does not exceed the maximum recommended by the manufacturer (IEE Regulations 522.1 and 522.2). PVC conduit also expands much more than metal conduit and so long runs require an expansion coupling to allow for conduit movement and help to prevent distortion during temperature changes. All conduit installations must be erected first before any wiring is installed (IEE Regulation 522.8.2). The radius of all bends in conduit must not cause the cables to suffer damage, and therefore the minimum radius of bends given in Table 4E of the On

Site Guide applies (IEE Regulation 522.8.3). All conduits should terminate in a box or fitting and meet the boxes or fittings at right angles. Any unused conduit-box entries should be blanked off and all boxes covered with a box lid, fitting or accessory to provide complete enclosure of the conduit system. Conduit runs should be separate from other services, unless intentionally bonded, to prevent arcing occurring from a faulty circuit within the conduit, which might cause the pipe of another service to become punctured. Cables should be fed into the conduit in a manner which prevents any cable crossing over and becoming twisted inside the conduit. The cable insulation must not be damaged on the metal edges of the draw-in box. Cables can be pulled in on a draw wire if the run is a long one. The draw wire itself may be drawn in on a fish tape, which is a thin spring steel or plastic tape. A limit must be placed on the number of bends between boxes in a conduit run and the number of cables which may be drawn into a conduit to prevent the cables being strained during wiring.

Flexible Conduit

Flexible conduit manufactured to BS 731-1: 1993 is made of interlinked metal spirals often covered with a PVC sleeving. The tubing must not be relied upon to provide a continuous earth path and, consequently, a separate CPC must be run either inside or outside the flexible tube (Regulation 543.2.1). Flexible conduit is used for the final connection to motors so that the vibrations of the motor are not transmitted throughout the electrical installation and to allow for modifications to be made to the final motor position and drive belt adjustments.

Conduit runs to outlets in walls

Sockets near skirting level should preferably be fed from the floor above rather than the floor below.

When the conduit is run to a switch and other positions in walls it is usually run in a chase in the wall. These chases must be deep enough to allow at least 10mm of cement and plaster covering. Steel conduits buried in plaster should be given a coat of protective paint, or should be galvanised if the extra cost is justified. Make sure that the plaster is finished neatly round the outside edges of flush switch and socket boxes; otherwise the cover plates may not conceal any deficiencies in the plaster finish. When installing flush boxes before plastering, it is advisable to stuff the boxes with paper to prevent their being filled with plaster.

Space factor

Regulations require that for groups of mixed diameter cables, a space factor of 40% should not be exceeded. This means that only 40% of the conduit diameter should be used.

Other relevant regulations

1. There should not be more than two, 90^0 bends in one conduit run.
2. All conductors of alternating current circuit should be contained in the same conduit. This is to prevent out of balance magnetic fields from setting up eddy currents.
3. The steel conduit can be used as an earth continuity conductor. Therefore no separate earth conductor is required.

Installation of steel wire armoured cable

These cables are used extensively for main cables and distribution circuits and also for circuit wiring in industrial installations. The cables consist of multi-core pvc sheath and steel wire armouring (SWA) and pvc sheathed overall.

Important Consideration

- Thermo-plastic insulation will sustain serious damage if subjected to temperatures over 70^0 C for a prolonged period, therefore proper protection against sustained overloads is required.
- The insulation will harden, and become brittle in temperatures, below 1^0 C, therefore the cables should not be installed or handled when temperatures are approaching freezing, otherwise the insulation may tend to split

Termination of Armoured Cable.

An armoured cable also known as steel wire armoured (SWA) cable is designed to carry power for underground systems. The steel wires are used to provide mechanical protection and serve as earth conductors.

The cable gland used for terminating an armoured cable is as shown in figure 20 below.

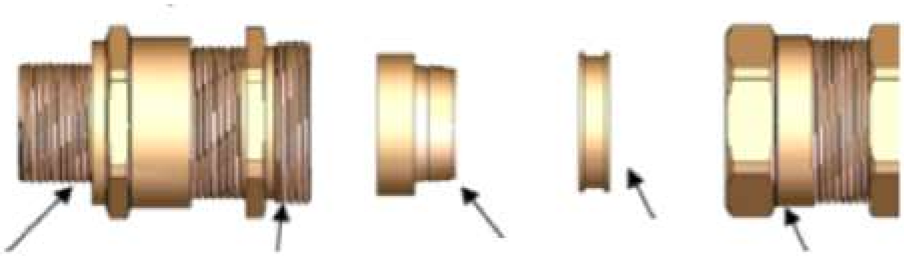


Figure 20 Exploded view of armoured cable gland

Procedure of Termination of Armoured Cable

1. Fit the shroud over the outer sheath and remove the cable outer sheath and the armour to suit the equipment. Remove a further 18mm of outer sheath to expose the armour. Remove any tapes or wrappings to expose cable inner sheath. Separate the gland into the assemblies "A and B". Ensure the outer seal is relaxed and pass the sub assembly "B" over the cable outer sheath and armour followed by the clamping ring "R". For large cable sizes the clamping ring may only pass over the armour.
2. Fix the detachable armour cone(C) in the recess of sub-assembly "A". Pass the cable through sub-assembly "A" and evenly space the armour around the cone.
3. Hold the main item with a spanner as you tighten sub-assembly "B" onto sub-assembly "A". Make sure that the two components have metal-to-metal contact. Disconnect sub-assembly "B" from sub-assembly "A".
4. Ensure that the inner seal is relaxed and secure sub-assembly "A" into the equipment as indicated.
5. Pass the cable through sub-assembly "A" and tighten the main item by hand until you get heavy resistance. Turn further a full turn with a spanner
6. Hold the main item with a spanner then retighten sub-assembly "B" onto sub-assembly "A".
7. Tighten the outer seal nut until either :

The outer seal nut makes a metal to metal contact with the gland body or

The outer seal nut cannot be further tightened because it is fully engaged.

Cable tray installations

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and commercial installations for sup-porting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes. Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged. The tray is supplied in standard widths from 50 to 900 mm, and a wide range of bends, tees and reducers is available. The tray can also be bent using a cable tray bending machine to create bends such as that shown in figure 21. The installed tray should be securely bolted with round-headed bolts where lengths or accessories are attached, so that there is a continuous earth path which may be bonded to an electrical earth. The whole tray should provide a firm support for the cables and therefore the tray fixings must be capable of supporting the weight of both the tray and cables.

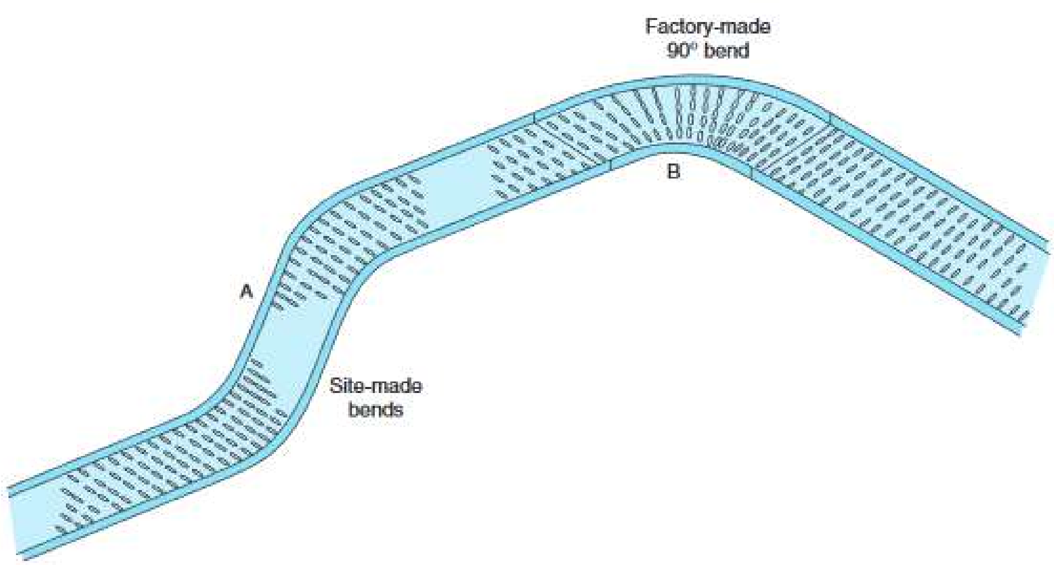


Figure 21 Cable tray with bends.

Types of Cable Trays

Several types of tray are used in different applications. A solid-bottom tray provides the maximum protection to cables, but requires cutting the tray or using fittings to enter or exit cables. A deep, solid enclosure for cables is called a cable channel or cable trough. A ventilated tray has openings in the bottom of the tray, allowing some air circulation around the cables, water drainage, and allowing some dust to fall through the tray. Small cables may exit the tray through the ventilation openings, which may be either slots or holes punched in the bottom. A ladder tray has the cables supported by a traverse bar, similarly to the rungs of a ladder, at regular intervals on the order of 4 to 12 inches (100 to 300 mm).

Ladder and ventilated trays may have solid covers to protect cables from falling objects, dust, and water. Tray covers for use outdoors or in dusty locations may have a peaked shape to shed debris including dust, ice or snow. Lighter cable trays are more appropriate in situations where a great number of small cables are used, such as for telephone or computer network cables. These trays may be made of wire mesh, called "cable basket", or be designed in the form of a single central spine (rail) with ribs to support the cable on either side. Channel Tray provides an economical support for cable drops and branch cable runs from the backbone cable tray system. Channel cable tray is used for installations with limited numbers of tray cable when conduit is undesirable. Large power cables laid in the tray may require support blocks to maintain spacing between conductors, to prevent overheating of the wires. Smaller cables may be laid unsecured in horizontal trays, or secured with cable ties to the bottom of vertically mounted trays. To maintain support of cables at changes of elevation or direction of a tray, a large number of specialized cable tray fittings are made compatible with each style and manufacturer. Horizontal elbows change direction of a tray in the same plane as the bottom of the tray and are made in 30, 45 and 90 degree forms; inside and outside elbows are for changes perpendicular to the tray bottom. These can be in various shapes including tees and crosses. Some manufacturers and types provide adjustable elbows, useful for field-fitting a tray around obstacles or around irregular shapes. Various clamping, supporting and splicing accessories are used with the cable tray to provide a complete functional tray system. For example, different sizes of cable tray used within one run can be connected with reducers

Metallic cable trays

The trays provide a safe open solution for routing cables and wires. Cable trays can be mounted onto a wall or suspended from a ceiling to provide a track that allows cables and wires to be routed around a building in an easily maintainable manner. Often made of galvanized or stainless steel cable trays not only provide a perfect cable management solution but also look aesthetically pleasing in any environment. Cable trays are available in three types, from light duty through to heavy duty; each system is supported by a fully integrated range of time saving fixings and fittings Suitable for installations in retail, industrial and offshore environments.

Trunking installations

A trunking is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes. A trunking system can have great flexibility when used in con-junction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current-using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point Trunking is supplied in 3 m lengths and various cross-sections measured in millimeters from 50 50 up to 300 150. Most trunking is available in either steel or plastic.

Metallic Trunking

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered and made to a specification defined by BS EN 500 85. A wide range of accessories is available, such as 45° bends, 90° bends, Tee and four-way junctions, for speedy on-site assembly. Alternatively, bends may be fabricated in lengths of trunking, as shown in Figure 22. This may be necessary or more convenient if a bend or set is non-standard, but it does take more time to fabricate bends than merely to bolt on standard accessories.

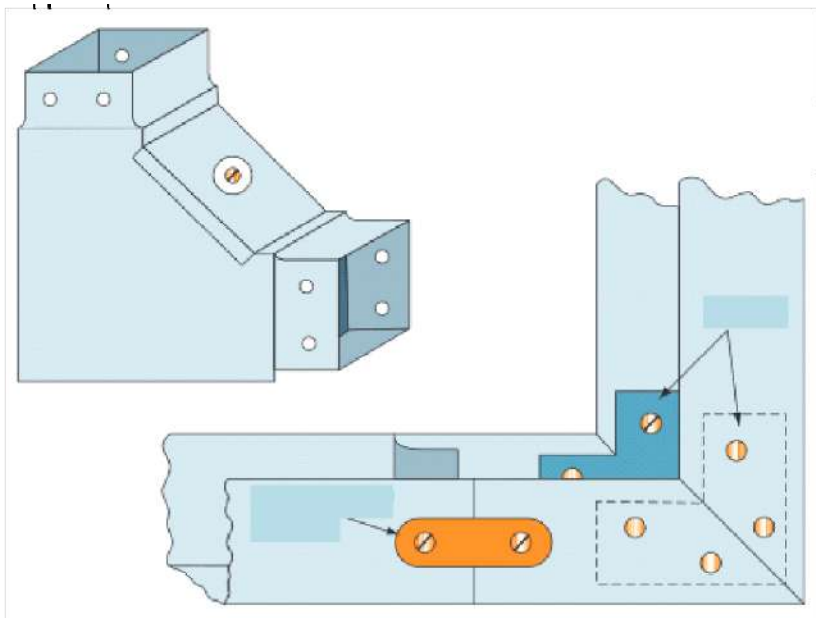


Figure 22 Trunking bends

When fabricating bends the trunking should be supported with wooden blocks for sawing and fi ling, in order to prevent the sheet-steel vibrating or becoming deformed. Fish plates must be made and riveted or bolted to the trunking to form a solid and secure bend. When manufactured bends are used, the continuity of the earth path must be ensured across the joint by making all fixing screw connections very tight, or fitting a separate copper strap between the trunking and the standard bend. If an earth continuity test on the trunking is found to be unsatisfactory, an insulated CPC must be installed inside the trunking. The size of the protective conductor will be determined by the largest cable contained in the trunking as per the IEE Regulations. If the circuit conductors are less than 16 mm ^{2}, then a 16 mm ^{2}CPC will be required.

Non-Metallic Trunking

Trunking and trunking accessories are also available in high-impact PVC. The accessories are usually secured to the lengths of trunking with a PVC solvent adhesive. PVC trunking, like PVC conduit, is easy to install and is non-corrosive. A separate CPC will need to be installed and non-metallic trunking may require more frequent fixings because it is less rigid than metallic trunking. All trunking fixings should use round-headed screws to prevent

damage to cables since the thin sheet construction makes it impossible to countersink screw heads.

Mini-Trunking

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices. The trunking has a cross-section of $16 \times 16\ mm$, $25 \times 16\ mm$, $38 \times 16\ mm$ **or** $38 \times 25\ mm$ **and is ideal for switch drops or for housing auxiliary circuits such as telephone or audio equipment wiring. The modern square look in switches and socket outlets is complemented by the mini-trunking which is very easy to install (see Figure 23).**

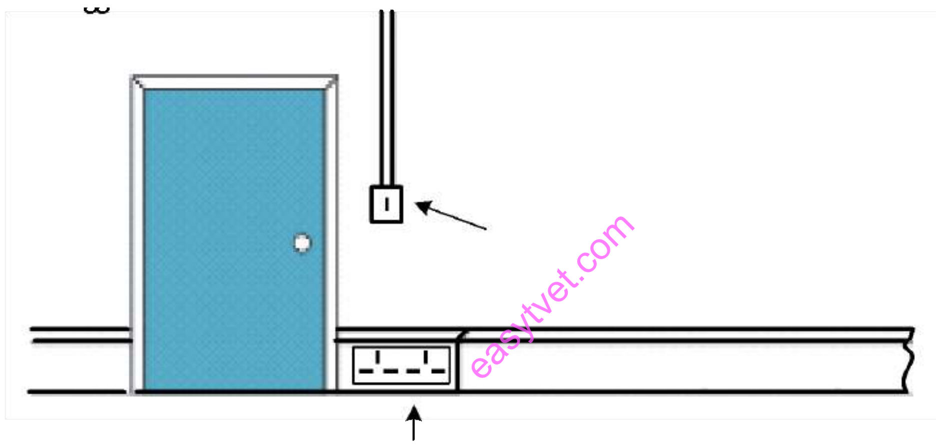


Figure 23 Typical installation of skirting trunking and mini-trunking.

Skirting Trunking

Skirting trunking is a trunking manufactured from PVC or steel and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices. The trunking is fitted around the walls of a room at either the skirting board level or at the working surface level and contains the wiring for socket outlets and telephone points which are mounted on the lid, as shown in Figure 23. Where any trunking passes through walls, partitions, ceilings or floors, short lengths of lid should be fitted so that the remainder of the lid may be removed later without difficulty. Any damage to the structure of the buildings must be made good with mortar, plaster or concrete in order to prevent the spread of fire. Fire barriers must be fitted inside the trunking every

5 m, or at every floor level or room dividing wall, if this is a shorter distance. Where trunking is installed vertically, the installed conductors must be supported so that the maximum unsupported length of non-sheathed cable does not exceed 5 m. PVC insulated cables are usually drawn into an erected conduit installation or laid into an erected trunking installation. Where a cable enclosure greater than 32 mm is required because of the number or size of the conductors, it is generally more economical and convenient to use trunking.

Final Circuits

Definition

A final sub-circuit is an outgoing circuit connected to a distribution board and intended to supply electrical energy to current-using apparatus, either directly or through socket outlets or fused spur-boxes.

Examples of final sub-circuits includes; lighting, socket-outlets, cooker and water heater. A final sub-circuit originates from the consumer control unit (CCU) or distribution board (DB). Each final sub-circuit is protected by an appropriate fuse or circuit breaker mounted in the consumer control unit.

IEE Regulations

i) Where an installation comprises more than one final sub-circuit, each shall be connected to a separate way in a distribution board.
ii) The wiring of each final sub-circuit shall be electrically separate from that of every other final sub-circuit.to facilitate disconnection of each final sub-circuit for testing.
iii) Every final sub circuit shall have means of protection against excess current
iv) The neutral conductor shall never be connected in the same order as that in which the live conductors are connected to the fuses or circuit breakers.
v) The neutral conductor shall never be connected to fuses, switches or circuit breakers.

Requirements for the consumer intake point

The IEE regulations requires that, every consumer's installation shall be adequately controlled by a switchgear readily accessible to the consumer which shall incorporate-

i) Means of isolating all the conductors of the installation of the premises from the supply.

ii) Means of excess current protection.

iii) Means of earth leakage protection.

Sequence of control

The sequence of the equipment forming the switchgear required shall be such that the means of isolation follows the consumer's terminals without the intervention of any other apparatus as shown in figure 24

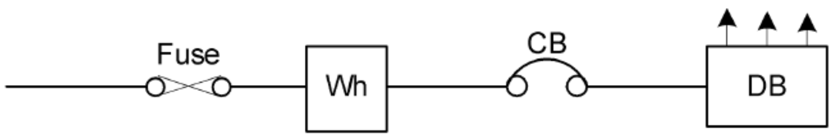


Figure 24 Sequence of control

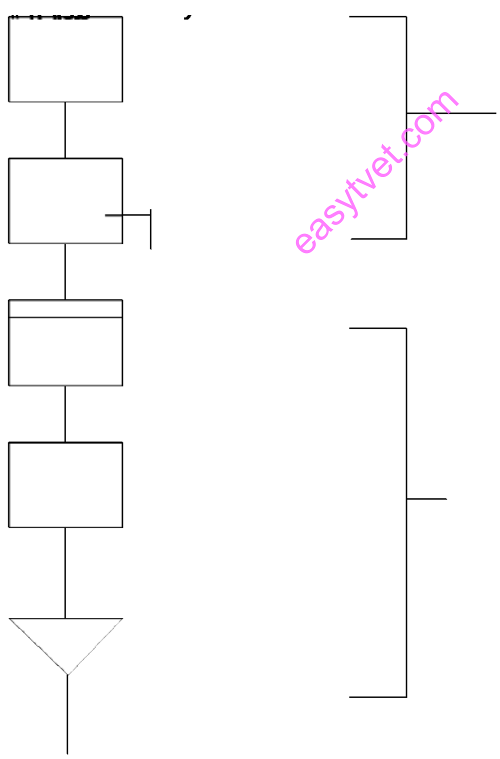


Figure 25 Single line diagram for the equipment at the consumer intake point

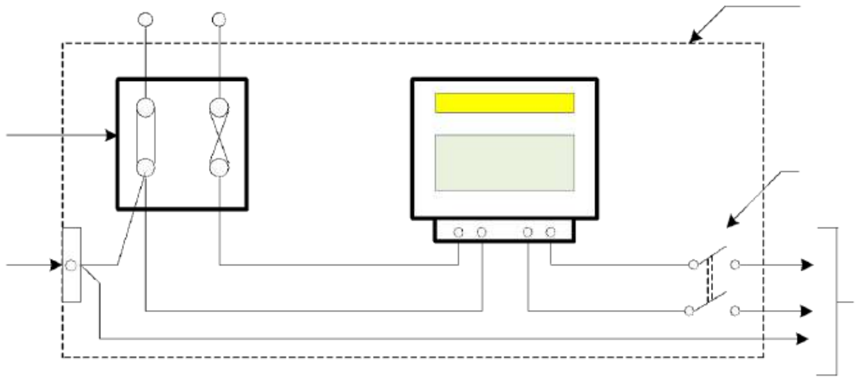


Figure 26 Circuit diagram for the equipment at the consumer intake point

Meter boxes can be mounted on the wooden /masonry surfaces or chased walls. When mounting a meter box, make sure that it is at the correct height which is reachable by a person standing on the ground. This is to make it easily accessible for energy meter reading, any repairs and replacements.

I.E.E regulations

i) Every consumer's installation shall have a means of isolation
ii) Every consumer's installation shall have a means of excess current protection.
iii) Every consumer's installation shall have a means of earth leakage protection.
iv) Where a consumer's installation comprises installation in two or more detached buildings, separate means of isolation shall be provided.
v) Every means of excess current protection shall be suitable for the maximum short-circuit current attainable.

Need For Switching

i. Used to put a circuit in use or out of use.
ii. Emergency switching.
iii. Isolating a circuit from the supply for maintenance.

Types of switches

1. Single pole switch
2. Double pole switch
3. Triple pole switch.

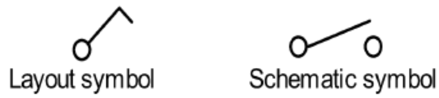
I.E.E regulation on switches

i) All single pole switches should always be connected in the live (phase) conductor only.

ii) Fuses shall also be inserted in the live only.

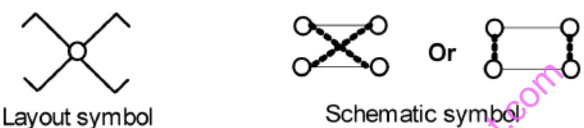
Types of single pole switches

1. One-way switch - This has one path only for current.



2. Two-way switch - This has two alternative paths for current (change over switch).

3. Intermediate switch – This has two double alternative current paths.



<u>Switching of lighting points</u>

One-way switching.

In the one-way switching, the lamp or set of lamps is switched from one particular point. An example is the switching at the entry of a room with one entry only.

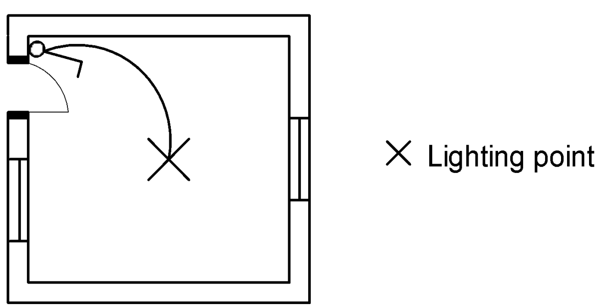


Figure 27 Layout of one room with one-way switching arrangement.

The ON and OFF control of the lighting point is only at one position.

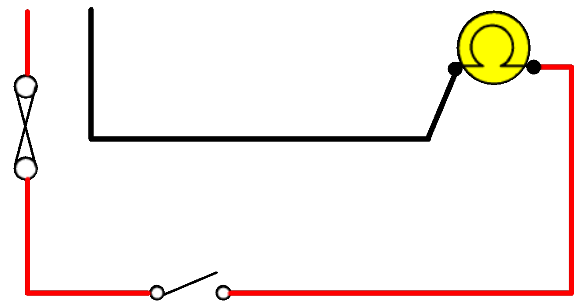


Figure 28 Schematic diagram showing one-way switch controlling one lamp.

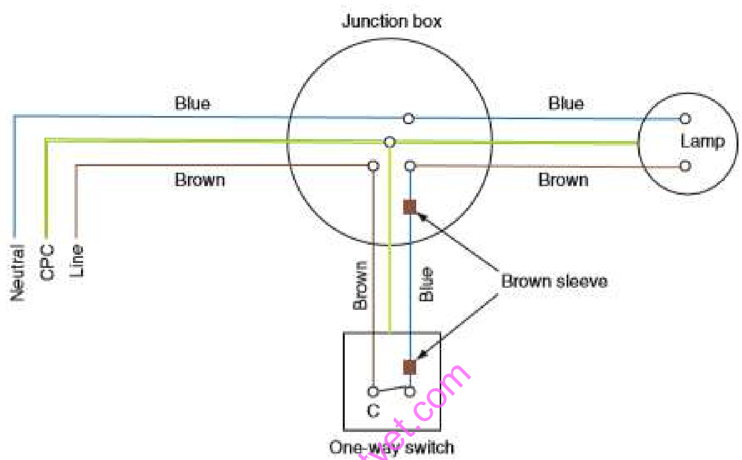


Figure 29 One way switching using a joint box

Two – Way Switching

Where it becomes necessary to have the lamp or set of lamps switched from two separate positions. An example is a long corridor or in a room with two entries.

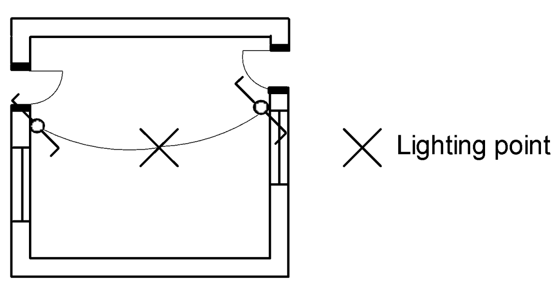


Figure 30 Layout of two-way switching arrangement.

The ON and OFF control of the lighting point is from two positions.

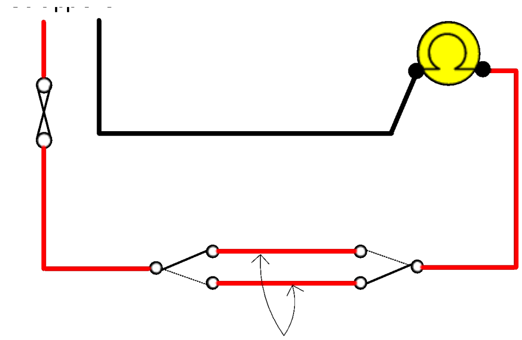


Figure 31 Schematic diagram showing two-way switch controlling lighting point.

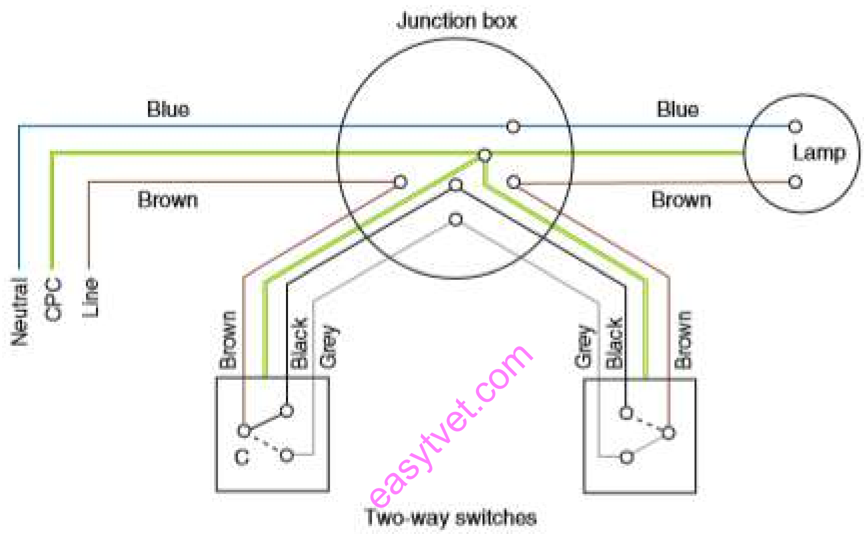


Figure 32 Two way switching using a joint box

Intermediate switching

This is used in conjunction with the *Two-way* switching where the switching of the lamps is from more than two points. All the other points of switching between the two two-way switches will be fitted with intermediate switches. An example of lamp controlled from THREE positions is shown in figure 33.

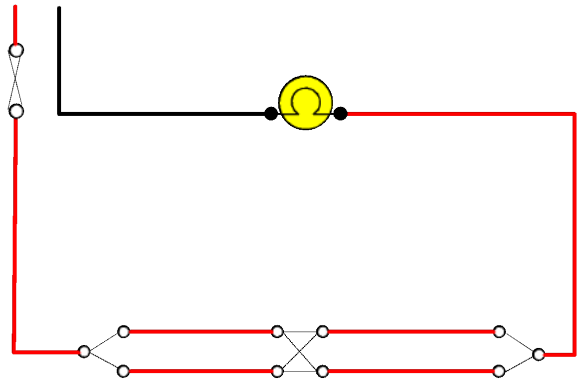


Figure 33. Intermediate switching

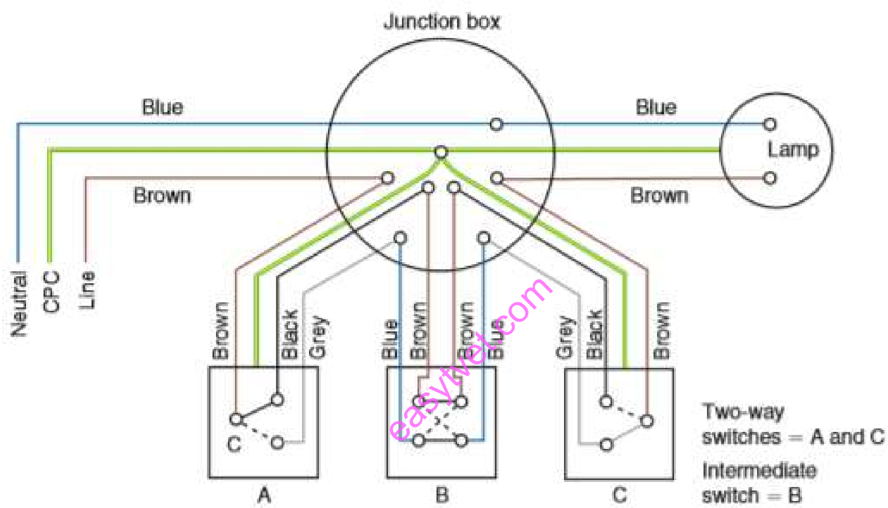


Figure 34 Intermediate switching using a joint box

Note

A lamp or set of lamps may be controlled from any number of positions provided we have 2 two-way switches and the rest of the switches been intermediate

Types of circuit connections

1. Series connection
2. Parallel connection

Series Connection

The current using equipment are connected in series or one after the other. One end of the equipment is connected to the other end *(End to End)* in series connection, the current flowing is the same and the voltage a cross each equipment will depend on the rating and its resistance

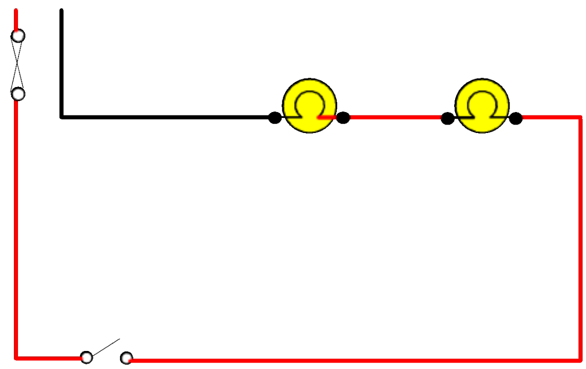


Figure 35 Series connection

The supply voltage is dropped individually across each lamp and depending on the ratings the voltage across each equipment will vary but the current flowing through all the equipment is the same. That is, if two lamps of equal resistance are connected in series to a $240\ V$ supply, the voltage which will appear across each lamp will be $120\ V$ and the current will be the same in all lamps

N.B

The lamps in above example may not produce light or be dim because the light produced is equal to

$$Power = V^{2/R}$$

And, V is below rated voltage

For a series connection to work, all lamps have to be good working condition in order to provide continuity of the circuit.

Disadvantages of series

1. If one lamp blows, all lamps go off.
2. Lamps will be dim (will not produce enough light) or may fail to light
3. Not reliable- Therefore for practical purposes series circuits are not used

Parallel connection

This is the most common arrangement for lighting circuits. All lamps are connected across the supply and each lamp receives the supply voltage a cross it. Each lamp can be controlled separately. If one lamp blows out, all the other will continue working.

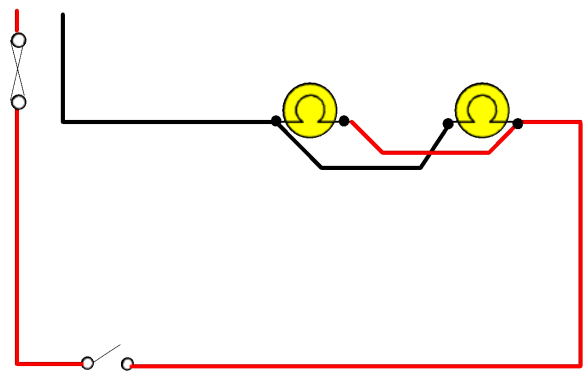


Figure 36 Parallel connection

Note:

If separately controlled, all switches are to be connected in the live conductor and that no wire goes directly to the lamp bypassing the switch.

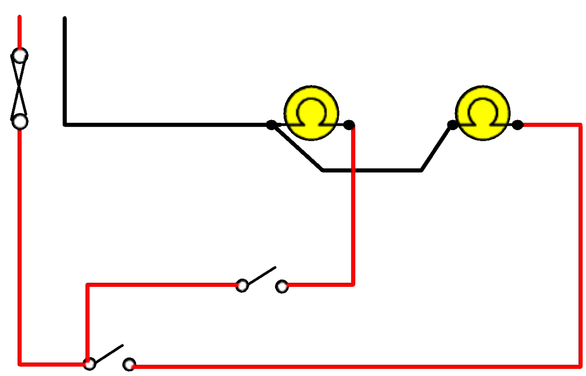


Figure 37. Separately controlled lamps

Advantages of parallel

i) All lamps receives rated voltage

ii) All lamps are bright

iii) If one lamp fails , other will not be affected

iv) Lamps can be controlled individually (separately)

Looping-In System

Looping-in of wires helps in saving materials and provides a clean piece of work. Looping – in can be done at:

i) Switches

ii) Lamp Holders

iii) Junction Boxes

iv) Ceiling Roses

If more than one lamp are to be switched from the same switch, it becomes cheaper to loop-in at the lamp holder for the second lamp. Figure 38 shows the theoretical diagram of a final sub-circuit of seven lamps, two controlled separately by 1-way switches, three controlled as a group by a 1-way switch, and two controlled by a 1-way switch. If the circuit were to be wired exactly as in the diagram, a large number of joints would be necessary. Figure 39 shows the same circuit as wired by the looping-in system. No joints are required except dry twisted joints in the terminals of the two-plate ceiling roses and of the single-pole one-way switches.

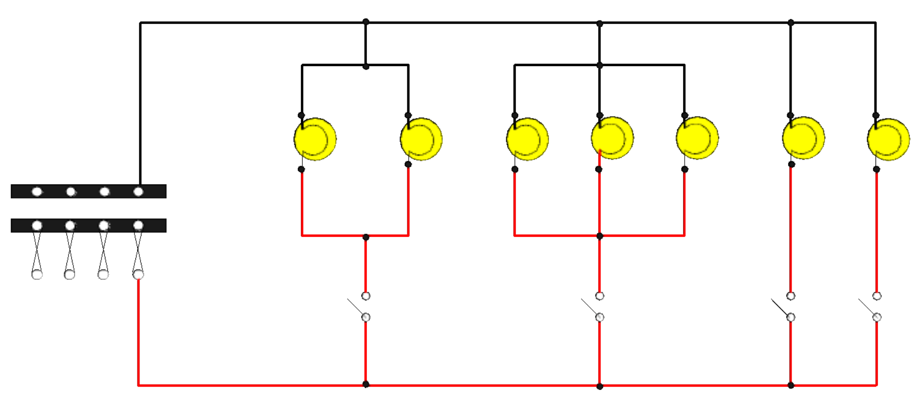


Figure 38 Control of lamps

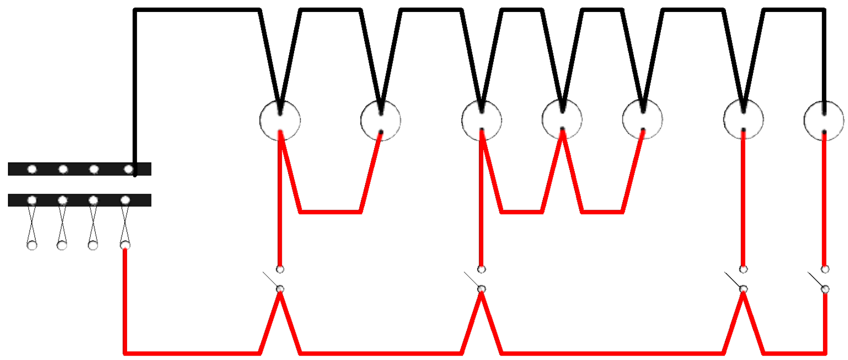


Figure 39 Looping in system

Looping in from a switch.

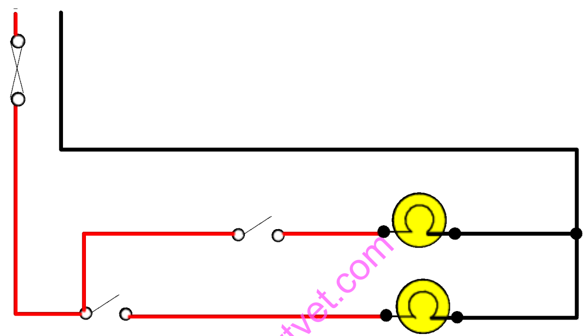


Figure 40 looping in from switch

In this system the Live to switch S_2 is normally looped from S_1.

Looping-in from a three plate ceiling rose

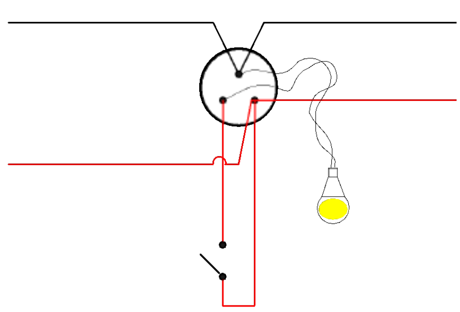


Figure 41. Looping in from ceiling rose

A ceiling rose must not be connected in such a manner that one that one terminal remains alive when the associated switch is OFF, unless that terminal cannot be touched when the ceiling rose is partially dismantled to allow flexible cord replacement.

Looping-in at Junction Boxes

In this method, all the circuit wires are brought to a common Box and distributed to the switches, ceiling roses, lamp holder's e.t.c.

This method of lopping in is only used where there are few lamps and more so where there is service wiring using twin core cables.

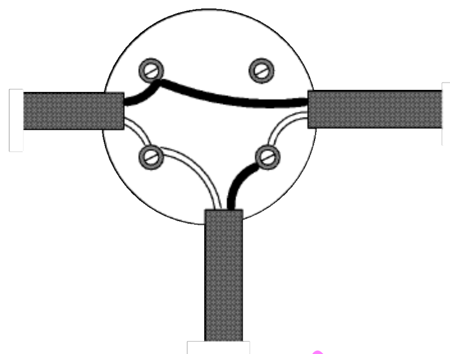


Figure 42 Looping in at joint box

Colour identification of cables

Single phase

Live - Red

Neutral- Black

Earth - Green or green /yellow

Three Phase

L_1 - Red - phase

L_2 - yellow - phase

L_3 - blue - phase

Neutral- black

Size of cables and rating of protective devices

Cables are manufactured in different sizes and compositions and each is designed to carry a maximum amount of current. The current a cable can carry are given in the I.E.E Regulation tables of current ratings. For lighting circuits the cable commonly used is the $1mm^{2\ or\ 1.5\ mm2}$ which is rated 18A depending on the type of cable. The most common cable used is single core and Twin flat and Twin with earth. Most lighting circuits will be rated at either 5A or 10A because most switches are rated 5A or 10A.

The I.E.E Regulations gives the protective ratings of different types of lamps as shown below.

Type of Holder	**Maximum Rating of fuse or Circuit Breaker.**
Small Bayonet type	5A
Small Edison –type screw	5A
Bayonet type	15A
Bi- pin type	15A

I.E.E Regulations on switches

1. Every switch or Circuit Breaker the purpose of which is not obvious shall be labeled to indicate the apparatus it controls.
2. All single pole switches shall be always connected to the live conductor.
3. Every switch or other electric control shall be placed so as to be out of reach of a person in contact with bath, shower unit etc.
4. In a two wire installation connected to a supply having neither pole connected with the earth, switch or circuit breaker shall be of double pole linked type and the fuses shall be installed in both poles.
5. In a two wire installation connected to a supply having one pole earthed, switches shall be connected in the live conductor only.

Power Circuits

Final power sub-circuits

A final power sub-circuit is a circuit that allows electrical appliances to access electrical power.

All final sub-circuits must be electrically separate that is there must be no “bunching” of neutral conductors. All neutral conductors must be connected at the distribution board in the same order as the line conductors.

Socket Outlet

A socket outlet is a device provided with female contacts which is intended to be fitted with the fixed wiring and intended to receive a plug. A device with protected current carrying contacts intended to be mounted in a fixed position and permanently connected to a fixed wiring of a an installation to enable the connection to it of a flexible cord or flexible cable by means of a plug, or is an accessory with 3 terminals marked *L*- live, *N*- Neutral and *E* – Earth fitted with the fixed wiring ready to receive a plug.

Plug




This is a device intended for connection to a fixed cord or flexible cable which can be engaged manually with a socket outlet and which has current carrying contact pins which may be exposed when not engaged. Socket outlet will be wired such that the terminal marked *L* will receive the live wire, the terminal marked *N* will receive the Neutral and the one marked *E* will receive the earth wire. Socket outlets must be installed in a place to wait for a plug but not the vice-versa

Note;

Sometimes the earth terminal is marked with the Earth symbol

There are two ways in which socket outlets may be wired

1. Radial circuit
2. Ring circuit

Radial Circuit

A radial circuit is a circuit in which the live, neutral and earth conductor start from the distribution board to sockets connected in series and terminate at the last socket.

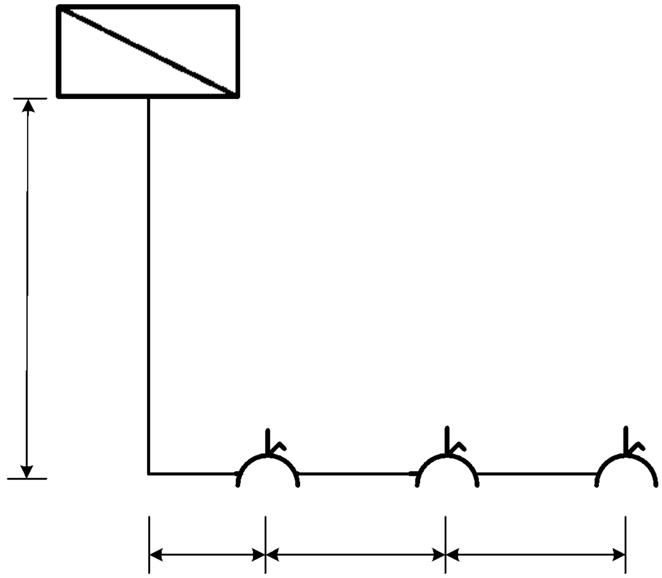


Figure 43. Layout diagram of a radial circuit

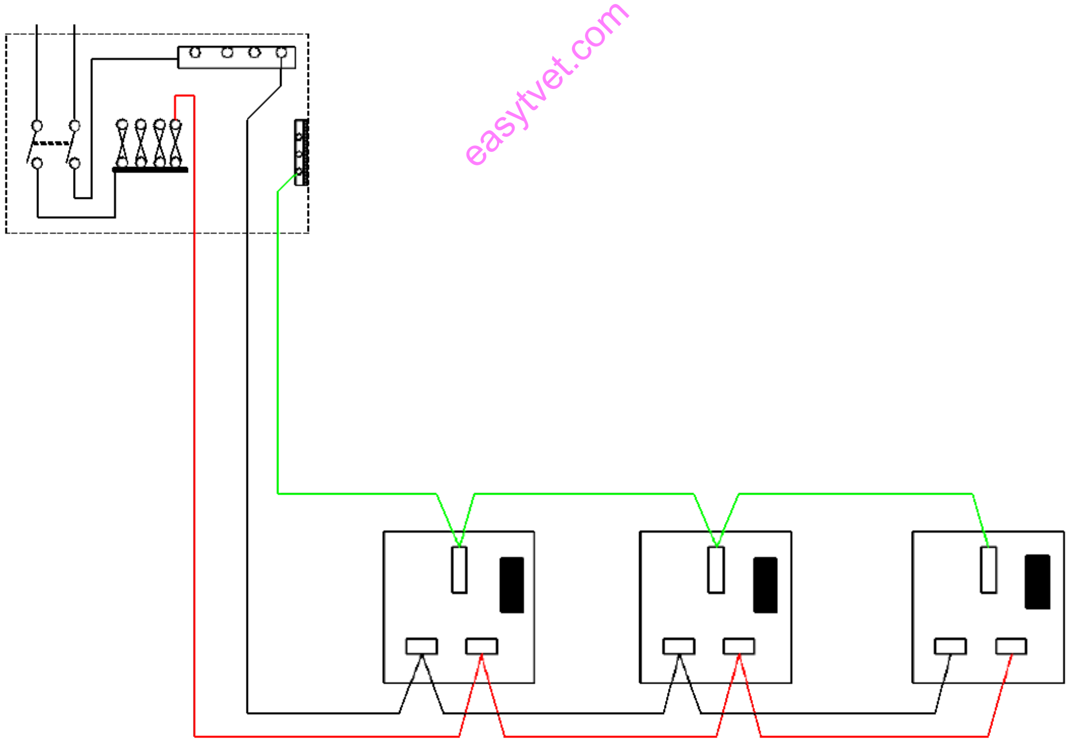


Figure 44 Wiring diagram for the radial circuit

Ring Circuits

A ring circuit is defined in the I.E.E. Regulations as " a final sub-circuit in which the current-carrying and the earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution board or its equivalent.

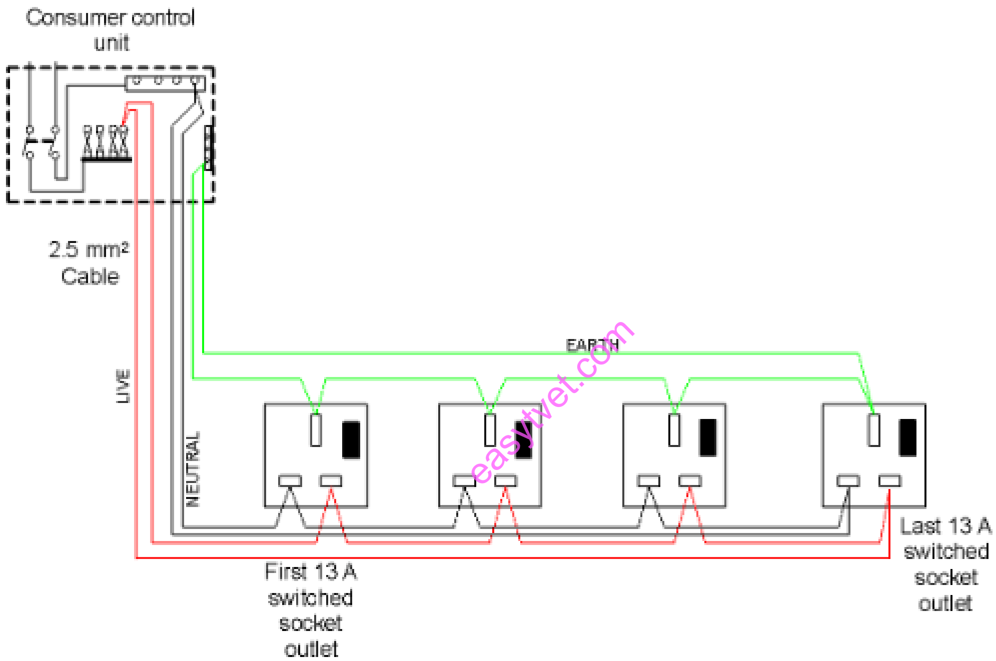


Figure 45. Wiring diagram for a ring circuit.

Spur

A spur is a socket that branches off a ring circuit. The number of spurs fed from a ring circuit must not exceed the number of sockets in the ring. The cables connecting the spur must be of the same size as that of the ring circuit. The minimum cable size for ring and radial circuit is $2.5mm^2$.

Advantages of a ring circuit over a Radial circuit

1. There is total safety in ring circuit than in Radial for the circuit is in form of a ring
2. An open circuit point in the Ring circuit will not affect any other socket in the system

This is because there are two paths of current and is one path is open the current will flow through the other

3. Smaller sizes of cables may be used in Ring than in a Radial. This is because the Ring has two parallel current paths
4. More loads may be fed or connected to a Ring circuit than a Radial circuit of the same capacity

Disadvantages of Ring over Radial

1. More cables lengths requires in a Ring than in Radial therefore becomes more expensive
2. It consumes more time to install a Ring circuit than Radial because more cables has to be installed.

I.E.E Regulations on Ring and Radial circuit

1. A Ring circuit it may serve an unlimited number of points but shall not serve an area of more than $100m^2$
2. For a Ring final sub-circuit the total number of spurs shall not exceed the total number of socket outlets and stationary appliances connected directly in the ring circuit.
3. Where two or more ring final sub circuit are installed, the socket outlet to be served shall reasonably be distributed among the separate ring circuit
4. For a Radial or Ring final sub circuit the Rating of the fuse or circuit breaker at the circuit breaker shall not exceed 30A
5. Each circuit conductor of a ring final sub circuit shall be run in the form of a Ring commencing and returning to the same way in the circuit breaker.
6. Except where Ring is run throughout in metallic conduct, Ducts or Trunking, Earth continuity conductor shall run in form of a ring originating and returning to same point in the circuit breaker.
7. For a Radial circuit the current rating of the circuit conductors shall not be less than Rating of the fuse or circuit breaker protecting the final sub- circuit

Electric Bell

There are various types of electric bells including the single stroke bell, the trembles, the buzzer and a continuously ringing bell, but all depend on the attraction exerted by the electromagnet or a soft iron armature.

i) Single stroke bell

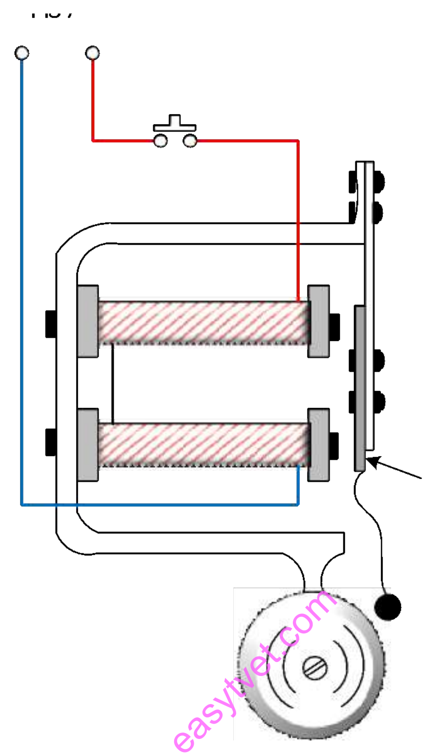


Figure 46 Single stroke bell

Construction

The bell is made up of two coils wound up with insulated copper wire on an insulated bobbin. The bobbins are slipped on to a U-shaped soft iron core and the magnetic circuit is completed by a soft-iron strip riveted to a spring-loaded armature. The striker is attached to the armature.

Operation.

1. the push-button is pressed
2. Current passes through the coil.
3. The coil is magnetized.
4. The soft-iron strip on the armature is attracted towards the coil.
5. The armature carries a striker which hits the gong.

6. The gong produces audible sound.
7. When the circuit is broken the coil becomes demagnetized and the spring pulls the armature back into its original position.
8. The striker will only operate when the push is operated hence a single stroke.

ii) **Trembler bell**

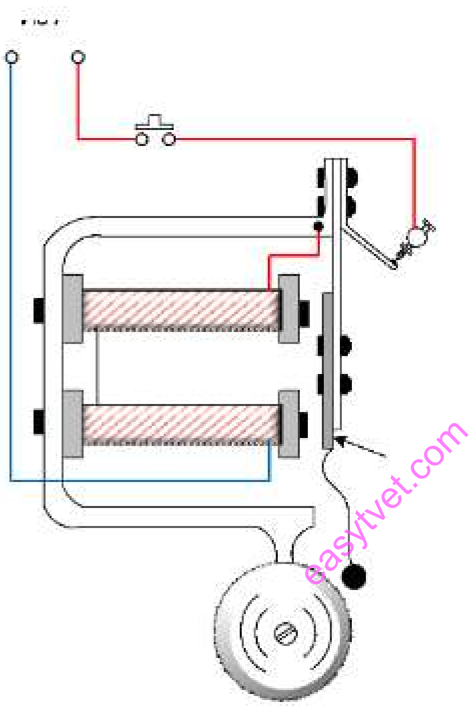


Figure 47 Trembler bell

Construction.

This type of bell is similar in construction to the single-stroke bell except that there is an adjustable pair of contacts between the armature and the push button contact.

Operation.

1. The push-button is pressed
2. Current passes through the coil.
3. The coil is magnetized.
4. The soft-iron strip on the armature is attracted towards the coil.

5. The armature carries a striker which hits the gong.
6. The gong produces audible sound.
7. When the circuit is broken the coil becomes demagnetized and the spring pulls the armature back into its original position.
8. The cycle is then repeated, giving a continual make-and-break action.

Continuous ringing bell

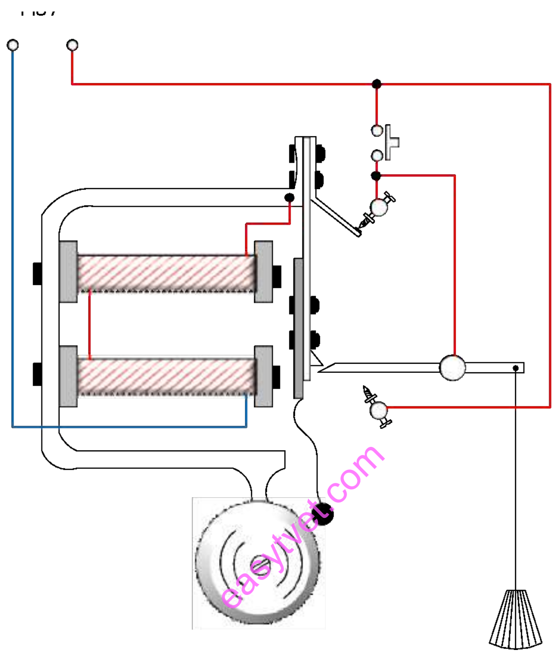


Figure 48 Continuous ringing bell

Construction

The continuous ringing bell differs in construction from the trembler bell in that a small lever is placed below the contact screw. This level drops automatically on the first stroke of the bell, and as it drop it shorts out the bell-push, thus causing the bell to ring continuously until the lever is reset by the cord. Confusion can arise in the drawing of this circuit if the operation of the lever is not understood.

Operation.

1. When the bell –push is operated the coils become an electromagnet and the armature is drawn towards them.
2. The lever drops on the first stroke and shorts the push.

3. The bell now operates as a trembler bell.
4. To stop the bell, pull the cord, thus resetting the lever.

iii) **The Buzzer**

The buzzer is a trembler bell without a striker and gong. The principle of operation is similar to that of the trembler bell, however, the sound it produces is like the buzz of a bee.

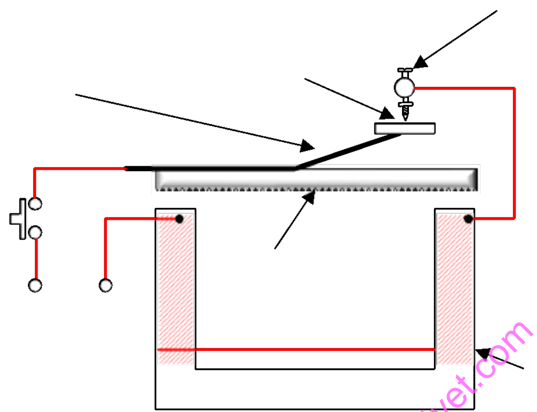


Figure 49 Buzzer

Bell Indicators

These are devices used to indicate the location where the bell is being rang by showing in the indicator board. These indicators coils are connected in series with the bell Indicator boards are situated at places where the intended person can access it. For example, it can be situated in the nurses' office to show when a patient is in need. During bell circuit installation comprising more than one bell push buttons operating the same bell, it is necessary to include an indicator board which will show from which push button the bell has been rung. There are three types of bell indicators.

1) Pendulum
2) Electrical replacement.
3) Mechanical replacement.

1. Pendulum type

In the pendulum type there are movements similar to that of the single stroke bell where a soft iron armature carrying a flag is pivoted at its end in front of an electromagnet. The coils of which are in series with the push concerned .When the push button is pressed, the electromagnet attracts the armature. When press the button is released, the electromagnet is demagnetized releasing the armature .The armature starts to swing in a pendulum motion before resting.

Disadvantages

i. When the person called happens to be away from the indicator board when the bell rings, the pendulum may stop swinging by he/she comes back.
ii. There may be confusion if more than one push buttons are pressed almost at the same time.

2. **Electrical replacement type**

In this arrangement, the element consists of two electromagnets, one of which is in series with the bell circuit. The second coil is connected in the replacement circuit. The armature is pivoted at its center about which it will rock. The flag arm is attached to the armature. When the current flows through the alarm circuit, one end of the armature is attracted, causing the flag to overbalance and fall to one side. To restore the flag, the current is passed through the replacement coil, which restores the flag to its original position.

3. **Mechanical replacement type**

Has an armature which is attracted by the electromagnet to show the flag in its appropriate space in the screen or window of the indicator board. The flag remains in this position even though the bell push button is released until it is reset by a lever that is pushed or turned around by hand.

Relays

This is an electrical device such that current flowing through it in one circuit can switch ON and OFF current in a second circuit.

Construction

Basic parts and functions of electromechanical relays include:

1. **Frame:** Heavy-duty frame that contains and supports the parts of the relay.
2. **Coil:** Wire is wound around a metal core. The coil of wire causes an electromagnetic field.

3. **Armature:** this is the relays moving part. The armature opens and closes the contacts.
4. **Contacts:** The conducting part of the switch that makes (closes) or breaks (opens) a circuit.
5. An attached **spring** returns the armature to its original position.

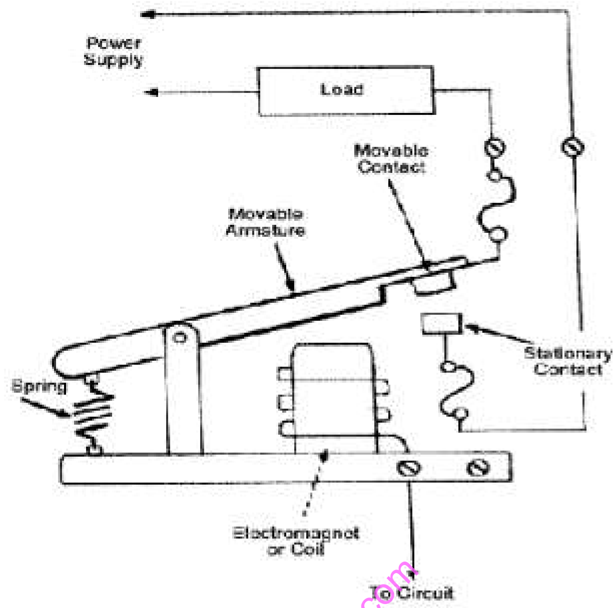


Figure 50 Electromechanical relay

Bell circuits

There are layout diagrams and wiring diagrams which use BS 3939 symbols.

An example of a layout diagram is shown in figure 51.

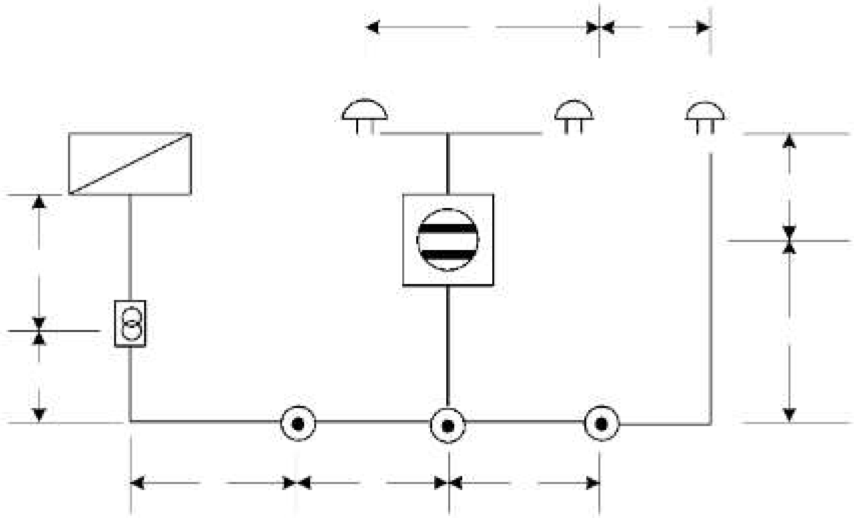


Figure 51layout diagram for alarm circuit

Description

Figure 51 shows a bell circuit layout diagram, push buttons A and B controls bells 1 and 2 simultaneously. The bells are connected in parallel, and push button C controls bell 3. Bells A and B are connected through an indicator board.

Figure 52 shows the wiring diagram of the layout diagram in figure 51

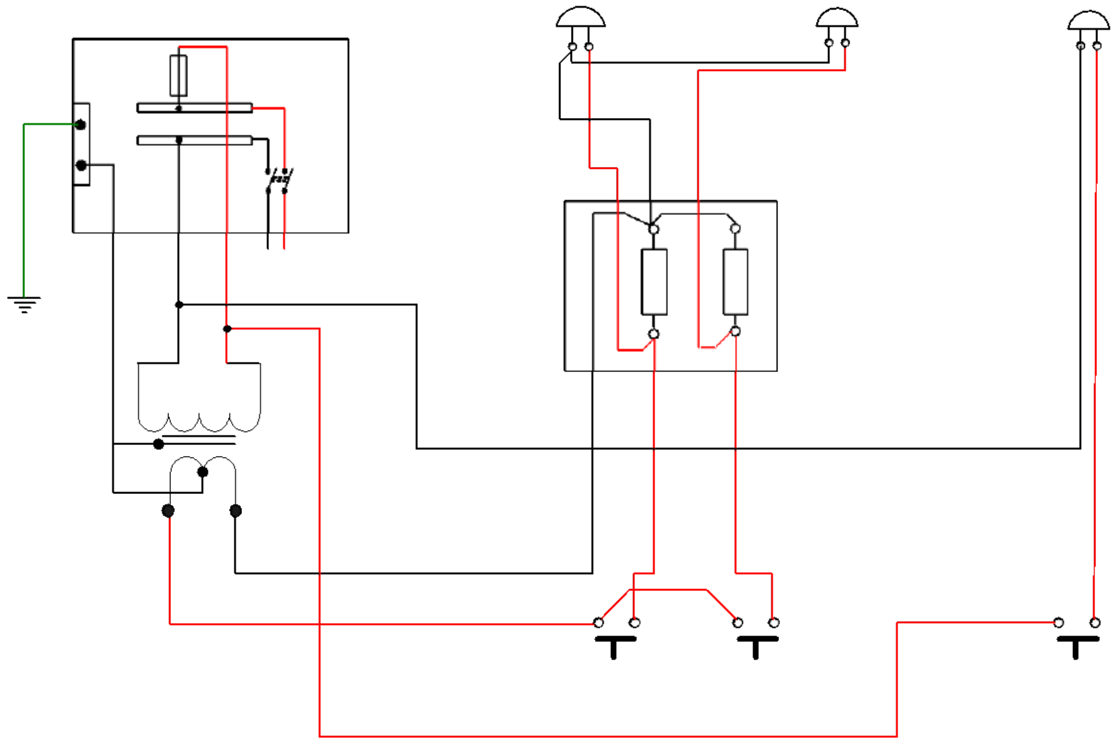


Figure 52 Bell circuit wiring diagram

ELECTRIC WATER HEATERS

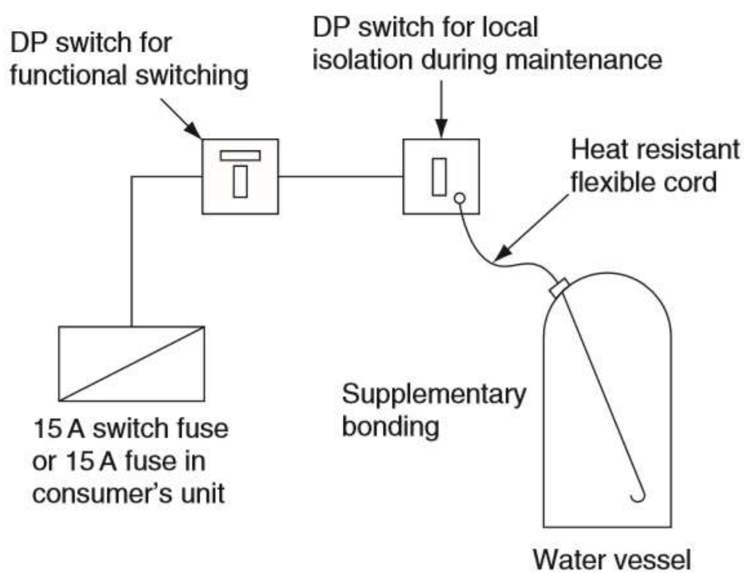


Figure 53. Water heater layout diagram.

There are two basic types of electric water heaters;

(a) The free outlet or non- pressure-type (N.P.T) and

(b) The pressure type.

Free Outlet Water Heater

Both types of water heater operate on the principle that water, when heated, becomes less dense (lighter) and rises. An immersion heater element is fitted at the bottom of the tank or vertically (through the center) so that all the water in the tank will be heated. The immersion heater will only heat the water above it. But in the free outlet type cold water is fed into the tank through an inlet valve. When this valve is opened, the incoming cold water pushes the less dense hot water in to the outlet pipe.

Construction

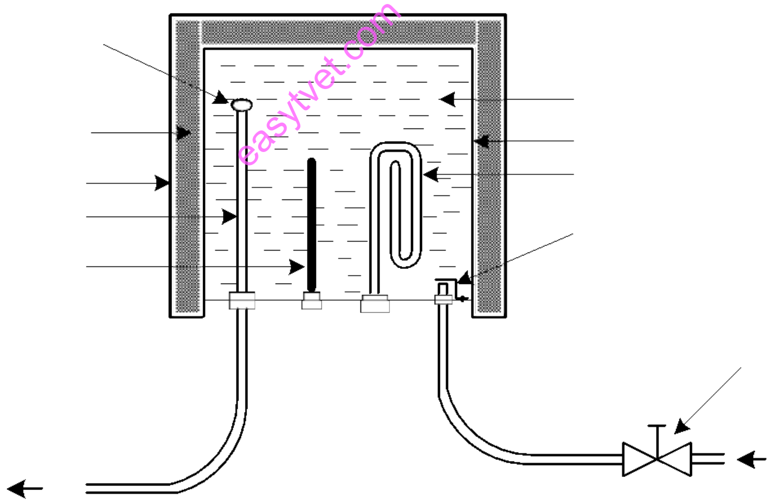


Figure 54 Free outlet water heater

Figure 54 shows the construction details of free outlet water heater. This type of water heater consists of a tinned-copper tank insulated against heat loss by a granulated cork or grass fiber lagging. The inlet valve is fitted with a baffle plate to keep the incoming cold water at the tank. The outlet pipe has an anti-drip syphon which is fitted to prevent the outlet from dripping when the inlet valve is closed. The heating element is composed of a nichrome wire spiral encased in a plated copper tube and insulated with a refractory (heat- resistant) material. The thermostat is used to control the temperature of the water in the tank.

Operation of the Thermostat

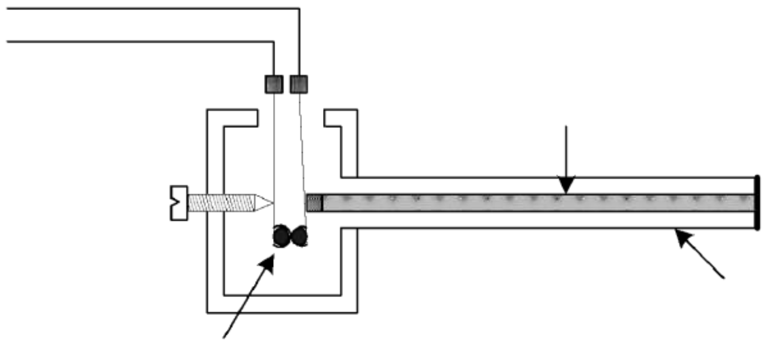


Figure 55 Water heater thermostat

The thermostat must be connected in the phase conductor.

The sequence of operation thermostat is as follows

- The heat from the water heats a brass tube, causing it to expand.
- An invar (non-expanding) rod is fixed at the end of the tube
- The movement of the brass tube draws the invar rod away from the contacts, breaking the heater circuit
- The point at which the contacts open is determined by the pressure on the contacts; an adjustable screw allows variations in the operating temperatures (generally $43^{0}C$ to $82^{0}C$).

Pressure Type Water Heater

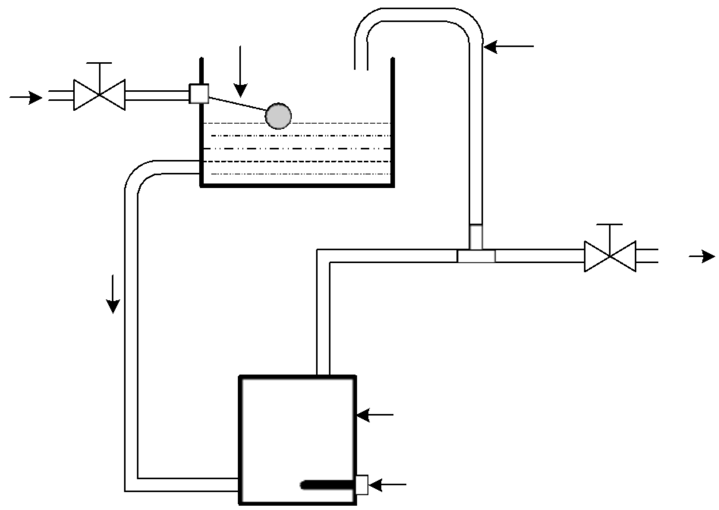


Figure 56 Pressure type water heater

In this type, the hot water tank is fed from a cold water cistern placed above it. The water supplying the cistern is controlled by a ball-valve. When hot water is drawn off the hot water tank (or cylinder) the cistern replenishes it and the ball-valve comes into operation to refill the cistern. In this way a constant pressure (or head) of water is kept on the hot water system.

Difference between pressure and free outlet types.

The free outlet type is controlled by one valve on the inlet side, and the pressure type is designed to supply one or more outlets on the hot water side.

Tank-less water heaters (Instantaneous)

These are water heaters that instantly heat water as it flows through the device, and do not retain any water internally except what is in the heat exchanger coil.

Copper heat exchangers are preferred in these units due to their high thermal conductivity and ease of fabrication.

Advantages

1. Plenty continuous flow of hot water
2. Plenty energy savings

Disadvantage

1. High initial cost

Operation

The heater is normally in the OFF position, but is equipped with flow sensors which will be activated when water flows through them. A feedback loop is used to bring water to the desired temperature. The water circulates through the copper heat exchanger and is heated by gas or electricity. Since there is no storage tank of hot water, the heater provides continuous supply of hot water.

Electric shower heads

In this type, an electric heating element is placed in shower heads to instantly heat water as it flows through. These self-heating shower heads are specialized point-of-use Tank-less water heaters and are widely used in some countries including Kenya.

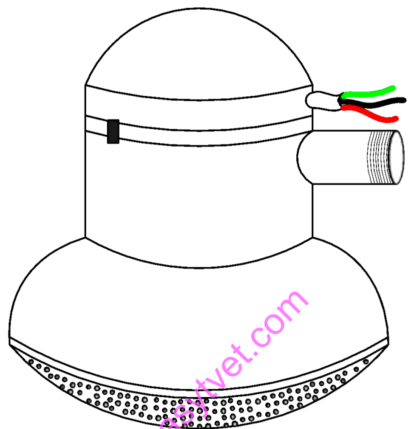


Figure. 57 Electric shower head

Electrical Machines

Electrical machines play an important role in industry as well as in our day to day life. They are used in power plants to generate electrical power and in industry to provide mechanical work, such as in steel mills, textile mills and paper mills

Alternating Current Motors

Motors that are designed to operate on alternating current are called alternating current motors. They convert electrical energy into mechanical energy. Alternating current motors are the most widely used type of motors because, all the generated electrical energy is in the form of alternating current. In addition, ac motors are simple in design, rugged in construction and require little maintenance.

All ac motors basically consist of a stationary part called the stator, a rotating part called the rotor and two end shields that house the bearings the rotor. The design of the rotor and the manner in which current is made to flow through it determines the classification of the motor and its performance characteristics. The stator contains windings which when connected to an alternating current source, creates a rotating magnetic field. At the same time a magnetic field is created in the rotor by electromagnetic induction which is similar to transformer action. The attraction between the stator and rotor fields causes the rotor field to follow the rotating stator field.Ac motors are particularly suitable for constant speed applications. However, variable speed motors are also manufactured. Alternating current motors operate on the either single-phase or three-phase supply.

Basic parts of ac motors

All ac motors have similar parts, with the exception of modifications or additions of special parts to a particular type of motor. AC motors essentially consist of:

(a) Frame: The frame is made of steel and it is the part into which the stator is pressed.

(b) Stator: The stator is made of a cylindrical core consisting of tightly held together steel laminations, with longitudinal slots around the inner circumference which firmly hold the stator coil windings.

Stator: During the manufacture of some stators, the windings are first wound into the stator slots and properly connected. The wound stator is then dipped into insulating vanish, baked and finally pressed into the frame. Figure 58 shows a completely wound stator and frame of an induction motor before assembly. In other words, the stator is first pressed into the frame and thereafter, individual wires of the coil are wound into the slots, as shown in figure 59. The completely wound stator is then dipped into insulating vanish and baked. Stator windings are made of copper wires

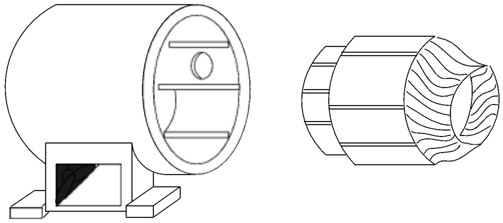


Figure 58. Completely wound stator before the core is pressed into the frame

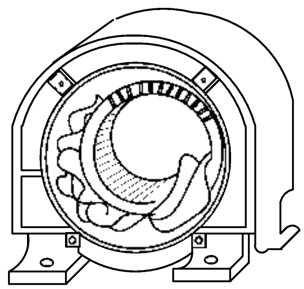
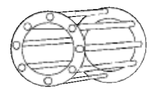


Figure 59. Partially wound stator after the core is pressed into the frame.

Rotor: There are two common types of rotors: the wound rotor and the squirrel-cage rotor. The wound rotor consists of a cylindrical core of steel laminations with longitudinal slots around the circumference. The slots hold coils of insulated copper wires which form the rotor windings. The ends of the windings are connected to slip rings in the three-phase motors and to commutator machines in single-phase repulsion and universal motors.

The squirrel-cage rotor consists of laminated cylindrical steel core with slots around its surface, but instead of holding coils of insulated copper wire, it is embedded with uninsulated large bars of copper or Aluminium conductors. The bars are short –circuited by brazing or welding them to end rings, made of identical material. If the structure formed by the bars and rings were to be viewed outside the core, it resembles a squirrel cage, and hence the name squirrel-cage rotor as illustrated in figure 60. In some rotors, however, the bars and rings are made of one piece of cast Aluminium. The rotor is always mounted on a high-grade steel shaft.



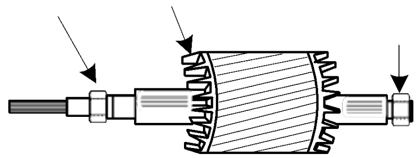


Figure 60 Squirrel-cage rotor

The rotor also carries cooling fans at both ends. These are important because a rise in temperature inside the motor lowers the motor output and in case of excessive temperatures, the insulation of the conductors would burn causing short circuits and fires.

End shields: The two end shields are made of cast steel and bolted to the frame. The end shields house the bearings. The purpose of the bearings is to support the weight of the rotor and to keep the rotor centered within the stator so that as it rotates, friction is minimized and also ensure that it does not strike or rub the stator core.

Single-phase motors

Single-phase ac motors are designed to operate from a single-phase ac supply. They are usually fractional kilowatt motors and are termed small motors. However, some single-phase motors are of 15kw and above and are manufactured for special applications. Single-phase motors are commonly found in house hold appliances such as refrigerators, food mixers, fans, vacuum cleaners and washing machines. They are also found in agricultural, commercial and industrial applications. Single-phase motors are small in size, robust in construction cheap easy to maintain and particularly useful where only the single-phase ac supply is available. Single-phase motors are divided into three classes:

i. Synchronous motors
ii. Induction motors
iii. Universal motors

The synchronous motor has a constant speed and is not self-starting. There are four types of single –phase induction motors, all named according to the method of starting them. The four in order of their increasing starting torque are: shaded pole, resistance start, capacitor start and repulsion motor. The universal motor also known as series motor, operates on either direct current or single-phase alternating current.

Single-phase synchronous motors.

The single-phase synchronous motor is usually used in timing devices such as wall clocks. It is very small in size and produces a small torque. It has a two-pole stator and the rotor is simply a slotted steel disk or a pile of disks bolted together but insulated from each other.

Operation

The stator contains two poles with their windings connected in series but in such a manner that the poles are of different polarities as shown in figure 55 (a). When single phase current is applied to the stator during the first alteration, the current increases from zero to maximum then falls to zero as shown in figure 61 (b). During the same period the pole pieces are magnetized and say, A becomes a north pole and B a south pole. The magnetic field so produced, varies in strength in similar pattern as the current. During the next alteration, the current changes direction and the polarity of the poles reverses; A becomes a South Pole and B a north pole. The magnetic field is said to be oscillating.

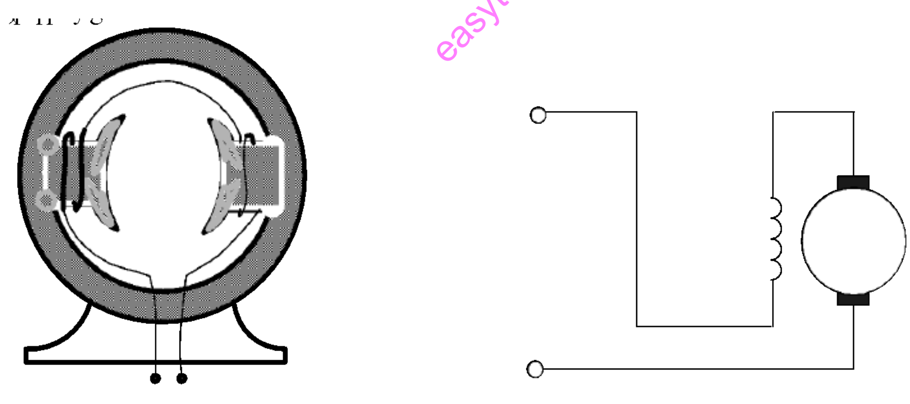


Figure 61 (a) Stator showing the two poles (b) Single- phase series motor

The change in magnetic field induces a voltage and therefore current in the rotor. This process is similar to induction in secondary winding of a transformer. The induced currents in the transformer create a magnetic field which always opposes the field causing it (Lenz’s law). This means that a N-stator pole will produce a N-pole field and a S-pole stator pole, a S-pole field. The polarity of the rotor field changes at the frequency of the alternating current in the stator field. Since these changes are simultaneous, the rotor field pulsates and does not produce a torque. The rotor does not therefore rotate.

If the rotor is caused to rotate by applying an external force, it cuts the magnetic field of the stator. This induces current in the rotor which creates a rotor magnetic field. The pulsating stator magnetic field interacts with the rotor field. Since the induced field is always of the same polarity as the one creating it, and like poles repel, the rotor poles are repelled causing the rotor to rotate. The induced voltage causes induced currents which in turn create a magnetic field in the rotor. This voltage is produced in the following two ways;

(a) The alternating magnetic field of the stator cuts the rotor conductors and induces the rotor voltage. Since the action is similar to induction of secondary voltage in transformers, this kind of induced voltage is called transformer emf.

(b) As the rotor rotates, its conductors cut, or are cut by the rotating magnetic field and this induces voltage in the rotor. Voltage induced this way is called speed emf.

It is the combined effect of these alternating emf's which produces the torque that causes the rotor to turn. This applies to all induction motors. The rotor will rotate in either clockwise or anticlockwise direction depending on the direction of the external force applied. Once the rotor has started to rotate, it accelerates until it reaches the synchronous speed. The speed of the rotating field is called the synchronous speed and it depends on the frequency of the supply voltage. The synchronous speed inn r.p.m is calculated by multiplying the frequency of the ac input by 60 (number of seconds per minute) and dividing the product by the number of pairs of poles in the motor

$$Speed = 60\times\frac{frequency}{number\ of\ pairs\ of\ poles}\ rpm$$

Suppose a motor has 8 poles and is connected to 240v, 50Hz line. Its synchronous speed will be;

$$Speed = (60x50)/4 = 750\ rpm.$$

The actual speed of the rotor is less than the synchronous speed. If the rotor was to rotate at the same speed as the rotating speed, it would not cut the field, no current would be induced and hence no magnetic field would be created in it, and consequently no torque would be produced. For the rotor to sustain motion, there must be some difference the synchronous speed and the actual speed. The difference in speed is called SLIP. Slip is expressed as a percentage of synchronous speed. In single-phase synchronous motors, it is less than 4% and for practical purposes, the motor is considered to rotate at synchronous speed.

Resistance- start induction run motor (split-phase)

The resistance start, induction run motor is also referred to as split-phase motor. The main parts of the motor are frame, stator, squirrel-cage rotor, two end shields and a centrifugal switch mounted on the rotor shaft. Figure 62 shows parts of a disassembled resistance-start induction run motor.

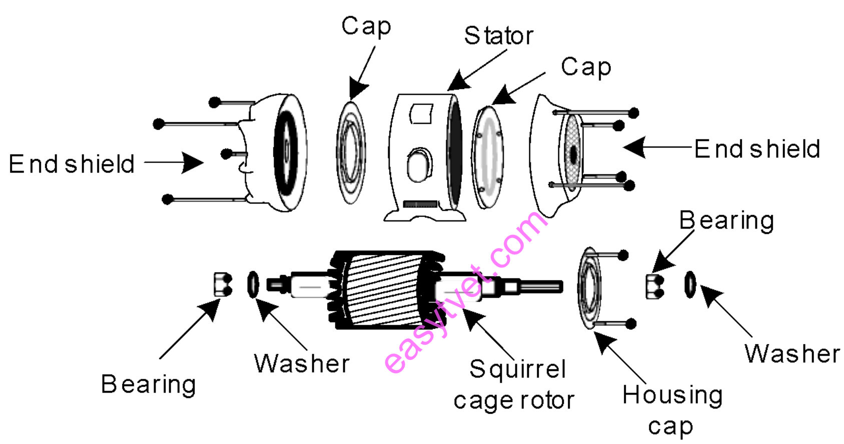
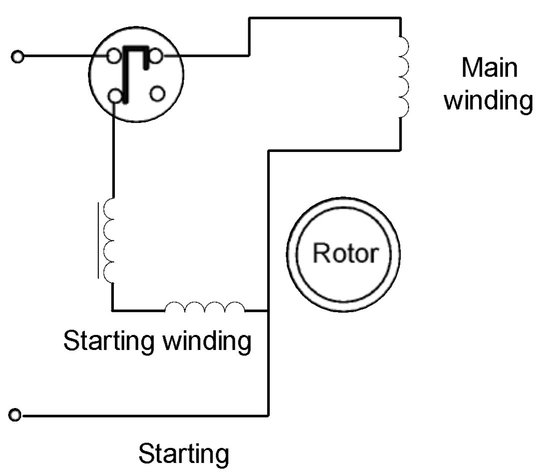


Figure 62 Parts of a disassembled resistance-start induction-run motor.



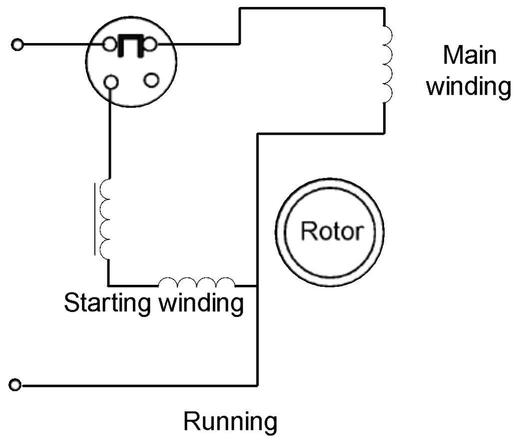


Figure 63. Split-phase motor.

Capacitor Start Motors.

There are two types of capacitor start motors, namely the capacitor start-induction run and capacitor start-capacitor run. The main difference between the two is that in the former, the starting winding and the capacitor are disconnected from the circuit when the motor attains 75% of the rated speed, while in the latter, the starting winding is permanently connected in the circuit.

Capacitor start-induction run motor

In this type of motor, a capacitor is connected in series with the starting winding as shown in figure 64. An electrolytic capacitor is commonly used.

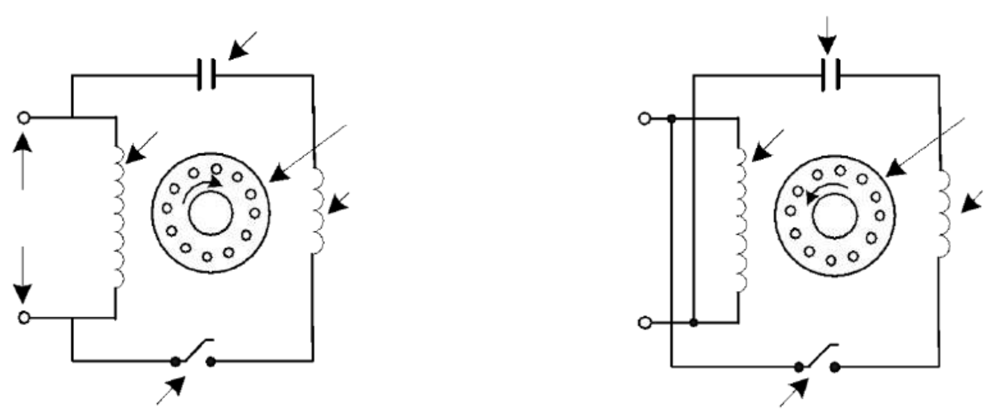


Figure 64. Connection of a capacitor-start induction-start run motor direction.

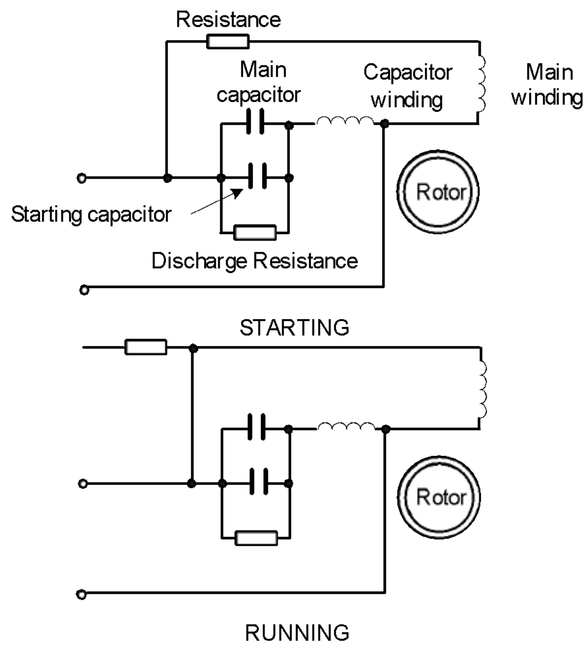


Figure 65. Single-phase capacitor start induction run.

Electrolytic capacitors have short duty service, and are easily damaged by frequent surge currents.

Therefore, the capacitor start-induction run motor is suitable for situations which require relatively few starts in a short period of time. Many manufacturers recommend that the motors be started less than 20 times in an hour.

Operation

The running winding of this motor is embedded in iron and therefore highly inductive. A capacitor of suitable size connected in the starting winding, causes a considerable phase difference between the currents in the two windings. The phase difference between these two currents gives the motor a high starting torque. It runs efficiently with fairly good power factor and its starting torque can be as high as three times its full load torque. It is essentially a constant speed machine and is used for light industrial work, office and domestic applications where better starting torque is required.

Capacitor start - Capacitor run motor

(i) Single-Capacitor Motor

This motor is known as capacitor start-capacitor run because the starting winding is left in the circuit during running. Figure 66 shows this type of motor with the centrifugal switch omitted meaning the motor continues running as a two phase machine. The running of this motor is smoother with good power factor but the capacitor and running winding be continuously rated. This motor is used where a high starting torque is not essential so that a lower value capacitor would be used for running continuously. It is mostly used in ventilating fans, small pumps, circulating pumps in central heating systems etc.

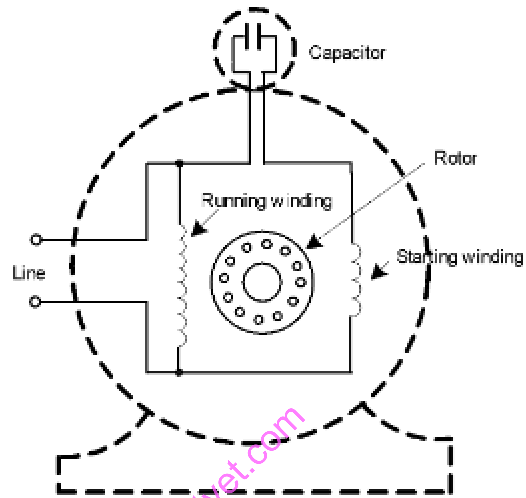


Figure 66. Connections in a single value capacitor-start, capacitor run motors

(ii) Two Value Capacitor Motor

This motor has two capacitors connected in parallel, and both connected in series with the starting winding as illustrated in figure 67. Usually an oil capacitor is connected permanently while an electrolytic capacitor is connected through a centrifugal switch. The motor starts with both capacitors in parallel and the switch opens the electrolytic capacitor when the motor has reached 75% of the rated speed. The motor then runs with the oil capacitor alone in series with the starting winding. This motor is a smooth running machine with high frequency, good power, and high starting torque with quiet running. It is used for light industries and office machines.

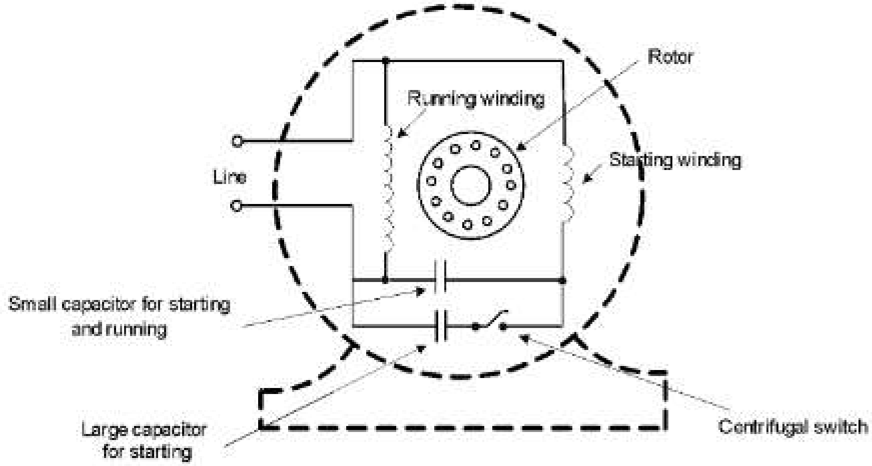


Figure 67. Internal connection of a two-value capacitor motor

Repulsion motors

Repulsion motors derive their names from the fact that they produce the torque required for rotation from the repulsion of two like poles. These motors have relatively high starting torque and draw less starting current than the other types of single phase motors.

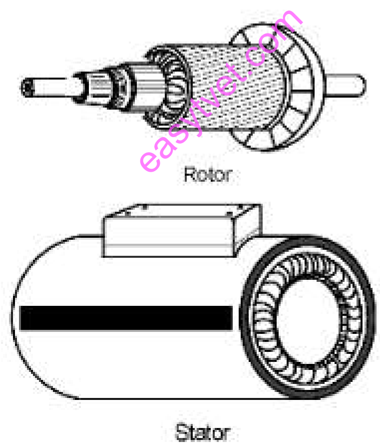


Figure 68. The main parts of a repulsion motor

Figure 68 illustrates the essential parts of a repulsion motor. These parts are;

(a) The stator, which has only one field winding similar to the running winding of single-phase motors. It usually contains four, six or eight poles.

(b) The rotor, which is the wound type. It has insulated copper windings and its terminations are connected to a commutator. Brushes ride on the commutator and short circuit the windings. Note that the rotor is not electrically connected to the ac source.

(c) The two end shields that house the bearings which support the rotor and the shaft

(d) The frame, whose purpose is to securely hold the stator core to which end-shields are bolted.

The construction of repulsion motors differs from split phase motors in that they have a wound rotor and the stator has only one type of field winding

Types of repulsion motors

There are three types of repulsion motors; these are the repulsion start- repulsion run motor, repulsion-start induction run and the repulsion induction motor. They are all reversible and have excellent starting torque.

(a) *Repulsion Start-Repulsion run motor.* This is the basic repulsion motor. Its speed can be varied by changing the value of the supply voltage. If all the mechanical load is removed, the motor will accelerate to a dangerous high speed called runaway speed. It is therefore used on permanent loads such as elevators.

(b) *Repulsion Start-Induction run motor.* This motor has a centrifugal device in the rotor. When the motor has attained approximately 75% of its rated speed, the centrifugal device passes a short-circuiting ring into the commutator, which short-circuits the commutator segments and current no longer flows through the brushes. The motor then runs as an induction motor. The motor has excellent starting torque and is reversible. The motor is used in commercial refrigerators, compressors and pumps.

(c) *Repulsion-Induction motor.* This type of repulsion motor has a squirrel cage winding on the rotor under the regular wound winding, as shown in figure 69. The added winding is inductive and serves to limit the no-load speed when the motor speeds above the synchronous speed. The motor has fairly constant speed from no-load speed because of the squirrel-cage winding. The motor does not have a centrifugal switch and therefore needs little maintenance and repairs. It starts as a repulsion motor and runs as an induction motor.

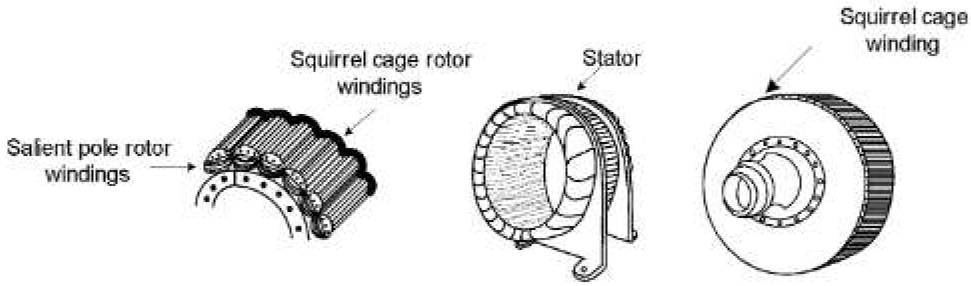


Figure 69 Details of the rotor of a repulsion-induction motor

Shaded pole motor

The shaded pole motor is a fractional kilowatt motor. It belongs to the group of split-phase motors. The motor does not have the regular starting winding, centrifugal switch or starter mechanism. The motor has a squirrel cage rotor. However, a short circuit ring is mounted around about a third of the pole area of each stator pole. The area covered by the ring is called the shaded pole and the ring is called the sheading coil. All the poles are shaded on the same side, and the shading coil is made of low resistance copper. Figure 70 shows a typical shaded pole motor.

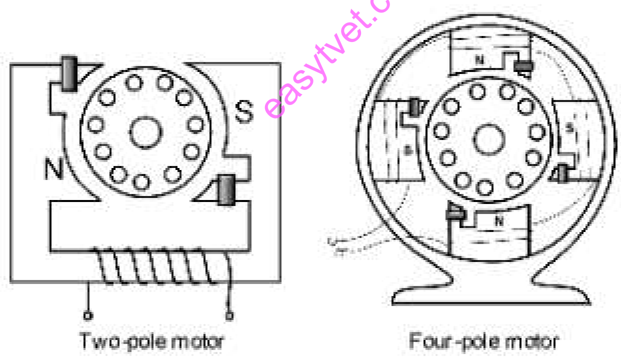


Figure 70 Shaded pole motor

Operation

The shading coil causes the building up and the collapse of magnetic field around the shaded pole to lag by opposing the change of current through it. This creates a shifting magnetic field along the surface of the pole.

UNIVERSAL MOTOR

Universal motor, also known as the series motor, is designed to operate on either single-phase alternating current or direct current. Figure 71 illustrates the main parts of the motor.

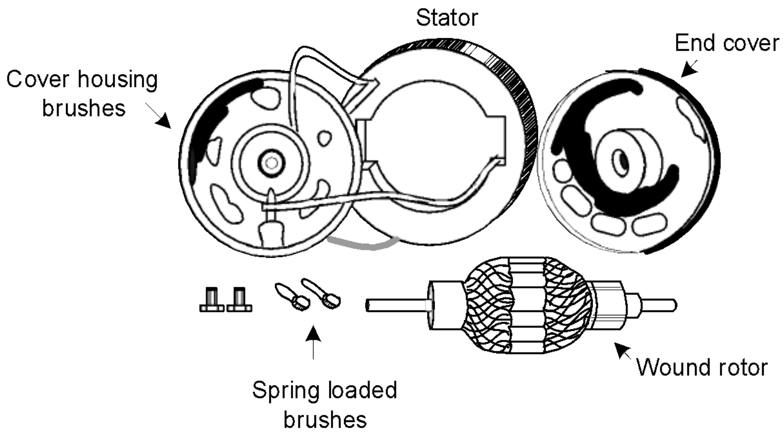


Figure 71 the main parts of a universal motor

The frame is made of cast Aluminium, cast iron or rolled steel. Two end shields, made of steel, serve the same purpose as in other motors. The stator is made of steel laminations securely held together and bolted to the frame. The rotor consists of a cylindrical core of steel laminations with longitudinal slots into which insulated copper windings are wound. The windings are wound in such a way that they create two opposite poles in the stator. The rotor windings are connected to commutator segments. Two carbon brushes ride on the commutator, and are connected to the field winding.

Operation

Stator and rotor windings are connected in series as shown in figure 72.

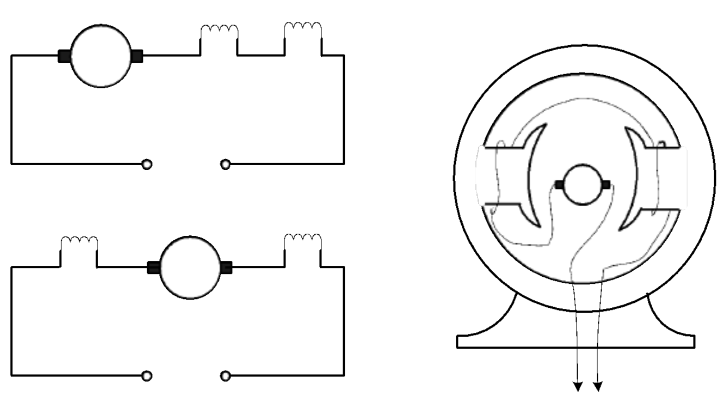


Figure 72 Series connected of field and rotor windings of a universal motor

When the motor is connected to single phase ac supply, the same amount of current flows through both the field and rotor windings because they are in series. By the method of connections, the magnetic field set up in the rotor will have the same polarity as the poles close to it. The two like poles will repel and produce torque, and the rotor therefore rotates, this is similar to torque production in a repulsion motor.

Universal motors are variable speed motors. The speed depends on the voltage applied and the load. The motor has very high starting torque. They are widely used in portable commercial such as saws, drills, grinders and sanders, domestic appliances such as food mixers, sewing machines and vacuum cleaners. They usually cause radio and TV interference because of sparking at the brushes. To obtain variable speeds, control rheostats, impedance coils tapped windings or centrifugal devices are used. The motors may achieve excessive high speeds and therefore they are normally started and operated with the load connected. The direction of rotation is changed by reversing either the field or armature connections

5.2.4.4 Learning activities

Field/Visit to an electrical Installation company

Visit Objective/Aim	Indicators	Special Instruction
To establish types of final circuits used during installation works	- Wiring systems used - Types of final circuits	-Take notes -Observe keenly types of final circuits - Observe keenly types of final circuits

Practical Assignment

Visit Objective/Aim	Indicators	Special Instruction
To experience and learn real electrical installation works	- Tools used - Procedures followed	Participate in real electrical installation work

5.2.4.5 Self-Assessment

1. What is a final power circuit?
2. Describe Consumer intake point
3. What are the requirements of a consumer intake point?
4. With the aid of a diagram, describe ring power circuit.

5. Which of the following is not part of a domestic consumer control unit?
   A. Neutral block
   B. Battery
   C. Double pole switch
   D. Earthing block/ terminal
6. When carrying out electrical installation work in a storey building, the following are safety measures to be observed except?
   A. Wearing of fitting suit with a proper neck tie
   B. Putting on helmets
   C. Wearing of safety boots
   D. Using properly insulated tools
7. A domestic consumer is usually supplied with a single-phase supply, what is the approximate value of supply voltage in this case?
   A. 415v
   B. 400v
   C. 240v
   D. 110v

5.2.4.5 Tools, Equipment, Supplies and Materials

5.2.4.6 References

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5.2.4.7 Answers to Self-Assessment

Apply and Adhere to Safety

1. *Dangers of electricity*
   - *Electric shock*
   - *Electrical burns*
   - *Fire*
2. *When a person gets into contact with a live wire and gets an electric shock, the following steps should be followed to save the victim:*
   i. *Use a dry insulator to remove the victim from electrical contact.*
   ii. *Take the victim away from the place where the shock occurred.*
   iii. *If the victim has stopped breathing lay he/she flat on the ground then apply first aid by KISS OF LIFE method of artificial respiration as follows.*
   iv. *Call for medical help*
3. *FOUR types of fire extinguishers.*
   i. *Dry water mist*
   ii. *Foam Extinguishers*
   iii. *Carbon Dioxide (CO_2) Extinguishers*
   iv. *Wet Chemical Extinguishers*
4. *Importance of wearing the following protective clothing in a work environment:*

i. Helmet – *To prevent head injury*

ii. Gloves – *To prevent hands from injuries/electric shock*

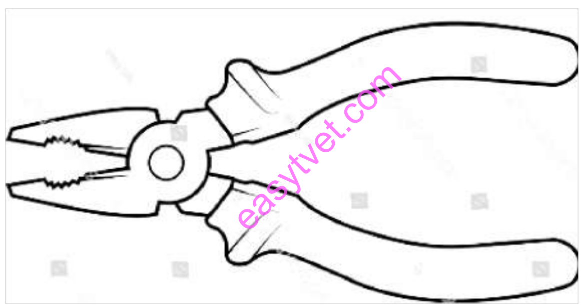
iii. Goggles – *to prevent eyes from injury*

iv. Safety boots – *To prevent foot injuries from sharp objects*

v. Dust coat – *To prevent soiling of inner clothing and injuries from rotating machines*

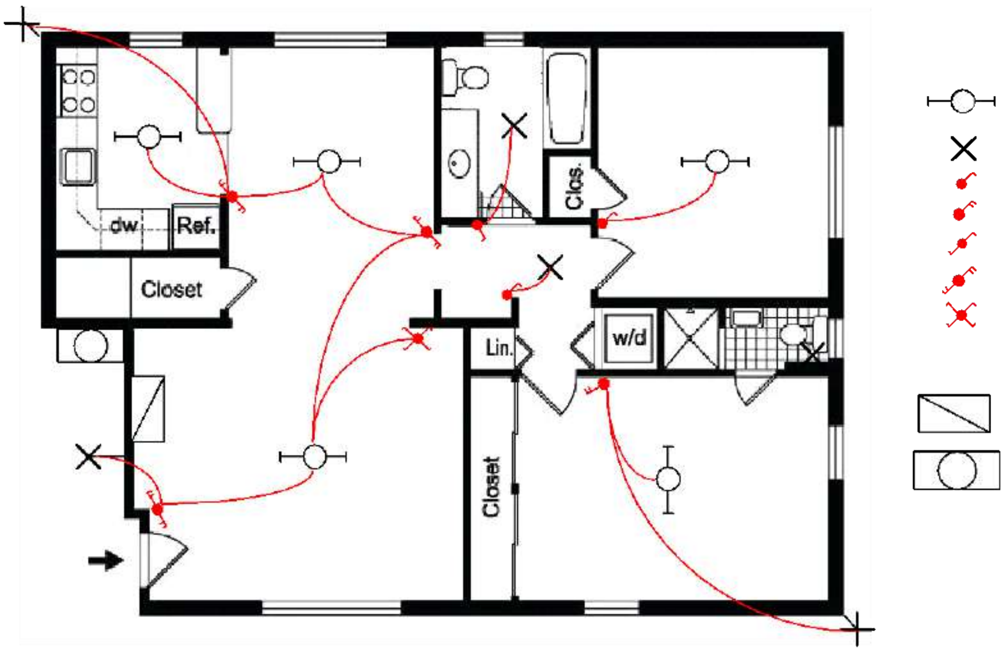
Prepare working Drawings

1. *A layout diagram shows the components position while a wiring diagram shows the actual wiring of the same components.*
2. *HB, 2H, 3H, H, B*
3. Sketch of combination pliers

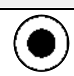
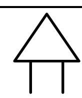
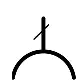
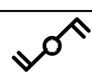
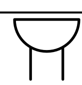
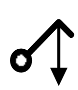
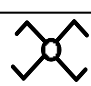


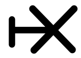
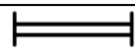
4. A

5. Lighting scheme and its switching arrangement.



6.

S/N	Symbol	Description
11.		Push button
12.		Siren
13.		Unswitched Twin socket outlet
14.		Two-way, 2 gang switch
15.		Buzzer
16.		Cord operated switch
17.		

		Intermediate switch
18.		Wall mounted switch
19.		Consumer control unit
20.		Twin Fluorescent fitting

Prepare Tools, Equipment & Materials

1. Tools used in electrical installation work (any four)
   i. *Combination pliers*
   ii. *Long nose pliers*
   iii. *Hacksaw*
   iv. *File*
   v. *Stock and die*
   vi. *Fish/draw wire*
   vii. *Screw driver*
   viii. *Measuring tape*
   ix. *Ladder*
   x. *Drilling machine*
   xi. *Bench vice*
   xii. *Reamer*

2. *How to calibrate a digital multimeter*
   (a) *Set the multimeter to the highest resistance range by turning the dial to the highest "ohm" setting.*
   (b) *Touch the test probes of your digital multimeter together.*
   (c) *Press the calibration knob until the display reads "0" on the digital multimeter if you don't see "0 ohms" initially.*
3. *Importance of calibrating multimeter.*
   A digital Multimeter is one of the most commonly used pieces of test and measurement instrumentation. Quality processes depend on its continual proper operation. However, time,

environment, and physical use (or abuses) change a digital multimeter's characteristics. That's why it's important to periodically calibrate or verify the performance of a digital multimeter. A multimeter should be calibrated or adjusted to a known zero-value prior to use for accurate readings.

4. B
5. B
6. *Tools used in break down maintenance*
   i. *Ladder*
   ii. *Hammer*
   iii. *Pliers*
   iv. *Screw drivers e.t.c*

Perform electrical Installation

1. Final power circuit

   A final power sub-circuit is a circuit that allows electrical appliances to access electrical power.

   All final sub-circuits must be electrically separate that is there must be no "bunching" of neutral conductors.

2. Consumer intake point

   This is the point where the electricity power supplier terminates the service line to the consumer's premises. It is commonly known as a meter box or power house.

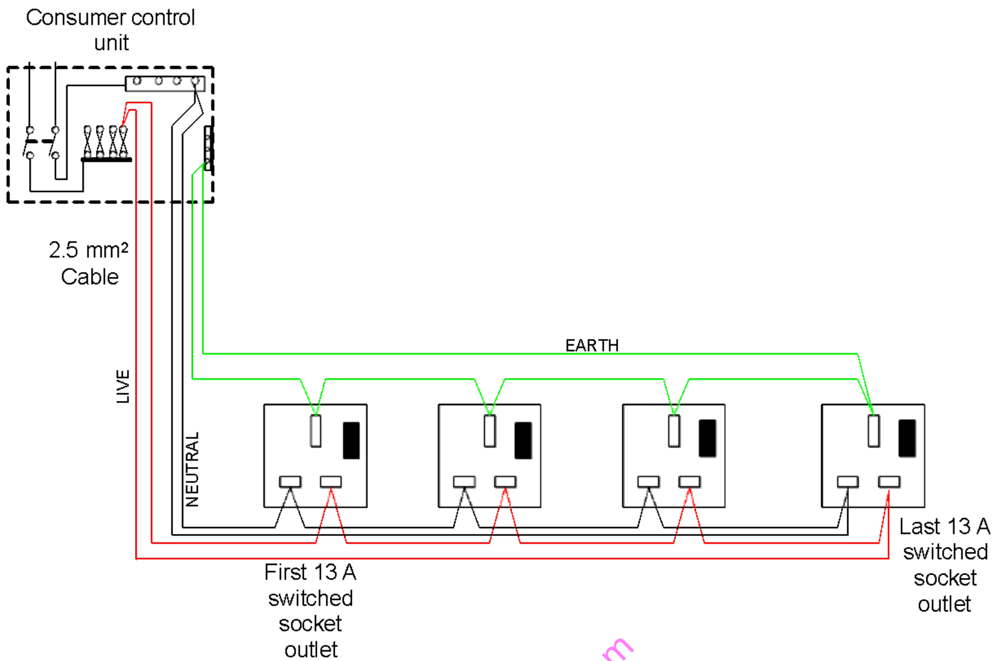
3. Requirements of a consumer intake point?

   The IEE regulations requires that, every consumer's installation shall be adequately controlled by a switchgear readily accessible to the consumer which shall incorporate-

   i) *Means of isolating all the conductors of the installation of the premises from the supply.*
   ii) *Means of excess current protection.*
   iii) *Means of earth leakage protection.*

4. Ring power circuit.

A ring circuit is defined in the I.E.E. Regulations as " a final sub-circuit in which the current-carrying and the earth-continuity conductors are connected in the form of a loop, both ends of which are connected to a single way in a distribution board or its equivalent.



Advantages of a ring circuit over a Radial circuit

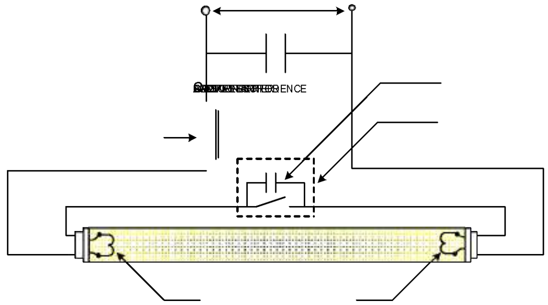
- i. *There is total safety in ring circuit than in Radial for the circuit is in form of a ring*
- ii. *An open circuit point in the Ring circuit will not affect any other socket in the system This is because there are two paths of current and is one path is open the current will flow through the other*
- iii. *Smaller sizes of cables may be used in Ring than in a Radial. This is because the Ring has two parallel current paths*
- iv. *More loads may be fed or connected to a Ring circuit than a Radial circuit of the same capacity*

Disadvantages of Ring over Radial

- i. *More cables lengths requires in a Ring than in Radial therefore becomes more expensive*
- ii. *It consumes more time to install a Ring circuit than Radial because more cables has to be installed.*

5. Glow type method of starting a fluorescent lamp

i. The glow type



- *The starter contains of a small bulb filled helium gas and containing two contacts, one contact is mounted on a bi-metallic strip. The two contacts are normally open such that when the mains supply is switched ON, full mains voltage is applied to the starter contacts.*
- *This causes a glow discharge which warms the bimetallic strip which eventually bends closing the starter contacts.*
- *Once the starter contacts closes, full heating current flows through the lamp electrodes. After sometime the bimetallic strip cools to open the circuit thus striking the lamp. A tiny capacitor is connected across the starter switch to suppress radio interference*

7. B
8. A
9. C