



MINISTRY OF EDUCATION

Electrical and Electronics Technology (Applied Technology)

for Senior High Schools

TEACHER MANUAL

YEAR 2



NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION



REPUBLIC OF GHANA

Electrical and Electronics Technology

(Applied Technology)

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Year Two



**NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION**

ELECTRICAL AND ELECTRONICS TECHNOLOGY TEACHER MANUAL

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Introduction

The National Council for Curriculum and Assessment (NaCCA) has developed a new Senior High School (SHS) curriculum which aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, competencies, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, further their education and enter the world of work.

This is the first time that Ghana has developed an SHS Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

This Teacher Manual for Electrical and Electronics Technology (Applied Technology) is a single reference document which covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively teach Year Two of the new curriculum. It contains information for all 24 weeks of Year Two including the nine key assessments required for the Student Transcript Portal (STP).

Thank you for your continued efforts in teaching our children to become responsible citizens.

It is our belief that, if implemented effectively, this new curriculum will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

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SECTION 1: DOMESTIC INSTALLATION

The section covers the following units (strands) for Electrical technology and Electronics technology.

In this section learners will acquire knowledge and understanding the processes involved in house wiring and classification of tools and equipment used in wiring and their functions as well as the sequence of supply-control equipment on a consumer's premises. All the above are treated from unit 1 to unit 4.

UNIT 1

STRAND: ELECTRICAL TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

HINT



- Assign Group Project in Week 2. This should be submitted after week 7. Refer to Teacher Assessment Manual and Toolkit pages 27–29 for how to conduct Project-Based Assessment. Refer to **Appendix A** which has been provided at the end of the section for the structure and rubrics of the group project.
- Assign Portfolio Assessment for the Academic Year by Week 3. Portfolio to be submitted by week 23. Refer to the Teacher Assessment Manual and Toolkit pages 22–25 for information on how to conduct Portfolio Assessment. Refer to **Appendix B** which has been provided at the end of the section for the structure and mark scheme/rubrics of the group project.

INTRODUCTION AND SECTION SUMMARY

This section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through introduction to the following: the definition and importance of house

wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection, It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting relevant tests on an installation work.

*The unit covers only week 2: **Explain house wiring and the processes involved in house wiring.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspects of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, and Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 1

Learning Indicator: *Explain house wiring and provide reasons for doing good house wiring*

Focal Area 1: Definition of House Wiring, Reasons for Good House Wiring, Planning for Good House Wiring and The Processes Involved in Good House Wiring

Definition of House Wiring

House wiring refers to the installation of electrical wiring system in a house in order to provide power to the various appliances in the house.



Figure 1.1: *Wiring being carried out*

Reasons for Good House Wiring

The following are the reasons for good house wiring

1. **Safety:** Well-crafted house wiring reduces the risk of electrical hazards such as short circuits, electric shocks and electrical fires.
2. **Functionality:** Good house wiring contributes to the satisfactory operation of electrical appliances and devices.
3. **Convenience:** Good house wiring provides convenience as a result of efficient use of electrical devices throughout the house and strategic placement of power outlets and other fixtures.
4. **Compliance:** Paying attention to building codes and regulation in house wiring seeks to achieve safety standards and satisfy legal requirements.

Planning for Good House Wiring

Steps involved in planning for good house wiring are as follows

1. Assess the electrical needs of the household by determining the number and locations of the outlets, switches, appliances and other fixtures needed for each room.
2. Create a wiring layout based on the building plan.
3. Calculate the load requirement by determining the total wattage of all appliances and devices that will be connected to each circuit taking into consideration the load bearing capacity of the electrical panel to avoid overloading.
4. Select appropriate wiring materials by choosing the right type and gauge of cables for wiring different circuits.
5. Plan circuit distribution by separating high power appliances from low power appliances.
6. Consider safety measures by adhering strictly to the IEE regulations while employing the services of a licenced electrician.
7. Develop a timeline for the completion of the wiring plan.

Processes Involved in Doing Good House Wiring

The following are the processes involved in house wiring

1. Planning and design: Before initiating any house wiring activity you should first have a detailed plan which should include the wiring diagram showing the location of the various outlets and the load requirements with the respective ratings.
2. Mark out areas cables will pass and chisel out if necessary.
3. Install conduits or trunking depending on which is applicable.
4. Run or draw in cables.
5. Fix accessories as required.
6. Install supply-control equipment (cut-out fuse, provision for meter, mains switch and distribution board) and complete termination.
7. Install the earth electrode.
8. Conduct relevant tests (continuity test, polarity test, insulation resistance test and earth electrode resistance test).
9. Connect installation to the main power supply and switch on power.
10. Check system for any defects that may arise and rectify them.



Figure 1.2: *Wiring of supply- control equipment*

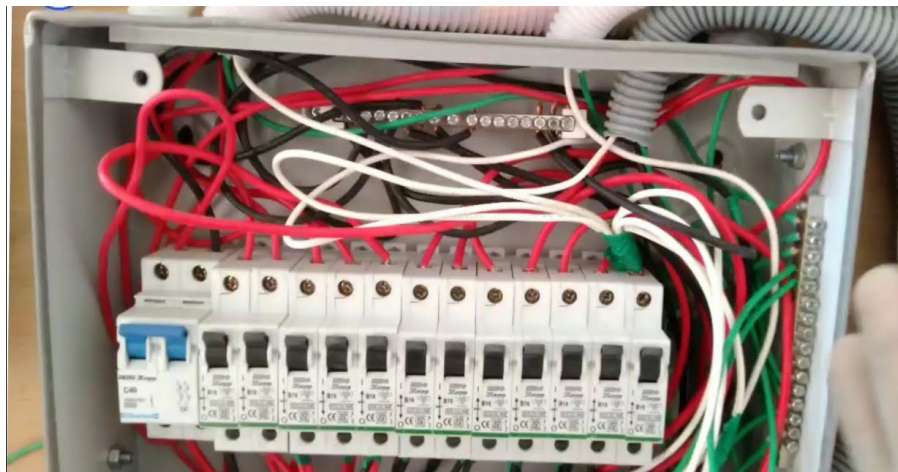


Figure 1.3: *A Typical 12-way Distribution Board*

Learning Tasks

1. Explain what is meant by house wiring.
2. Describe the processes involved in house wiring.

PEDAGOGICAL EXEMPLARS

1. **Talk for learning approaches:** Guide learners through discussion to brainstorm the meaning of house wiring making sure that all learners take part in the discussion. Teachers should ask leading questions to ensure the discussion for the concept of house wiring is clearly understood.
2. **Group Work/Collaborative Learning:** Put learners into mixed-ability groups and task each group to come out with at least two processes involved in wiring a house after

watching a video on processes involved in wiring a wire. Summarise and detail the various processes on the board.

KEY ASSESSMENT

Level 1: Define house wiring.

Level 2

1. Describe the processes involved in house wiring.
2. Describe two benefits of safely wiring a house.
3. Explain the concept of house wiring.

Level 3: Write out the steps involved in house wiring.

HINT



*The recommended mode of assessment for week 1 is **class exercise**. Use the level 2 question 3 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 63 for additional information on how to use this mode of assessment.*

UNIT 1 REVIEW

This unit introduced learners to the concept of house wiring and the processes involved in wiring a new house. The pedagogical exemplars used in this unit includes Talk for learning approaches and Groupwork/Collaborative learning. These strategies are expected to instil in learners the skills of communication, collaboration, critical thinking and problem solving. Various assessment strategies such as oral/written presentations, class exercises, homework and practical group activities are structured to take care of varied activities of learning. These assessments are classified under DOK Level 1, 2 and 3.

UNIT 2

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through the following; the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 2: Classify tools and equipment used in wiring and their functions.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstrations on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real situations hence the assessment should cover all the levels. Teachers should employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 2

Learning Indicator: Describe tools and equipment used for house wiring

Focal Area 1: Tools and Equipment Used in House Wiring

In carrying out their duties, the electrician is always repairing, installing or troubleshooting faults in electrical circuits and equipment. The items they use to carry out these responsibilities are referred to as tools and equipment. These are different from materials because materials are consumed in the work that is done.

Electrical Tools and Equipment May Be Grouped into The Following Classes

1. **Basic Hand Tools:** Basic hand tools are the most essential tools of the electrician which they use almost all the time. Basic hand tools include the following
 - a. **Screwdrivers:** Various types
 - b. **Pliers:** Various type
 - c. Side-cutting pliers
 - d. Wire strippers
 - e. Cable cutters
 - f. Utility knife
 - g. Measuring tape
 - h. Level
 - i. Hammer
 - j. Fish tape
 - k. Voltage tester



Figure 1.4: Basic Electrician's Hand Tools

2. **Power / Machine Tools:** Power Tools are tools that are powered by electricity. They require less effort from the electrician but are highly efficient and more precise. Power tools include the following:
- a. Impact driver
 - b. Wall chaser machine
 - c. Power chisel
 - d. Drill/driver
 - e. Rotary hammer
 - f. Jigsaw
 - g. Angle grinder



Figure 1.5: *Basic Electrician's Power Tools*

3. **Testing and Measuring Equipment:** This is equipment used in conducting tests, taking measurements and checking the availability of power. They include the following:
- a. Multimeter
 - b. Clamp meter
 - c. Insulation resistance tester
 - d. Circuit tester
 - e. Continuity tester
 - f. Non-contact voltage detector



Figure 1.6: *Testing and Measuring equipment*

4. **Safety Equipment:** This is equipment that provides safety for the electrician, equipment and the environment as a whole. Safety Equipment includes the following:
 - a. Ear protection
 - b. Fire extinguisher
 - c. Face shield
 - d. Insulated gloves
 - e. Safety glasses
 - f. Hard hat



Figure 1.7: *Safety equipment*

5. **Special Tools**
 - a. Crimping tool
 - b. Cable stapler
 - c. Conduit bender

Functions of Tools and Equipment

Some tools and equipment and their functions are as follows:

1. **Screwdrivers (various types):** Used for tightening and removing screws.
2. **Wire strippers:** For stripping the insulation off wires.
3. **Cable cutters:** For cutting electrical cables and wires.
4. **Utility knife:** For general cutting tasks.
5. **Measuring tape:** For measuring distances and lengths of wire.
6. **Spirit Level:** To ensure installations are level and plumb.
7. **Hammer:** For driving nails or securing items.
8. **Fish tape:** For pulling wire through conduits.
9. **Voltage tester:** To test for the presence of electrical current.
10. **Drill/driver:** For drilling holes and driving screws.
11. **Rotary hammer:** For drilling into concrete and masonry.
12. **Jigsaw:** For cutting shapes and holes in panels and other materials.

13. **Angle grinder:** For cutting, grinding, and polishing metal and other materials.
14. **Impact driver:** For driving screws and bolts with high torque.
15. **Wall chaser machine:** For cutting channels in walls for electrical cables.
16. **Power chisel:** For chiseling and carving tasks, especially in masonry and concrete.
17. **Multi-meter:** For measuring voltage, current, and resistance.
18. **Clamp meter:** For measuring current without direct contact.
19. **Insulation resistance tester (Megger):** For testing insulation resistance.
20. **Circuit tester:** For checking the functionality of electrical circuits.
21. **Continuity tester:** For checking if a circuit is complete.
22. **Non-contact voltage detector:** For detecting voltage without touching wires.
23. **Conduit bender:** For bending electrical conduits.
24. **Cable puller:** For pulling cable through conduits.
25. **Punch down tool:** For terminating wire into punch-down blocks.
26. **Crimping tool:** For crimping connectors onto cables.
27. **Cable stapler:** For securing cables to wooden structures.
28. **Insulated gloves:** To protect hands from electrical shocks.
29. **Safety glasses:** To protect eyes from debris and sparks.
30. **Hard hat:** For head protection on construction sites.
31. **Ear protection:** For protecting ears from loud noises.
32. **Fire extinguisher:** For handling electrical fires.
33. **Face shield:** For protection against sparks and flying debris.

Care and Maintenance of Tools and Equipment

It is very important to keep tools and equipment in perfect working condition all the time. The following points must be noted to prolong their lifespan.

1. **Always use the appropriate tool for each job:** Every job that is to be done requires the use of a specific tool or item of equipment. It is therefore important to use the appropriate tool for each job. For instance, using a flat screwdriver to remove a star screw is inappropriate.
2. **Regular Cleaning of Tools:** Most tools and equipment are prone to collecting dirt and grease. This could accelerate their rate of damage. Most electrical tools are also prone to rust, particularly when dirt clings on metal, as it traps moisture which, in turn, can promote rusting. Cleaning these tools regularly can minimize or eliminate rust.

Dirt also leads to sharp edges of cutting tools becoming blunt. Tiny bits of dirt particles can also abrade the tools and reduce their precision.

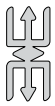
To clean tools properly, first brush off loose dirt with a dry cloth or soft brush, then use appropriate cleaning agents to remove the grease. For power tools, it is appropriate to

use an air compressor and carefully blow a gust of air through the tubes, vents, and crevices to remove the dirt within. Ideally, all tools should be cleaned after every use, and should be properly dry before storage, especially if they have been cleaned with a liquid.

3. **Correct Storage:** Correct storage is just as important as regular cleaning. In fact, one of the best practices for caring for hand and power tools is ensuring they are spotless before putting them away. The reasons are the same as above: to prevent rusting and to keep your tools in great shape for as long as possible. The best place for storing power and hand tools is anywhere that's dry and away from dust and others like elements that could potentially harm the tools' metal and wiring parts. A better approach is to store the smaller tools in a large toolbox with compartments.
4. **Lubricating tools that need it:** Some tools have moving parts that rub on metal surfaces. Typical examples are circular saws, adjustable wrenches and die sets. Without lubricating oil, the tools can wear down quickly, starting from the point of contact. It is important to note that lubrication is different from the grease that accumulate on tool surfaces. Dirty grease is bad for the tools, while lubricants or basic machine oil are formulated specifically to assist the tool. Despite that, the lubricants must be applied sparingly as too much would turn it into dirt-trapping grease.
5. **Checking tools for damage:** It is best practice to regularly check for damage to your tools, especially the ones that run on electricity. Always look out for loose cable joints, exposed wires and blunt points or edges, bearing in mind that defects in the electrical wiring are fire and safety hazards, so you need to be very cautious when using power tools.
6. **Check the Cords of power appliances:** It is very important to always check for damage to the insulation of electrical cables. There can be damage to the insulation, and you should look out for loose wires. This will ensure that your electric tool can get the power that it needs to function without an accident. Clean the cords frequently to make sure they are not damaged by oil and grease and that all terminals are sound, and the casing is intact.

Learning Tasks

1. What are the tools and equipment used in electrical operations?
3. What is the difference between tools and materials used in electrical operations?
4. Electrical tools and equipment can be put into groups. Identify any 3 groups and provide 4 tools under each group.
5. Explain the functions of any 5 electrical tools.
6. Describe any 4 actions you can take to keep your tools in a perfect working condition

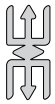


Note

1. Learners with special educational and support needs should be given more time to complete a given task.
2. During presentations, ensure that everyone, regardless of their background, is encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain tools and equipment and differentiate between tools and materials used in house wiring.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to identify 3 groups of tools and equipment and provide 4 tools under each of them. Encourage learners to pool their knowledge and skills to brainstorm and research and explain the functions of any 10 tools. Learners should also explore the various ways they take care of tools and equipment.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to demonstrate practically, and how to identify defects in power tools especially, the cords. Challenge them to come up with what specifically to look out for when inspecting power cords for defects.

Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps to take when carrying out maintenance of electrical tools and equipment.

Additionally, they will collaboratively brainstorm and discuss care and maintenance measures, drawing from their simulated experiences to reinforce understanding of maintenance procedures. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply maintenance in real-world contexts.

KEY ASSESSMENT

Level 1

1. Identify any four groups of electrical tools and equipment employed in house wiring.
2. List 5 hand tools and 5 power tools used in house wiring

Level 2

1. What is the difference between electrical tools and electrical materials?
2. Explain the functions of any 3 measuring tools.
3. Describe the appropriate process of cleaning electrical tools
4. Discuss 2 differences between electrical tools and electrical materials

Level 3

1. Why do you think measuring tools are indispensable to the electrician?
2. Compare and contrast hand tools and power tools in terms of performance?
3. The electrician can carry out their work without safety equipment, therefore that equipment is not necessary. Explain why this is incorrect.
4. How do you identify defects in the power cord of a power tool?

HINT

*Assign Group Project in Week 2. This should be submitted after week 7. Refer to Teacher Assessment Manual and Toolkit pages 27–29 for how to conduct Project-Based Assessment. Refer to **Appendix A** which has been provided at the end of the section for the structure and rubrics of the group project.*

UNIT 2 REVIEW

This unit introduced learners to the tools and equipment employed in house wiring. The tools have been categorised into Hand Tools, Power Tools, Testing and Measuring Equipment, Safety Tools and Special Tools. The function of each tool and how to carry out maintenance on them to prolong their lifespan have equally been discussed. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities

UNIT 3

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at Domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following: the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

*The unit covers only week 3: **Identify the various materials and accessories used for house wiring.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstrations on the various aspects of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situations: hence, the assessment should cover all levels. Teachers should therefore employ a variety of formative assessment strategies, both oral and written, to collect data from learners' progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 3

Learning Indicator: *Identify the various materials and accessories used for house wiring*

Focal Area 1: Materials and Accessories for House Wiring

The following are examples of materials and accessories used in house wiring:

1. Conductors
2. Insulators
3. Wire connectors
4. Junction boxes
5. Switches and outlets
6. Electrical tape
7. Circuit breakers
8. Cable clips and staples
9. Conduit
10. Grounding rods and clamps.
11. Plugs



Figure 1.8: *Examples of materials and accessories*

Uses of materials and accessories in house wiring

1. **Conductors:** usually made of copper and are used to carry electrical power from one point to another within an electrical system.
2. **Insulators:** they are materials of high resistivity value used to encase and protect conductors from coming into contact with other conductive materials. Insulators are also used to provide mechanical support and protection to the conductors.
3. **Wire connectors:** they are used to join and secure electrical wires firmly together.
4. **Junction boxes:** they are used to house electrical connections and protect them from damage.
5. **Switches and outlets:** these materials are used to provide connection points for electrical devices and appliances.
6. **Electric tape:** this material is used to provide insulation to electrical connections and enhance protection.
7. **Circuit breakers:** these materials are essential for the protection of the general electrical system against electrical overloads and shock circuits.
8. **Cable clips and staples:** they are used to organise and hold firmly routed cables.
9. **Conduits:** they are protective tubes used to encase electrical wires and provide extra safety.
10. **Grounding rods and clamps:** they are used to ensure proper grounding of the general electrical system to prevent electrical shock and other electrical hazards.

Table 1: Current carrying capacity of various cable sizes

Size of cable(mm ²)	Surface (Amps)	Conduit (Amps)
1.5	16	13
2.5	23	18
4	30	24
6	38	31
10	51	42
16	68	56

Learning Tasks

1. List six materials and accessories used in house wiring.
2. Describe the importance of five materials and accessories used in house wiring.
3. Discuss the correct gauges of cables used in lighting and socket outlets wiring.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning/Collaborative Learning:** In mixed ability or mixed-gender groups, guide learners to undertake the following activities: Identify materials and accessories required for carrying out house wiring and state the purpose of each of them.
2. **Problem-Based Learning:** Guide learners to work in pairs to determine the current-carrying capacity of various cables.

KEY ASSESSMENT

Level 1: List six materials and accessories used in house wiring.

Level 2: Describe the importance of five materials and accessories used in house wiring.

Level 3

1. Discuss the correct gauges of cables used in lighting and socket outlet wiring.
2. The importance of materials and accessories used in house wiring.

Scenario: Madam Kiiki's house was wired using cables with weak insulation: Identify two possible effects of this wiring system when put to use.

HINT



*Assign Portfolio Assessment for the Academic Year by Week 3. Portfolio to be submitted by week 23. Refer to the Teacher Assessment Manual and Toolkit pages 22–25 for information on how to conduct Portfolio Assessment. Refer to **Appendix B** which has been provided at the end of the section for the structure and mark scheme/rubrics of the group project.*

UNIT 3 REVIEW

This unit covered the materials and accessories required to carry out a good house wiring as well as the purpose of each of the materials and accessories with emphasis been laid on the current-carrying capacity of various sizes of cables in wiring for safe and workable installation work.

UNIT 4

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared toward equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through coverage of the following: the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection, wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

*The unit covers only week 4: **Describe the sequence of Supply-control equipment on a Consumer's Premises.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 4

Learning Indicator: Describe the sequence of Supply-control equipment on a Consumer's Premises

Focal Area 1: Supply Control Equipment on A Consumer's Premises

In providing power to a consumer, steps must be taken to ensure the power can be controlled. This is to ensure that in times of danger the supply can be switched off. Maintenance work can also be carried out in the house without having to switch off power to the entire locality. This calls for supply-control equipment provision, and that is discussed in this section. In distributing power to consumers whether large or small the position of the supply intake devices (equipment for controlling as well as providing protection to the installation) needs to be agreed upon by both the supply authorities and the electrical installation contractor. This is to ensure that the position is convenient to make it economical for both parties. The meter's position is equally important because readers must always have unimpeded access to it at any time.

1. **The supply cutout fuse:** This is a combination of a fuse and a switch, used to protect distribution transformers from current surges and overloads. A typical cutout fuse is shown in *Figure 1.6*

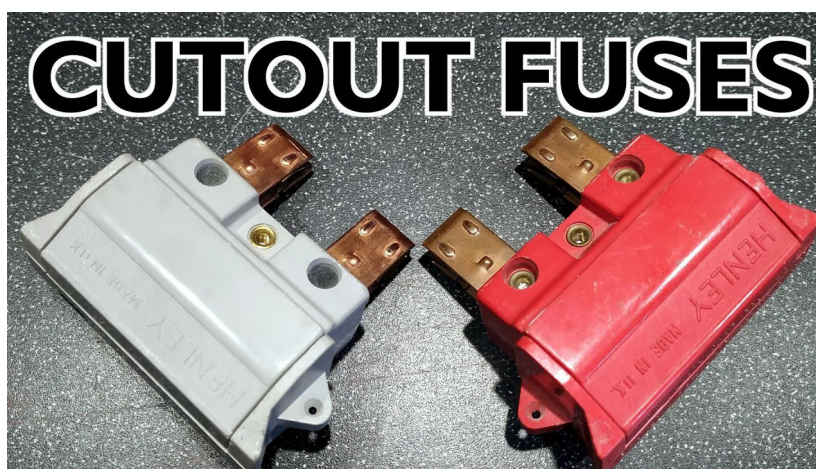


Figure 1.9: A typical cutout fuse

(Source: Cutout Fuses, Red links, Distribution and Building Network Operations)

2. **The Meter:** The meter is a device that measures the amount of electrical energy a residence, a business, or an electrically powered device consumes over a specific period. They are usually installed at the customers' premises and used to monitor electrical energy consumption, which is then used to bill them at the end of the month. They are usually calibrated in Kilowatt hour (KWh) The following shows a typical single-phase meter.

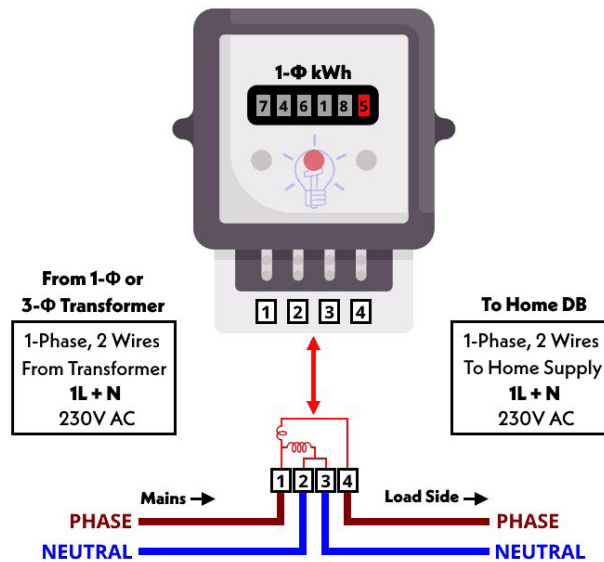


Figure 1.10: A single-phase meter

3. **Isolator (Switchgear):** The isolator is a device used to disconnect an installation from the supply, particularly for maintenance purposes. Some incorporate protective devices to protect the installation.



Figure 1.11: A single-phase isolator

4. **Distribution Board:** The Distribution Board is the final device in the supply–control equipment. It is the intermediary between the isolator and power-consuming devices in the installation.

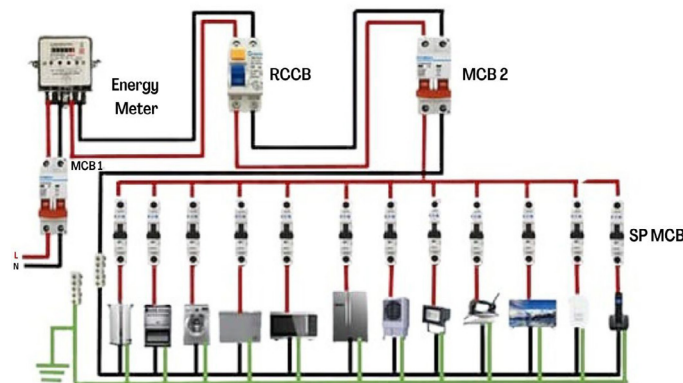


Figure 1.12: Single Phase Distribution Board wiring | distribution board wiring



Figure 1.13: Picture of a DB

Sequence of the Supply – Control Equipment

The sequence of the supply–control equipment on a consumer’s premises is as follows:

1. Supply Cutout Fuse
2. Meter
3. Mains Switch (Mains Isolator). In some cases, an Earth Leakage Circuit Breaker (ELCB) is incorporated
4. Distribution Board

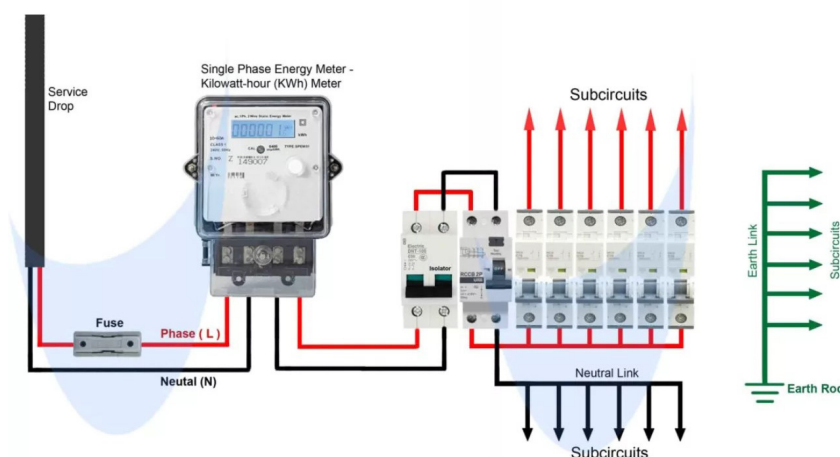


Figure 1.14: Sequence of Supply-Control Equipment

Functions of the various Equipment

The function of the various Equipment is as follows:

1. **The Supply Cutout Fuse:** This fuse protects the entire installation in times of dangerous current flowing in the installation. It also isolates the supply during maintenance of the meter to protect the electrician from electric shock.
2. **The Meter:** The meter measures the amount of power or energy consumed over a period. It is usually installed at the customers’ premises and used to monitor electrical energy consumption, which is then used to bill them at the end of the month. They are usually calibrated in Kilowatt hours (KWh). It must be noted, however, that even though the meter is installed on the customer’s premises, it belongs to the supply authorities and must never be tampered with by the customer. Any such actions warrant prosecution.

3. **The Isolator (Mains Switch or Switchgear):** After the meter, comes the main switch, which must be of double pole type. It should isolate the installation completely from the supply when the switch is turned off. A moulded-case circuit breaker, however, is used in large installations. This not only serves as a switch but also serves as protection against faulty current.

All of the equipment responsible for switching off power manually and automatically, under both normal and abnormal conditions, is referred to as switchgear. It includes isolators and circuit breakers. The supply to a consumer can be single phase or three-phase depending on the equipment to be used, and the total load. Whatever the size of the installation, there must be provision for effective control and protection. The type and size of the switchgear to be installed depends on the type and size of the installation and its total load. This switchgear performs the following functions:

- a. Isolates the entire installation from the supply (both live and neutral should be easily isolated)
 - b. Provides excess current protection
 - c. Provides protection against earth leakage.
4. **The Distribution Board (DB):** The DB contains all the protective devices like the Miniature Circuit Breakers (MCBs) of varied ratings and provides power supply to all the final sub-circuits like the lighting, fans, socket outlets, cookers, etc. through the various MCBs.

Wiring of the Meter

Even though the meter does not belong to the customer, the installation technician must make provision for its installation by ensuring proper sequencing of the supply cables. The following are critical steps to install the meter.

1. Disconnect the power supply by removing the cutout fuse.
2. Position the meter vertically on its centreline and securely tighten the bolts and nuts.
3. Connect the incoming live wire (L) to the 1st slot on the meter.
4. Connect the incoming Neutral (N) wire to the 2nd slot on the meter.
5. Connect the outgoing Neutral (leading to the isolator) to the 3rd slot.
6. Finally, connect the outgoing live wire (leading to the isolator) to the 4th slot

The following image shows the basic connection of a Single-Phase, 2-Wires meter.

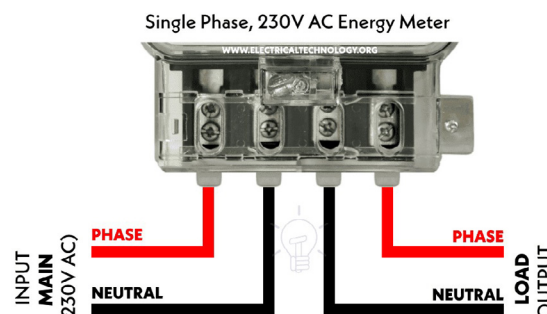
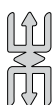


Figure 1.15: Wiring a single-phase meter

Caution: Please note that there may be some variations in meter connections depending on meter designs, supply systems and specific countries. Therefore, you should obtain information on every meter before commencing its connection.

Learning Tasks

1. What do you understand by sequence of supply-control equipment?
2. Describe the sequence of connections of the supply-control equipment.
3. Explain the functions of each of the supply-control equipment:
 - a. *Demonstrate how to properly wire a meter*
 - b. *What caution must be taken when wiring any meter?*

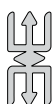


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that everyone is encouraged to present on behalf of the groups and become a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain what is meant by sequence of supply-control equipment and describe the sequence of connection of the equipment.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learner learners to pool their knowledge and skills to brainstorm and research the functions of each of the items of supply-control equipment. Learners should also describe the process of wiring the meter and give reasons why caution should be taken when wiring any meter.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them individually to draw the sequence of the supply control equipment and demonstrate practically, the correct process of wiring a meter.

KEY ASSESSMENT

Level 1: List 4 pieces of equipment installed on a consumer's premises for the control of electrical power supply.

Level 2

1. What do you understand by sequence of supply-control equipment?
2. Describe the sequence of connection of the supply-control equipment.
3. Explain the function of each of the items of supply-control equipment on a consumer's premises.

Level 3: Draw the diagram of the supply-control equipment on a consumer's premises.

HINT



*The recommended mode of assessment for Week 4 is a **quiz**. Use the level 3 question as a sample question.*

UNIT 4 REVIEW

This unit introduced learners to supply-control equipment on a consumer's premises. They are the service cutout fuse, the meter, the isolator/switchgear, and the distribution board. The sequence of how this equipment is connected and the functions of each have been discussed.

Also discussed is how to properly wire the meter and the caution that must be taken when wiring it. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities.



APPENDIX A: GROUP PROJECT

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
Heading (Caption of the Project)	Heading includes 4 of the following: clear, concise, accurately reflects the project's content and follows syntax rules.	Heading includes 3 of the following: clear, concise, accurately reflects the project's content and follows syntax rules.	Heading includes 2 of the following: clear, concise, accurately reflects the project's content and follows syntax rules.	Heading includes 1 of the following: clear, concise, accurately reflects the project's content and follows syntax rules.
Project Design Brief	Brief is based on 4 of the following: has a project specification (50–60 words), provides a comprehensive overview of the project and correct spelling of keywords	Brief is based on 3 of the following: written (50–60 words), provides a comprehensive overview of the project and correct spelling of keywords	Brief is based on 2 of the following: written (50–60 words), provides a comprehensive overview of the project and correct spelling of keywords	Brief is based on 1 of the following: written (50–60 words), provides a comprehensive overview of the project and correct spelling of keywords
Teamwork	Exhibit 4 of these Contributing to the group. 1. Respecting the views of others 2. Tolerating others 3. Resolving conflicts 4. Taking responsibility	Exhibit 3 of these: Contributing to the group. 1. Respecting the views of others 2. Tolerating others 3. Resolving conflicts 4. Taking responsibility	Exhibit 2 of these: Contributing to the group. 1. Respecting the views of others 2. Tolerating others 3. Resolving conflicts 4. Taking responsibility	Exhibit 1 of these Contributing to the group. 1. Respecting the views of others 2. Tolerating others 3. Resolving conflicts 4. Taking responsibility
Technical Specification	Final work shows 4 of the following: test meets specifications, accurately documented, all parts functional and eco-friendly.	Final work shows 3 of the following: test meets specifications, accurately documented, all parts functional and eco-friendly.	Final work shows 2 of the following: test meets specifications, accurately documented, all parts functional and eco-friendly.	Final work shows 1 of the following: test meets specifications, accurately documented, all parts functional and eco-friendly.



APPENDIX B: SAMPLE PORTFOLIO ASSESSMENT

Task: Compile and submit a comprehensive portfolio that represents your work for the entire academic year. The portfolio should include a selection of exercises/assignments, project work, reflective pieces, and both mid-semester and end of semester examination papers.

STRUCTURE AND ORGANISATION OF THE PORTFOLIO

As part of the structure of the portfolio assessment, make sure the following information has been provided:

1. **Cover Page with**
 - a. *learner's name*
 - b. *class*
 - c. *subject*
 - d. *period/date, etc.*
2. Table of Contents which has the list of items included with page numbers.
3. Brief description/background of items such as background information for each included artefact, etc.

LEARNERS' WORKS TO BE INCLUDED IN THE PORTFOLIO

1. Class Exercises/Assignments
2. Folios
3. Project works
4. Mini-research work
5. Mid-semester examination papers
6. End of semester examination papers, etc.

MODE OF ADMINISTRATION FOR PORTFOLIOS

1. Clearly explain the purpose of the portfolio and its various components to the learners. Provide examples and templates for each section to guide them in their work.
2. Set up regular review sessions, every 4 weeks, to monitor learners' progress. During these checkpoints, they offer feedback and guidance to help them improve their portfolios.
3. Share the scoring rubrics with the learners and thoroughly explain how their work will be evaluated.
 - Set the final due date for portfolio submission in Week 22 of the academic calendar. Offer a grace period for learners to make revisions based on the final feedback they receive.

MODE OF SUBMISSION/PRESENTATION

1. Clearly inform all learners of the final deadline for portfolio submission to ensure that all work is completed and submitted on time.
2. Learners should organise their portfolios in a clear and logical manner, with each section clearly labelled and easy to access.
3. Learners may submit their portfolios either in physical form or via the school's online submission system.
4. For digital submissions, learners should upload their portfolios either as a single file or in well-organised folders within the online platform.
5. Ensure the portfolio contains all required components: assignments, projects, quizzes, tests, reflective pieces, mini-research work, as well as mid-semester and end of semester examination papers.

FEEDBACK STRATEGY

1. Schedule regular meetings to review learners' progress, set new goals, and make any necessary adjustments to their learning strategies.
2. Provide helpful comments throughout the learning process to support learners' development. Ensure that learners clearly understand how to use this feedback to continually improve their work and achieve better results.

SCORING RUBRIC/ MARKING SCHEME

Learner's pieces of work	Items	Marks per Item	Total Marks
Assignments/Exercises	2	1 mark each	2 marks
Projects works (Individual/ Group)	2	2.5 marks each	5 marks
Mini-project work	1	2 marks	2 marks
Folio	1	2 marks	2 marks
Mini-research Work	1	2 marks	2 marks
Mid-semester Examination Papers	2	2 marks each	4 marks
End of semester Examination Paper	1	3 marks	3 marks
Total Marks			20 marks

SECTION 2: DOMESTIC INSTALLATION

The section covers the following units (strands): Electrical technology and electronic technology. In this section learners will acquire knowledge and understanding of how circuit is protected against excess current and be able to wire final circuits in accordance with IEE regulations. All the above are treated from unit 5 to unit 8.

UNIT 5

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: Apply appropriate tools and wiring systems to carry out key wiring processes.

Content Standard: Demonstrate understanding of house wiring

HINT



Remind learners of Mid-Semester examination in week 6. Refer to Appendix C for more sample tasks and the Table of Specification to guide you to set the questions.

INTRODUCTION AND SECTION SUMMARY

This unit looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following: the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 5: Describe how a circuit is protected against excess current.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspects of domestic installation through a wide range of pedagogical exemplars

such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situations hence, the assessment should cover all levels. Teachers should employ a variety of formative assessment strategies, both oral and written, to collect data from the learner's progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 5

Learning Indicator: Describe how a circuit is protected against excess current

Focal Area 1: Excess Current Protection

Definition of Excess Current

Excess current is a situation where the current flowing through a circuit exceeds the designated current range of the system. This situation if not promptly attended to can lead to overheating and damage of components in the circuit. Measures and devices must be put in place to safeguard electrical circuits and equipment and this is known as excess current protection.

Excess current protection devices: Devices that are used to take care of excess current are circuit breakers and fuses.

Types of circuit breakers

1. Miniature circuit breakers
2. Residual current circuit breakers
3. Electronic circuit breakers
4. Thermal circuit breakers
5. Magnetic circuit breakers

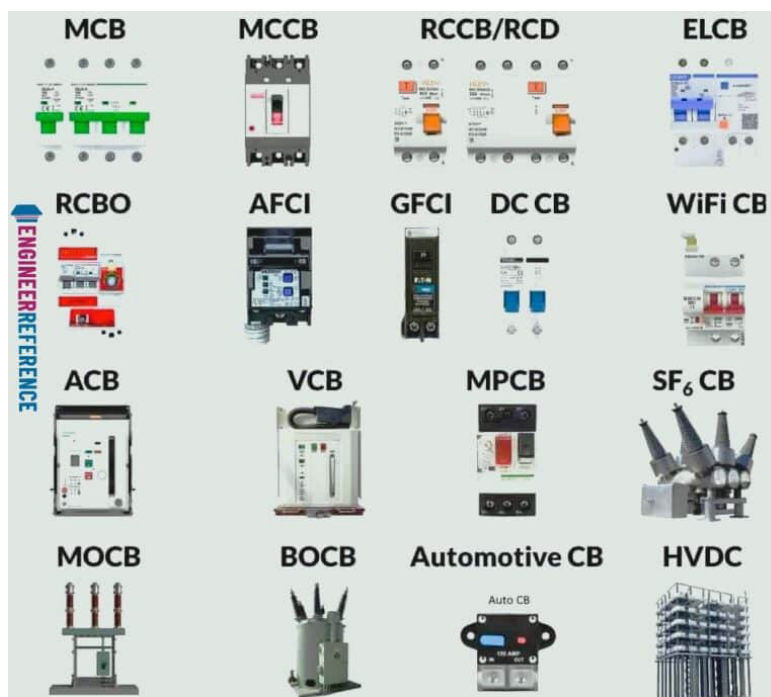


Figure 2.1: Types of circuit breakers

Types of fuses

1. Rewirable fuse
2. Cartridge fuse
3. High-Rupturing-Capacity fuse



Figure 2.2: *High-Rupturing Capacity fuses*



Figure 2.3: *Cartridge fuses*

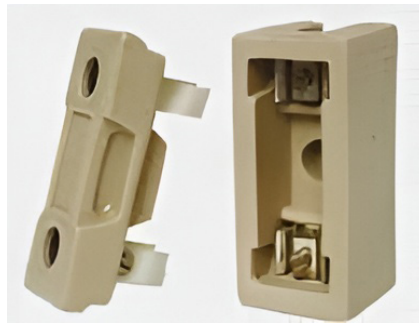


Figure 2.4: *Rewirable fuse*

Advantages and Disadvantages of Fuses and Circuit Breakers

Advantages of fuses

1. Easily replaceable
2. Cost effective
3. Specific protection
4. Reliable operation

Disadvantages of fuses

1. Slow response time
2. One time use
3. Limited short-circuit protection

Advantages of circuit breakers

1. Faster response time
2. Resettable
3. Greater short-circuit protection

Disadvantages of circuit breakers

1. Complex design
2. Higher cost
3. Potential unnecessary tripping

Determination of a fusing factor of a fuse

The fusing factor of a fuse can be determined by dividing the value of the fusing current by the value of the current rating, mathematically:

$$\text{Fusing factor} = \frac{\text{Fusing current}}{\text{Current rating}}$$

Learning Tasks

1. Explain the concept of excess current.
2. Describe the relevance of excess current protection.
3. Identify at least three causes of excess current in an electrical system.

PEDAGOGICAL EXEMPLARS

1. **Group work/Collaborative learning/Digital learning:** Place learners in a mixed ability groups and task them to come up with the concept of excess current and the relevance of excess current protection.
2. **Critical thinking and talk for learning approaches:** Guide learners through critical thinking and talk for learning approaches to identify at least three causes of excess current in an electrical system.

KEY ASSESSMENT (DOK)

Level 1: Define excess current.

Level 2: Describe the relevance of and need for excess current protection.

Level 3

1. Identify at least three causes of excess current in an electrical system.
2. Design and implement a system to protect an electrical circuit from excess current.

HINT



The recommended mode of assessment for week 5 is **project**. Use the level 3 question 2 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 63 for additional information on how to use this mode of assessment.

UNIT 5 REVIEW

Unit 5 covered excess current, the causes of excess current and the need to include excess current protection in an electrical system, and further talks about fuses and circuit breakers as devices for excess current protection as well as their types, advantages and disadvantages and finally the determination of a fusing factor of a fuse.

UNIT 6

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following, the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 2: Describe the various wiring methods employed in house wiring.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teachers can consult the Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 6

Learning Indicator: *Describe the various methods of house wiring*

Focal Area 1: Wiring Methods Employed In House Wiring

Conduit Wiring System

Conduit wiring system is a system in which the cables from the consumer unit to the load are passed through metal or PVC pipes. This is done to protect the cables from mechanical damage and other unpleasant consequences of weather conditions, physical breakdown, fire dangers, and atmospheric effects. It is the most widely used system, but care is needed during drawing-in of the cables to avoid damage to them.

Types of Conduit Wiring

There are two types of conduit wiring. They are:

1. Surface conduit wiring
2. Concealed conduit wiring

Surface Conduit Wiring

Surface wiring is one in which the conduits are installed on the surface of a roof or wall. The process is as follows:

1. Measure, mark-out and punch holes in a straight line and at equal distances on the wall surface
2. Fix rowel plugs into the holes and screw in saddles
3. Install conduits and conduit boxes. Note that the size of conduit depends on the number of cables.
4. Draw in cables using a fish tape, fix accessories and do termination.



Figure 2.4: *A picture of surface conduit wiring*

Precautions in Surface Conduit Wiring

Precautions should be taken when doing surface conduit wiring. The following are some of them

1. Conduits should be selected based on the number and sizes of cables such that a reasonable space is available after drawing cables in.
2. An earth wire of an appropriate size should also be run along the pipes and it should be earthed at reasonable distances by combining with conduits. Also, all junction boxes, iron-clad switches, and distribution boards, etc. should be properly earthed.
3. Conduits should be separated from water and gas pipes
4. PVC pipes must not be used in places where the danger of mechanical disruption or wear and tear are prevalent
5. All bends on pipes should be rounded so that insulation of cables is not scratched at the time of drawing in
6. Conduits less than 16 mm in size should never be used

Advantages of Surface Conduit Wiring

1. Extensions can be done in the future
2. Repairs and maintenance can be done easily
3. Wiring looks beautiful if it is expertly done
4. In the case of PVC conduit, this wiring remains protected from rust as well as fire
5. This type of wiring can also be used in places prone to weather as well as chemical impacts
6. The danger of an electric shock is minimized because of the earthing
7. Many of the accessories used in this type of wiring, can be reused if the need arises

Disadvantages of surface Wiring

1. It affects the visual beauty of walls
2. It requires significant labour and skilled technicians
3. Occasional cleaning or dusting must be done to remove dust particles and other impurities
4. There is high risk of mechanical damage to conduits since they are exposed
5. There is risk of electric shock in metal conduits if earthing is not properly done
6. Installing this system takes a lot of time
7. It requires a lot of conduit fittings like elbows and T joints thus making comparatively expensive
8. Fault tracing and repair works can take a lot of time

Concealed Conduit Wiring

Concealed wiring is where the conduit is placed in grooves carved on the wall. This is done before the wall is plastered, thus concealing the conduits inside. As such, the wiring is not visible from outside, it is only the accessories (socket outlets, switches and lamp holders) that are visible, hence, the name, concealed conduit wiring. The wiring is done inside a conduit which is buried or concealed inside the wall.

The procedure is as follows:

1. Locate positions of switches, socket outlets, cooker control units etc.
2. Mark out and chisel grooves for the conduits and conduit boxes
3. Position conduits and conduit boxes and temporary secure them
4. After walls are plastered, which completely conceals the conduits, the cables are then drawn in through the conduit boxes, using fish tape.
5. Fix accessories and test the installation for continuity and polarity (Flush-type switches and socket outlets are used here)

Note that the conduits and conduit boxes are placed before walls are plastered. On the roof, conduits are installed before the ceiling is done. If it is a concrete roof, the conduits and boxes are put in place before the concrete is poured over. In this type of wiring, the cables are protected against fire, water, moisture, and other weather conditions. This type of wiring is commonly used in houses, offices, bungalows, and all other modern buildings.

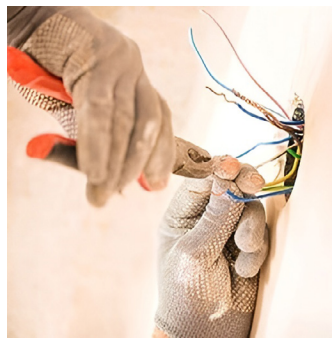


Figure 2.5: *Concealed conduit wiring*

Precautions in Concealed Conduit Wiring

The precautionary measures being employed for concealed conduit wiring are very similar to those being adopted for surface wiring, however some precautions are specifically associated with concealed wiring, which must be kept into mind:

1. The entrance of conduits should be properly covered with paper, so that cement does not enter inside during plastering
2. All pipes must end up within the box
3. All metal boxes must be properly earthed
4. The loop-in method should be adopted to avoid making joints inside conduits
5. While passing cables through a conduit, wires must be dragged in such a fashion that their insulation does not damage

6. The number of cables going to be passed through a conduit should be such that enough space or capacity remains available even after the existence of these wires.

Advantages of concealed wiring

1. This system brings out the beauty of the walls since conduits are not exposed.
2. It is protected against mechanical damage and the effects of weather and other chemicals
3. It remains protected against fire eruption
4. It is less time consuming and less costly
5. It is one of the safest wiring systems
6. It minimizes the risk of shock and other accidents
7. Conduits do not require earthing since they are plastic

Disadvantages of concealed wiring

1. There is difficulty in making extensions once the wiring has been completed.
2. It is difficult to find out the defect and remove it
3. Walls are weakened by the masking of grooves on it
4. Making grooves on walls is quite laborious.

Trunking System

Trunking is an enclosure with a removable lid, used to contain and protect electrical cables, mostly in industrial or commercial buildings where large volumes of cables may be required around a very large space. They are square or rectangular in shape and lately smaller sections also find applications in domestic installations for extension purposes. This system of wiring allows for easy accessibility and extension. To attach new wiring to the existing trunking, one can simply drill a hole in the preferred side and make the necessary connections.



Figure 2.6: *Trunking system*

Types of Trunking

The following are a few types of trunking

1. **Cable trunking:** This type of trunking involves the use of a lid that is kept in its place using turnbuckles.

2. **Bus-bar trunking:** This type uses copper and aluminium as protection of electrical cables and their related components.
3. **Lighting trunking:** With this type, the opening is placed so that it faces downward and is mostly used in luminaries.
4. **Multi-Compartment trunking:** This type is mostly used in places where different voltages are involved and there is a need to separate them.

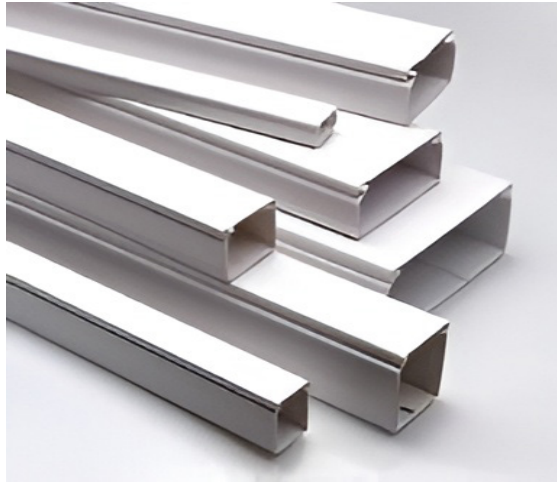


Fig 2.7: Various sizes of trunking

Advantages of trunking system

1. Maintenance and alterations can easily be carried out.
2. Trunking is durable.
3. Wiring is kept safe and free from dust, damage, and humidity.
4. Wiring is well organized and kept clean
5. It prevents interference of electrical signals.

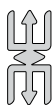
Disadvantages of trunking system

1. Can be heavy if steel trunking is used
2. Steel trunking is also vulnerable to rusting
3. Plastic trunking can break and splinter under physical stress.
4. Plastic trunking may need to be supported in longer runs to prevent sagging
5. When exposed to flame, plastic trunking can release toxic gases like iodine, bromine, chlorine, and fluorine. These gases can be fatal at high levels

Learning Tasks

1. What do you understand by Systems of wiring?
2. What is the difference between Surface wiring and concealed wiring?
3. What is the difference between conduit wiring and the trunking system?

4. Explain some of the precautions to be borne in mind during surface conduit wiring.
5. Describe the process of carrying out surface conduit wiring.

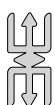


Note

1. Learners with additional needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain each of the wiring systems used in house wiring.
2. **Group work/Collaborative learning:** In small mixed-ability groups, task learners pool their knowledge and skills to brainstorm and research and explain the differences between surface wiring and concealed wiring. Learners should also describe the process of carrying out concealed wiring.



Note

Through this group work, learners not only enhance their understanding of wiring systems but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by taking them to the nearest house being wired to see how the wiring is done. Challenge them to come up with what specifically to look out for and write a report on what they have seen. Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps involved in carrying out some methods of house wiring.

Additionally, they will collaboratively brainstorm and discuss the processes involved in house wiring, especially concealed wiring which is the most common type found. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply house wiring in real-world contexts.

KEY ASSESSMENT

Level 2

1. What is *Surface Wiring*?

2. Explain Concealed wiring.
3. Describe the appropriate process of carrying out each type of conduit wiring

Level 3

1. Why do you think concealed wiring is mostly the preferred choice?
2. Compare and contrast surface wiring and concealed wiring.
3. Why would you prefer trunking system to a conduit system?

HINT



*The recommended mode of assessment for week 6 is **mid-semester examination**. Refer to the Appendix C for more sample task and the Table of Specification.*

UNIT 6 REVIEW

This unit introduced learners to some of the methods or systems employed in house wiring. The systems are categorised into surface wiring, concealed wiring, and trunking systems. The processes of carrying out each of them as well as their advantages and disadvantages have also been discussed. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities

UNIT 7

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical systems design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services, is geared toward equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through coverage of the following the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection, wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 7: Wire final circuits in accordance with IEE regulations.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 7

Learning Indicator: Wire final circuits in accordance with IEE regulations

Focal Area 1: Wiring of Final Circuits

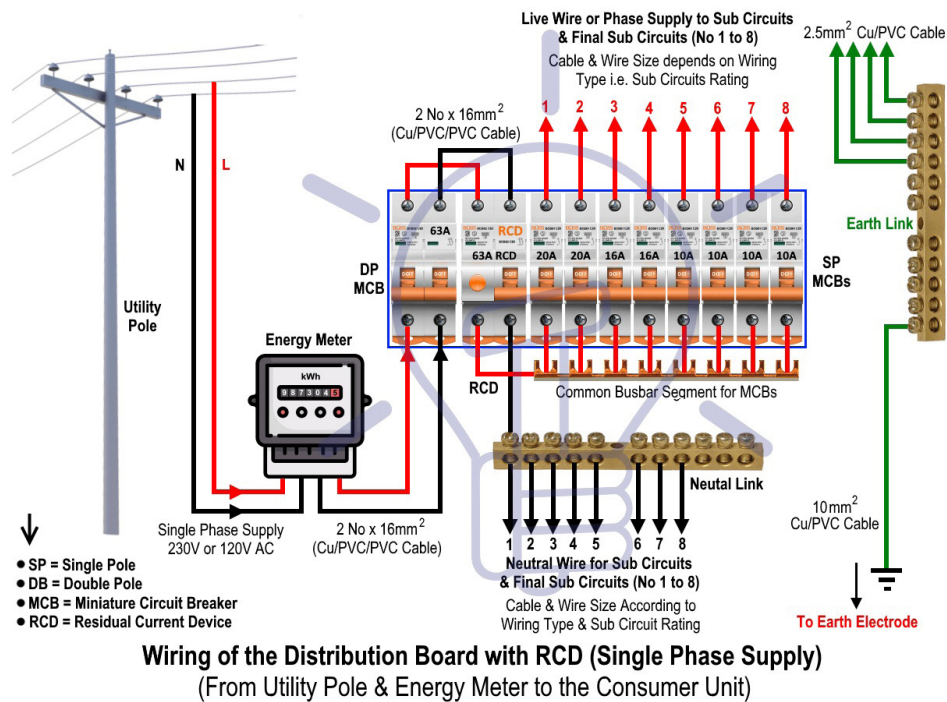


Figure 2.8

A final circuit could be described as a circuit connected directly to current using equipment, or to a socket outlet(s) or other points for the connection of such equipment.

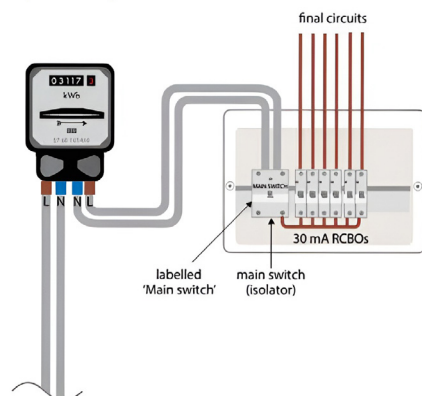


Figure 2.9

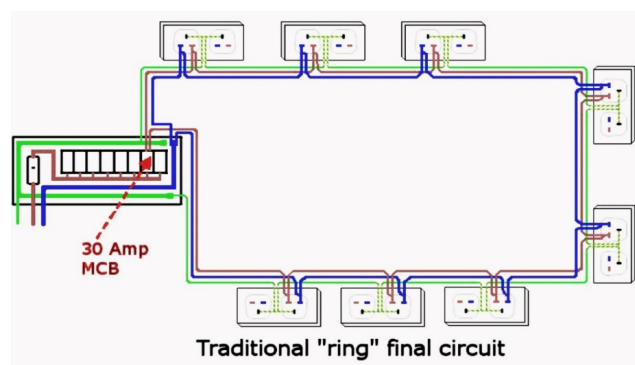


Figure 2.10: Diagram of consumer unit showing various final circuits with their protective devices

Regulations Governing Final Circuits

1. Every final circuit should be taken separately from the distribution board.
2. Every final circuit should be wired separately from every other circuit.

3. The neutral should be taken in the same order as the live.
4. Selection and installation of wiring systems: BS7671 specifies requirements for the design, selection and installation of wiring systems to ensure safe and reliable operation of final circuits.
5. Circuit protection: The correct specifications as to the types and rating of protective devices such as fuses, circuit breakers and residual current devices must be followed to protect final circuits against overloads and faults.
6. Earthing and bonding: Requirements for earthing and bonding in final circuits are outlined in BS7671 to minimise the risk of electric shock and ensure proper functionality of electrical installation work.
7. Accessibility and labelling: Final circuit components should be easily accessible and well labelled to facilitate maintenance and troubleshooting thereby ensuring clarity and safety.
8. Verification and testing: Periodic inspection, testing and certification of final circuits are necessary to verify compliance with standards and ensure safety.

Wiring of Lamps Controlled From Various Locations

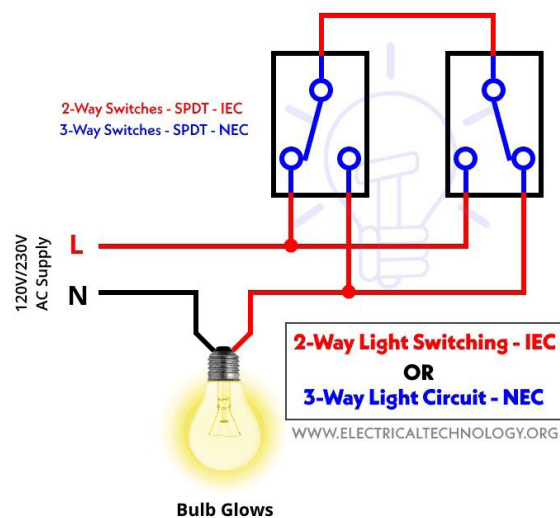


Figure 2.11: Wiring of light bulb controlled from two locations

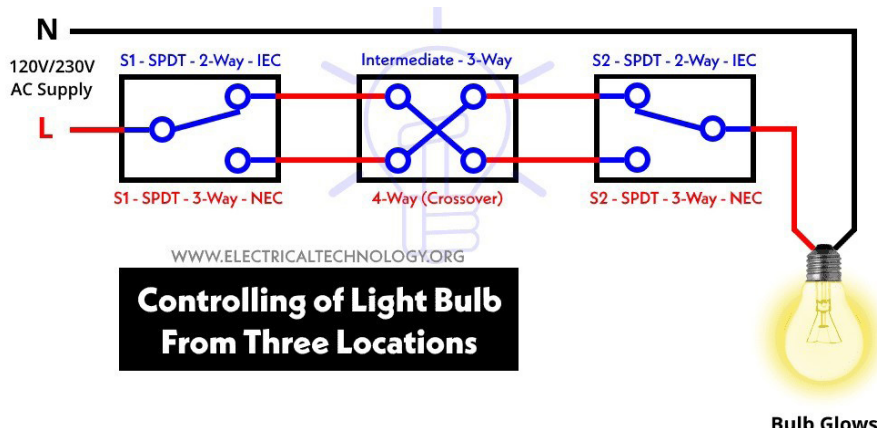


Figure 2.12: Wiring of light bulb controlled from three locations

Typical Radial Circuit

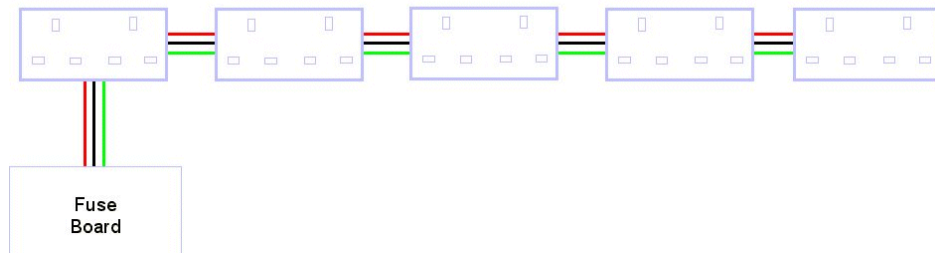


Figure 2.13: *Wiring of socket outlets in radial circuits*

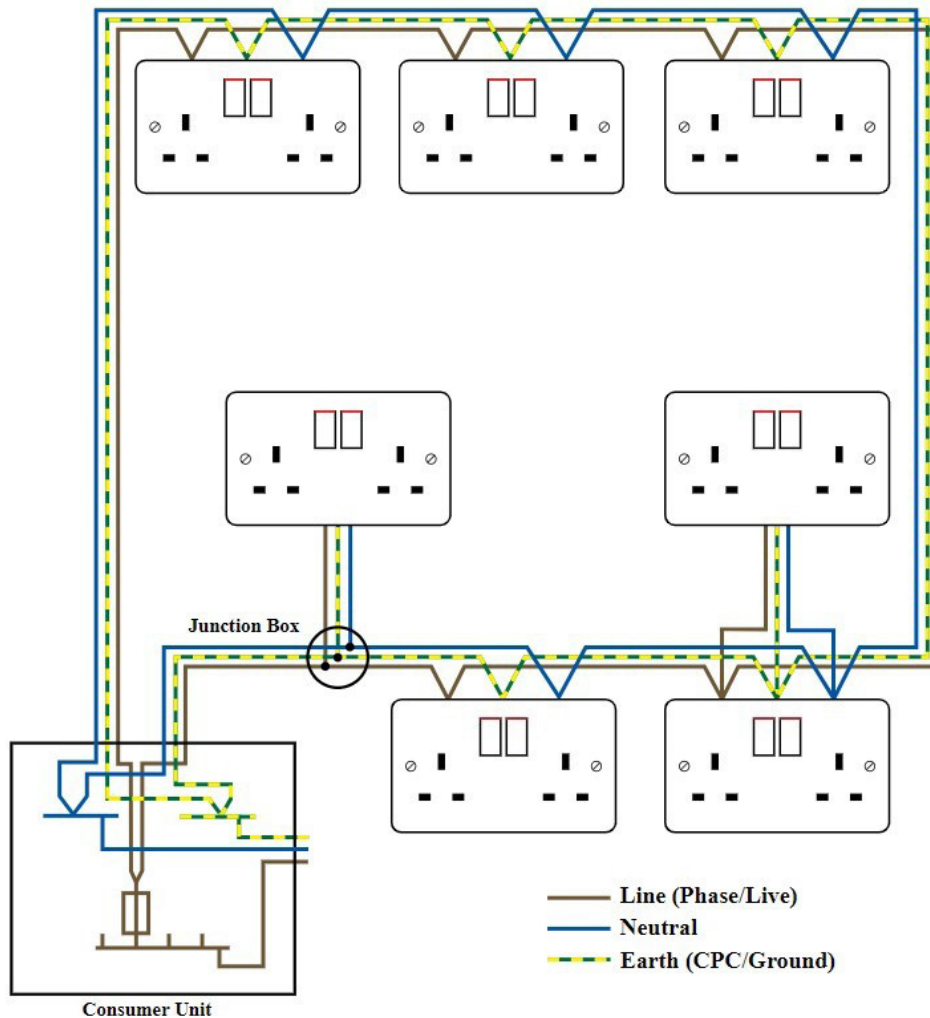


Figure 2.14: *Wiring of socket outlets in ring circuit*

Learning Tasks

1. Explain the concept of final circuit.
2. Outline the regulations governing final circuits to ensure safety in an electrical system.
3. Describe through diagrams the wiring of socket outlets in ring and in radial circuits.

PEDAGOGICAL EXEMPLARS

1. **Collaborative Learning/Talk for Learning/Digital Learning:** In mixed ability groups, task learners to watch video on final circuits, brainstorm and come up with the concept of final circuits: outline the regulations governing final circuits through the help of the internet: describe through sketches a consumer unit showing various final circuits with their protective devices: a diagram showing wiring of light bulb controlled from two and three locations: and finally a diagram showing wiring of socket outlets in ring and in radial circuits.

KEY ASSESSMENT

Level 1: Define final circuit.

Level 2

1. Outline the regulations governing final circuits to ensure safety in an electrical system.
2. Explain the concept of final circuit in wiring system.

Level 3: Draw the wiring diagrams of socket outlets in ring and in radial circuits.

HINT



*The recommended mode of assessment for week 7 is **questioning**. Use the level 2 question 2 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 63 for additional information on how to use this mode of assessment.*

UNIT 7 REVIEW

This unit introduced learners to the concept of final circuits in wiring systems, a diagram of the consumer unit showing various final circuits with their protective devices, regulations governing final circuits, wiring of light bulbs controlled from different locations and finally wiring of socket outlets in ring and in radial circuits.

UNIT 8

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through coverage of the following the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 8: Apply knowledge of final circuits in a Practical situation.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 8

Learning Indicator: Apply knowledge of final circuits in a Practical situation

Focal Area 1: Wiring of Final Circuits

Requirement for Wiring a Single-Phase Distribution Board

1. Double Pole MCB (The main isolator or main switch).
2. Single Pole MCB (Circuit Breakers and Fuses).
3. Miniature Circuit Breaker and Circuit Breaker.

The double pole MCB enables the circuit to be switched OFF and ON, the electric supply to your home. It is the main operating switch to control and manage the flow of electric supply in the wiring system. **The Main Switch** enables you to switch OFF the electric supply in the home in case of emergency.

Safety Precautions To Follow When Wiring A Circuit

There are many risks associated with installing any type of wiring system. These risks include harming yourself, someone else or loss of property if the necessary precautions are not taken. It is therefore very important to adhere to preventive measures whenever you are working with or doing wiring. The following tips, if strictly adhered to, can help you avoid causing any harm to yourself or your property.

1. **Wear Safety Protective Clothing:** Covering your eyes is a must when dealing with electricity. You do not want sparks or other debris to get into your eyes. Also, wearing long shirts, pants, gloves, and thick soled shoes are also a good idea. If the environment is outdoor or large scale, working on a project like laying pipeline with tracer wire, a hard hat may also be needed along with other construction environment safety gear.
2. **Have the Right Tools on Hand:** As with any job, you need the correct tools to complete it properly and do it with safety in mind. Having the right tools for a wire installation is essential. Some of the key tools include: a voltage tester, wire cutters, wire and cable strippers, needle nose pliers, continuity tester, and others. For large scale jobs such as installing ground cables, you may need a wire trencher or other digging equipment or heavy machinery.
3. **Make Sure Power is off**
 - a. Always make sure the circuit is dead before starting any work. So, check and be sure circuit breakers or isolators are off. If possible, lock the breaker. You may equally consider informing everyone around that the power has been turned off and give reasons and possibly, place a notice on the consumer unit to warn people.
 - b. Test the cables and connections before you begin working on them to make sure they are indeed dead.

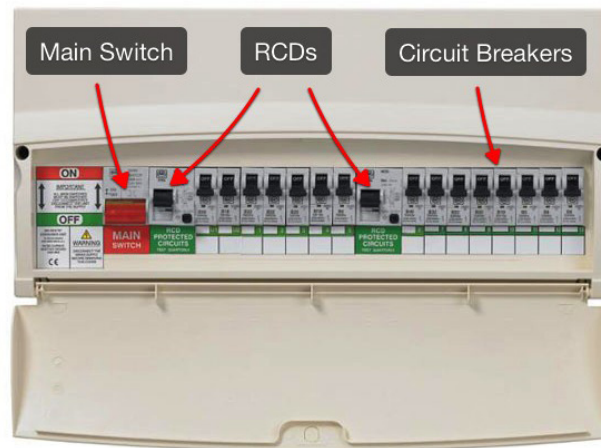


Figure 2.15: Mains switch in off position

Test the Final Work

When you are done, you must use a multimeter to test the finished work to ensure there are no loose connections or short circuits, and everything is wired correctly and safely. You can then turn on the electricity and make sure everything works correctly and starts up without incident. Also, check any metal parts with a voltage tester to make sure there are no leaks.



Figure 2.16: Testing of a circuit

It is necessary to follow all safety precautions from the beginning to the end of a project to help ensure your safety, that of your neighbours and your property. It will also guarantee the longevity of the work **SECTION 5**. Be prepared and check your work.

Wiring of an Extension Board

Learners are to wire the circuit shown in *Figure 2.17* practically

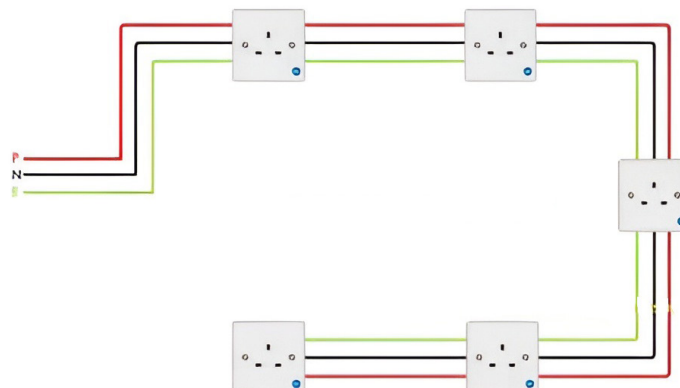


Figure 2.17: Wiring of socket outlets in radial circuit

Tools and Materials Required

The following materials are required to do the wiring

Table 2.1: Tools and Materials Required

S/N	ITEM	QUANTITY
1	Meter board (90cm x 90cm)	1
2	Double Pole MCB	1
3	Twin Socket outlets	4
4	13A plug	1
5	2.5mm ² , 3-core Flexible cable	4 meters
6	Portable Hand Drill	1
7	Screw Drivers	1 set
8	Wire stripper	1
9	Plier	1
10	Side cutter	1
11	Multimeter	1

Procedure for Construction

1. Mark out the positions of the socket outlets and the MCB.
2. Remove the covers of the socket outlets and MCB and place them on their various positions.
3. Mark positions of cables for live, neutral and earth.
4. Take off the socket outlets and drill the holes for the various cables. In the case of the MCB, only Live and Neutral positions are marked for incoming and outgoing.
5. Pass cables through holes and do termination for the input to the double pole of the MCB.
6. Use short pieces of wires to connect the output of the MCB to the first socket outlet making sure that Red goes into the terminal labelled L, Blue goes into the terminal marked N, then the green and yellow cable goes into the terminal marked E.
7. Connect to each of the other socket outlets using the loop in system.
8. Position MCB and the socket outlets and screw them tightly to the board.
9. Open the 13Amp plug and terminate the other end of the flexible cord into it, ensuring that the red wire goes into the L terminal, Blue to the N and Green/Yellow into the E terminal.
10. Test for continuity, Polarity and short circuit.
11. Close plug.
12. Over the base of the board with plywood and battens.
13. Plug circuit to power and test with a gadget.

Learning Tasks

1. Explain the basic requirements for wiring a circuit.
2. Outline the precautions to follow when wiring a circuit.
3. Describe the procedure of building an extension board.

PEDAGOGICAL EXEMPLARS

1. **Collaborative learning/Talk for learning/Digital learning:** In mixed-ability groups, task learners to brainstorm and come up with the basic requirements for wiring a circuit as well as the precautions to follow when wiring a circuit to ensure the safety of themselves and that of others. Learners are also expected to also describe the procedure for building an extension board
2. **Experiential learning:** Engage learners in an experiential learning by allowing them to draw the radial circuit of Figure 2.17 and use the procedure outlined to practically carry out the wiring process.

Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps involved in carrying out some methods of house wiring.

KEY ASSESSMENT

Level 2

1. Explain the basic requirements for wiring a circuit.
2. Outline the precautions to observe when wiring a circuit.

Level 3

1. Build the radial circuit shown in Figure 2.17.
2. Create a concept map that include the following power supply, conductors, protective device and compliance with codes as basic requirements for wiring a circuit.

HINT



*The recommended mode of assessment for week 8 is **concept mapping**. Use the level 3 question 2 as a sample question. Refer to the Teacher Assessment Manual and Toolkit for additional information on how to use this mode of assessment.*

UNIT 8 REVIEW

This unit introduced learners to the basic requirements of wiring a circuit, precautions to be observed during wiring and the application of the knowledge of final circuits in the design and construction of a radial circuit on a board.



APPENDIX C: MID-SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

15 Multiple Choice Questions (MCQ) to be answered individually within **20 minutes**, questions should be selected from DoK level 1 to 3.

RESOURCES

Scannable sheets or A4 papers

SAMPLE QUESTIONS

Multiple Choice- 20 mins

1. Which of the following is the **primary** cause of electrical shock?
 - a. **Contact with live conductors [correct Answer]**
 - b. Overvoltage in the mains
 - c. Poor grounding in homes
 - d. Undervoltage on the lines

TABLE OF SPECIFICATION FOR MID SEMESTER 1

WKS	LEARNING INDICATORS	DoK Level	DoK Level	DoK Level	DoK Level	TOTAL
		1	2	3	4	
1	Explain house wiring and provide reasons for doing good wiring.	1	1	1		3
2	Classify tools and equipment used in wiring and their functions.	1	1	1		3
3	Identify the various materials and accessories used for house wiring.	1	1	1		3
4	Describe the sequence of Supply-control equipment.	1	2			3
5	Describe how a circuit is protected against Excess current.		2	1		3
	TOTAL	4	7	4		15

SECTION 3: DOMESTIC INSTALLATION

The section covers the following unit (strands) Electrical technology and electronic technology. In this section learners will acquire knowledge and understanding of earth as an installation work in accordance with rules and regulations as well as conducting relevant tests on an electrical circuit. All the above are treated from *unit 9* to *unit 12*.

UNIT 9

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

HINT



*Remind learners of the end of semester examination in **Week 12**. Refer to **Appendix D** at the end of this section for Table of Specification that will guide you to construct the test items.*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following: the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

*The unit covers only week 9: **Earth and installation work in accordance with rules and regulations***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For the effective delivery of this unit through active involvement and cooperation of learners, teachers should consider pedagogical exemplars like collaborative/talk for learning approaches and experiential/collaborative learning approaches

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 9

Learning Indicator: Earth an installation work in accordance with rules and regulations

Focal Area 1: Earthing an Installation Work

Earthing or grounding is the system of connecting all non-current carrying metal parts of an electrical installation to the general mass of the earth.

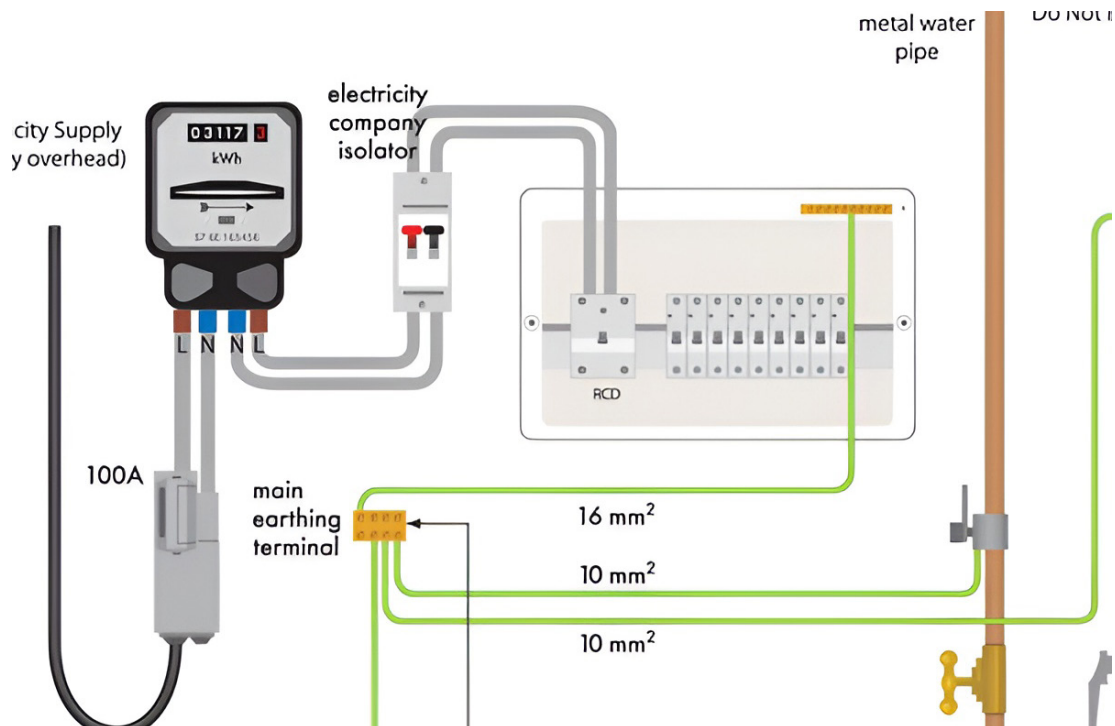


Figure 3.1: Earthing of an electrical system

Reasons for Earthing

The following are examples of reasons for earthing:

1. Earthing helps to protect both people and property from the possible risk of electric shock and fire by providing low resistance path for fault current to flow to the ground.
2. It protects equipment from damage because non-current conductive parts been energised.
3. Proper earthing of electrical systems is a statutory requirement to ensure safety and reliability of installation works and its compliance leads to the avoidance of legal issues.
4. Earthing contributes to the reduction of electromagnetic and radio frequency interference.

Types of Earthing Methods

It is important to select the appropriate type of earthing method based on factors like soil conditions, type of installation and the level of fault currents anticipated to ensure the safety and proper functioning of the electrical system. The following are examples of types of earthing methods:

1. **Chemical earthing:** this involves the use of chemical compounds to enhance the efficiency of the earthing system.
2. **Strip earthing:** In this method a strip of metal is buried horizontally in the trench to provide an effective earthing system.
3. **Rod earthing:** Here a metal rod is driven into the ground to provide a low-resistance path for fault currents to be safely dissipated.
4. **Pipe earthing:** with this method a galvanised iron or steel pipe is buried vertically in the ground to enhance the earthing system.
5. **Plate earthing:** In this method a metal plate is buried in the ground to create a low resistance connection to the earth for electrical systems.

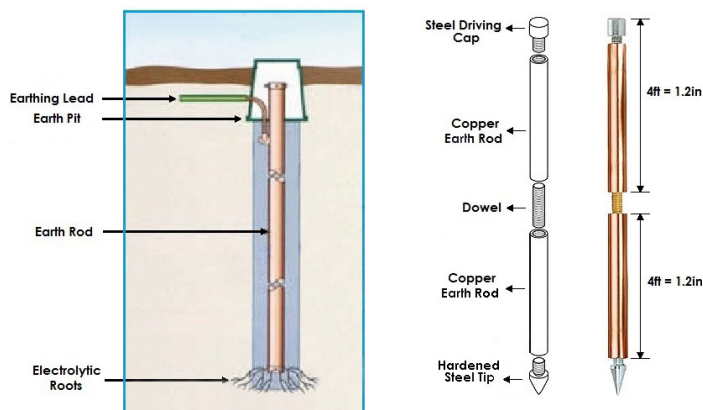


Figure 3.2: *Copper rod electrode earthing system*

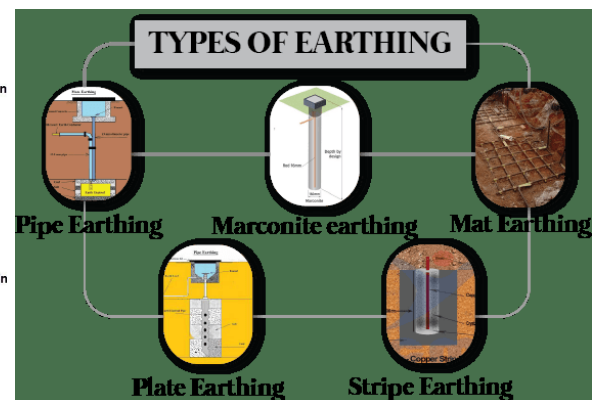


Figure 3.3: *Types of Earthing*

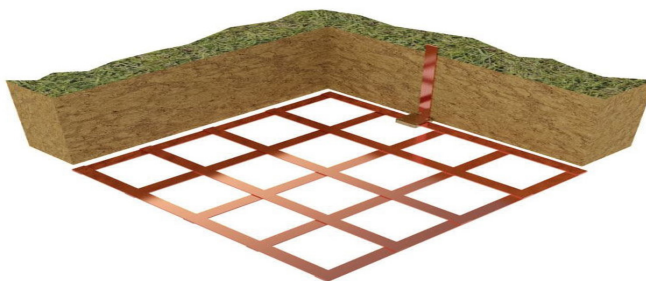


Figure 3.4: *Lattice-copper-earth-mat*



Figure 3.5: *Copper earthing strip*



Figure 3.6: *Marconite earthing compounds*



Figure 3.7: *Plate earthing*

Earthing Procedure

To undertake a successful earthing of an equipment or installation work the following steps are followed:

1. Secure the appropriate electrodes such as copper rod, copper plate or copper earthing tape.
2. Dig the ground to bury the electrode, about 1.5m depth will do, (Charcoal or salt could be added to enhance earthing).
3. With suitable crimp connect the electrode to the earth lead cable and fix it to run to the meter box.
4. Depending on the electrical utility of your power provider terminate the lead wire appropriately. Install a termination block that electrically connects earth lead wire, meter box and earth cables for sub-circuits of the installation.
5. Test the earthing by measuring the earth's resistance, and ensure it is within acceptable limits.
6. For an electrical supply with a neutral, connect it with the earth termination box.
7. Run an earthing wire or continuous protective conductor from the main earthing terminal that connects all exposed conductive parts of your installations.

Note: Key areas that require earthing are all metal casing of electrical equipment, electric generators, motors and transformers needing at least two separate earthing points, stay wires of overhead cables installation, and the earth pin of a plug.

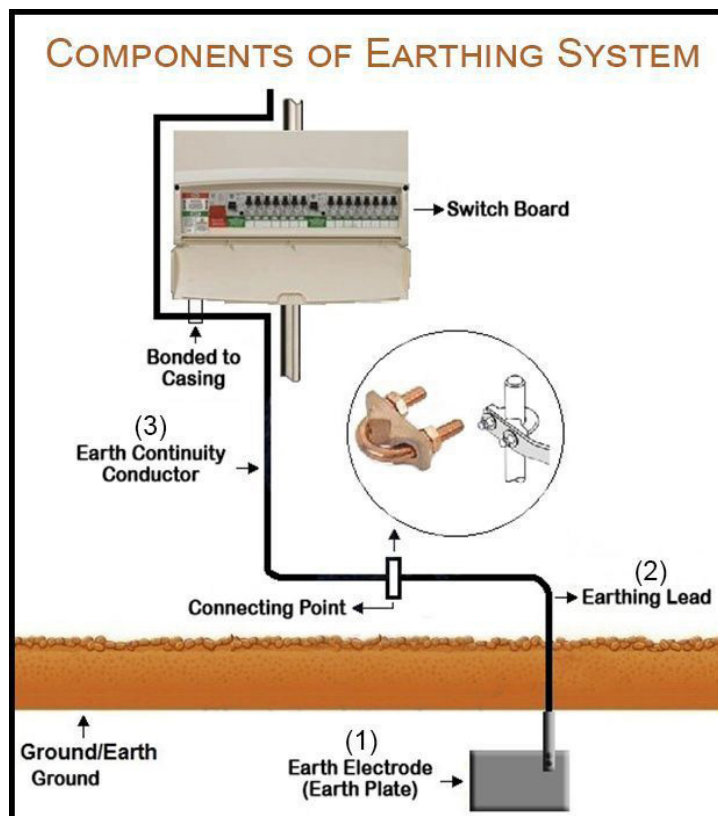


Figure 3.8: Earthing/Grounding system

Learning Tasks

1. Explain the concept of earthing.
2. Write out the procedure involved in earthing.
3. Describe at least three materials used in earthing.
4. Explain at least four reasons on the importance of earthing.

PEDAGOGICAL EXEMPLARS

Collaborative/Talk For Learning: In mixed ability groups and with the use of the internet, task learners to undergo the following activities:

1. Explain the term earthing.
2. Outline various reasons for earthing.
3. Describe the process of earthing.

Experiential Learning/Collaborative Learning: Engage learners in groups to conduct the following activities

1. Watch videos on how earthing is done.
2. Demonstrate the process of earthing.

KEY ASSESSMENT

Level 2

1. Explain the concept of earthing.
2. Write out the procedure involved in earthing.

Level 3

1. Describe at least three materials used in earthing.
2. Specify at least four importance points of earthing

HINT



*The recommended mode of assessment for Week 9 is **peer critique**. Use the level 2 question 1 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 58 for additional information on how to use this mode of assessment.*

UNIT 9 REVIEW

Earthing is a critical need in every electrical system to ensure safety and satisfactory operation of electrical gadgets and equipment. This unit exposed learners to the concept of earthing, the reasons or importance of earthing, the materials and procedure involved in earthing.

UNIT 10

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories and the various methods used in house wiring. Other areas include sequence of supply control equipment, excess current protection, wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting relevant tests on an installation work.

*The unit covers only week 15: **Conduct Relevant Tests on an electrical circuit.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 10

Learning Indicator: Conduct Relevant Tests on an electrical circuit that has been completed

Focal Area 1: Relevant Tests on An Electrical Circuit

Definition of Testing

Electrical testing is an assessment of electrical systems, components, or devices to ensure they function correctly, meet safety standards, and specified regulations. Testing is crucial in ensuring that electrical products and installations are safe, identify deviations from standards, and to ensure the reliability and safety of electrical equipment throughout its lifecycle.

Types of Electrical Testing

There are various types of electrical testing, each serving a specific purpose in assessing different aspects of electrical systems and components. Some of the common tests carried out in electrical installation include Continuity test, Polarity Test and Insulation Resistance test.

1. **Continuity Test:** A Continuity test is the assessing of an electric circuit to see if the current flows throughout the circuit or not. This test ensures there is no open circuit to prevent the circuit from performing its function. One way of conducting continuity test is by applying a small voltage to one end of the circuit and measuring on the other end.

Why Do We Use a Continuity Test?

A Continuity test is a very important test in troubleshooting of any circuit. Some purposes of continuity tests are:

- a. To check the **cable connections** of the circuit for possible breaks in conductors.
- b. For identifying **damaged components**.
- c. To check the quality of **soldering**.
- d. For identifying specific cables or **connections**.

The most common and basic way of performing a continuity test is with the help of an ohmmeter or any simple Multimeter with resistance function.

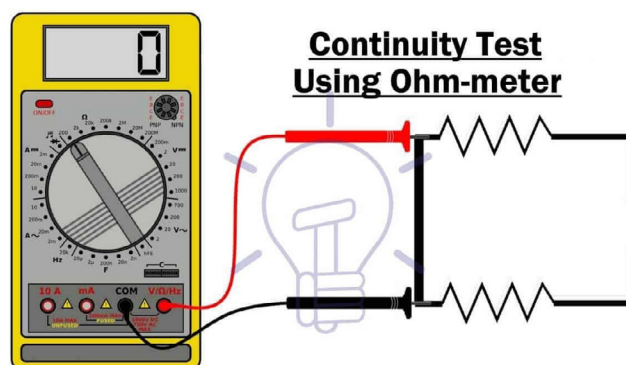


Figure 3.9: Continuity testing using a multimeter

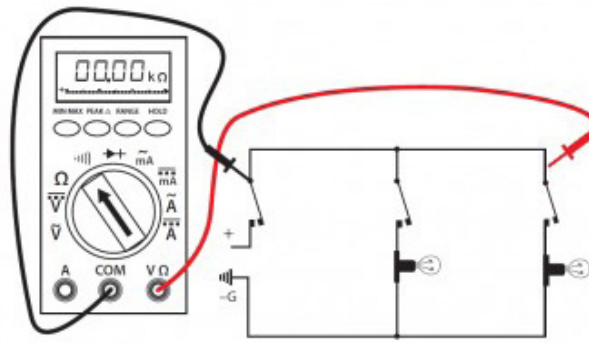


Figure 3.10: Continuity testing of a lighting circuits

Procedure for Conducting Continuity Test on An Installation

- a. Make sure the circuit is dead by switching off circuit breakers or isolators. If possible, lock the breaker. You may equally consider informing everyone around that the power has been turned off and give reasons and possibly, place a notice on the consumer unit to warn people.
- b. Disconnect all loads connected to the circuit.
- c. Be sure the instrument is in a good working condition.
- d. Select the final circuit to be tested in the distribution board and remove the line conductor from the MCB.
- e. Connect the line conductor to the earth conductor (for simplicity, connect it to one of the spare terminals on the Earth bar). This way you will form a circuit which is half made up of the line conductor and half made of the earth conductor (provided that the terminations within the electrical accessories such as wall sockets are correct).
- f. Select the correct test function on the test equipment, which is the low reading ohm meter function.
- g. Null the test instrument by connecting the two test leads together and pressing the TEST button until the measured value on the display becomes zero ohms.
- h. Connect the probes between live and any CPC on the circuit and measure between line and larth. Record the highest reading on the Schedule of Test Results as the value of $(R1+R2)$.
- i. Connect the line conductor back to its original terminal in the MCB.
- j. Repeat these steps for every circuit except for the main ring circuit.



Figure 3.11: Setting the meter

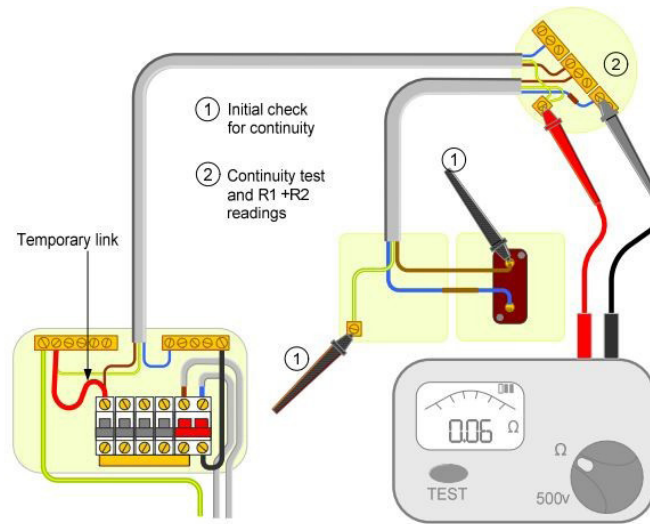


Figure 3.12: Conducting continuity test

2. **Polarity Test:** Another test that should be conducted on an installation is the polarity test. However, if specific notes are taken during continuity test, polarity testing may no longer be necessary.

Purpose of A Polarity Test

A Polarity test is conducted to ensure that:

- a. The polarity of the mains supply is done correctly. That is, the incoming live and neutral cables are in their right terminals.
- b. All single pole devices like fuses, switches and circuit breakers are connected to the live conductor only.
- c. Live conductor is connected to the centre terminal of Edison screw lamp holders.
- d. The polarities of all socket outlets are correctly wired.

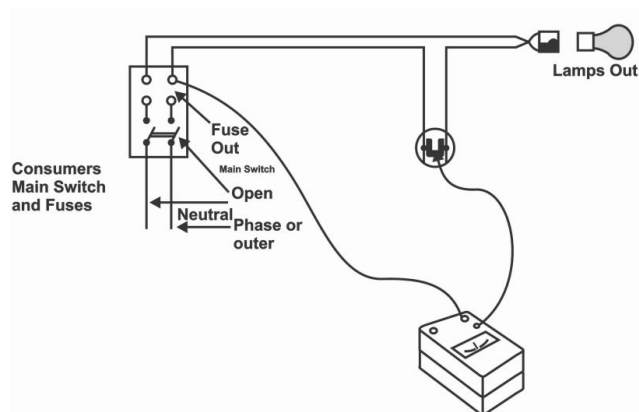


Fig 1.17 Testing for polarity of switch with circuit dead.

Figure 3.13a: Polarity test on a lighting circuit

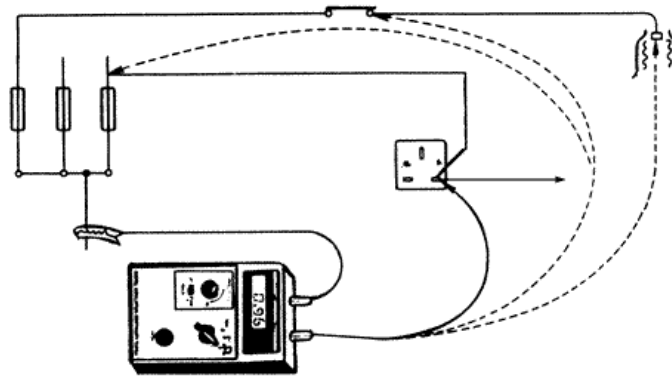


Figure 3.13b: *Polarity test on a radial circuit*

Procedure for Conducting Polarity Test

A Polarity test can be conducted:

- a. With the circuit dead
- b. With the circuit live

A Polarity test may be conducted by extending the leads of the meter with a long cable and testing between the mains isolator and the various final circuits as shown in figs 3.13a and 3.13b. However, a general procedure for conducting polarity test with circuit dead is as follows

- a. Switch off the circuit breaker supplying the circuit.
- b. Disconnect all loads and put on all single pole switches.
- c. From the specific circuit, connect the live conductor to the CPC.
- d. Conduct the continuity test by placing the test leads across the live conductor and the nearest CPC, using an ohmmeter.
- e. If the instrument indicates zero reading (continuity sound) then the switch is properly connected to the live conductor.
- f. However, If the instrument shows some significant resistance value or infinity reading, then the switch is not connected to the live conductor. You can solve the problem by Interchanging the connections.

To test for polarity while the circuit is live, use the following procedure

- a. Change to the volts section of the multimeter and select a value higher than the voltage of the circuit to be measured.
- b. Test between live and neutral terminals. It should read about 230V.
- c. Test between live and earth terminals. It should read about 230V.
- d. Test between neutral and earth terminals. It should read 0V.
- e. If the readings are as indicated, then there is correct polarity.

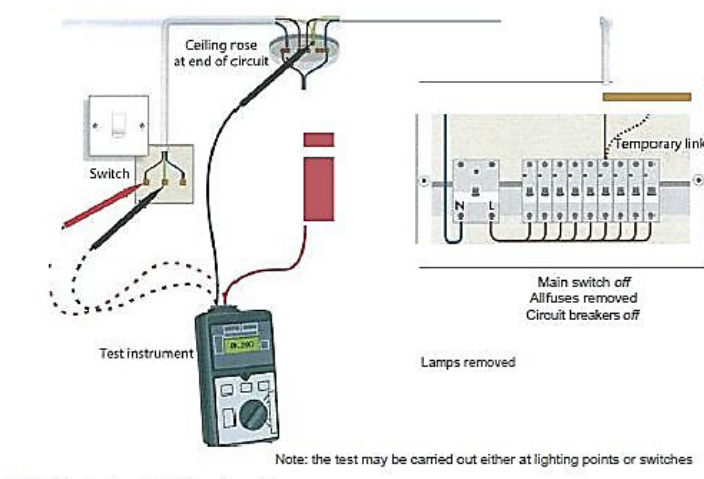


Figure 3.14: Polarity test

A **Polarity test** can also be conducted on a live circuit using a test lamp as shown in fig 10.7. In the figure, (Fig 10.7) the test is conducted between the neutral at the mains isolator and a terminal in a switch. The lamp should light, indicating that the switch is properly connected in the live circuit.

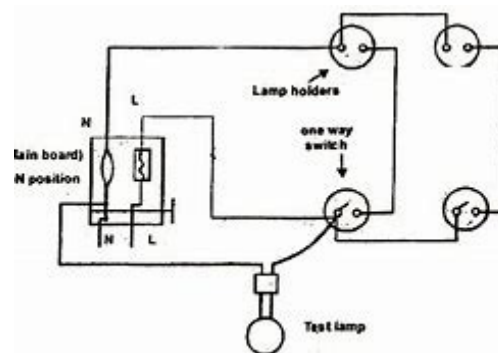


Figure 3.15: Polarity test using a test lamp

3. Insulation Resistance Test

Definition: An Insulation Resistance test is a test that measures the total resistance between any two points separated by electrical insulation. It is used to determine how effective the dielectric or insulation is at ensuring that current is restricted to the conductors. The tests do not only verify insulation quality at the time of manufacture, but also throughout the product's life. The instrument used for testing insulation resistance is the Megger or Insulation Resistance Tester.

Purpose of conducting Insulation Resistance

Insulation Resistance test is conducted to ensure that

1. There is no current leakage, as this leakage could be extremely dangerous.
2. Injuries to people and damages to equipment are avoided.
3. Electrical equipment items are dependable.
4. Electrical equipment items are in good working condition throughout their life of service.
5. Short-circuits are identified.

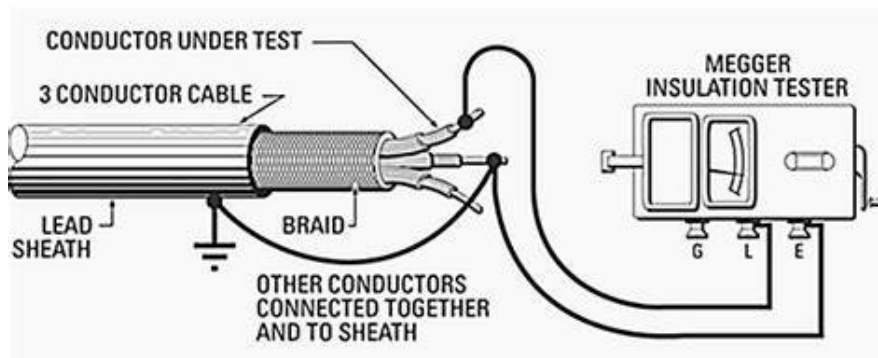
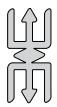


Figure 3.16: *Insulation resistance test*

Procedure for Testing Insulation Resistance

The procedure for testing Insulation Resistance is as follows:

1. Disconnect the power supply by opening the isolator
2. Disconnect all loads connected in the circuit
3. Be sure the instrument is in a good working condition
4. Separate both ends of the conductors to be tested
5. Connect the leads of the megger to the conductors to be tested
6. Take the reading on the instrument



Note

1. An infinity reading, indicates good insulation
2. Zero reading indicates short-circuit condition

Learning Tasks

1. Explain each of the following tests: (Continuity test, Polarity test, Insulation resistance Test).
2. Outline the purpose of carrying out each test.
3. Describe the procedure of conducting each test.
4. Demonstrate practically how to conduct insulation Resistance Test.

PEDAGOGICAL EXEMPLARS

1. **Collaborative Learning/Talk for Learning/Digital Learning:** In mixed-ability groups, task learners to brainstorm and explain each of the tests as well as outline the purpose of each test. Learners are also expected to also describe the procedure for carrying out each test

2. **Experiential Learning:** Engage learners in experiential learning by allowing them to watch videos on YouTube on how each of the tests is carried out. Learners should discuss the procedure for carrying out each test and use the procedures to conduct the tests practically.

Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps involved in carrying out tests on a wiring that has been done.

KEY ASSESSMENT

Level 2

1. What is the purpose of conducting a Polarity test, Continuity test and Insulation resistance test?
2. Describe the procedure involved in carrying out each of the tests.

Level 3

1. Conduct each of the tests practically. What readings from each test would be considered satisfactory?
2. Draw a schematic diagram of continuity test in electrical systems.

HINT



*The recommended mode of assessment for week 10 is **test of practical knowledge**. Use the level 3 question 2 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 33 for additional information on how to use this mode of assessment.*

UNIT 10 REVIEW

This unit introduced learners to the basic requirements of wiring a circuit, precautions to be observed during wiring and the application of the knowledge of final circuits in the design and construction of a radial circuit on a board

UNIT 11

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 11: Apply knowledge of wiring in a practical situation

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 11

Learning Indicator: *Apply knowledge of house wiring in a practical situation*

Focal Area 1: Field Trip Experience

Students are to undertake field trips to nearby wiring projects to observe the following issues and use the experience to carry-out their final projects

1. Safety Precautions to follow when wiring a circuit

1. Wearing safety protective clothing
2. Having the right tools on hand and how to use them appropriately
3. Ensuring power is always off when doing any work
4. Testing any finished job before connecting it to power

2. How to be wiring of an Installation

Learners are to observe the correct way wiring is done.

3. Equipment for the consumer unit

Learners are encouraged to observe the following equipment required for the consumer unit so they can use them appropriately

1. 60A cutout fuse with neutral link
2. 20A double pole MCB (*Figure 3.17*)
3. Single-phase MCCB (*Figure 3.18*)
4. 6-way Distribution Board (As shown in part of *Figure 3.19*)



Figure 3.17: Double pole MCB



Figure 3.18: Single-phase RCCB

4. Wiring of the consumer unit

Learners are to observe how a consumer unit as indicated in the following diagram (*Figure 3.19*) is wired so they can equally carry that out

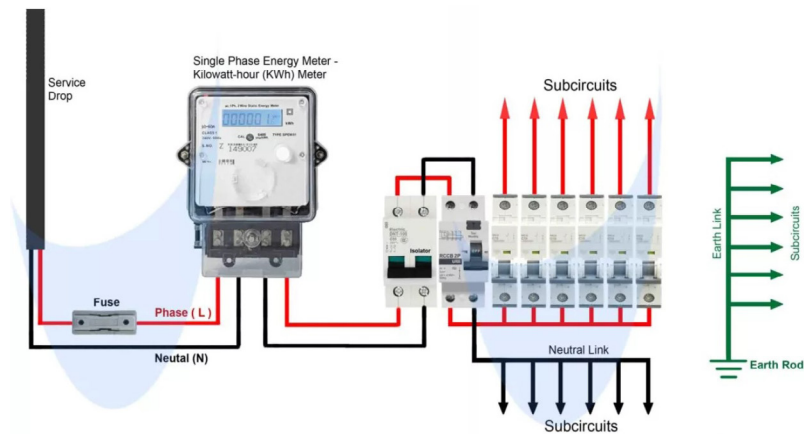


Figure 3.19: Wiring diagram of the consumer unit (with 6-way DB)

5. Procedure for wiring a final circuit

Learners are expected to observe the following keenly

1. How various final circuits are wired
2. Tools and equipment required for each job, and to properly use each tool
3. The procedure for carrying out each aspect of the wiring process

Learning Tasks

Write a report covering the following

1. Basic requirements for wiring a circuit
2. Precautions to follow when wiring a circuit
3. The procedure of building the circuit

PEDAGOGICAL EXEMPLARS

1. **Collaborative Learning/Talk for Learning/Digital Learning:** In mixed-ability groups, task learners to brainstorm and come up with the basic precautions to follow when wiring a circuit to ensure the safety of themselves and that of others. Learners are also expected to also describe the procedure for connecting the consumer control unit.
2. **Experiential Learning:** Engage learners in experiential learning by allowing them to draw the circuit and use the procedure outlined to practically carry out the wiring process.

Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps involved in carrying out some methods of house wiring.

KEY ASSESSMENT

Level 2

1. Explain at least two basic requirements for wiring a circuit.
2. Outline the precautions to observe when wiring a circuit.

Level 3: Build a radial circuit.

HINT



*The recommended mode of assessment for week 11 is a **test of practical knowledge**. Use the level 2 question 1 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 33 for additional information on how to use this mode of assessment.*

UNIT 11 REVIEW

This unit introduced learners to the precautions to be observed during wiring, some tools and materials needed to wire an installation and the application of the knowledge of wiring in the design and construction of a home installation.

UNIT 12

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Systems Design

Learning Outcome: *Apply appropriate tools and wiring systems to carry out key wiring processes.*

Content Standard: *Demonstrate understanding of house wiring*

INTRODUCTION AND SECTION SUMMARY

This Section looks at domestic installation as one of the electrical services. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in domestic installation through exposure to the following the definition and importance of house wiring, tools and equipment used in house wiring, materials and accessories, the various methods used in house wiring, sequence of supply control equipment and excess current protection. It also includes wiring of final circuits, earthing an installation work in accordance with IEE regulations and finally conducting a relevant test on an installation work.

The unit covers only week 11: Apply knowledge of wiring in a practical situation

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of domestic installation through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 12

Learning Indicator: Apply knowledge of house wiring in a practical situation

Focal Area 1: Wiring of A Single-Phase Installation as A Project Work

Safety Precautions to follow when wiring a circuit

1. Wear safety protective clothing
2. Have the right tools on hand and use them appropriately
3. Make sure power is always off when doing any work
4. Always test any finished job before connecting it to power

Wiring of an Installation

Learners are to wire the circuit practically.

Equipment for the consumer unit

The following are required for the consumer unit

1. 60A cutout fuse with neutral link
2. 20A double pole MCB (*Figure 3.17*)
3. Single phase MCCB (*Figure 3.18*)
4. 6-way Distribution Board (As shown in part of *Figure 3.19*)



Figure 3.20: Double pole MCB



Figure 3.21: Single-phase RCCB

Wiring of the consumer unit

The following diagram (Fig 3.19) is how the consumer control unit is to be wired

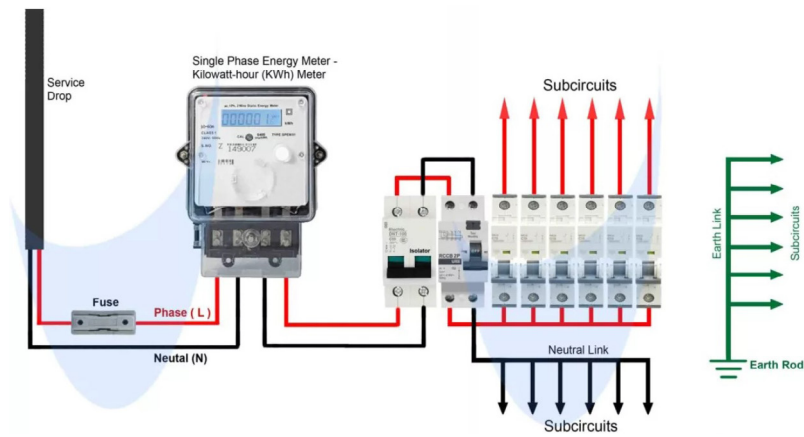


Figure 3.22: Wiring diagram of the consumer unit (with 6-way DB)

Final circuit to be wired

The following (**Fig 3.20**) is the final circuit to be wired as a project work

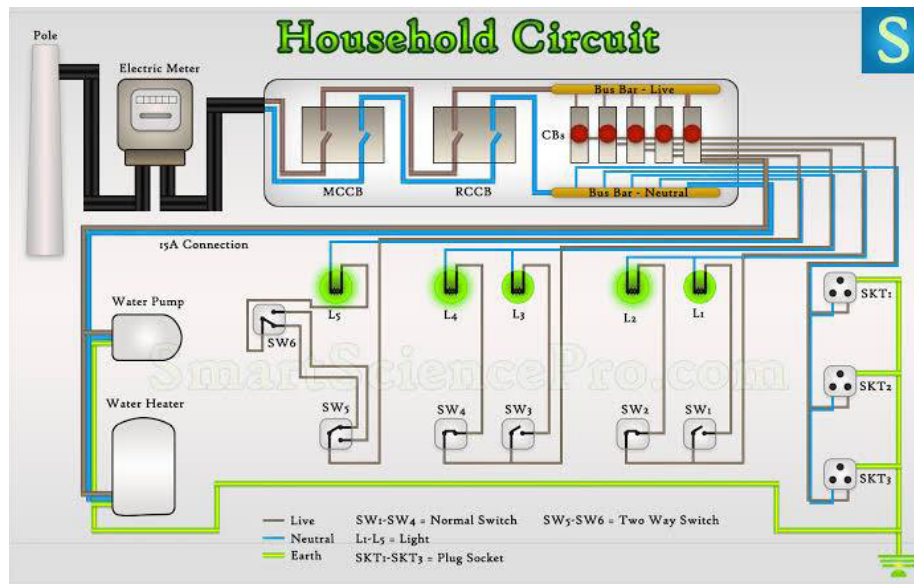


Figure 3.23: Wiring of the final circuits

Tools and Materials Required

The following materials and tools are required to do the wiring

Table 3.1: Tools and materials required

S/N	MATERIALS AND ACCSSORIES	QUANTITY
1	Plywood (120cm x 240cm)	1
2	6-way Distribution Board	1
3	Double Pole MCB	1
4	Single phase RCCB	1
5	60A cutout	1
6	16mm x 25mm Trunking	3
7	16 x 16mm	3

8	Twin Socket outlets	4
9	2-way switch	2
10	Single pole switch	4
11	Batten Lamp holder	5
12	Cooker control unit	1
13	1.5mm ² cable (Red)	1 roll
14	1.5mm ² cable (Blue)	1 roll
15	2.5mm ² cable (Red)	1 roll
16	2.5mm ² cable (Blue)	1 roll
17	2.5mm cable (Yellow/green)	1 roll
18	6mm ² cable (Red)	5 yards
19	6mm ² cable (Blue)	5 yards
20	6mm ² cable (Green/Yellow)	5 yards
21	16mm ²	12 yards
22	Pattress boxes	12
TOOLS		
1	Portable Hand Drill	1
2	Screw Drivers	1 set
3	Wire stripper	1
4	Plier	1
5	Side cutter	1
6	Hacksaw	1
7	Multimeter	1

Procedure for Wiring The Circuit

Learners are to use the following procedure to wire the circuit

1. Mark out positions of the MCB, RCCB, DB and accessories on the board
2. Measure and cut the trunking to the appropriate lengths
3. Position trunking on board and secure them with screws
4. Fix the consumer control unit as well as boxes
5. Run cables of the various final circuits (1.5mm² for the lighting, 2.5mm² for the socket outlets and 6mm² for the cooker control unit)
6. Do termination at all the accessories taking the various colours into account
7. Screw all accessories in place
8. Do termination at the consumer unit with the 16mm² cable by following the sequence on the wiring diagram (**Figure 11.3**)
9. Test for short-circuit by conducting an insulation resistance test. The reading should show as infinity.

10. Conduct continuity test and polarity test
11. Fix all loads and connect circuit to power source
12. Check if every load works satisfactorily.

Learning Tasks

1. Explain the basic requirements for wiring a circuit
2. Outline the precautions to follow when wiring a circuit
3. Describe the procedure of building the circuit

PEDAGOGICAL EXEMPLARS

1. **Collaborative Learning/Talk For Learning/Digital Learning:** In a mixed-ability groups task learners to brainstorm and come out with the basic precautions to follow when wiring a circuit to ensure the safety of themselves and that of others. Learners are also expected to also describe the procedure for connecting the consumer control unit.
2. **Experiential Learning:** Engage learners in experiential learning by allowing them to draw the circuit and use the procedure outlined to practically carry out the wiring process.

Through active participation in these activities, learners will gain first-hand experience and understanding of the necessary steps involved in carrying out some methods of house wiring.

KEY ASSESSMENT

Level 2

1. Explain the basic requirements for wiring a circuit.
2. Outline the precautions to observe when wiring a circuit.

Level 3: Build a radial circuit.

HINT



*The recommended mode of assessment for week 12 is **end of semester examination**. Refer to Appendix D at the end of this section for Table of specification to guide the setting of the questions.*

UNIT 12 REVIEW

This unit introduced learners to the precautions to be observed during wiring, some tools and materials needed to wire an installation and the application of the knowledge of wiring in the design and construction of a home installation.



APPENDIX D: END OF SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

1. Duration: 2 hrs 45 minutes
2. SECTION A

30 Multiple Choice Questions (MCQ) – all questions should be answered.

3. SECTION B

10 essay-type questions – answer 7 out of 10 questions.

Both MCQs and essay-type questions will cover lessons taught from weeks 1 to 12. Questions will cover DoK levels 1 to 3.

RESOURCES

Scannable sheets, A4 paper, answer booklets, class list, etc.

SAMPLE QUESTIONS

SECTION A

Multiple Choice Questions - 1 hour

1. Which of the following scenarios **best** illustrates the importance of workplace safety protocols? An employee.....
 - a. attends team meetings regularly.
 - b. follows the dress code policy.
 - c. reports a minor injury to their supervisor.
 - d. uses PPE while handling hazardous materials, etc.

SECTION B

Essay type – 1 hour 45 minutes

- a. Explain the concept of house wiring, etc.

MARKING SCHEME

Multiple Choice - 1 mark for each correct answer

1. Which of the following scenarios **best** illustrates the importance of workplace safety protocols? An employee.....
 - a. attends team meetings regularly.
 - b. follows the dress code policy.
 - c. reports a minor injury to their supervisor.
 - d. uses PPE while handling hazardous materials. [1 mark]

There will be a total of **30 marks for Section A**

Essay - 70 marks (7 questions to be answered out of 10)

1. Explain the concept of house wiring, etc.

Expected response should include an explanation of the concept with key technical words such as *protection, cables and wires, switches, earthing*, etc. **[10 marks]**

See the table below for a breakdown of mark allocation.

Mark Allocation	Description of Expected Response
1–2 marks	Basic explanation: The learner provides a very general or superficial definition. They may mention wires and electricity but lack specific detail. For example, “ <i>It’s how you get electricity in a house</i> ”
3–4 marks	Partially correct explanation: Learner mentions some key components like the main switch, meter, and fuse box. Understand the basic flow of electricity but may confuse the roles of different wires or components.
5–6 marks	Good explanation: Correctly identifies the main components of a house wiring system, including the metre, consumer unit (fuse/breaker box), main switch , and different circuits (lighting, power outlets) . Can explain the purpose of each component, but their explanation of the wiring types or safety features might be incomplete.
7–8 marks	Detailed explanation: Provides a comprehensive explanation of the entire process, from the power supply entering the house to distribution to different circuits. Correctly identify the three types of wires (live, neutral, and earth) and explain their functions. Also mention key safety features like fuses or circuit breakers .
9–10 marks	Comprehensive explanation: A complete and accurate explanation of the house wiring concept. Correctly identify all components, including the metre, consumer unit, main switch, and different circuits. Explain the function of each of the three wires (live, neutral, and earth) and clearly describe key safety devices like fuses and Residual Current Devices (RCDs). The answer is well-structured, logical, and may include a brief mention of different wiring systems (e.g., ring vs. radial circuits).

TABLE OF SPECIFICATION FOR END OF SEMESTER EXAMINATION

Weeks	Learning Indicators	Item	DoK Level			TOTAL
			1	2	3	
1	Explain house wiring and provide reasons for doing good wiring.	MCQ	1	1	1	4
		Essay	1			
2	Classify tools and equipment used in wiring and their functions.	MCQ	1	1	1	3
		Essay	–	–	–	
3	Identify the various materials and accessories used for house wiring.	MCQ	1	1	1	4
		Essay	–	–	–	
4	Describe the sequence of Supply–control equipment.	MCQ	1	1	1	4
		Essay		1		
5	Describe how a circuit is protected against Excess current.	MCQ	1	1	1	4
		Essay		1		
6	Describe the various methods of house wiring.	MCQ	1	1	1	4
		Essay			1	
7	Wire final circuits in accordance with IEE regulations.	MCQ	1	1	1	4
		Essay	1			
8	Apply knowledge of final circuits in a practical situation.	MCQ		1	1	3
		Essay			1	
9	Earth an installation work in accordance with regulations.	MCQ		1	1	3
		Essay		1		
10	Conduct relevant tests on an installation work that has been complete.	MCQ	1	1		3
		Essay			1	
11	Apply the knowledge of house wiring in practical situations.	MCQ	1			3
		Essay		1		
12	Describe the construction of a cell and explain how it is able to generate electrical energy.	MCQ	1		1	3
		Essay			1	
TOTAL			12	14	14	40

SECTION 4: PASSIVE ELECTRONIC COMPONENTS AND CELLS

In this section, learners will acquire knowledge and understanding of types of resistors as passive electronic components, types of capacitors, and the inductor as a passive electronic component. All the above are treated from unit 13 to unit 16.

UNIT 13

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Components And Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Demonstrate understanding of cells and passive electronic components and apply them in designing electronic circuits.*

HINT



Give learners Individual Projects in Week 16 to be submitted in Week 22. Refer to Appendix E for more guidance on the project.

INTRODUCTION AND SECTION SUMMARY

This section looks at cells and passive components as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following: Construction, principles of operation and application of cells, resistors, capacitors and inductors.

*The unit covers only week 13: **Describe types of resistors as passive electronic components***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For the effective delivery of this unit through active involvement and cooperation of learners, teachers should consider pedagogical exemplars like collaborative/talk for learning approaches and experiential/collaborative learning approaches.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 13

Learning Indicator: Describe types of resistors as a passive electronic component

Focal Area 1: Passive Electronic Components (Resistors)

Passive electronic components are components in an electronic circuit that do not require power to operate. Resistors are electronic components that opposes or control the amount of flow of electrons in a circuit.

Types of Resistors

There are different types of resistors that are used in electronic circuits such as:

1. **Carbon resistors:** A resistor made of a thin layer of carbon deposited on an insulating core.
2. **Wire-wound resistors:** A resistor made of a wire wound around insulating core.
3. **Thermistor:** A resistor that changes its value with changes in temperature.
4. **A Light Dependant Resistor (LDR):** A resistor whose value changes in accordance with light intensity.
5. **Varistor:** A resistor that the value varies with voltage.
6. **Fixed resistors:** A resistor with a fixed value.
7. **Variable resistor:** A resistor that the value can be changed.



Figure 4.1: Carbon resistors

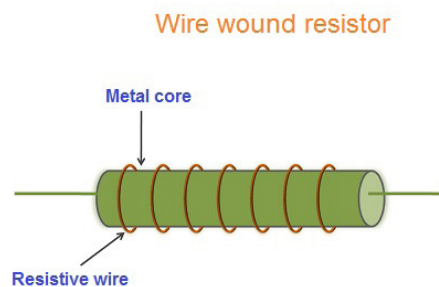


Figure 4.2: Wire wound resistor



Figure 4.3: Thermistors



Figure 4.4: Light Dependent Resistor



Figure 4.5: Varistors



Figure 4.6: Fixed resistor



Figure 4.7: Variable Resistors

Functions of A Resistor

Resistors can be used for the following functions:

1. **Voltage divider:** Resistors can be used as a voltage divider to divide up voltages into specific ratios in a circuit.
2. **Current limiting:** Resistors are used to control the flow of electrons in a circuit.
3. **Timing and Filtering:** Resistors are used together with capacitors and inductors for the purposes of timing, filtering and frequency response shaping in electronic circuits.
4. **Load resistor:** Resistors can be used as load resistors to simulate the presence of a load in a circuit.

Determination of The Value of A Resistor Using The Colour Codes

Resistor Color Table

1st Digit	2nd Digit	Multiplier	Tolerance
0	0	$\times 1\Omega$	$\pm 1\%$
1	1	$\times 10\Omega$	$\pm 2\%$
2	2	$\times 100\Omega$	
3	3	$\times 1K\Omega$	
4	4	$\times 10K\Omega$	
5	5	$\times 100K\Omega$	
6	6	$\times 1M\Omega$	
7	7		$\pm 5\%$
8	8	$\times 0.1\Omega$	$\pm 10\%$
9	9	$\times 0.01\Omega$	

Figure 4.8: Resistor colour chart

For the calculation of the value of a four-band colour resistor follow the steps below:

Example: Calculate the value of the resistor with colours red, green, brown, gold

1. Refer to the chart above to look for the corresponding number for the first colour red thus 2, (red = 2).
2. Repeat the step 1 to look for the corresponding number for the second colour green thus 5,
3. The third band (colour) is the multiplier, here refer to the chart above again to look for the corresponding number for the third colour brown thus 1, (brown = 1).
4. Now write the first and second digits as one number thus 25 and multiply by 10 if the third colour corresponds with 1, multiply by 100 if the third colour corresponds with 2 and 1000 if it corresponds with 3 and so on and so forth. Finally, the nominal value for the resistor with the colours red; blue; brown; gold is $25 \times 10 = 250\Omega$.
5. The fourth colour determines the tolerance of the resistor, here the gold colour corresponds with $\pm 5\%$. Calculate for 5% of the nominal value 250 thus 12.5. Now add and subtract 12.5 from 250, $250 + 12.5 = 262.5$ and $250 - 12.5 = 237.5$.

Now the tolerance ranges from 237.5Ω to 262.5Ω .

Learning Tasks

1. Explain the concept of passive electronic components.
2. Describe at least four types of resistors.
3. Describe at least three functions of resistors.
4. Determine the value of a carbon resistor with the colour bands yellow, blue and red.

PEDAGOGICAL EXEMPLARS

Collaborative Learning: Using videos and pictures engage learners in mixed ability groups to undergo the following activities:

1. Define resistors.
2. Outline the types of resistors **e.g.**, carbon resistors, wire wound resistors etc.
3. Explain the functions of a resistor.
4. Calculate the values of resistors using colour codes.

KEY ASSESSMENT

Level 2

1. Explain the concept of passive electronic components.
2. Describe at least four types of resistors.

Level 3: Describe at least three functions of a resistor.

Level 4

1. Determine the value of a carbon resistor with colour bands yellow, blue and red.
2. Draw and label the schematic diagram of a resistor.

HINT



*The recommended mode of assessment for week 13 is **chart or diagrams**. Use the level 4 question 2 as a sample question.*

UNIT 13 REVIEW

This unit covered resistors as an example of passive electronic components with emphasis on the concept of resistors, types of resistors, functions of resistors and calculation of the values of resistors using colour codes.

UNIT 14

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Components and Circuits

Learning Outcome: Apply knowledge and understanding of electronic components and use them to design and construct electronic circuits.

Content Standard: Demonstrate understanding of cells and passive electronic components and apply them in designing electronic circuits.

INTRODUCTION AND SECTION SUMMARY

This section looks at cells and passive components as part of electronic components. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following Construction, principles of operation and application of cells, resistors, capacitors and inductors.

The unit covers only week 14: Describe types of capacitors

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 14

Learning Indicator: Describe types of capacitors as passive electronic components

Focal Area 1: Capacitors And Cells

Definition of Capacitor

A capacitor is a passive electronic component that stores electrical energy by accumulating electric charges on two closely spaced surfaces that are insulated from each other. A capacitor is made of two conductors that are separated by a dielectric material. These dielectric materials are in the form of plates which can accumulate charges. One plate is for a positive charge while the other is for a negative charge.

Construction of a Capacitor

A capacitor consists of two parallel conductive plates separated by an insulating material. Current cannot flow between the plates because of the insulation. Consequently, the charge is retained at the plates. The plates may be rectangular, square, circular, and can be formed into different shapes like cylindrical, bead, or disc. Whatever the shape, a constant insulation level between the plates is always maintained. The power handling capacity of each capacitor dictates what its size should be. Specific insulating materials that can maintain the charge on the plates such as ceramic, paper, polymer, oil, etc. are used as the dielectric. In some cases, however, air may be the insulating medium. To charge the capacitor, it must be connected across a voltage source and the charging current will flow to the capacitor until it is fully charged. When fully charged, the capacitor becomes a voltage source.



Figure 4.9: Construction of a capacitor

Capacitor Symbols

The symbols of capacitors

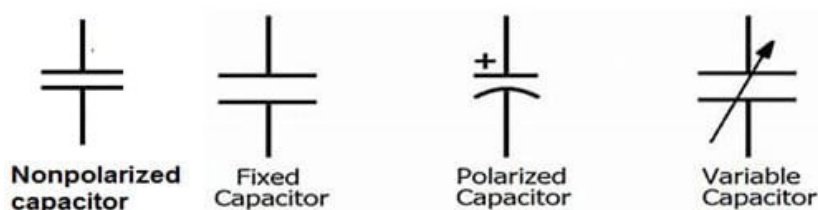


Figure 4.10: Capacitor symbols

Principle of a Capacitor

A conductor charges when a voltage source V , is connected to it. This charge, Q , is proportional to the applied voltage. That is: $Q \propto V$

Therefore, $Q = kV$.

Where the constant k , is the capacitance C , of the conductor

Therefore, $Q = CV$ and $C = Q/V$

In capacitors, capacitance is the ability of the capacitor to store electric charge. The capacitance of a capacitor depends on the following factors:

1. **Area A , of the plate.** The larger the plate area, the greater the charge accumulation on it.
2. **Distance, d , between plates.** The larger the distance between the plates, the more capacitance gets reduced due to a reduction in charge binding/field force or reduction in permittivity.
3. **The dielectric medium.** Capacitance increases if a material with high permittivity is used.

Specifications of Capacitors

Capacitors may be specified in terms of the following:

1. **Capacitance Value:** The value of the capacitor is measured in terms of its capacitance value and is expressed in farads, microfarads, and nano-farads.
2. **Voltage Rating:** Voltage rating is the operating voltage of the capacitor and it is measured in volts.
3. **Dielectric Strength:** Dielectric strength is the ability of the capacitor to withstand the voltage per unit thickness of the dielectric material without breakdown. It is measured in Kv/mm or Kv/cm . It depends on the thickness of the dielectric, temperature, and supply frequency.
4. **Dielectric Constant:** The dielectric constant is the property of the dielectric that affects the capacitance value.
5. **Temperature Co-efficient:** The temperature co-efficient represents the stability in capacitance value with the change in temperature. It is expressed in $ppm/^{\circ}C$.
6. **Frequency Range:** The frequency range is the maximum frequency up to which the capacitor can work safely.
7. **Power Factor:** Power factor indicates the minimum loss in the capacitor. It states the fraction of input power dissipated as heat loss in the capacitor. Therefore, the quality of the capacitor depends on how low the power factor is. This is because the reciprocal of the power factor is the quality factor (Q) of the capacitor. *For instance*, if the power factor is 0.0001 then the quality factor (Q) is the reciprocal of 0.0001. So, $Q = 1/0.0001 = 10000$. Thus, the lower the power factor, the higher the quality factor, hence, the better the quality of the capacitor.

Types of Capacitors: There are numerous types of capacitors including the following

1. Fixed Capacitors
2. Mica Capacitors
3. Ceramic Capacitors
4. Paper Capacitors
5. Plastic Capacitors
6. Electrolytic Capacitors
7. Film capacitors
8. Adjustable Capacitors
9. Variable Capacitors

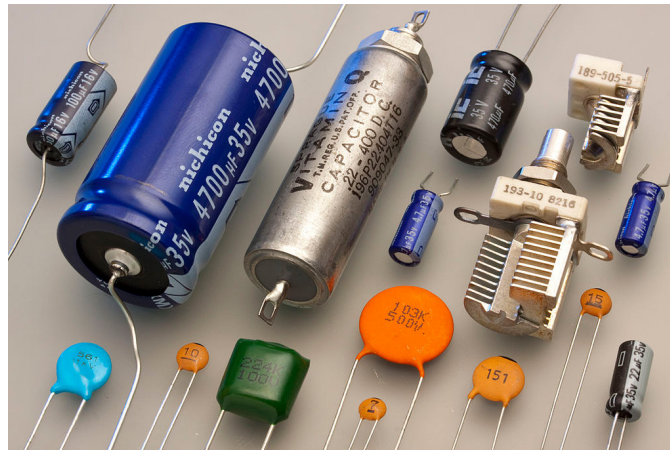


Figure 4.11: Types of capacitors

Classification of Capacitors

Capacitors are classified according to Structure or Polarisation. In terms of structure, capacitors are classified as follows:

1. Fixed Capacitors
2. Variable Capacitors
3. Trimmer Capacitors

In terms of polarisation, capacitors are classified into two as follows:

1. Polarised
2. Non-polarised

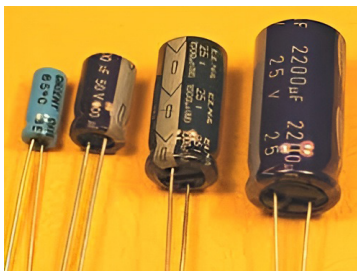


Figure 4.12: Picture of polarised capacitors

A **polarised capacitor** is one that has distinct positive and negative terminals, operates with a specific polarity, and requires one terminal to be connected to positive voltage and the other to negative voltage. It is often termed an electrolytic capacitor and is mostly used to achieve high capacitive density. Example is **Figure 4.12**



Figure 4.13: Examples of non-polarised capacitors

Non-polarised capacitors are those with neither positive nor negative polarity. The two electrodes can be put into the circuit at random and will not leak. Owing to that, non-polarised capacitors are mostly preferred to polarised ones and can be used in both AC and DC circuits. They are mostly used in coupling, decoupling, compensation, feedback, and oscillation circuits.

Uses of capacitors in circuits

1. Capacitors are used to store electrical energy.
2. To smoothen rectified dc voltage
3. Used to couple two circuits.
4. It improves the power factor of a circuit.
5. To start single-phase a.c. motors.
6. Used as filters in frequency circuits.

Values of Capacitors Using Colour Codes

The value of capacitors, mostly in microfarads (μF), is always printed on the body of the capacitors. However, in color-coded capacitors, the values are represented as colour bands, and by using a capacitor colour code chart as shown in Table 4.1, the value of the capacitor can be obtained.

Table 4.1: Capacitor colour code chart

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	1%
Red	2	100	2%
Orange	3	1.000	
Yellow	4	10.000	
Green	5	100.000	0,5%
Blue	6	1.000.000	0,25%
Violet	7	10.000.000	0,1%
Grey	8		0,05%
White	9		
Gold		0,10	5%
Silver		0,01	10%

Each colour band on the chart has a value and it's the same as that of resistors. The value of each capacitor is determined as follows:

1. First band is the first digit on the colour chart
2. Second band is the second digit

3. Third band is the multiplier
4. Fourth band is the tolerance of the capacitor.
5. Fifth band is the working voltage of the capacitor. (Red is 250 volts and Yellow is 400 volts).

The working voltage of capacitors used in AC circuits should be 400 volts. It is very important always to select a capacitor whose working voltage is about three times higher than the power supply voltage. For instance, if the power supply is 15 volts, use a 50v capacitor and eliminate ripples completely in smoothing circuits. It is better to use capacitors with very high capacitance otherwise there will be humming, particularly in audio circuits. Values such as 2200 μ F, 3300 μ F or 4700 μ F will give satisfactory results. Tantalum capacitors have low leakages and are most suitable for timer circuits.

Capacitors in Series And In Parallel

Capacitors in series

When capacitors are connected in series, the combine capacitance is given by the relation:

Capacitors in Parallel

When capacities are connected in parallel, the equivalent or total capacitance is the sum of the individual capacitors:

$$i.e. C_T = C_1 + C_2 + C_3 + \text{etc.}$$

Advantages and disadvantages of capacitors

Capacitors are widely used in electrical and electronic circuits. They have numerous advantages including the following:

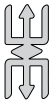
1. Fast energy storage
2. Quick release of stored energy
3. Low losses
4. Capacitors require no maintenance
5. Long service life
6. Simple method of operation
7. Capacitors can work with both AC and DC
8. Relatively cheap components
9. Used in a wide range of applications

Capacitors have disadvantages as well. These include

1. Less capacity compared to batteries
2. Limited energy storage
3. Stored energy eventually depletes
4. Stored voltage level varies

Learning Tasks

1. What is a capacitor, and how is it constructed?
2. What 3 factors does the capacitance of a capacitor depend on?
3. Explain any 3 things that determine the specification of a capacitor.
4. Differentiate between a fixed capacitor and a variable capacitor.
5. What is the difference between a polarised capacitor and a non-polarised one?

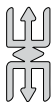


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as to become a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to describe the construction of a capacitor and explain three factors that determine the value of the capacitance of a capacitor. Learners should also provide 4 areas where capacitors are employed and state 4 advantages and 4 disadvantages of capacitors.
2. **Group work/Collaborative learning:** In small mixed-ability groups, task learners to identify any 4 things that indicate the specification of capacitors and differentiate between a fixed capacitor and a variable one. Encourage learners to pool their knowledge and skills to brainstorm, research and explain the difference between a polarised capacitor and a non-polarised one.



Note

Through this group work, learners not only enhance their understanding of capacitors, but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to calculate for total capacitance of capacitors connected in series and in parallel. Challenge them to determine capacitor values given various colour bands. Through active participation in these activities, learners will gain first-hand experience and understanding of how to determine capacitor values.

Additionally, they will collaboratively brainstorm and discuss care and maintenance measures, drawing from their simulated experiences to reinforce understanding of

maintenance procedures. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply maintenance in real-world contexts.

KEY ASSESSMENT

Level 1

1. Define a capacitor.
2. List 3 uses of capacitors.
3. List 4 advantages and 4 disadvantages of capacitors.
4. In which areas are capacitors employed?

Level 2

1. What is the difference between fixed capacitors and variable capacitors?
2. Explain any 3 things that determine the specification of a capacitor.

Level 3

1. Determine the values of a capacitor with the following color bands: Orange, orange, red, Gold, red.
2. Compare polarised capacitors and non-polarised ones
3. Three capacitors have values of 10 μ F, 12 μ F, and 15 μ F. Determine their total capacitance if they are connected in series and parallel.

HINT



*The recommended mode of assessment for week 14 is **homework**. Use the level 1 question 2 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 46 for additional information on how to use this mode of assessment.*

UNIT 14 REVIEW

This unit covered capacitors as an example of passive electronic components with emphasis on the concept of capacitors, types of capacitors, functions of capacitors and calculation of the values of capacitors using colour codes. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities

UNIT 15

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Components And Circuits

Learning Outcome: *Apply knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Demonstrate understanding of cells and passive electronic components and apply them in designing electronic circuits.*

INTRODUCTION AND SECTION SUMMARY

This section looks at cells and passive components as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following: Construction, principles of operation and application of cells, resistors, capacitors and inductors.

The unit covers only week 15: Describe the inductor as a passive electronic component and cells

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 15

Learning Indicator: Describe types of inductors as a passive electronic component

Focal Area 1: Passive Electronic Components (Inductors)

Inductors are passive electronic components that store energy in a magnetic field when an electric current flows through them.

Functions of Inductors

Inductors play a many significant roles in an electronic circuit such as

1. **Energy storage:** Inductors store energy in a magnetic field and releases it back into the system anytime is needed.
2. **Current limiting:** Inductors can limit the current in a circuit thereby protecting it from excessive values.
3. **Filtering:** Inductors can serve as low-pass or high-pass filters, enabling or blocking certain frequencies.
4. **Impedance matching:** Inductors can match the impedance of different circuits, leading to maximum energy transfer.
5. **Oscillation:** Inductors can produce oscillations when combined with capacitors to form a resonant circuit.

Types of Inductors

The following are types of inductors that are usually used in electrical and electronics circuits;

1. **Iron-core inductors:** This type of inductor uses ferromagnetic core, suitable for low frequency applications.
2. **Air-core inductors:** No core material is used for high-frequency applications.
3. **Choke inductors:** Designed to block high frequencies while allowing low frequencies to pass.
4. **Toroidal inductors:** Doughnut-shaped, offering high inductance and low radiation.

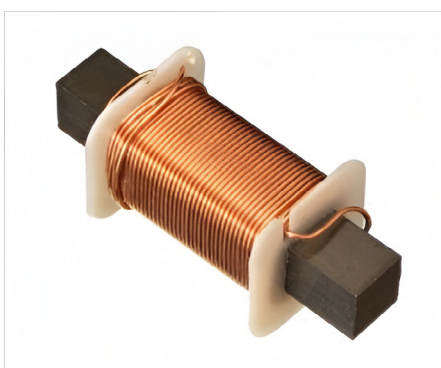


Figure 4.14: Iron-core inductor

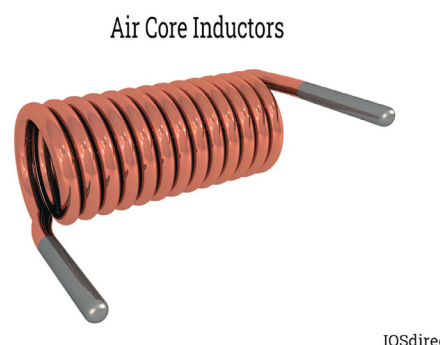


Figure 4.15: Air-core Inductor

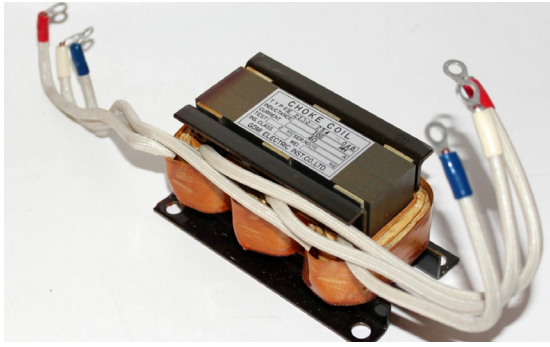


Figure 4.16: A choke inductor

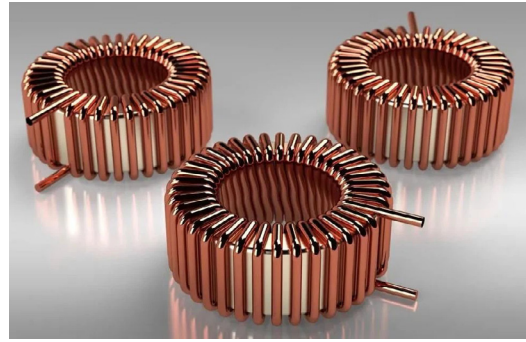


Figure 4.17: Toroidal inductor

Learning Tasks

1. Explain the concept of inductors as a passive electronic component.
2. Describe at least four types of inductors.
3. Identify at least four roles that inductors play in a circuit.

PEDAGOGICAL EXEMPLARS

Collaborative Learning: Using videos and pictures engage learners in mixed ability groups to undergo the following activities:

1. Define inductor
2. Describe the types of inductors
3. Explain the functions of an inductor

KEY ASSESSMENT

Level 2

1. Explain the concept of inductors as a passive electronic component.
2. Describe at least four types of inductors.
3. Identify at least four roles that inductors play in a circuit.

Focal Area 2: Cells and Batteries

Definition

A cell is a device that converts chemical energy into electrical energy. It typically consists of two electrodes and an electrolyte, a substance that conducts electricity. A battery is a device made up of two or more cells that supply a steady source of electrical energy. There are different types of batteries including alkaline batteries, lithium-ion batteries, and lead-acid batteries. Batteries are used in a wide range of applications, from powering small electronic devices to starting cars in the automobile industry.

Construction of a Cell

A cell consists of two electrodes, a cathode and an anode, positioned in an electrolyte as shown in **Figure 3.21**. An electrolyte is a substance that conducts electricity and is mainly used in cells and batteries.

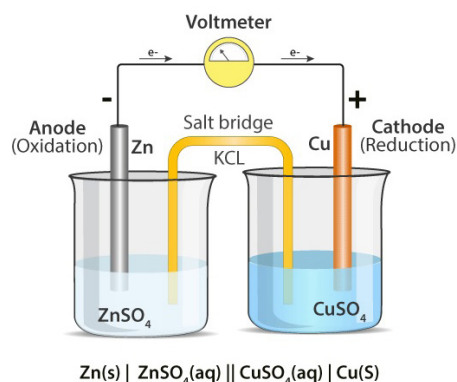


Figure 3.21: Construction of a chemical cell.

Production of Electricity From Cells

From **figure 3.21**, electricity is produced through a chemical reaction between the electrodes and the electrolyte, a substance that contains positively and negatively charged ions, which flow freely and provide a means of generating electrical current. When the electrodes are connected to an external circuit, the chemical reaction generates a flow of electrons, which creates an electric current.

Difference between a cell and a battery

A cell is a single device that converts chemical energy into electrical energy, while a battery is a collection of cells that provide a steady source of electrical energy. A battery provides a higher voltage and more energy than a single cell.

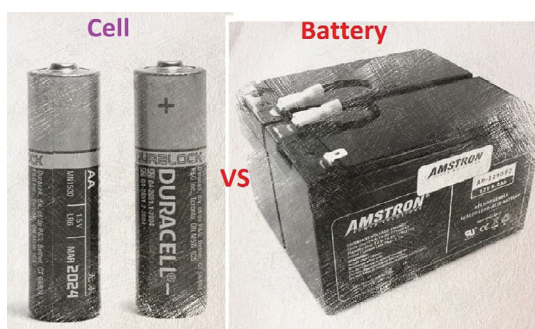


Figure 3.22: Picture of cells and a battery

Types of Cells

There are two types of cells, the **primary cell** (non-chargeable cell) and the **secondary cell** (rechargeable).

Primary Cells

Primary cells are cells that have a definite number of reactants and are non-rechargeable. In such cells, the reactants are specific in number and once they are exhausted, reactions cannot

happen again and so the cell cannot be recharged even if an external current is connected to it. This means that once the reactants are used-up, all reactions stop and the cells no longer produce charge. At this point, they must be replaced.

Alkaline batteries fall into this category. These batteries no longer produce a charge after a period of time, are non-rechargeable and must be replaced.

Secondary Cells

Some of the cells or batteries are **rechargeable**. A **rechargeable battery** is the type in which the chemical reaction can be reversed. This is attained by passing an external current through the battery in a reverse direction. Such a battery can be used many times, and typical applications of these batteries include portable lamps, laptop computers and smartphones. Comparatively, rechargeable batteries are cost-effective and environmentally friendly as against disposable ones.

Differences Between Primary Cell and Secondary Cell

Primary cells cannot be recharged and should be disposed of after their expiration whereas secondary cells are rechargeable when the charge is exhausted. Both types of battery are used extensively in various appliances and these cells differ in size and material used in them. **Table 3.2** shows the differences between the two types of cells.

Table 3.2: Differences between primary cells and secondary cells

Difference Between Primary Cell and Secondary Cell	
Primary Cell	Secondary Cell
Have high energy density, slow in discharge and easy to use	They have smaller energy density
There are no fluids in the cells which can spill: hence it is also called dry cells	These are made up of wet cells (flooded and liquid cells) and molten salt (liquid cells with different composition)
It has high internal resistance	It has a low internal resistance
It has an irreversible chemical reaction	It has a reversible chemical reaction
Its design is smaller and lighter	Its design is more complex and heavier
Its initial cost is cheap	Its initial cost is high

Factors Affecting Cell Voltage

The voltage a cell produces depends on the types of electrodes and electrolyte present.

1. If the difference in reactivity between the electrodes is large, then the voltage of the cell will be big.
2. The type of electrolyte equally affects cell voltage. This is because different ions react differently with the metal electrodes.

Cells In Series And In Parallel

The value of the voltage produced by cells depends on the number of cells, the voltage of each cell and the way they are connected, whether in series or parallel.

If cells are connected in series, the total supply voltage will be the sum of the voltages of all the cells connected in the circuit. However, the total current will be the current of one cell. On the other hand, if cells are connected in parallel, the supply voltage will be the voltage of one cell but the total current will be the sum of the currents of all the cells connected in the circuit.

Example

A cell is rated 1.5V, 20mA. What will be the supply voltage and the total current if six of such cells are:

1. connected in series
2. connected in parallel

Solution

1. In series, the voltage = $1.5 \times 6 = 9V$
the current, $I_s = 20mA$
2. In parallel, the voltage = 1.5V
the current = $20mA \times 6 = 120mA$

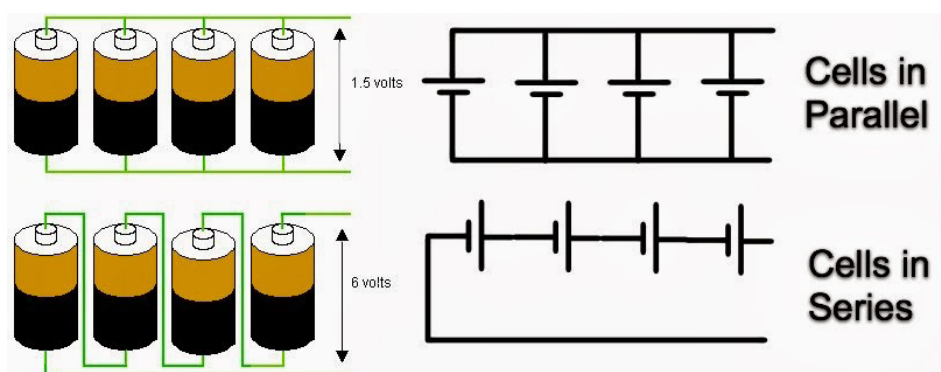


Fig 3.23: Cells in series and parallel

Advantages and disadvantages of batteries

Advantages of batteries include the following

1. They are portable.
2. Batteries are a source of energy for the transport sector.
3. Compared to generators, most batteries do not produce carbon dioxide.
4. Batteries are used to store surplus electricity, thus reducing energy waste.

Batteries also have the following disadvantages

1. They are expensive to use.
2. The amount of energy a battery can store is small.

3. Batteries contain precious metals which are exhaustible.
4. The processes leading to battery production include mining of precious metal thus producing toxic waste that is detrimental to the environment.
5. The electrolyte is a corrosive chemical, and care must be taken to prevent it from leaking.

Learning Tasks

1. Explain what is meant by a cell and differentiate between a cell and a battery.
2. How is a cell able to produce electric current?
3. Explain two factors that affect cell voltage.
4. What key differences exist between primary cells and secondary cells?

PEDAGOGICAL EXEMPLARS

1. **Collaborative Learning/Talk For Learning/Digital Learning:** In mixed-ability groups task learners to brainstorm and come out with a description of how a cell is constructed, compare primary cells and secondary cells, calculate for the voltages of cells connected in series and parallel and outline the advantages and disadvantages of cells.
2. **Experiential Learning:** Engage learners in experiential learning by allowing them to watch videos on YouTube on how to construct a simple cell. Allow learners to draw a cell diagram and construct a simple cell.

Through active participation in these activities, learners will gain first-hand experience and understanding of how a cell is constructed.

KEY ASSESSMENT

Level 2

1. Describe the construction of a simple chemical cell.
2. Explain two factors that affect cell voltage.
3. What are typical applications of secondary cells?
4. Outline the advantages and disadvantages of a cell.

Level 3

1. Compare primary cells and secondary cells.
2. Draw a diagram of a simple cell and label it properly.
3. Calculate for circuit voltage of 5 cells connected in series and in parallel if the voltage of each cell is 1.5V.
4. Analyse 2 key differences between active and passive electronic components in a tabular form.

HINT

*The recommended mode of assessment for week 15 is **task analysis**. Use the level 3 question 4 as a sample question.*

UNIT 15 REVIEW

This unit introduced learners to the basic construction of a cell, and how the cell can produce electric current. The factors that affect cell voltage, difference between a cell and a battery as well as the differences between primary and secondary cells have equally been discussed. The discussion further looked at the advantages and disadvantages of cells and the supply voltage of cells connected in series and in parallel

UNIT 16

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Demonstrate understanding of Transistors as electronic devices and apply them in designing electronic circuits*

INTRODUCTION AND SECTION SUMMARY

This section looks at transistors as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following Construction, principles of operation and application of the various type of electronic components and be able to design electronic circuits with them.

The unit covers only week 16: Illustrate the construction of the transistor (BJT)

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section require learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 16

Learning Indicator: *Illustrate the construction of transistors*

Focal Area 1: Bipolar Junction Transistor

A transistor is a semiconductor device that controls voltage or current flow in electronic signals and can amplify these signals and act as a switch for them. A bipolar junction transistor is a three-terminal semiconductor device, made up of two p-n junctions with the ability to amplify or magnify signals that are applied to it. This type of transistor is often regarded as one of the most common types.

Construction of Bipolar Junction Transistor

The BJ transistor consists of two PN junctions separating three regions. These regions are the emitter, base, and collector regions. Basically, there are two types of BJ transistors. The NPN and the PNP. The NPN is made up of two N regions separated by a P region (fig 16.1a) while the PNP consists of two P regions separated by one N region (fig 16.1b). The transistor has three terminals each connected to one of the three regions and are denoted as Base (B), Collector (C) and Emitter (E).

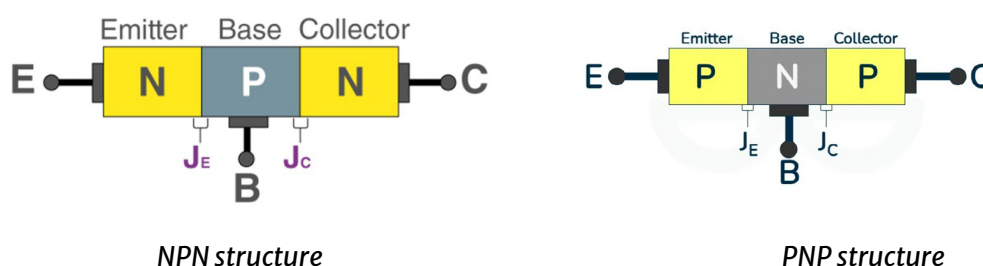


Figure 4.18: *Bipolar Junction Transistor*

The symbols of the NPN and PNP BJ transistors are shown in, note that the arrow indicates the direction of current flow through the transistor and should be a guide when connecting the transistor in a circuit.

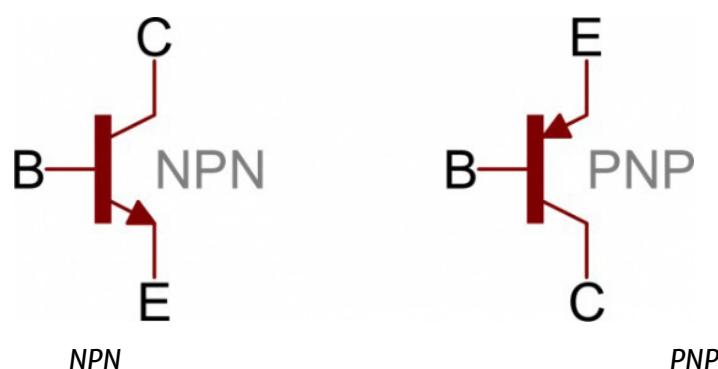


Figure 4.19: *NPN and PNP BJ transistors*

NPN Configuration

Electrons are the main charge carriers in the NPN configuration and when the base-emitter junction is forward biased (making the base positive and emitter negative). As shown in fig 16.3, electrons drift from emitter into the base region with the view to forming base current. However, if the collector is connected to a positive potential, the majority of the electrons that enter the base region are attracted into the collector region causing a current to flow from the collector to the emitter. It is obvious that the emitter emits electrons and the collector collects these electrons. However, it is the base that controls the drift of these electrons. From the NPN symbol in Figure 16.3, both collector current, I_C and base current, I_B , converge at the emitter, forming emitter current, I_E . Consequently, $I_E = I_C + I_B$

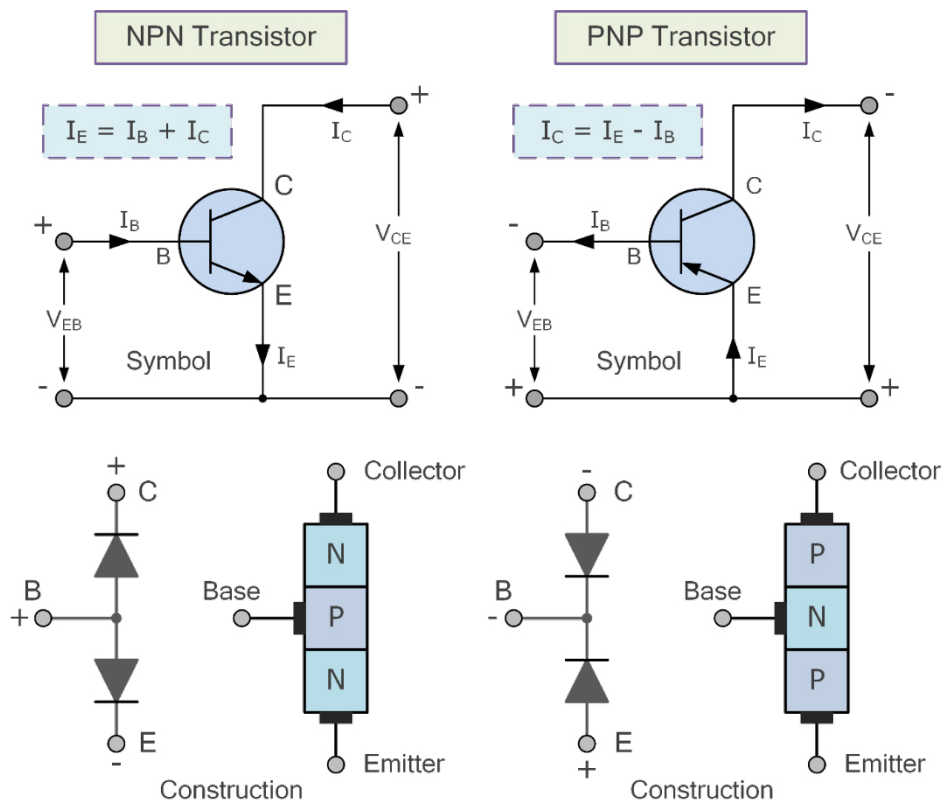


Figure 4.20: Configurations of BJ transistor

PNP Configuration

Holes are majority charge carriers in the PNP configuration and when the emitter-base junction is forward biased (making the emitter positive and the base negative), as shown in fig 16.3, holes are drawn into base region with the view to forming base current. However, if the collector is connected to negative potential, the majority of the holes drift into the collector's region. Thus, current flows from the emitter to the collector. The emitter emits holes and the collector collects them.

However, it is the base that controls the drift of these holes. From the PNP symbol in Figure 16.3, part of the emitter current, I_E , flows into the base, forming base current, I_B . The rest then flow into the collector to form collector current, I_C . and base current, I_B , **Consequently**, $I_C = I_E - I_B$

The BJT can be likened to two diodes with their anodes connected as with NPN or cathodes connected as with PNP. Note, however, that the action of the transistor goes beyond that and diodes should never be used to replace a transistor.



Figure 4.21: A typical BJ transistor

Application of the BJ transistor

The BJ transistor is used in so many designs, including the following

1. It is used as a switch
2. It is used as an amplifier
3. It is used as an oscillator
4. It is used as a demodulator

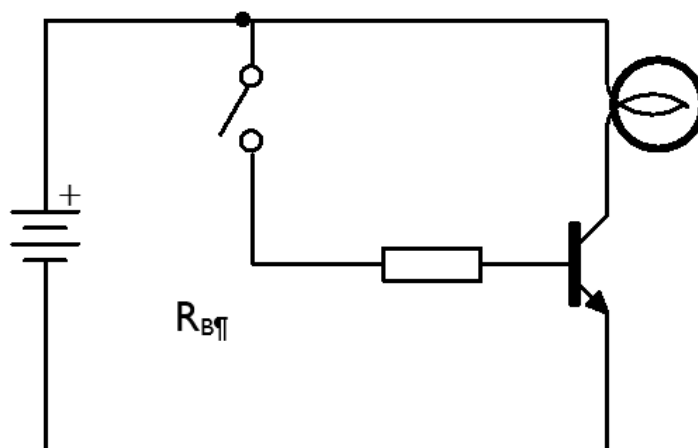


Figure 4.22: using the transistor as a switch

From the *figure (fig 4.23)*, the supply voltage is applied across the collector-emitter region. However, the lamp does not light because I_B is at zero due to the opened switch. Collector current, I_C , therefore, is zero. However, if the switch is put on, base current begins to flow and as a result, collector current flows. This will cause the lamp to light. The lamp's output can vary by introducing a variable resistor at the base. When the base resistance is varied, I_B will vary, thus causing I_C to vary. This will cause the lamp's brightness to vary, an indication that I_C depends on I_B .

The BJ transistor can also be used as an amplifier. A simple amplifier can be obtained by introducing a resistor in the collector circuit R_C and one at the base circuit, R_B . The input signal V_{IN} is fed in at the base, and the output signal is taken across V_{CE} .

Figure 4.24 shows how the output will vary with the input.

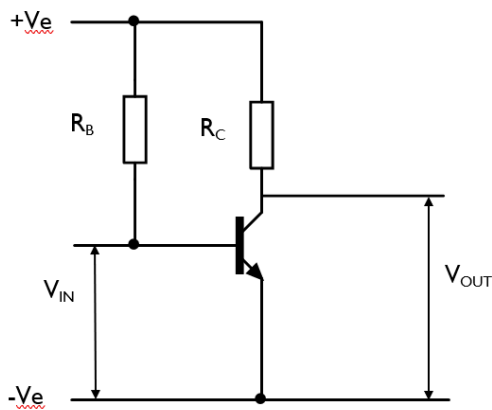


Figure 4.23: Circuit diagram

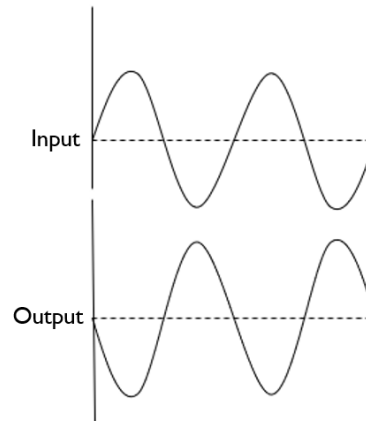


Figure 4.24: Variation of output with input

Advantages of Bipolar Junction Transistor

The bipolar junction transistor has the following advantages:

1. It has a large gain bandwidth.
2. Forward voltage drop is low
3. It shows better performance at high frequency.
4. Better voltage gain.
5. The transistor can be operated in low or high-power applications.
6. High current density.

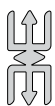
Disadvantages of bipolar junction transistor

The following are some disadvantages:

1. Produces more noise.
2. The BJT are more effect by radiation.
3. Low thermal stability.
4. Has low switching frequency
5. It has a very complex base control

Learning Tasks

1. What do you understand by a transistor?
2. How many types of BJT are there? Describe the construction of each type
3. How different is the symbol of the NPN from the PNP?
4. Explain the action of each type of the bipolar junction transistor

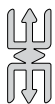


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the bipolar junction transistor in terms of its construction and operation.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to identify symbols of NPN and PNP transistors and explain how they differ from each other. Encourage learners to pool their knowledge and skills to brainstorm and research and explain the operation of each type of the bipolar junction transistors. They should also come up with the advantages and disadvantages of bit.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to draw the diagram of the BJT as a switch and explain how it works. Challenge them to draw a simple diagram of the BJT as an amplifier and explain how it works.

Through active participation in these activities, learners will gain first-hand experience and understanding of typical applications of the BJT.

Additionally, they will collaboratively brainstorm and discuss the construction of the types of BJT and typical applications drawing from their simulated experiences to reinforce understanding of the bipolar junction transistor. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply their knowledge of bipolar junction transistors in real-world contexts.

KEY ASSESSMENT

Level 1

1. What are the two types of bipolar junction transistors?
2. List 4 advantages and 4 disadvantages of bipolar junction transistors.

Level 2

1. What is the difference between the NPN and PNP in terms of their structure?
2. Explain the operation of each type of the BJ transistor.
3. Describe how the base of the BJ transistor can control current flow through the transistor.

Level 3

1. How is the base able to control the flow of current through the transistor?
2. Differentiate between the NPN and PNP in terms of their operations.
3. In both NPN and PNP configurations, the base must always be at a positive potential. Why do you agree or disagree with this statement?
4. In using the BJT as a switch, why does the collector current not flow when the switch is off?
5. Run simulation on bipolar junction transistors to identify at least one role it plays in circuit?

HINT

Give learners Individual Projects in Week 16 to be submitted in Week 22. Refer to Appendix E for more guidance on the project.

UNIT 16 REVIEW

This unit introduced learners to transistors and specifically, the bipolar junction transistor as one of the electronic components. The unit discusses definition of Bipolar junction transistor, the two types, NPN and PNP transistors, the structure of each of them and their operation. The discussion also included the uses of the transistors and their advantages and disadvantages.

Learners have also been taken through how to calculate for I_C and I_E in the various configurations of the transistor. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities.



APPENDIX E: INDIVIDUAL PROJECT

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
Heading (Caption of the Project)	Heading includes 4 of the following: clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 3 of the following: clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 2 of the following: clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 1 of the following: clear, concise, accurately reflects the project's content and follow syntax rule.
Project Design Brief	Brief is based on 4 of the following: has project specification, (50–60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 3 of the following: written, (50–60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 2 of the following: written, (50–60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 1 of the following: written, (50–60 words), provides comprehensive overview of the project and correct spelling of keywords
Technical Specification	Final work shows 4 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 3 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 2 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 1 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.

SECTION 5: TRANSISTORS

In this section learners will acquire knowledge and understanding of principles of operation of the various transistors, circuits and their application of various circuit laws, effects of alternating current on RLC circuits as well as types of control systems. All the above are treated from unit 17 to unit 20.

UNIT 17

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Demonstrate understanding of Transistors as electronic devices and apply them in designing electronic circuits.*

HINT



Remind learners of **mid-semester examination** in Week 18. Refer to the Appendix F for sample tasks and the Table of Specification to guide the writing of the items.

INTRODUCTION AND SECTION SUMMARY

This section looks at transistors as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following Construction, principles of operation and application of the various type of electronic components and be able to design electronic circuits with them.

*The unit covers only week 17: **Illustrate the principles of operation of the various transistors***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars

such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 17

Learning Indicator: *Illustrate the principles of operation of the various transistors*

Focal Area 1: Field Effect Transistors (FET)

A Field Effect Transistor is a semiconductor three-terminal amplifying device. Its terminals are known as the source, gate, and drain, and correspond respectively to the emitter, base, and collector of a normal transistor. It is also a unipolar transistor.

1. **Source:** It is the terminal through which the majority carriers enter the bar.
2. **Drain:** It is the terminal through which the majority charges leave the bar.
3. **Channel:** It is the space between two gates through which the majority of carriers pass from source to drain when V_{DS} is applied.

Families/Groups of Field Effect Transistor

Basically, there are two families of field effect transistors in general use: The first one is the junction gate field effect transistor or simply the junction field effect transistor (JFET) and the second one is Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

Structure of the Field Effect Transistor

The structure of the N-channel junction field effect transistor is shown in the following figure. It is a structure where a PN junction is fabricated on each side of the N-type semiconductor silicon wafer, forming a structure in which two PN junctions sandwich an N-type channel. The two P regions are the gates, one end of the N-type silicon is the drain, and the other end is the source.

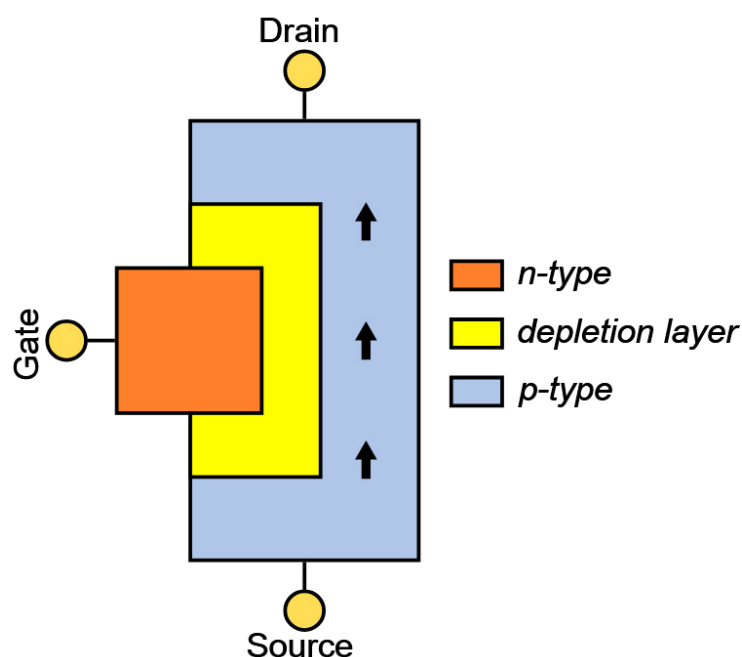


Figure 5.1: *Structure of the field effect transistor*

Working Principle Of Field Effect Transistor

In the FET, current flows along a semiconductor path called the channel. At one end of the channel, there is an electrode called the source. At the other end of the channel, there is an electrode called the drain. The physical diameter of the channel is fixed, but its effective electrical diameter can be varied by the application of a voltage to a control electrode called the gate. The conductivity of the FET depends, at any given instant in time, on the electrical diameter of the channel. A small change in gate voltage can cause a large variation in the current from the source to the drain. This is how the FET amplifies signals.

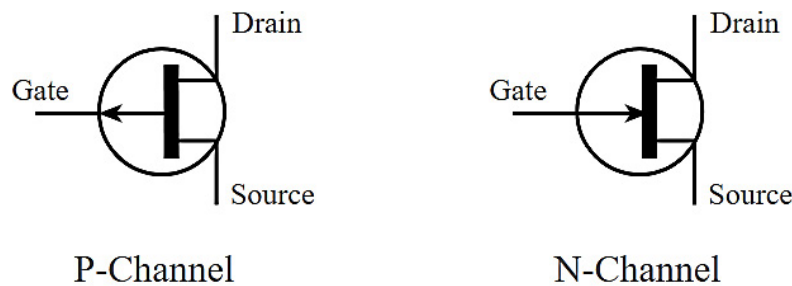


Figure 5.2: Symbols of field effect transistors

The Junction Field Effect Transistor (JFET)

The junction FET has a channel consisting of N-type semiconductor (N-channel) or P-type semiconductor (P-channel) material the gate is made of the opposite semiconductor type. In P-type material, electric charges are carried mainly in the form of electron deficiencies called holes. In N-type material, the charge carriers are primarily electrons. In a JFET, the junction is the boundary between the channel and the gate. Normally, this P-N junction is reverse-biased (a DC voltage is applied to it) so that no current flows between the channel and the gate. However, under some conditions there is a small current through the junction during part of the input signal cycle.

The Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

In the MOSFET, the channel can be either N-type or P-type semiconductor. The gate electrode is a piece of metal whose surface is oxidised. The oxide layer electrically insulates the gate from the channel. For this reason, the MOSFET was originally called the insulated-gate FET (IGFET), but this term is now rarely used. Because the oxide layer acts as a dielectric, there is essentially never any current between the gate and the channel during any part of the signal cycle. This gives the MOSFET an extremely large input impedance. Because the oxide layer is extremely thin, the MOSFET is susceptible to destruction by electrostatic charges. Special precautions are necessary when handling or transporting MOS devices.

Advantages of Field Effect Transistors (FET)

1. Low noise
2. High switching speed
3. Low voltage operation
4. High current capacity
5. Immunity to thermal runaway

Disadvantages of Field Effect Transistor (FET)

1. Limited voltage range
2. High output capacitance
3. Temperature dependence
4. Noise sensitivity
5. Limited gain bandwidth product.

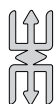
Applications of Field Effect Transistors

Field effect transistors are used in manufacturing the following

1. Amplifier
2. Power supplies
3. Switching circuits
4. Medical equipment
5. Power management circuits.

Learning Tasks

1. Explain the concept of Field Effect Transistors
2. Describe the two types of Field Effect Transistors
3. Describe three advantages and three disadvantages of Field Effect Transistors
4. Outline four applications of Field Effect Transistors

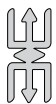


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the concept of Field Effect Transistors as well as the two main types of field effect transistors thus JFET and MOSFET.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to identify symbols of N-Channel and P-Channel field effect transistors and discuss the advantages and disadvantages of field effect transistors as well as their applications.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

KEY ASSESSMENT

Level 1: List two (2) field effect transistors (FET).

Level 2

1. Explain the concept of Field Effect Transistors.
2. Describe the two types of Field Effect Transistors.

Level 3: Describe three advantages and three disadvantages of Field Effect Transistors.

Level 4: Outline four applications of Field Effect Transistors.

HINT



*The recommended mode of assessment for week 17 is **checklist**. Use the level 1 question as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 57 for additional information on how to use this mode of assessment.*

UNIT 17 REVIEW

This unit introduced learners to transistors and specifically, the Field Effect Transistors as one of the electronic components. The unit discusses definition of Field Effect transistor, the two types of field effect transistors namely the Junction Field Effect Transistor (JFET) and Metal Oxide Semiconductor Field Effect Transistor (MOSFET), the structure of each of them as well their operation.

The advantages and disadvantages of Field effect transistors and the applications of field effect transistors. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities.

UNIT 18

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Circuit Theory

Learning Outcome: *Apply knowledge and understanding of circuit theory in analysing electrical circuits*

Content Standard: *Demonstrate understanding of electrical circuits*

INTRODUCTION AND SECTION SUMMARY

This section looks at circuit theory as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in analysing electrical circuit through exposure to the following: Series circuits, parallel circuits, Series-parallel circuits, application of ohm's, law and Kirchhoff's laws in analysing dc circuits, principles of Ac and the application of Ac to resistive, inductive and capacitive circuits

The unit covers only week 18: Analyse DC circuits and solve problems on them by applying various circuit laws

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electrical circuits through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 18

Learning Indicator: Analyse DC circuits and solve problems on them by applying various circuit laws

Focal Area 1: DC Circuits

Series Circuit

A series circuit is a circuit in which the connection of the loads is such that the same current flows through each resistor but the voltage is shared among them. The total resistance (R_T) has a value that is greater than the value of the highest individual resistor in the circuit. A break anywhere in the circuit affects the entire circuit. Figure 5.3 shows a series circuit having three resistors, R_1 , R_2 and R_3

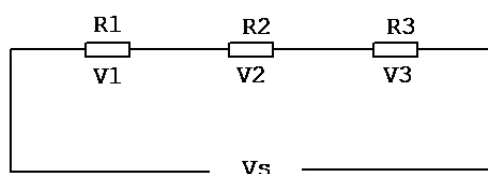


Figure 5.3: Three resistor in series

Since figure 5.3 is a series circuit, the voltage is shared among the various components (as stated earlier) therefore, the supply voltage $V_s = V_1 + V_2 + V_3$. But according to ohm's law $V = IR$ and since I is common to all resistors, therefore,

$$V_1 = IR_1, V_2 = IR_2 \text{ and } V_3 = IR_3$$

$$\therefore V_s = IR_1 + IR_2 + IR_3. \text{ But } V_s = IR_T$$

$$\therefore IR_T = IR_1 + IR_2 + IR_3. \text{ Dividing through by } I \text{ we have}$$

$$R_T = R_1 + R_2 + R_3$$

Total Resistance (R_T) in a series circuit therefore is $R_1 + R_2 + R_3 \dots R_n$

Parallel Circuit

A parallel circuit is a circuit in which the connection of the resistors is such that the same voltage appears across each resistor while the current is shared among them. The total resistance has a value less than the lowest resistor connected in the circuit. A break in any branch does not affect the entire circuit. Figure 5.4 shows a parallel circuit having three resistors R_1 , R_2 and R_3 .

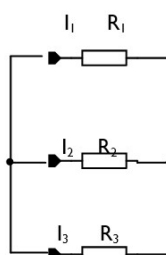


Figure 5.4: Three resistors in parallel

Since **figure 5.4** is a parallel circuit, the current is shared among the various resistors (as stated earlier). The **total current** $I_T = I_1 + I_2 + I_3$. But according to **ohm's law** $I = V/R$.

$$\text{Therefore, } \frac{I}{R_T} = \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}$$

$$\text{Multiplying through by we have } \frac{I}{R_T} = \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}$$

EXAMPLE 2.2

Calculate the equivalent resistance of four resistors of 6Ω , 18Ω , 4Ω and 12Ω , which are connected in parallel.

SOLUTION

The **figure 5.5** shows the circuit

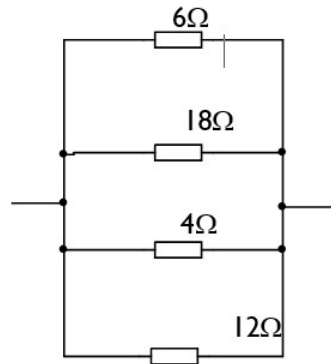


Figure 5.5: Four resistors in parallel

The reciprocal of the total Resistance $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$

$$\frac{1}{R_T} = \frac{1}{6} + \frac{1}{18} + \frac{1}{4} + \frac{1}{12} = \frac{20}{36} = \frac{5}{9}$$

$$\frac{I}{R_T} = \frac{9}{5} = 1.8\Omega$$

Series - Parallel Circuit

A series - parallel circuit is one in which a parallel branch is connected in series with one, two or more other resistors which are also connected in series as shown in **Figure 5.6** or a parallel branch connected in series with another parallel branch as shown in **Figure 5.7**.

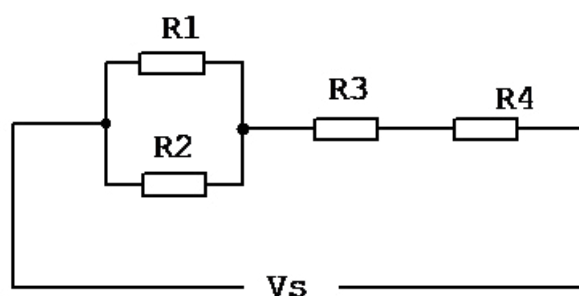


Figure 5.6: A series-parallel circuit

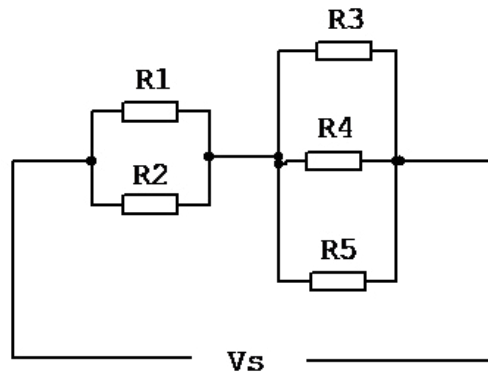


Figure 5.7: A series- parallel circuit

After calculating the total resistance in a series circuit, and a parallel circuit, let's look at a series-parallel circuit. To find the total resistance in any of the cases, the individual parallel resistances are first solved, to find the total resistance there. The circuit is therefore re-drawn as a series circuit with each parallel branch being replaced with one resistor with a value, which equals the total resistance in that branch. The circuit thus becomes a series circuit and its total resistance solved as such.

EXAMPLE 2.3

Find the total resistance in **Figure 5.8**

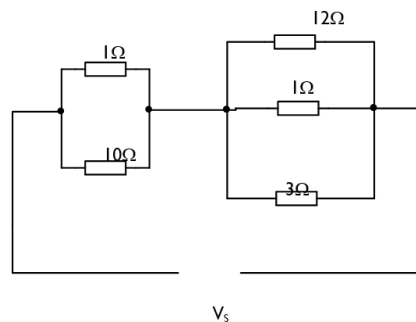


Figure 5.8

SOLUTION

For **Figure 5.8** the total resistance for the first parallel branch would be

$$\frac{1}{1} + \frac{1}{10} = \frac{11}{10} = \frac{10}{11} = 0.9\Omega$$

For the R_T of the second parallel branch

$$= \frac{1}{12} + \frac{1}{1} + \frac{1}{3} = 0.67$$

The circuit is then re-drawn as shown in **figure 5.8**

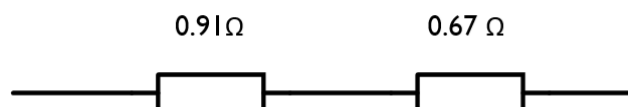


Figure 5.9

$$\begin{aligned} R_T &= 0.91 + 0.67 \\ &= 1.58\Omega. \end{aligned}$$

Ohms Law

Ohm's law states that, at a constant temperature, the current flowing through a fixed linear resistance is directly proportional to the voltage applied across it, and also inversely proportional to the resistance. This relationship between the Voltage, Current and Resistance forms the bases of **ohm's law**.

Ohms Law Relationship

By knowing any two values of the Voltage, Current or Resistance quantities we can use **Ohms Law** to find the third missing value.

- **To find the Voltage (V)**
 $[V = I \times R] \text{ V (volts)} = I \text{ (amps)} \times R \text{ (}\Omega\text{)}$
- **To find the Current (I)**
 $[I = V \div R] \text{ I (amps)} = V \text{ (volts)} \div R \text{ (}\Omega\text{)}$
- **To find the Resistance (R)**
 $[R = V \div I] \text{ R (}\Omega\text{)} = V \text{ (volts)} \div I \text{ (amps)}$

Ohm's Law Application

Ohm's law can be better understood by working through the following examples. Three resistors of values 10Ω , 12Ω and 15Ω are connected in series to a voltage source. If a current of $5A$ flows as a result, calculate

1. The pd across each resistor
2. The supply voltage.

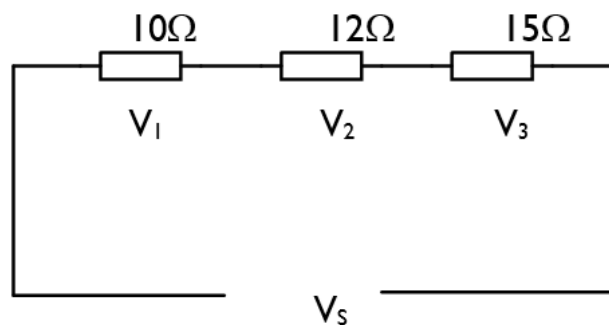


Figure 5.10

SOLUTION

Let the Pds across the resistors be V_1 , V_2 and V_3 . Since it is a series circuit the current is common.

$$\begin{aligned} \therefore V_1 &= I \times 10\Omega & V_2 &= I \times 12\Omega & V_3 &= I \times 15\Omega \\ &= 5 \times 10 = 50v & &= 5 \times 12 = 60v & &= 5 \times 15 = 75v \end{aligned}$$

$$\begin{aligned} \text{The supply voltage (Vs)} &= V_1 + V_2 + V_3 \\ &= 50 + 60 + 75 \\ &= 185V \end{aligned}$$

Kirchhoff's First Law

A parallel circuit is made up of a number of junctions. Kirchhoff's first law states that at any instant the total current flowing towards a junction in a circuit is equal to the total current flowing away from the junction. That is to say the algebraic sum of all the currents at any junction in a circuit is equal to zero. Considering the figure below, I_1 , I_3 and I_4 are flowing away from the junction while I_2 and I_5 flow towards it.

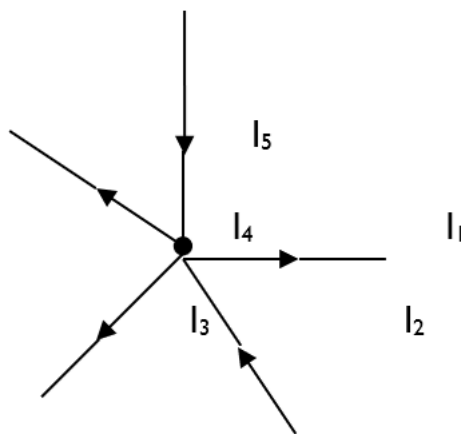


Figure 5.11: Directions of current flow around a junction

$$\begin{aligned}\text{By the law, } I_1 + I_3 + I_4 &= I_2 + I_5 \\ &= I_1 + I_3 + I_4 - I_2 - I_5 = 0 \\ &= I_1 + I_3 + I_4 + (-I_2) + (-I_5) = 0\end{aligned}$$

In **Figure 5.11** supposing that $I_1 = 3\text{A}$, $I_2 = 4\text{A}$, $I_3 = 1\text{A}$, and $I_4 = 2\text{A}$. then I_5 can be calculated as follows.

$$\begin{aligned}I_1 + I_3 + I_4 &= I_2 + I_5 \\ &= I_1 + I_3 + I_4 - I_2 = I_5 \\ &= (3 + 1 + 2) - 4 = I_5 \\ &= 6 - 4 = I_5\end{aligned}$$

$$I_5 = 2\text{A}$$

$$\begin{aligned}\text{As a proof, } I_1 + I_3 + I_4 &= I_2 + I_5 \\ 3 + 1 + 2 &= 4 + 2 \\ 6 &= 6\end{aligned}$$

OR

$$\begin{aligned}I_1 + I_3 + I_4 - I_2 - I_5 &= 0 \\ 3 + 1 + 2 - 4 - 2 &= 0 \\ 6 - 6 &= 0\end{aligned}$$

The current law is applicable to any point within a circuit. For example, determine the relationship between I_1 , I_2 , I_3 , I_4 , I_5 , and I_6 in **figure 5.12**.

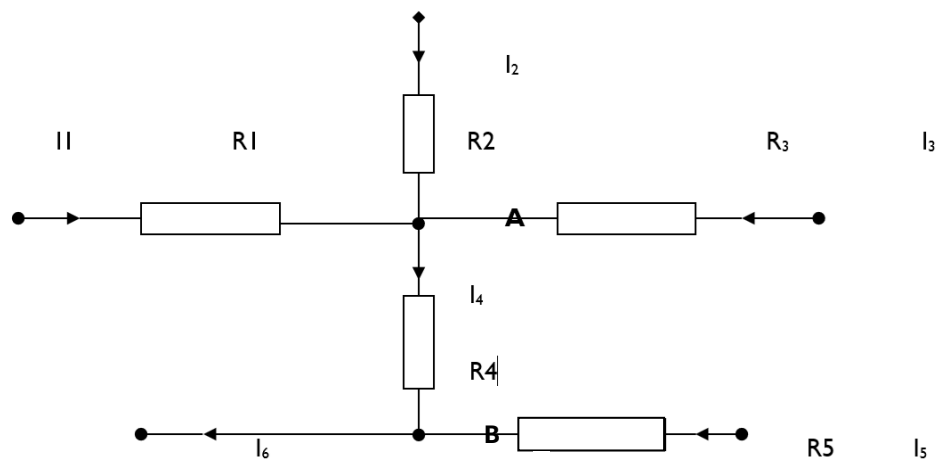


Figure 5.12

For junction A: $I_1 + I_2 + I_4 - I_3 = 0$

$$\text{Hence } I_1 + I_2 + I_4 = I_3$$

$$\text{and } I_3 = I_1 + I_2 + I_4$$

At junction B: $I_3 + I_5 - I_6 = 0$

$$I_3 = I_6 - I_5$$

$$I_1 + I_2 + I_4 = I_6 - I_5$$

$$\text{And } I_1 + I_2 + I_4 + I_5 - I_6 = 0$$

Supposing that in figure above $I_1 = 2\text{A}$, $I_2 = 6\text{A}$, $I_3 = 12\text{A}$ and $I_6 = 15\text{A}$.

Calculate for I_4 and I_5 .

SOLUTION

At junction A: $I_1 + I_2 + I_4 = I_3$

$$I_4 = I_3 - (I_1 + I_2)$$

$$I_4 = 12 - (2 + 6) \text{ v f}$$

$$I_4 = 4\text{A}$$

At junction B: $I_3 + I_5 = I_6$

$$I_5 = I_6 - I_3$$

$$I_5 = 15 - 12$$

$$I_5 = 3\text{A}$$

Second Law

Kirchhoff's second law is applicable to a series circuit. Remember that in a series circuit the supply voltage (V_s) $= V_1 + V_2 + V_3$ etc. This law states that in any closed circuit the algebraic sum of the pds around the circuit is equal to the algebraic sum of the emfs. This implies that in any closed circuit the algebraic sum of the pds and emfs is equal to zero. This is illustrated in **Figures 5.13 and 5.14**.

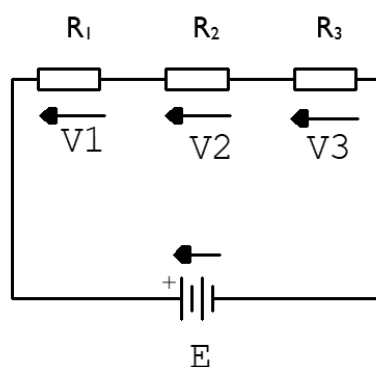


Figure 5.13

$$E = V_1 + V_2 + V_3$$

$$V_1 + V_2 + V_3 + (-E) = 0$$

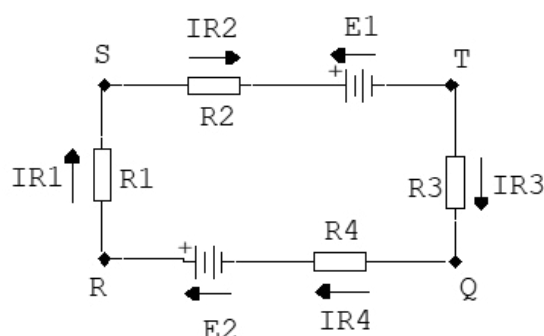


Figure 5.14

In a situation like this, make sure that arrows are indicated against the cells and point in the direction of the positive terminal of the cell. The second step is to determine the direction of the current flow. For **figure 5.13** it is obvious since it is only one cell. In the case of **figure 5.14**, however, the direction of current flow will be assumed since the magnitudes of the emfs of the cells are not known. If a clockwise direction is assumed, then draw arrows indicating the various pds. These arrows are drawn opposite to the direction of the assumed current flow. For **figure 5.14** an anticlockwise direction of flow of current is assumed. Therefore, the arrows for the pds are indicated in the clockwise direction.

Using ohm's law equations, write out the equations of the various pds across the resistors by the various arrows e.g. IR_1 , IR_2 and IR_3 .

From any point in the circuit, write down the closed-circuit equation comprising emfs and pds ensuring that the whole round circuit is considered. In doing this each emf or Pd whose voltage arrow points in the direction in which the direction is moving around the circuit is given a positive sign. For example, considering loop QRSTQ starting from point Q (**Figure 5.14**):

$$IR_4 + E_2 + IR_1 + IR_2 - E_1 + IR_3 = 0$$

It could also be written as

$$IR_1 + IR_2 + IR_3 + IR_4 = E_1 - E_2$$

Considering loop TSRQT starting from point T

$$E_1 - IR_2 - IR_1 - E_2 - IR_4 - IR_3 = 0$$

It could also be written as

$$E1 - E2 = IR1 + IR2 + IR3 + IR4,$$

EXAMPLE

The following figure shows two cells with internal resistances of 2.4Ω and 1Ω respectively which are connected to a 40Ω resistance. What current will flow in each branch?

B. Calculate the power that will be dissipated by the 40Ω resistor.

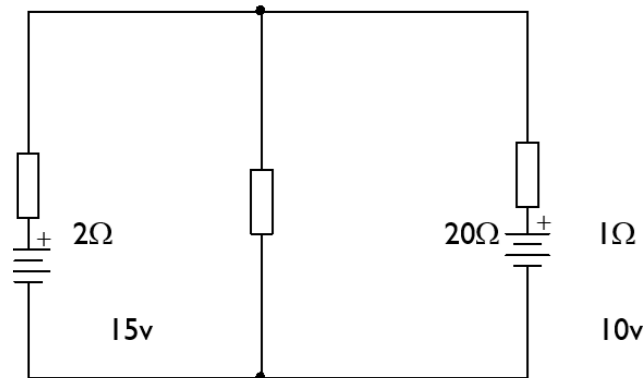


Figure 5.15

Since both cells will be supplying current to the 40Ω resistor, the arrows will be indicated as shown in *fig 5.16*.

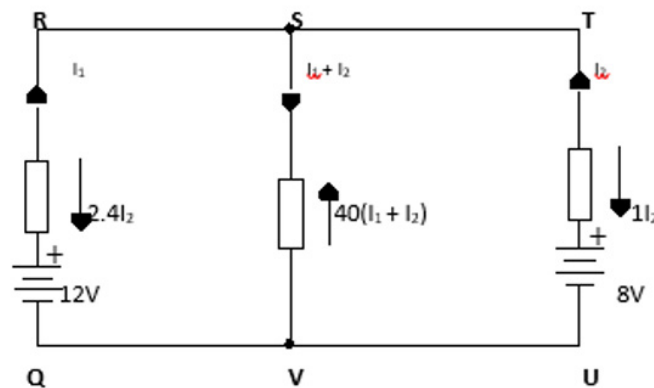


Figure 5.16

It is important to note that since both I_1 and I_2 are not known, two equations are necessary which will be solved together (simultaneous equations) and they can be taken from any two of the three closed loops that can be identified from the figure. That is **QRSVQ**, **QRSTUVQ** and **STUVS**.

Using loop **QRSVQ** and starting from Q1 the following will be achieved:

$$\begin{aligned} 12 - 2.4I_1 - 40(I_1 + I_2) &= 0 \\ &= 12 - 2.4I_1 - 40I_1 - 40I_2 = 0 \\ &= 12 - 42.4I_1 - 40I_2 = 0 \\ &= 42.4I_1 + 40I_2 = 12 \dots\dots\dots \text{equation 1} \end{aligned}$$

Considering loop QRSTUVQ

$$\begin{aligned}
 12 - 2.4I_1 + 1I_2 - 8 &= 0 \\
 &= 4 - 2.4I_1 + 1I_2 = 0 \\
 &= 2.4I_1 - 1I_2 = 4 \dots\dots\dots \text{equation 2}
 \end{aligned}$$

The two simultaneous equations are

$$\begin{aligned}
 42.4I_1 + 40I_2 &= 12 \dots\dots\dots (1) \\
 2.4I_1 - 1I_2 &= 4 \dots\dots\dots (2) \text{ (multiply equation 2 by 40)} \\
 42.4I_1 + 40I_2 &= 12 \\
 96I_1 - 40I_2 &= 80
 \end{aligned}$$

Adding the two equations will result in one equation

$$\begin{aligned}
 138.4 I_1 &= 92 \\
 I_1 &= 92/_{138.4} = \underline{\underline{0.664A}}
 \end{aligned}$$

Substituting I_1 in equation 1 becomes

$$\begin{aligned}
 42.4 (0.664) + 40I_2 &= 12 \\
 &= 28.15 + 40I_2 = 12 \\
 &= 40I_2 = 12 - 28.15 \\
 &= 40I_2 = -16.15 \\
 I_2 &= -16.15/_{40} \\
 I_2 &= \underline{\underline{-0.404A}}
 \end{aligned}$$

It is negative indicating that I_2 is flowing in an opposite direction to that indicated.

The **power (P)** dissipated in the 40Ω resistor.

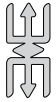
$$P = I^2 R \text{ But } I \text{ here} = I_1 + I_2$$

$$\begin{aligned}
 P &= (I_1 + I_2)^2 R \\
 &= \{0.664 + (-0.404)\}^2 \times 40 \\
 &= 0.26^2 \times 40 \\
 &= 0.0676 \times 40 \\
 &= \underline{\underline{2.704W}}
 \end{aligned}$$

Learning Tasks

1. Explain Ohm's law
2. What are the characteristics of a series circuit?
3. What are the steps involved in solving the total resistance of a series-parallel circuit?

4. Explain Kirchhoff's current law
5. Three resistors, R_1 , R_2 and R_3 are connected in series. Prove that the total resistance $R_T = R_1 + R_2 + R_3$

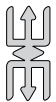


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the bipolar junction transistor in terms of its construction and operation.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to explain ohm's law and state typical application of this law. Encourage learners to pool their knowledge and skills to brainstorm and research and come up with the steps to follow in solving for total resistance in a series-parallel circuit, hence solve for total resistance in a typical series-parallel circuit. They should also apply Kirchhoff's law in analysing typical circuits.



Note

Through this group work, learners not only enhance their understanding of circuit analysis but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to conduct experiments to prove ohm's law and present their findings. Challenge them to analyse various circuits using Kirchhoff's laws. Through active participation in these activities, learners will gain first-hand experience and understanding typical application of circuit laws.

Additionally, they will collaboratively brainstorm and discuss and analyse circuit laws and their applications, it will reinforce their understanding of electrical circuits. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply their knowledge of electrical circuits in real-world contexts.

KEY ASSESSMENT

Level 1

1. State ohms law.
2. List the steps involved in finding the total resistance of a series parallel circuit?

Level 2

1. Explain Kirchhoff's voltage law.
2. What is the difference between Kirchhoff's current law and the voltage law?
3. Describe the steps to follow when analysing a circuit using Kirchhoff's voltage law.

Level 3

1. Three resistors, R_1 , R_2 and R_3 are connected in parallel. Prove that $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$
2. The following figure shows two cells with internal resistances of 2Ω and 1Ω respectively which are connected to a 20Ω resistor.
 - a. What current will flow in each branch?
 - b. Calculate the power that will be dissipated by the 20Ω resistor.

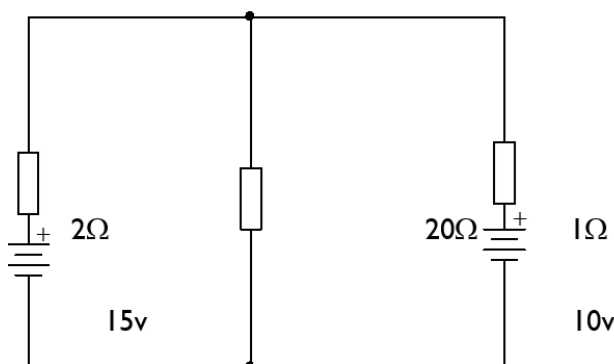


Figure 5.17

HINT



The recommended mode of assessment for week 18 is **mid-semester examination**. Refer to the Appendix F for more sample task and the Table of Specification.

UNIT 18 REVIEW

This unit introduced learners to circuit theory and specifically, DC circuits. The unit discussed Ohm's law, Kirchhoff's current and voltage laws. The discussion also included deriving equations for total resistance for a series circuit, parallel circuit and how to solve for the total resistance of a series-parallel circuit. Learners have also been taken through how to analyse circuits using Kirchhoff's current and voltage laws. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities.

UNIT 19

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electrical Circuit theory

Learning Outcome: *Apply knowledge and understanding of circuit theory in analysing electrical circuits*

Content Standard: *Demonstrate understanding of electrical circuit theory*

INTRODUCTION AND SECTION SUMMARY

This section looks at transistors as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following: Construction, principles of operation and application of the various type of electronic components and be able to design electronic circuits with them.

The unit covers only week 19: Effects of Alternating current on RLC circuits

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 19

Learning Indicator: Effects of Alternating current on RLC circuits

Focal Area 1: Alternating Current And Terms Associated With It Sinusoidal Waveforms

Alternating current (ac) or voltage is one which periodically changes its direction. There are several forms of ac wave forms including sine wave (sinusoidal), square wave and saw-tooth. The most common type of ac wave form is the sine wave and all the formulas that are used to analyse ac are derived from the sine wave. **Figure 5.17** shows an ac sin wave.

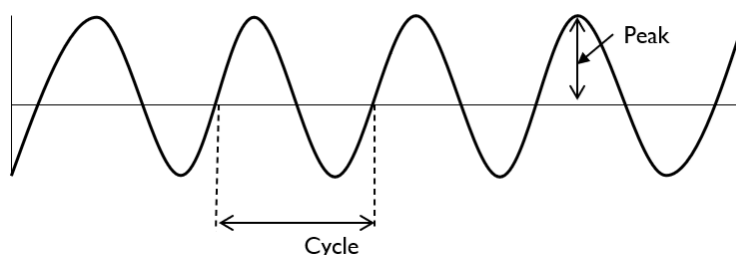


Figure 5.18: Sine wave

The positive maximum value occurs at 90° and the negative value occurs at 270° .

AC Quantities

1. **Cycle:** that part of the wave, which does not repeat itself.
2. **Period:** The time (t) required to complete one cycle.
3. **Frequency, (f):** the number of cycles that occur in 1 second. It is measured in hertz, Hz. Frequency, f and period, t are related by the relation

$$f = \frac{1}{t} \text{ Thus } t = \frac{1}{f}$$

4. **Peak value:** the maximum value of a wave measured from its zero value.
5. **Instantaneous value:** The instantaneous value is the magnitude of waveform at any instant in time or position of rotation. Instantaneous values are denoted by lower case such as i , v , x , e .

The instantaneous value of current i at any angle q is given by

$$i = I_m \sin q \text{ where } I_m \text{ is the positive value and that of voltage, } v, \text{ is given as } v = V_m \sin q$$

6. **Angular frequency (ω):** A complete cycle of a waveform is equivalent to a rotation of 360° or 2π radian of the generator. Since f complete cycles occur in one second, the angular frequency, ω is given by $\omega = 2\pi f \text{ rad } \frac{d}{s}$

The angle of rotation q is the angular frequency $\times$ time, that is $q = \omega t = 2\pi f t / i = I_m \sin \omega t$

$$\text{and } v = V_m \sin \omega t = V_m \sin 2\pi f t \quad = I_m \sin 2\pi f t$$

If θ is given in degrees, convert it to radian by using the expression

$$\theta \text{ radians} = \theta \text{ degrees} \times \frac{2\pi}{360}$$

Mean or Average Value of An AC

The average value of an ac is the average value taken over the positive half-cycle. This can be done by finding the instantaneous values of the waveform at equally spaced intervals. The values are then added together and divided by the number of intervals $I_{av} = \frac{I_1 + I_2 + I_n}{n}$.

It is also derived from calculus as $I_{av} = \frac{2I_m}{\pi} = 0.637I_m$

And the average or mean value of alternating voltage is also given by $V_{av} = \frac{2V_m}{\pi} = 0.637V_m$

Root mean square (rms) Value or Effective Value of AC

The value of ac that produces the same heat in a resistive circuit as a dc of the same value. It is obtained mathematically by finding the square root of the mean of the squares of the instantaneous values.

$$I_{rms} = \sqrt{\frac{I_1^2 + I_2^2 + I_n^2}{n}}$$

It is also derived from calculus as $I_{rms} = 0.707I_m$. Similarly for an alternating voltage, the rms value is $V_{rms} = 0.707V_m \Rightarrow V_m = 1.414V_{rms}$

Resistive, Capacitive and Inductive circuits

1. **Impedance:** This is the total opposition to current due to resistance and reactance. The symbol is Z. A circuit containing resistance and only one type of reactance will have the phase difference between current and voltage to be between 0 and 90°. If the circuit contains resistance and inductance, the current lags voltage and when it contains resistance and capacitance, the current leads voltage. When it contains all three, the phase difference will depend on the relative values of the capacitance and inductance.
2. **Phasors:** A phasor is a line, the length of which represents the magnitude of an electrical quantity and the direction, the phase angle in electrical degrees. When handling questions involving phasors it is convenient to draw one phasor on the 0° line. This phasor thus becomes the reference to which the other phasors are related. By convention, phasors are assumed to move in an anticlockwise or counterclockwise direction.

Adding Phasors

Phasors can be added either graphically or mathematically much in the same way as vectors.

Adding phasors which are 90° apart

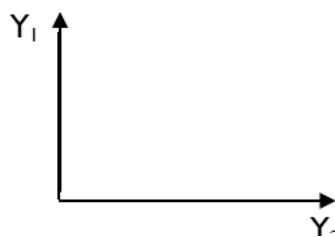


Figure 5.19

The two phasors Y_1 and Y_2 can be added by using parallelogram of vectors. The total of the two phasors Y_T is the resultant of the two phasors

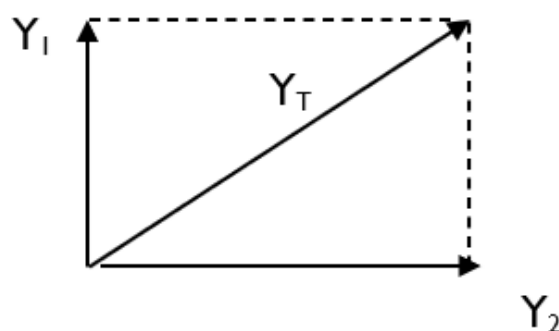


Figure 5.20

The **value of Y_T** can thus be calculated using Pythagoras theorem

$$Y_T^2 = Y_1^2 + Y_2^2$$

Adding phasors 180° apart

When 2 phasors are 180° apart, the resultant Y_T is equal in length to the differences between the two phasors being added. The resultant phasor will then move in the direction of the longest phasor.

Adding 3 phasors which are displaced at 90°

To add 3 phasors which are displaced at 90° from each other, the first step is to add the two phasors that are 180° apart. This reduces the phasors to 2 phasors displaced at 90° to each other. The general formular is thus

$$Y_T = \sqrt{(Y_1^2 - Y_2^2) + Y_3^2}$$

Phasors displaced at 180° with Y_1 having the greatest value

Resistive circuits: A purely resistive circuit is shown in **Figure 5.21**. It is one which contains only resistance and without any inductance or capacitance. If an alternating voltage whose value is given as $v = V_m \sin t$ is applied to the circuit, the wave form in **figure 5.22** results

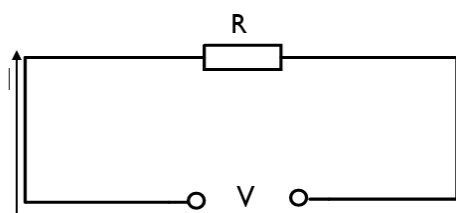


Figure 5.21

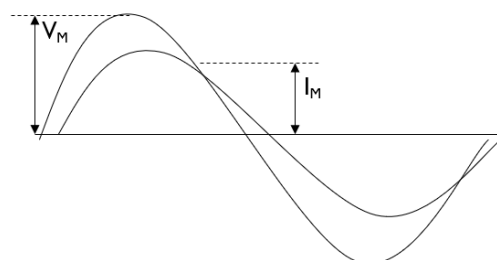


Figure 5.22

You can see from the wave form that current and voltage start at the same time, attain maximum at the same time both in the positive and negative directions, and get to zero at the same time. They are therefore said to be in phase. The sin wave in **Figure 5.22** shows that both current and voltage are in phase.

If the value of the voltage at any instant is v volts, the value of current (i) at that instant is given by $I = \frac{v}{R} = \frac{V_m \sin \omega t}{R} = I_m \sin \omega t$

Where V_m is the maximum voltage, I_m the maximum current, R the resistance and the angular frequency of the wave.

In relation to the rms values in a resistive current is given by $I = \frac{V}{R}$

3. RESISTIVE, INDUCTIVE AND CAPACITIVE CIRCUITS

Resistive circuits: A purely resistive circuit is shown in **figure 5.23**. It is one which contains only resistance and without any inductance or capacitance. If an alternating voltage whose value is given as $v = V_m \sin t$ is applied to the circuit the wave form in **figure 5.23 results**.

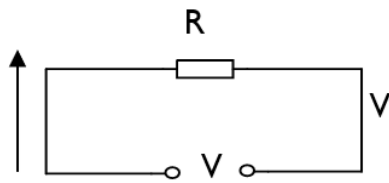


Figure 5.23

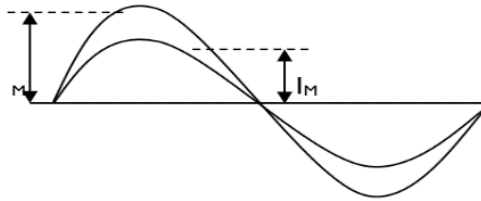


Figure 5.24



Figure 5.25

You can see from the wave form that, current and voltage start at the same time, attain maximum at the same time both in the positive and negative directions and also get to zero at the same time. They are therefore, said to be in phase. The sin wave in **figure 5.24** shows that both current and voltage are in phase. The phasor diagram is shown in **figure 5.25**. If the value of the voltage at any instant is v volts, the value of current (i) at that instant is given by

$$I = \frac{V}{R} = \frac{V_m \sin \omega t}{R} = I_m \sin \omega t$$

where V_m is the maximum voltage, I_m the maximum current, R the resistance and ω the angular frequency of the wave form and its value

$$= 2\pi f \text{ rads/s}$$

$$= I_m = \frac{V_m}{R}$$

The root mean square (rms) values of the sine wave = 0.707 times the maximum value. Thus, the rms value of the voltage $V = 0.707V_m$. But it is also equal to $\frac{V_m}{\sqrt{2}}$

The rms value of the current $I = 0.707I_m$, or $\frac{I_m}{\sqrt{2}}$

In relation to the rms values in a resistive circuit therefore, $I = \frac{V}{R}$

Inductive Circuits

A circuit made up of coils contains inductance and is called an inductive circuit (**Figure 5.25**). A component, which has inductance, is called inductor. This inductance is measured in Henry.

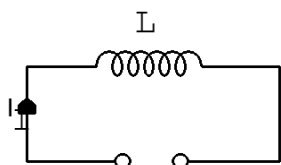


Figure 5.26

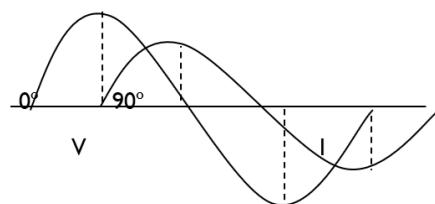


Figure 5.27

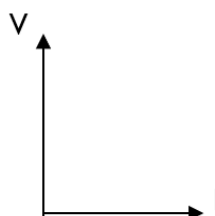


Figure 5.28

If you connect such a circuit to an ac supply the current flowing through the circuit lags behind the voltage by 90° (or $\pi/2$ rads). This means that the voltage leads the current by 90° . From the sign wave in **Figure 5.27**, you can see that while the voltage is at 90° (its maximum), the current at that instant is zero (just about to start). The phasor diagram is figure 5.27. In such a circuit, the only opposition to the flow of ac current is referred to as inductive reactance (X_L). It is measured in ohms (Ω). And $X_L = \frac{V_L}{I_L} = 2\pi fL \Omega = \omega L \Omega$

Effects of Frequency on Inductive Reactance

For an ac signal, the number of cycles completed in one second is called frequency (f). This frequency has an effect on inductive reactance. Remember that $X_L = 2\pi fL$. It implies that an increase in frequency will result in an increase in inductive reactance. $X_L \propto f$. This also implies that the current will reduce if the frequency is increased and vice versa. **Figures 5.29** and **5.30** show this effect of frequency on inductive reactance and on current flowing in the circuit.

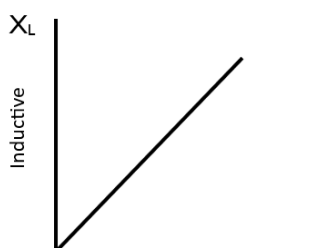
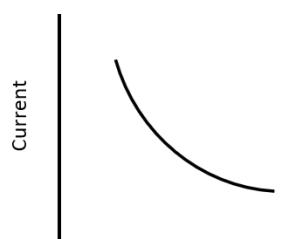
Figure 5.29: Frequency (f)

Figure 5.30: Frequency

Capacitive Circuits

A circuit containing only capacitance is called a capacitive circuit (**figure 5.31**). This capacitance is measured in Farads.

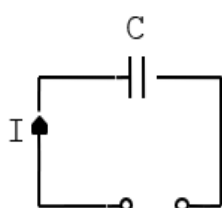


Figure 5.31

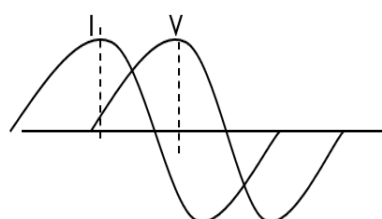


Figure 5.32

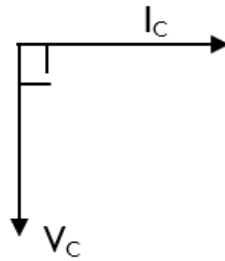


Figure 5.33

If you connect an ac supply to this circuit the current flowing through it will lead the voltage by 90° (or $\pi/2$ rads) **Figure 5.32**. It could also be said that the voltage across the capacitor lags behind the current by 90° . Notice from the sin wave in **5.32** that at 90° , the current is at peak, in the positive direction, while the voltage is zero (just about to start). **Figure 5.33** shows the phasor diagram for the capacitive circuit.

The only opposition to the flow of current in this circuit is called capacitive reactance (X_C). It also measured in ohms (Ω).

And $X_C = \frac{V}{I} = \frac{1}{2\pi fC}$ where C is the capacitance of capacitor in farads.

Effects of Frequency on Capacitive Reactance

The equation for capacitive reactance as has been seen is given by $X_C = \frac{1}{2\pi fC}$

This implies that an increase in frequency will result in a decrease in capacitive reactance. Therefore, $\frac{X_C \propto 1}{f}$

This also implies that an increase in frequency will result in an increase in the circuit current and vice versa since $I = \frac{V}{X_C}$

Figure 5.34 shows the effect of frequency on capacitive reactance and on current.

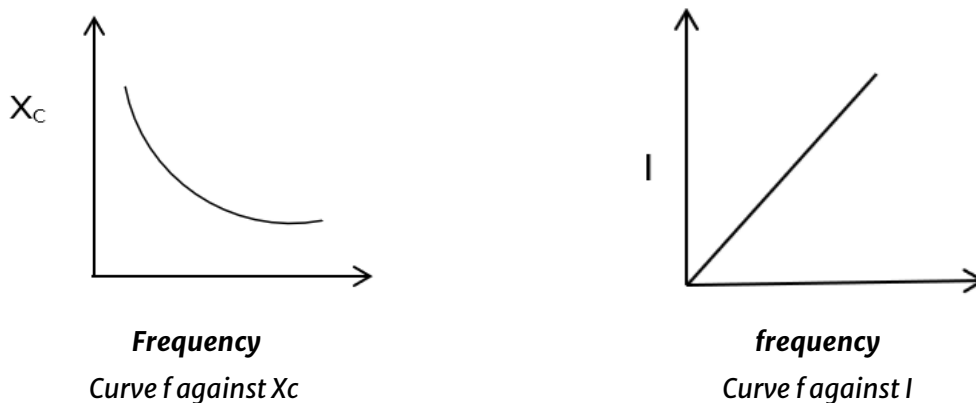


Figure 5.34

Resistive and Inductive Loads in Series

Figure 5.35 is a circuit consisting of a resistor and an inductor connected in series. Remember that since it is a series circuit the same current (I) flows through both components. The pd across the resistor is the product of the current and the resistance of the resistor (IR) and that of the inductor is the product of the current and the inductive reactance of the inductor (IX_L).

In drawing the phasor diagram (**Figure 5.36**), note that the current and voltage are in phase in the resistance while the voltage leads to current by 90° in the inductor.

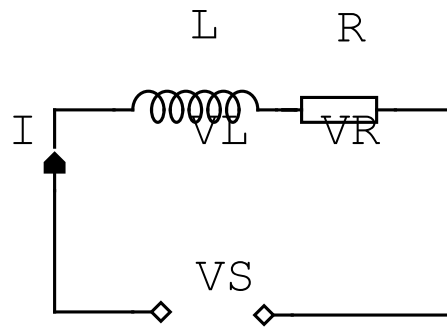


Figure 5.35: Resistive inductive circuit

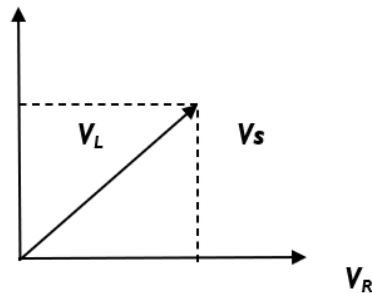


Figure 5.36: Characteristic curve

The supply voltage can be calculated using Pythagoras' theorem.

Hence $V_s = \sqrt{(V_L)^2 + (V_R)^2}$. But $V_L = IX_L$ and $V_R = IR$

$$\therefore V_s = \sqrt{(IR)^2 + (IX_L)^2}$$

In an ac circuit like this, the resultant opposition to the flow of current is called impedance (Z), which can also be achieved through Pythagoras' theorem as in **Figure 5.37**. **Figure 5.38** is called the resultant triangle.

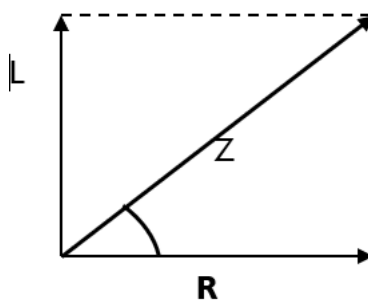


Figure 5.37

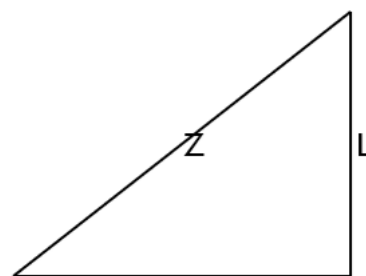


Figure 5.38: Resultant triangle

From **Figure 5.37**, the impedance (Z) is calculated as follows:

$$Z^2 = R^2 + X_L^2$$

$$Z = \sqrt{R^2 + x^2}$$

Recall that in a purely inductive circuit voltage leads the current by 90° . The addition of the resistance in series with the inductor (using Pythagoras's theorem) results in the phase angle being $\emptyset$. Therefore, $\cos \emptyset$ is equal to $\frac{R}{Z}$

$\cos \emptyset$ could also be $\frac{V_R}{V_s}$

But since $V_R = IR$ and $V_S = IZ$

$\cos \Phi$ can also be $\frac{I_R}{I_C}$

$\tan \Phi$ and $\sin \Phi$ can also be used to calculate in which case the appropriate equations will have to be used. For instance, $\sin \Phi = \frac{V_L}{V_S} = \frac{IX_L}{I_Z} = \frac{X_L}{Z}$

Resistive and Capacitive Loads in Series

A circuit containing resistance and capacitance in series is shown in **figure 5.39** below. As in the case of resistive/inductive loads, the same current flows through the resistor and the capacitor and so the pd across each of them is the same as in the case of resistive/inductive circuit.

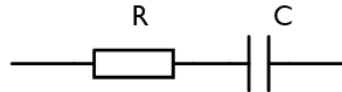


Figure 5.39: Resistor and a capacitor in series

Current and voltage are in phase in the resistor but the current leads the voltage by 90° in the capacitor.

The supply voltage $V_S = \sqrt{V_C^2 + V_R^2}$. But since $V_C = IX_C$ and $V_R = IR$

$$V_S = \sqrt{(IX_C)^2 + (IR)^2}$$

The resultant opposition to the flow of current in the circuit is the impedance (Z) **figure 5.40**.

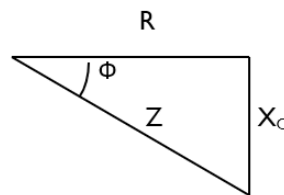


Figure 5.40

$$Z^2 = R^2 + X_C^2$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$\cos \Phi = \frac{R}{Z}$$

You also need to realize that since $\cos \Phi = \frac{R}{Z}$, $\tan \Phi = \frac{X_C}{R}$ and $\sin \Phi = \frac{X_C}{Z}$

Resistor, Capacitor and Inductor in Series

Consider a resistor R , an inductor L and a capacitor C connected in series as in **figure 5.41**. Note once again that the current (I) is common to all components since it is a series circuit. Therefore $V_R = IR$, $V_L = IX_L$ and $V_C = IX_C$.

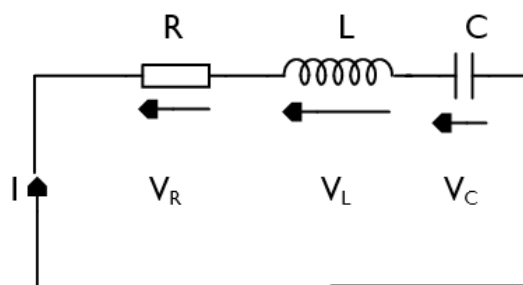


Figure 5.41: RLC series circuit

The phasor diagram of such a circuit depends on the respective values of X_L and X_C . For instance, if the inductive reactance is greater than the capacitive reactance then V_L will be greater than V_C . The resultant reactance will be inductive and the voltage will lead the current. The phasor diagram therefore will be as shown in **figure 5.42**. **Figure 5.43** shows the impedance triangle. Hence the impedance, Z is obtained from $Z^2 = R^2 + (X_L - X_C)^2$

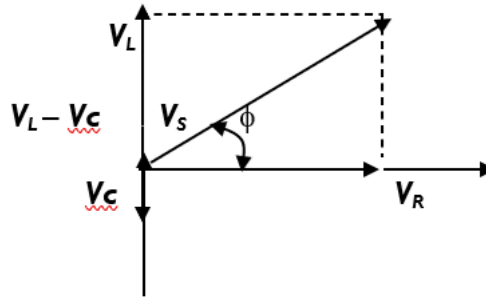


Figure 5.42: Phasor diagram

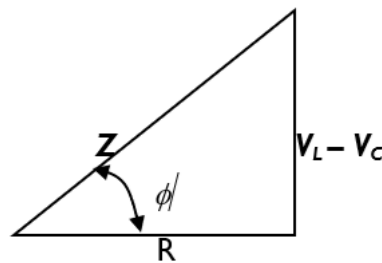


Figure 5.43: Impedance triangle

The supply Voltage (V_s) therefore, will be $V_s^2 = V_R^2 + (V_L - V_C)^2$

$$V_s = \sqrt{V_R^2 + (V_L - V_C)^2}$$

On the other hand if X_C is greater than X_L then the resultant reactance will be capacitive, and the current will lead the voltage. The reactive component in the circuit will be capacitive.

Resonance

You realised from section 2 that **capacitive reactance** (X_C) = $\frac{1}{2\pi fC}$

From this equation, notice that an increase in frequency (f) will lead to a decrease in capacitive reactance and vice versa.

Capacitive reactance therefore, is said to be inversely proportional to frequency ($X_C \propto \frac{1}{f}$)

Inductive reactance on the other hand is directly proportional to the frequency ($X_L \propto f$). Therefore, an increase in f will lead to an increase in X_L

In a series circuit containing both inductive reactance and capacitive reactance therefore, note that as the frequency increases the inductive reactance also increases while the capacitive reactance decreases. At a particular frequency both X_C and X_L will be the same ($X_C = X_L$). This frequency is called resonant frequency f_0

Therefore, at f_0 $\frac{1}{2\pi fC} = \frac{2\pi fL}{1}$

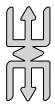
$$1 = 4p^2 f_0^2 LC$$

Making f_0 the subject, we have $f_0 = \frac{1}{2p\sqrt{LC}}$

Note that at this resonant frequency the only opposition to the flow of current is the resistance, therefore, current and voltage are in phase and the impedance Z is equal to R . It is important to realise that Z is at its lowest value at the resonant frequency (f_0) therefore, the largest current flows at that frequency.

Learning Tasks

1. What is the peak value of a voltage of $230V_{\text{rms}}$
2. An alternating voltage is described by the equation . Calculate
 - a. *r.m.s voltage*
 - b. *frequency*
 - c. *the instantaneous voltage when $t = 5\text{ms}$*
3. Define the following ac quantities
 - a. *cycle*
 - b. *period*
 - c. *frequency*

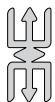


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the following ac terms: Cycle, period, frequency, peak value, instantaneous value, root-mean square value, average value and angular frequency.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to explain the following: Resistive circuit, Inductive circuit, Capacitive circuit, Inductive reactance and capacitive reactance. Encourage learners to pool their knowledge and skills to brainstorm and research and come out with the relationship between frequency and Inductive reactance as well as capacitive reactance.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to plot graphs of frequency against X_L and X_C and use the graph to find the resonance frequency. Through active participation in these activities, learners will gain first-hand experience and understanding typical application of the Resistive, capacitive and inductive circuits.

Additionally, they should watch videos on YouTube to see how the experiments are conducted. They should collaboratively brainstorm, discuss and calculate X_C , X_L , Z , Phase angle. This experience will reinforce understanding of RLC circuits. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply their knowledge of electrical circuit theory in real-world contexts.

KEY ASSESSMENT

Level 1

1. Define the following terms

- a. Cycle
- b. Period
- c. Frequency
- d. Effective value

Level 2

1. How do you add phasors that are displaced at 90° to each other?
2. Explain the effect of frequency on inductive reactance.
3. Outline three characteristics of impedance in RLC circuit?

Level 3

1. A resistor of 10Ω , an inductor of $0.02H$ and a capacitor of $100\mu F$ are connected in series to a $120V$ $50Hz$ supply. Calculate
 - a. The impedance of the circuit,
 - b. The circuit current
 - c. The pd across each component.
 - d. At what frequency will the highest current flow in the circuit and what is the value of the current at that frequency?

HINT

*The recommended mode of assessment for week 19 is **gamification**. Use the level 2 question 3 as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 83 for additional information on how to use this mode of assessment.*

UNIT 19 REVIEW

This unit introduced learners to ac circuit theory and specifically, resistive, capacitive and inductive circuits as one of circuit theory. The unit discusses terms associated with sine wave, resistive circuits, capacitive circuit and inductive circuits. The discussion also included the effect of frequency on inductive and capacitive reactance.

Learners have also been taken through how to calculate for impedance, phase angle and the pd across the various components. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities

UNIT 20

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Demonstrate knowledge and understanding of control system principles and how to use them*

INTRODUCTION AND SECTION SUMMARY

This section looks control system as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in control system through exposure to the following: the concept of control system, types of control systems, the importance of applications of control system in automation.

The unit covers only week 20: Describe the types of control systems and give practical examples

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 20

Learning Indicator: Describe the types of control systems and give practical examples

Focal Area 20: Control System

Control System

The control system is a combination of devices that manage the commands and directs the behaviour of other systems, ensuring seamless operation. They are used in many fields like electronics, automation, manufacturing sectors etc. The output in the control system is governed by the input given to it and provides the desired response by controlling the output. Many components contribute to the control system for its proper functioning and each of them has some specific function. The output quantity is called **controlled variable** or **response** and the input quantity is called **command signal** or **excitation**. When many elements or components are connected in a sequence to perform a specific function, the group thus formed is called a system. Bottom of FormControl systems can basically be put into two groups known as the Open Loop Control System and the Closed Loop Control System.



Figure 5.44: Block diagram of open loop control system

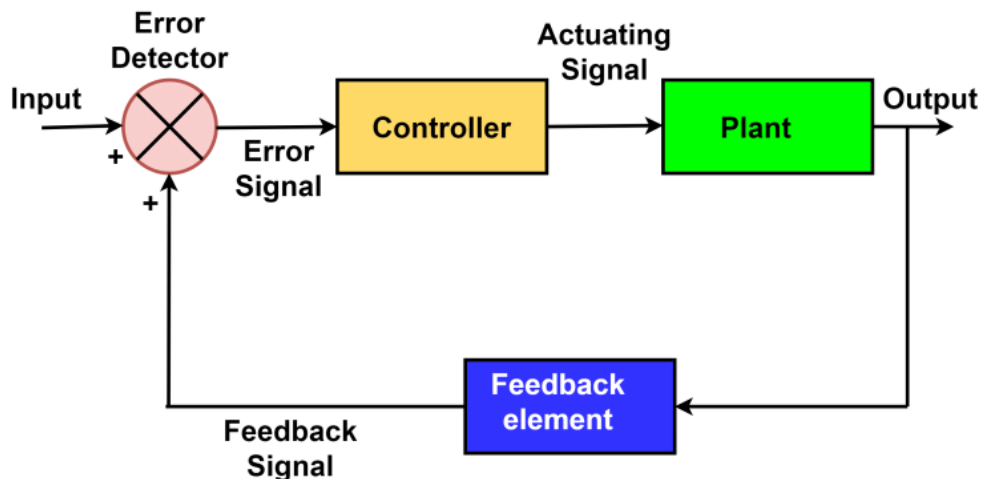


Figure 5.45: Block diagram of a closed loop control system

1. **Open loop control system:** Is the type of control system in which the output quantity has no effect on the input quantity. Examples are the irrigation sprinkler and the traffic light system.
2. **Closed loop control system:** This is the type of control system that the output quantity has effect on the input quantity. It is also called the automatic control system, consisting of the **sensor** that collects information, the **controller** that is used to adjust the functions

in the control system to the desired results and the **actuator** that does the task. Examples here are the air conditioner and smoke detector.



Figure 5.46: *Irrigation sprinkler*



Figure 5.47: *Traffic light system*



Figure 5.48: *An Air conditioner*



Figure 5.49: *A smoke detector*

Advantages and disadvantages of open loop control system

Advantages	Disadvantages
1. Simple and economical	1. Inaccurate and unreliable
2. Easier to construct	2. Changes in the output due to external disturbances are not corrected automatically
3. Generally stable	

Advantages and disadvantages of closed control system

Advantages	Disadvantages
1. Accurate	1. Complex and costlier
2. Less affected by noise	2. Feedback reduces the overall gain of the system.
3. Changes in the output due to external disturbances are corrected automatically.	3. More care is needed to make it stable.

Applications of Control System

There are several applications of control system such as in

1. Manufacturing and production processes
2. Transportation systems
3. Building and home automation.
4. Power generation, transmission, and distribution.
5. Military and defense systems.
6. Medical equipment and operations.
7. Robotics.

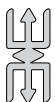
Programmable Logic Controller (PLC)

The Programmable Logic Controller (PLC) is an industrial computer in which control devices such as limit switches, push buttons, proximity or photoelectric sensors, etc. are used in controlling signals. The Programmable Logic Controller is the tool that provides the control for an automated process. Automation helps a manufacturing facility among others to:

1. Increase productivity
2. Lower cost of quality, scrap and rework.
3. Work in difficult or hazardous times.
4. Improve quality and accuracy.
5. Achieve consistency in manufacturing.

Learning Tasks

1. Explain the concept of control systems.
2. Differentiate between an open loop control system and a closed loop control system.
3. Discuss at least three advantages and disadvantages of the open loop control system and closed loop control system.
4. Discuss at least four applications of control systems.

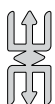


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the concept of the control system, the types of control system and their advantages and disadvantages.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to discuss the applications of control systems, concept of automation and importance of automation.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

KEY ASSESSMENT

1. **Level 1:** Explain the concept of control systems.
2. **Level 2:** Differentiate between open loop control system and closed loop control system.
3. **Level 3:** Discuss at least three advantages and disadvantages of the open loop control system and closed loop control system.
4. **Level 4:** Discuss at least four applications of control system.

HINT



The recommended mode of assessment for week 20 is **peer assessment**. Use the level 4 question as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 72 for additional information on how to use this mode of assessment.

UNIT 20 REVIEW

This unit introduced learners to control systems and specifically types of control systems, advantages and disadvantages of the types of control systems as well as the applications of control systems, the concept of automation and importance of automation. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities



APPENDIX F: MID-SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

15 Multiple Choice Questions (MCQ) all to be answered within **20 minutes**. Questions cover DoK level 1 to 4

RESOURCES

Scannable sheets, A4 sheets, class list, etc.

SAMPLE QUESTIONS

Multiple Choice

1. The correct Mathematical equation of Kirchhoff's current law is...
 - a. $\sum I_{in} = \sum I_{out}$
 - b. $\sum I_{in} \pm \sum I_{out}$
 - c. $\sum I_{in} \leq \sum I_{out}$
 - d. $\sum I_{in} \geq \sum I_{out}$

TABLE OF SPECIFICATION

WK	LEARNING INDICATOR	DoK level				TOTAL
		1	2	3	4	
13	Describe types of resistors as passive electronic components.	1	2			3
14	Describe types capacitor as passive electronic components.	1	1	1		3
15	Describe the inductor as a passive electronic component.	1	1	1		3
16	Illustrate the construction and operation of bipolar junction transistors.	1	1	1		3
17	Illustrate the principles of operation of the various transistors (FET).		2	1		3
	TOTAL	4	7	4		15

SECTION 6: DIGITAL ELECTRONICS

In this section learners will acquire knowledge and understanding on how to solve problems on binary numbers, house wiring, converting the moving iron instrument into a meter and apply knowledge of electronic components in designing circuits. All the above are treated from unit 21 to unit 24.

UNIT 21

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits*

Content Standard: *Demonstrate knowledge and understanding of Digital Electronics*

HINT



Remind learners of End of Semester Examination in Week 24. Refer to Appendix G at the end of this section for Table of specification to guide you to set the questions.

INTRODUCTION AND UNIT SUMMARY

This unit looks at digital electronics as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure on the following concept of digital electronics, the conversion of binary numerals to decimal numerals and from decimal numerals back to binary numerals, the types of logic gates and the symbols of the various logic gates.

*The unit covers only week 21: **Solve problems on binary numbers***

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars

such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 21

Learning Indicator: *Solve problems on binary operations*

Focal Area 21: Digital Electronics

Digital Electronics

Digital electronics is the field of electronics that deals with the representation and manipulation of data in digital form. It uses devices such as transistors, diodes, and microcontrollers to process and transmit digital signals.

1. **Binary Number System:** A binary number system is defined as a number that is used in binary systems. It is also called base 2 numeral system. It represents the numeric values with two distinct symbols, basically 1 (one) and 0 (zero).
2. **Decimal Number System:** The decimal number system is also known as the base 10 numeral system. It uses ten digits from 0 to 9. In the decimal number system, the positions continuous to the left of the decimal point represent units, tens, hundreds, thousands, and so on. Thus, the base of the decimal number system is 10.
3. **Binary to Decimal Conversion:** Binary to decimal conversion is done to convert a number in a binary number system (base-2) to a number in a decimal number system (base-10). It is very necessary to understand binary to decimal conversion for computer programming applications. The binary number system is represented by only two digits, i.e., 0 and 1, whereas the decimal number system includes all 10 digits from 0 to 9.

How to Convert Binary to Decimal Numbers

To convert the binary number to a decimal number, we use the multiplication method. In this conversion process, if a number with base n must be converted into a number with base 10, then each digit of the given number is multiplied from the Most Significant Bit (MSB) to the Least Significant Bit (LSB) by reducing the power of the base.

Binary to Decimal Conversion Steps

1. First, write the given binary number and count the powers of 2 from right to left (powers starting from 0)
2. Now, write each binary digit (right to left) with the corresponding powers of 2 from (right to left), such that the first binary digit (MSB) will be multiplied with the greatest power of 2.
3. Add all the products in the above step
4. The final answer will be the required decimal number

Let us understand this conversion with the help of an example.

EXAMPLE OF BINARY TO DECIMAL CONVERSION

Convert the binary number $(1101)_2$ into a decimal number.

SOLUTION

Given binary number = $(1101)^2$

Now, multiplying each digit from MSB to LSB reduces the power of base number 2.

$$1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

$$= 8 + 4 + 0 + 1$$

$$= 13$$

Thus, the equivalent decimal number for the given binary number $(1101)^2$ is $(13)^{10}$

Decimal to Binary Conversion

The systematic method to convert decimal numbers into binary equivalence involves a successive division by 2 and recording the remainder. The division is stopped when a quotient of 0 with a remainder of 1 is obtained. The remainders when read upwards give the equivalent binary number.

EXAMPLE 1

Convert decimal number 10 into a binary numeral.

SOLUTION

Table 6.1: The binary number is 10102

2	10	Remainder
2	5	0 (LSB)
2	2	1
2	1	0
	0	1 (MSB)

EXAMPLE 2

Convert the decimal number 25 into a binary number.

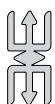
SOLUTION

Table 6.2: The binary number is 110012

2	25	Remainder
2	12	1 (Least significant bit LSB)
2	6	0
2	3	0
2	1	1
2	0	1 (Most significant bit MSB)

Learning Tasks

1. Explain the concept of binary numerals.
2. Convert the binary numeral 110012 to a decimal number.
3. Convert the decimal number 45 to a binary numeral.

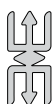


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and discuss the concept of digital electronics and hence binary numerals.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to follow the steps in converting binary numerals to decimal number to convert some binary numerals to decimal numbers and converting decimal number back to binary numeral.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

KEY ASSESSMENT

1. **Level 1:** Explain the concept of binary numeral.
2. **Level 2:** Convert the binary numeral 110012 to a decimal number.
3. **Level 3:** Convert the decimal number 45 to a binary numeral.
4. **Level 4:** Make a poster on the step-by-step procedure to follow when converting binary to decimal for presentation.

HINT

*The recommended mode of assessment for week 21 is **poster presentation**. Use the level 4 question as a sample question. Refer to the Teacher Assessment Manual and Toolkit page 76 for additional information on how to use this mode of assessment.*

UNIT 21 REVIEW

This unit introduced learners to digital electronics, binary numerals and decimal numbers, the steps to follow in converting binary numerals to decimal numbers and converting decimal numbers to binary numerals.

UNIT 22

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits*

Content Standard: *Demonstrate knowledge and understanding of electronic measuring instrument and how to use them to take measurements*

INTRODUCTION AND SECTION SUMMARY

This section looks at measuring instruments as part of electronic devices and circuits. The section starts with electromagnetism since most instruments operate based on magnetism. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electromagnetism as a foundation for the working principles of most electrical instruments and machines. This is achieved through exposure of learners to the following principles of electromagnetism, effects of passing a current through a conductor, effects of placing a current-carrying conductor, effects of passing a conductor through a magnetic field. Other areas include self-induction and mutual induction as well as the Construction, principles of operation and application of the various type of measuring instruments so that with this knowledge and understanding learners will be well equipped to understand the operation of electrical machines as well as use measuring instruments in taking measurements.

The unit covers only week 22: Electrical measuring instruments

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electromagnetism and principles of electrical instruments through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 22

Learning Indicator: Explain the operation of electrical measuring instruments through Principles of electromagnetism

Focal Area 1: Measuring Instruments and Control Principle

Electromagnetism

Electromagnetism is the production of magnetic fields by an electric current. In a straight current-carrying conductor, a magnetic field will surround the conductor. The strength of this field is directly proportional to the supplied current. Thus, a high current will produce a strong magnetic field and vice versa. The magnetic property of an electromagnet can thus be controlled by varying the current supply.

Differences between Electromagnets and Permanent Magnets

Table 6.3: Differences between electromagnets and permanent magnets

Permanent magnets	Electromagnets
1. Require no power 2. Strength of magnetic flux depends on the type of material and the physical size 3. Magnetic flux strength and polarity are constant	1. Require electric power 2. strength of the magnetic field depends on the current and the number of turns. 3. Magnetic flux strength and polarity are not constant.

Effect Of Passing A Current Through A Conductor

When a current is passed through a conductor, a magnetic flux is set up around the conductor, the direction of which can be detected using the corkscrew rule. Turning the screw clockwise will cause it (the screw) to move forward as indicated in figure below and that indicates the direction of current flow in to the conductor. The clockwise direction that the screw is being turned represents the direction in which the flux circulates around the conductor.

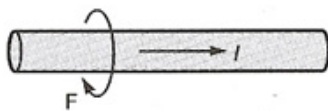


Figure 6.1: Direction of magnetic flux around a current-carrying conductor

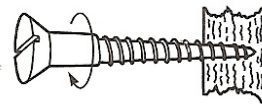


Figure 6.2: Screw

Note that the forward movement of the screw represents the direction of current flow into the conductor.

The following figures show how the flux is set up in the conductor. Current moving into a conductor is represented by the tail end or back of an arrow as a plus or cross sign. Thus, the flux around it is clockwise. However, the tip of the arrow, denoted by a dot, represents current

moving out of a conductor. Magnetic flux from that point of view is in the anticlockwise direction. This is shown in the figure below.



Figure 6.3

Effect Of Placing a Current Carrying Conductor in a Magnetic Field

Magnetic lines of force exist when a North Pole (N) and South Pole (S) are placed close to each other. These lines of force are like elastic bands and can stretch. They always act parallel to each other from the north pole to the south pole as shown in the figure below.

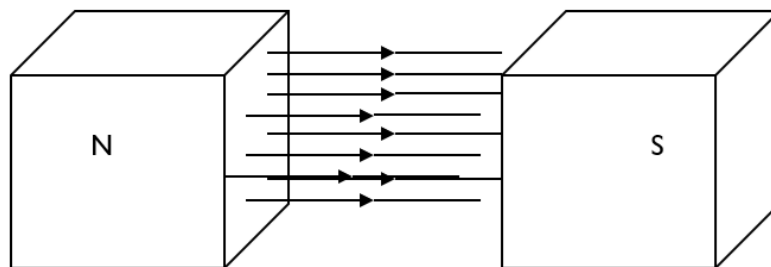


Figure 6.4: *Magnetic field of two magnetic pole pieces*

If you place a current - carrying conductor in this magnetic field, there will be an interaction between the main magnetic field and that produced by the current - carrying conductor. This interaction will cause a force to be exerted on the current carrying conductor, the direction of which depends on the relative direction of current flow into the conductor, to the movement of the main magnetic lines of force.

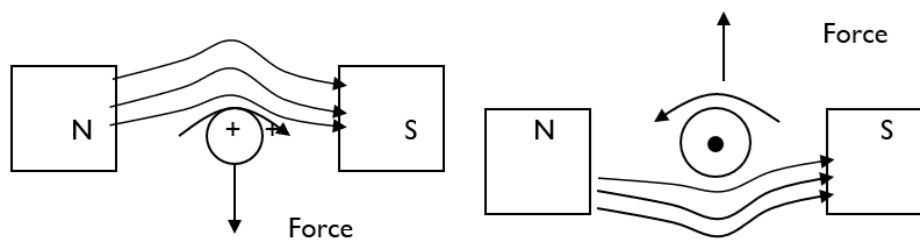


Figure 6.5: *Direction of force exerted on a current-carrying conductor placed in a magnetic field*

The direction of the force exerted on the conductor is determined by Fleming's left-hand rule. By Fleming's left-hand rule:

- The first finger points in the direction of the magnetic lines of force (from north to south).
- The second finger points in the direction of current flow through the conductor.
- The thumb indicates the direction of force exerted on the conductor.

From the figure above, the force is downwards with the current moving into the conductor and upwards with the current moving out of the conductor. When both conductors are placed in the magnetic field, the effect is shown in the figure below.

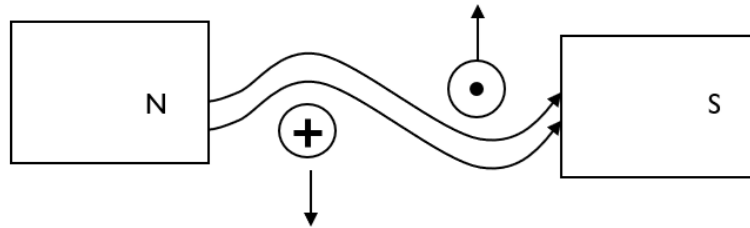


Figure 6.6: Direction of force in the two conductors

Factors Upon Which the Force Depend

As explained earlier, when a current carrying conductor is placed in a magnetic field, the conductor would experience a force F . The amount or size of the force acting on the conductor depends on three factors namely:

1. The magnetic flux density (B) measured in Tesla (T)
2. The length (l) of the conductor lying in the magnetic field in meters (m).
3. The amount of current (I) flowing through the conductor in amperes (A)

An increase in I brings about an increase in the force.

The force $F = BlI$. Newton

Electromagnetic Induction

Whenever a conductor moves across a magnetic field, there is an interaction between the conductor and the magnetic field resulting in an induction of voltage into the conductor. On the other hand, if the magnetic field linking a coil changes, an emf is induced into the conductor.

This is in accordance with Faraday's laws.

1. An emf is induced in a conductor whenever the magnetic field linking with the conductor changes.
2. The magnitude of the induced emf is proportional to the rate of change of the magnetic flux linking the conductor.

Magnitude of Induced emf

The magnitude of the induced emf into a conductor moving through a magnetic field depends on the following factors:

1. The strength of the magnetic field, B :
2. The active length of the conductor l
3. The velocity, v : If the conductor cuts the magnetic field at a very high velocity, then the induced emf will also be greater.

Thus, the magnitude of an induced emf into a conductor cutting a magnetic field at a right angle is given by $emf = BLv$

If the conductor moves at an angle, the induced emf is given by $emf = BLv \sin \theta$

The induced or generated emf can also be expressed as the rate of change of the magnetic flux. ie $emf = N \frac{d\Phi}{dt}$

Types of Induction

According to Faraday's first law of electromagnetic induction, there are 2 main possible ways by which an emf can be induced in a circuit or conductor. These are self-induction and mutual induction.

Self-induction

This can be defined as a phenomenon by which an emf is induced into a conductor or coil by changing current resulting from a changing magnetic flux linking the circuit. The symbol for self-inductance or simply inductance is L . The unit of measurement is the Henry. Henry (H) is defined as the inductance when an emf of 1 volt is induced into an inductor or coil as a result of changing current flowing at a rate of 1 ampere per second. Induction occurs only if the wire moves at right angles to the direction of the magnetic field. The emf induced as a result of self-induction is referred to as back emf.

Back emf depends on the rate of change of the current flowing in the circuit.

$$E \propto \frac{di}{dt}$$

$$\therefore E = L \frac{di}{dt}$$

This relation is sometimes written with a negative sign according to Lenz's law

$$E = -L \frac{di}{dt}$$

$$\text{thus } L = \frac{E}{di/dt}$$

EXAMPLE

Calculate the inductance of a circuit which has a voltage of 230V induced in it when the current changes at a rate of 20A/s

SOLUTION

$$\text{Given } E = 230V, \frac{di}{dt} = 20A/s$$

$$L = \frac{E}{di/dt} = \frac{230}{20} = 11.5H$$

1. What is the value of the induced emf in a circuit with an inductance of 8H, if the rate of change of the current is 13A/s

SOLUTION

$$E = -L \frac{di}{dt} = 8 \times 13 = 104V$$

Relationship between inductance and number of turns

It has been established that

$$E = L \frac{di}{dt} \dots\dots\dots (1)$$

$$E = N \frac{d\phi}{dt} \dots\dots\dots (2)$$

Combining the two equations

$$L \frac{di}{dt} = N \frac{d\phi}{dt}$$

$$L = N \frac{d\phi}{dt} \times \frac{dt}{di}$$

$$\Rightarrow L = N \frac{d\phi}{di}$$

$$\text{Also, } \phi = \frac{mmf}{s} \text{ Thus, } d\phi = \frac{\text{change in mmf}}{s} = \frac{N di}{s}$$

$$\therefore L = N \frac{N di / s}{di} = \frac{N^2 di}{dis} = \frac{N^2}{s}$$

$$\therefore L = \frac{N^2}{s}$$

Thus, if the reluctance remains constant

$$L \propto N^2$$

EXAMPLE

A coil of 500 turns with an air core has an inductance of 0.01mH. Calculate:

1. The reluctance of the circuit
2. The inductance if the number of turns is reduced to 350 turns. Assume the core's reluctance remains constant.

SOLUTION

Given $N = 500$ turns, and $L = 0.01 \times 10^{-3}$

$$\text{a. } L = \frac{N^2}{S} \Rightarrow S = \frac{N^2}{L} = \frac{500^2}{0.01 \times 10^{-3}} = 2.5 \times \frac{10^{104}}{w^b}$$

$$\text{b. } L = KN^2 \therefore K = \frac{L}{N^2} = \frac{L_1}{N_1^2} = \frac{L_2}{N_2^2}$$

Given $N_2 = 350$ turns

$$\frac{0.01 \times 10^{-3}}{500^2} = \frac{L_2}{350^2}$$

$$500^2 L_2 = 350^2 \times 0.01 \times 10^{-3}$$

$$\therefore L_2 = 4.9 \times 10^{-6} H$$

Mutual Induction

Mutual induction occurs when a changing magnetic field created by one conductor or coil links with another coil and thus induces an emf into that coil. Transformer operation is based on

mutual induction. The unit of mutual induction is also the Henry. The emf induced in the secondary coil is proportional to the change of current in the primary coil. That is:

$E_s \propto \text{rate of change of primary coil}$

$$E_s \propto \frac{di_p}{dt}$$

$$\therefore E = M \frac{di_p}{dt} \dots\dots\dots 1$$

where M = mutual inductance

$$M = \frac{E_s}{di_p/dt}$$

$$\text{Also } E_s = N_s \frac{d\phi_s}{dt} \dots\dots\dots 2$$

where ϕ = useful flux linking the two winding

N_s = number of turns in the secondary coil

Combining equations (1) and (2)

$$E_s = N_s \frac{d\phi_s}{dt} = M \frac{di_p}{dt}$$

Making M the subject

$$M = N_s \frac{d\phi_s}{dt} \times \frac{dt}{di_p}$$

$$\Rightarrow M = -N_s \frac{d\phi_s}{di_p}$$

EXAMPLES

1. If two coils have a mutual inductance of 300uH, calculate the emf induced in one of the coil when the current in the other coil varies at a rate of 400A/s.
2. The mutual inductance between two coils is 0.1H. If the current in the primary winding changes from 0.4A to 0.90A in 3ms, calculate the average value of the induced emf in the secondary winding

SOLUTIONS TO EXAMPLES

1. $E = M \frac{di}{dt} = 300 \times 10^{-6} \times 4000 = 1.2V$
2. $E_s = M \frac{di_p}{dt} = 0.1 \times \frac{0.90 - 0.40}{5 \times 10^{-3}} = 10V$

Application of Electromagnetism

1. Analogue measuring instruments
2. Relays
3. Electric bells
4. Transformers
5. Horns
6. Generators
7. Motors

Construction and Principles Of Analogue Measuring Instruments

The following figure shows the basic construction of a measuring instrument. The deflection system is the heart of every analogue instrument and this is achieved by suspending a coil of wire, wound on a piece of soft iron, in between two permanent magnetic pole pieces, north and south poles, shaped in horseshoe form. The coil is called an armature, and it is pivoted in a way that allows it to move freely.

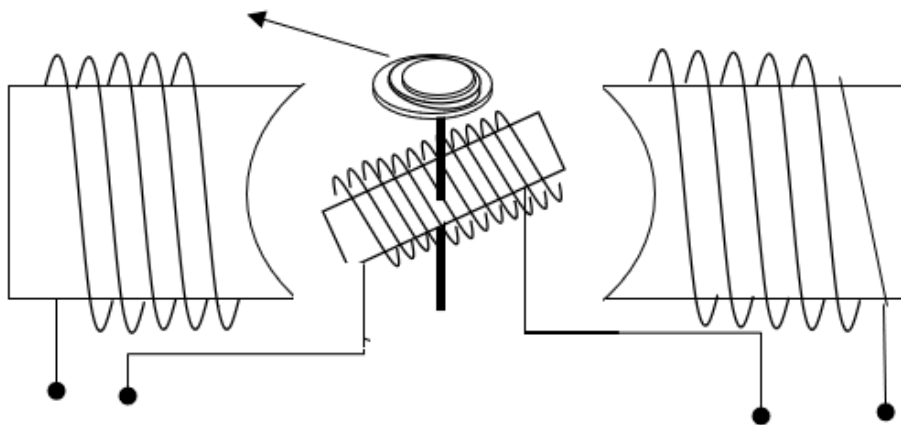


Figure 6.7: Construction of a basic instrument

When current flows through the coil (as indicated by the '+' and '-' signs) a magnetic field will be developed in it with the polarity as shown in the figure.

Notice from the diagram that its north pole of the magnetic field created in the coil faces the north pole of the permanent magnet, and its south pole faces the south pole of the permanent magnet. Also remember, however that like poles repel, and so there will be a deflection of armature resulting in the movement of the pointer. The strength of the magnetic fields involved however, determines the rate at which the armature and the pointer will turn.

The magnetic field of the permanent magnet is constant, but that of the armature depends on the strength of the electric current flowing through it. The movement of the armature therefore, is directly proportional to the magnitude of the electric current.

There is a spring which opposes the movement of the armature and pointer, and so they return to their original position when the current stops flowing.

The Moving Coil Instrument

A type of instrument that may be used as a meter is the moving coil instrument. As the name implies, it has a movable coil, which carries the pointer and uses magnetic fields. Its range can be extended by using shunts and multipliers.

Construction

The moving coil instrument (MCI) is made up of the following parts

1. Two permanent magnetic pole pieces (North and South Pole)
2. Soft iron ring
3. copper coil
4. aluminium former and restoring springs

The following figure shows the construction of a moving coil instrument (MCI). This is called the external magnet type. It consists of two pole pieces of permanent magnet providing a permanent magnetic field and a rectangular current-carrying conductor (coil) wound around an aluminium former.

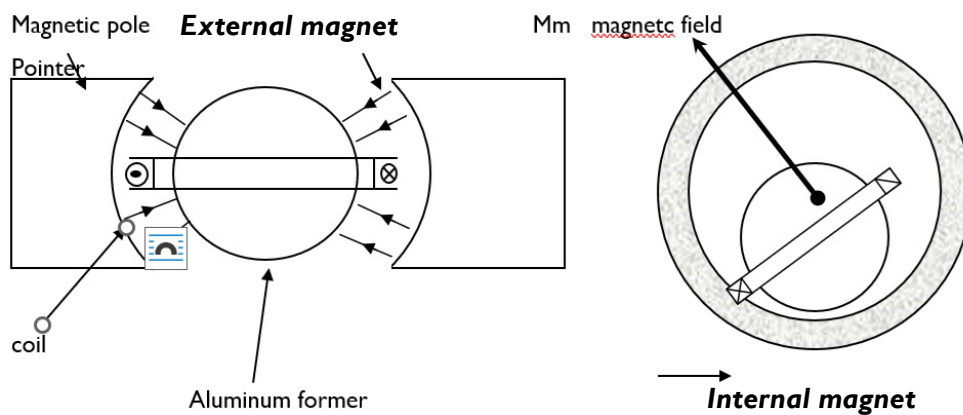


Figure 6.8: Construction of MCI

Notice the following

1. The pointer is attached to the rectangular coil.
2. When current flows through the coil, a magnetic field is set up in it (the coil),
3. The field in the coil interacts with the field of the permanent magnet.
4. A turning force is consequently exerted on the coil, which then turns and causes a deflection of the pointer.
5. The amount of current or voltage passing through is thus registered on the scale.
6. The average torque developed in the moving coil instrument is proportional to the value of the current applied. Hence, the instrument has a linear scale.
7. Damping in this instrument is by eddy-current

In the external magnetic field type, powerful magnetic fields around the instrument can bring about errors in the reading of this type. The internal magnet type solves this problem.

The average torque developed in the moving coil instrument is proportional to the value of the current applied. Hence, the instrument has a linear scale. Damping in this instrument is by eddy-current.

In this type of instrument, the accuracy of the reading increases towards the upper end of the scale, therefore in selecting one, you must ensure that the value of the quantity to be measured is not less than 30% of fsd.

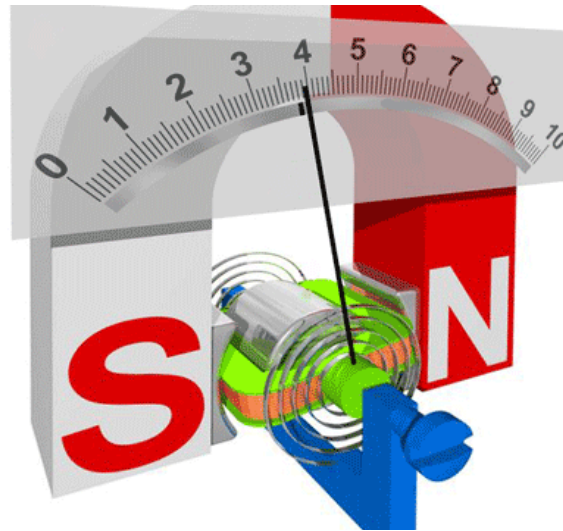


Figure 6.9: A moving coil instrument

Extension of Instrument Range

1. Extending the range of this instrument is achieved using shunts and multipliers
2. They are made from manganin to minimize the effect of temperature on the instrument.

Its Major Disadvantage Is That It Has Fixed Polarity

A typical full-scale deflection may be 1mA and such a meter is not good for general-purpose. Two reasons account for this.

1. The maximum current of 1mA is too low for most measurements.
2. A high current will cause damage to the meter.

To measure a wide range of current, a resistor of very low value, called shunt, is connected in parallel with the instrument as shown below. Because of this, more current flows through the shunt so that the instrument receives a safe value of current.

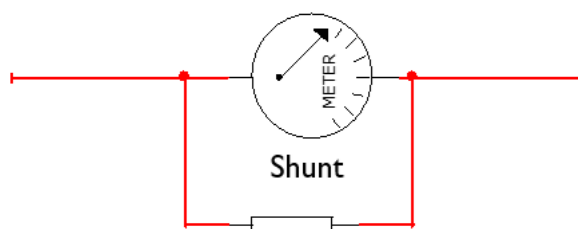


Figure 6.10: Extending the current range of an instrument

The instrument can also be converted into a voltmeter, capable of measuring very high values, by connecting a resistor (made of manganin) of very high value, called multiplier, in series with it as shown below

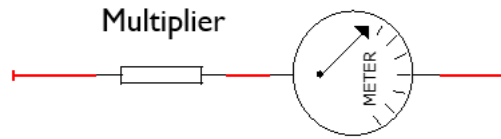


Figure 6.11: Extending the voltage range

The scale may then be calibrated to read higher voltages that are applied directly to the terminals, without damaging the instrument.

EXAMPLE

A moving-coil galvanometer gives full-scale deflection (FSD) with 15mA and has a resistance of 5Ω . How can the instrument be used as:

- an ammeter capable of measuring 2A (FSD)
- a voltmeter capable of measuring 100V (FSD)

SOLUTION

Using the instrument as an ammeter (the circuit diagram is shown below)

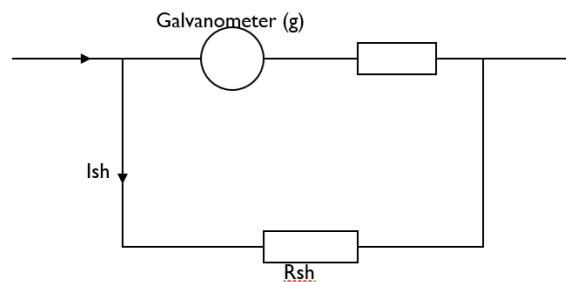


Figure 6.12

The shunt current (I_{sh})

$$\begin{aligned} I_{sh} &= I - I_g \\ &= 2 - 0.015 \\ &= 1.985\text{A} \end{aligned}$$

$$\begin{aligned} V_g &= I_g R_g \\ &= 15\text{mA} \times 5\Omega = 0.075\text{v} \end{aligned}$$

$$\text{But } V_{sh} = V_g = 0.075$$

For the unknown shunt resistor (R_{sh})

$$\begin{aligned} R_{sh} &= \frac{V_{sh}}{I_{sh}} \\ &= \frac{0.075}{1.985} = 0.038\Omega \end{aligned}$$

To use the instrument as an ammeter, capable of measuring 2A (FSD), a shunt, of value 0.038W, should be connected in parallel with it so that a greater amount of the applied current is diverted through it (the shunt).

Using the instrument as a voltmeter (the circuit diagram is figure 6.13)

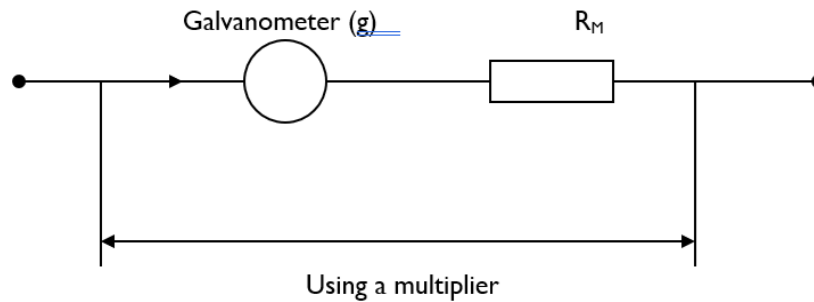


Figure 6.13: Using a multiplier

$$R_m = \frac{V_m}{I_m}$$

But $V_m = V_I - V_g$

$$V_I = 100V$$

$$V_g = I_g \times R_g$$

$$= 0.015 \times 5$$

$$= 0.075V$$

$$\therefore V_m = 100 - 0.075$$

$$= 99.925V$$

Also, $I_g = I_m = 0.015A$

$$\Rightarrow R_m = \frac{99.925}{0.015}$$

$$= 6661.67\Omega$$

Factors to Consider When Using An Instrument

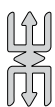
Two important factors are needed

1. **Safety:** Personal safety, safety of the instrument being used and safety of the circuit under test
2. **Accuracy:** Inherent accuracy of the instrument, accuracy in the way measurements are taken and the degree of accuracy you need.

Learning Tasks

1. Upon what principle does the moving coil instrument operate?
2. State one advantage and one disadvantage of the moving coil instrument.
3. What method of damping is used in the moving coil instrument?

4. How is the influence of external magnetic fields minimised in this instrument?
5. How can you convert a moving – coil instrument into:
 - a. *An ammeter*
 - b. *A voltmeter*
6. State the factors that must be considered under the following, when using an instrument.
 - a. *Safety*
 - b. *Accuracy*
7. What are five of the quantities that may be measured when using the instruments?
8. How is the effect of temperature minimised in a measuring instrument?
9. What method of damping is employed in the moving iron instrument?
10. Why is the scale of the moving iron instrument non-linear?
11. A moving – iron meter has a resistance of 5 ohm and gives FSD when a current of 15mA passes through it. What modification must be made to the instrument to convert it into:
 - a. *an ammeter reading to 15A*
 - b. *a voltmeter reading to 15V.*
12. State three advantages, and three disadvantages, of the moving-iron I instrument.
13. Compare permanent magnets and electromagnets.
14. What is the effect of placing a current-carrying conductor in a magnetic field?
15. State and explain 3 factors that affect the emf induced into a conductor moving in a magnetic field.
16. How can you convert a moving – coil instrument into:
 - a. *An ammeter*
 - b. *A voltmeter*



Note

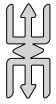
1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the effect of placing a

current-carrying conductor inside a magnetic field. Learners should also state and explain 4 factors the effect depends on.

2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to Explain the following: Self-induction, mutual induction Encourage learners to pool their knowledge and skills to brainstorm and research and come out with the effect of passing a current through a conductor and indicate the symbols of current going into and coming out of a conductor.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

3. **Experiential Learning:** Engage learners in an experiential learning process by inviting them to use Flemings left hand rule to determine the direction of force exerted on a current-carrying conductor placed in a magnetic field. Students should also calculate for the induced emf into a conductor moving across a magnetic field at various angles.

Through active participation in these activities, learners will gain first-hand experience and understanding the effect of placing a current-carrying conductor in a magnetic field as well as understanding how to calculate for induced emf in a conductor moving in a magnetic field.

Additionally, they should watch videos on YouTube to see how the experiments are conducted. They should collaboratively brainstorm discussing a moving coil galvanometer that can be converted to an ammeter and voltmeter. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply their knowledge of electromagnetism electrical measuring instruments in real-world contexts.

KEY ASSESSMENT

Level 1

1. Define electromagnetism
2. List 3 application of electromagnetism

Level 2

1. Explain Faraday's laws of electromagnetic induction
2. Explain the following
 - a. Self-induction
 - b. Mutual induction

Level 3

1. The active length of a conductor moving in a magnetic field of 0.05T is 0.4m. If the velocity at which the conductor moves through the magnetic field is 500m/s. calculate the average value of the induced emf if:
 - a. The conductor moved at right angles to the field.
 - b. The conductor moved at an angle of 30° to the field solution.
2. Write field trip report on applications of properties of electromagnets

HINT

*The recommended mode of assessment for week 22 is **field trip report**. Use the level 3 question 2 as a sample question.*

UNIT 22 REVIEW

This unit introduced learners to electromagnetism and analogue measuring instruments and specifically, the effects of passing a current through a conductor, the effect of placing a current-carrying conductor in a magnetic field, and the effect of passing a conductor across a magnetic field. Other areas discussed are Faraday's laws of electromagnetic induction, self-induction and mutual induction, and the application of electromagnetism. The discussion also included the principles of operation of analogue measuring instruments and how to convert a moving coil galvanometer into ammeters and voltmeters. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities.

RESOURCES

The following resources will be needed to successfully teach this unit

1. Electromagnets,
2. Permanent magnetic pole pieces (north and south poles)
3. A source of dc power supply
4. Conductors
5. Galvanometer
6. Resistors
7. Internet
8. Computers installed with multism

UNIT 23

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits*

Content Standard: *Demonstrate knowledge and understanding of electronic measuring instruments and how to use them to take measurements*

INTRODUCTION AND UNIT SUMMARY

This unit looks at measuring instruments as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in measuring instruments through exposure to the following: Construction, principles of operation and application of the various type of measuring instruments and be able to use them in taking measurements.

The unit covers only week 23: Convert the moving iron instrument into a meter and use it with other instruments in taking measurements.

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 23

Learning Indicator: Convert the moving iron instrument into a meter and use it with other instruments in taking measurements

Focal Area 1: Moving-Iron Instrument

The Moving-Iron Instrument

Most analogue meters employ the effect of magnetism in their operation which brings about a movement of a mechanism, which in turn causes a pointer to deflect. The moving iron meter is no exception. There are two types of the moving iron meter, the repulsion type and the attraction type.

Repulsion Moving-Iron Meter

The diagram below shows the most common repulsion type of moving-iron meter. Its features include: a solenoid (a temporary magnet), a fixed iron, a movable iron, a hairspring, a scale, and a pointer.

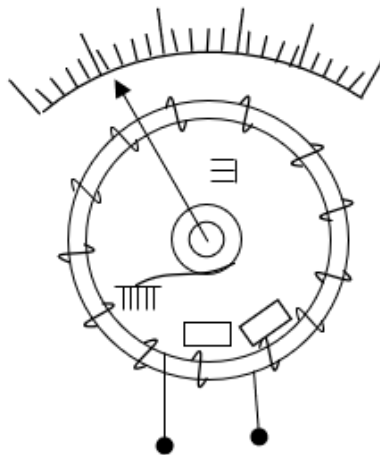


Figure 6.14: The repulsion type of moving iron instrument

Its principle is based on the fact that two pieces of soft iron will repel and move away from each other if they are magnetized in a manner that they have the same polarity, either north and north or south and south. A magnetic field would be created by the solenoid when current flows through the coil and both soft iron rods (fixed and movable) will become magnetized. It is obvious that they will both be of the same polarity, when magnetized. Therefore, they will repel each other and so the movable one will drift away and move the pointer along the scale, against the action of the control spring. The strength of the magnetic field, however, depends on the magnitude of the current, therefore, the greater the current that flows through the coil, the more powerful the repulsion will be and the further (along the scale) the pointer will move. The instrument has a non-linear scale because the deflecting force is proportional to the square of the current. Simple air vane damping is employed in this instrument to contain oscillation, which sometimes occurs.

The Cathode-Ray Oscilloscope

The oscilloscope is one of the most important measuring instruments developed. It is used mainly as a “*graph-plotter*” to display the waveform of the voltage applied to its input, and to show how it varies with time. It can measure frequencies and values of signals (voltages) applied to its inputs, and this is done using a spot of light.

Definition of an Oscilloscope?

An oscilloscope (O-scope) is an electronic test instrument that allows signal voltages to be viewed, usually as a two-dimensional graph of one or more signals. It is used mainly as a “*graph-plotter*” to display the waveform of the voltage applied to its input, and to show how it varies with time. It can measure frequencies and values of signals, (voltages) applied to its inputs, this is done using a spot of light. It is widely used for measuring time-varying signals. It shows features of signals you cannot otherwise see.

Types of Oscilloscopes

There are two types of oscilloscopes in use today, the Cathode Ray Oscilloscope (CRO) and Liquefied Crystal Display (LCD). For some time oscilloscopes were based on cathode-ray tubes (CRTs), which are relatively bulky, heavy, unreliable, high-power consuming, and expensive. Lately, however, many CRT oscilloscopes are being replaced with flat-panel LCD screens, which are much cheaper, more compact, and very convenient. LCD oscilloscopes use digital electronics to draw a trace instead of using moving electron beams to draw traces. LCD oscilloscopes are generally **digital**: they use analogue-to-digital converters to turn incoming (analogue) signals into numeric (digital) form and then plot those numbers on the screen instead.

The following table compares analogue and digital oscilloscopes

Component	Analogue Oscilloscope	Digital Oscilloscope
Display	CRT (Cathode Ray Tube)	LCD/LED Screen
Vertical Controls	Potentiometers usually control amplitude	Digital controls, often with touch capability
Horizontal Controls	Controlled manually	Digital controls, zoom and pan functionalities

Construction of the CRO

This type of oscilloscope consists of a cathode-ray tube (CRT) as its main part. This is a vacuum tube with a screen, which is coated with fluorescence. The cathode ray tube is made up of a highly evacuated glass tube with two electrodes: cathode and anode (electron gun), and a set of plates, the X plate and the Y plate

A typical diagram of a Cathode Ray Tube (CRT) is shown below

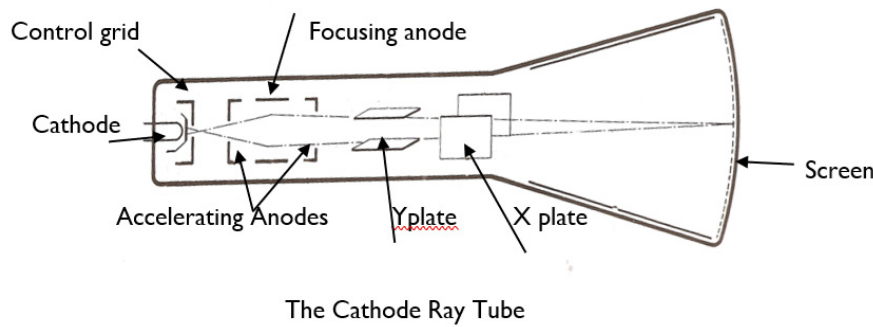


Figure 6.15: *The Cathode Ray Tube*

Functions of the Parts

1. **Indirectly heated cathode:** This produces the electron beam from thermionic emission.
2. **Control grid:** It has a small hole through which electrons flow to form an electron beam. By varying this hole, the intensity of the beam is altered.
3. **Accelerating Anode:** This helps to speed up the movement of electrons. Usually maintains a higher potential relative to the cathode.
4. **Focusing anode:** Works in conjunction with the accelerating anode and acts as an electron lens, which helps to create a pinpoint beam on the screen.
5. **Y plates or verticals:** They are connected to an alternating power source which changes the polarities of the Y plates alternatively, thus causing the beam to move up and down in a vertical direction.
6. **X plates:** these plates are connected to the saw tooth input generated by a time base oscillator. This causes the beam to move uniformly during the sweep part of the wave form and then drops quickly to the original starting point. This is known as flyback.
7. **Screen:** This is made of a fluorescent material coated with zinc sulphide.

Operation

The electron gun emits electrons in the form of a beam, which is focused on the screen. A very high voltage of several kilovolts connected onto the tube helps to accelerate the electrons in a manner that the beam strikes the screen in the form of a spot as shown below. This spot is an illuminated dot that moves across the screen when there is no signal. The spot moves across the X-axis. It moves from the left to the right (SWEEP) and then FLYBACK to the left, and at a particular velocity, its movement is seen as only a line across the X-axis. This line is called Trace and forms the time base of the graph.

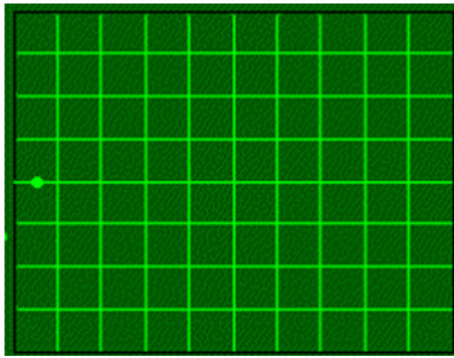


Figure 6.16: *The spot*

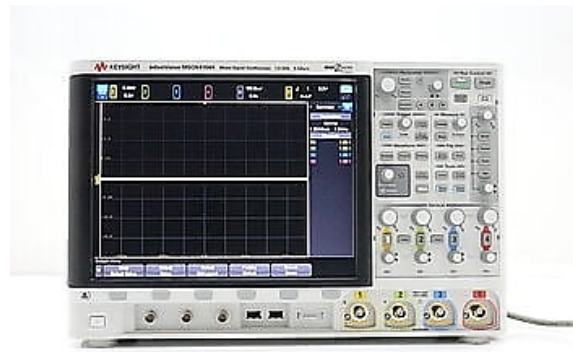


Figure 6.17: *Analogue Oscilloscope displaying a trace*

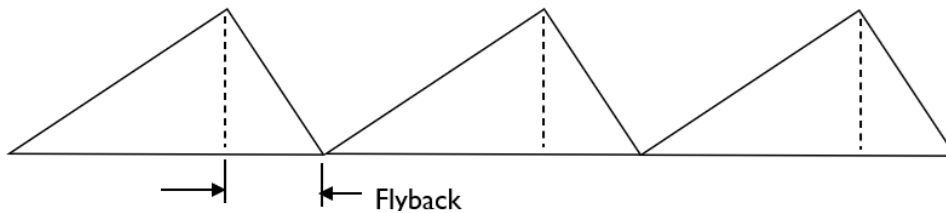


Figure 6.18: *Time base waveform*

The deflector plates (the X plate and Y plate) are so arranged that they can deflect the beam in different directions. While the X plate deflects it horizontally, the Y plate deflects it vertically.

Uses of Cathode Ray Tube

1. As a screen in TV and computer monitors
2. Measure frequency of AC
3. To measure phase difference
4. To measure voltage (both dc and ac)

Uses of an oscilloscope

The oscilloscope is used for the following

1. Measuring time-varying signals - by showing details of the wave shape
2. Measuring aspects of time-varying signals
 - a. Frequency of a signal
 - b. Peak value of a signal

Taking Measurements

When a signal is inputted, voltages are applied to the two sets of deflector plates (X and Y plates) and they influence the beam in a manner that plots the waveform of the signal being examined.



Figure 6.19: *An ac signal displayed*

Two signals are inputted at the same time to enable this to happen. The time base signal, which is a saw tooth waveform as seen in figure 6.19 is applied to the X plates while the signal to be observed is applied to the Y plates. The interaction of the two signals converts the beam into the waveform of the signal to be observed.

How do you use an oscilloscope

1. Plug it in.
2. Turn it on by pressing the push button at the lower right edge of the screen.
3. Make sure that the settings match the signal.
4. Apply a signal to the input terminals. In case the oscilloscope has provision for more than one signal input, choose channel 1 if that is the case.

Application

The instrument is used for many purposes including the following:

1. Observing waveforms in circuits.
2. Measurement of voltage, frequency, time difference between signals
3. Measurement of current and resistance when used in conjunction with other circuits.
4. Plotting graphs when used in conjunction with other electronic apparatus.

Multimeters

In electricals, a meter is a measuring instrument. Ammeters, voltmeters and ohmmeters are all types of electrical measuring instruments. Whilst an **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points with an **ohmmeter** measuring resistance. A **multimeter, on the other hand**, combines all these functions, and in some cases additional ones as well, in one instrument. An important feature of the multimeter is the means of switching it on. While some have a Push-on, Push-off switch, others have an off position, which can be selected using the selection knob. There are two types of multimeters. These are the digital and analogue types.

Digital Multimeters

Digital meters give an output in numbers, usually on a liquid crystal display. A typical multimeter is shown below



Figure 6.20: A digital multimeter

Notice that the central knob has lots of positions, and you must choose which one is appropriate for the measurement you want to make. Also notice that it has an off position which can be selected using the knob.

Common Features of a Multimeter

The front of the multimeter is divided into six sections, the large knob in the center allows you to choose the type of measurement and voltage (DC – direct current, or AC –alternating current) to be used. The sections which are common to most instruments are as follows,

1. **OHM:** For measuring resistance. ranging from 200 Ω (ohms), to 20 M Ω (megohms). There is a beeping sound if resistance is less than 30 Ω .
2. **DCV:** For measuring DC voltage ranging from 200 mV (millivolts) to 1000 V (volts).
3. **ACV:** For measuring AC voltage, ranging from 200 mV to 700 V.
4. **ACA:** For measuring AC current, ranging from 200 μ A (microamperes) to 2 A (amperes).
5. **DCA:** For measuring DC current, ranging from 200 μ A to 2 A.
6. **hFE:** For measuring the dc current gain of transistors. This position has the diode symbol and is used to test diodes and transistors.

Connecting Measuring Leads (Wires) To The Multimeter

Connection of measuring leads (probes) to the multimeter depends on the quantity to be measured There are four ports for connecting wires at the bottom of the multimeter which are T labelled as follows:

1. **COM:** This is the common port. The ground or negative probe is plugged into this port.
2. **V/ Ω :** This is referred to as the positive terminal of the voltmeter/ohmmeter. When using the multimeter as a voltmeter or ohmmeter, the red wire gets plugged into this port.
3. **A:** When using the multimeter as an ammeter, the red wire typically gets plugged into this port.
4. **20A:** This port is used for measuring very high Currents.

Analogue Multimeters

An analogue meter moves a needle along a scale. Switched range analogue multimeters are very cheap but are difficult for beginners to read accurately, especially on resistance scales. The following figure is a typical analogue multimeter.



Figure 6.21: An analogue meter

Each type of meter has its advantages. For voltage readings, a digital meter is usually better than the analogue because its resistance is much higher, $1\text{ M}\Omega$ or $10\text{ M}\Omega$, compared to $200\text{ k}\Omega$ for an analogue multimeter on a similar range. On the other hand, it is easier to follow a slowly changing voltage by watching the needle on an analogue display. For current measurements, an analogue multimeter has a very low resistance and is very sensitive, with scales down to $50\text{ }\mu\text{A}$. More expensive digital multimeters can equal or better this performance.

Using the multimeter

To use the multimeter to take measurements, you must first consider what you want to measure, whether current, voltage or resistance, and the approximate value. You also need to consider whether the quantity you are measuring is AC or DC. These considerations will help to make the necessary adjustments to the meter.

Measuring current in a circuit

To measure current in a circuit, the following procedure must be followed:

1. Break the positive wire of the circuit and ensure that the conductors are exposed.
2. Insert the black lead jack of the meter into the port marked 'COM'
3. Insert the red lead jack into the port marked 'A'. Note that if the current being measured is very high use the port marked '10A'
4. Select the appropriate current range on the meter depending on whether it is ac (ACA) or dc (DCA)
5. Connect the red probe of the meter to the wire leading to the source of power supply.
6. Connect the black probe to the other wire leading to the circuit. The meter is thus connected in series with the circuit.
7. Take the reading on the meter.

The following diagrams show a dc circuit before and after connecting an ammeter: Notice that the ammeter is connected in series with the circuit. To measure current, the circuit must be broken to allow the ammeter to be connected in series to ensure that all the current in the circuit flows through the meter. Also note that ammeters must have a low resistance.

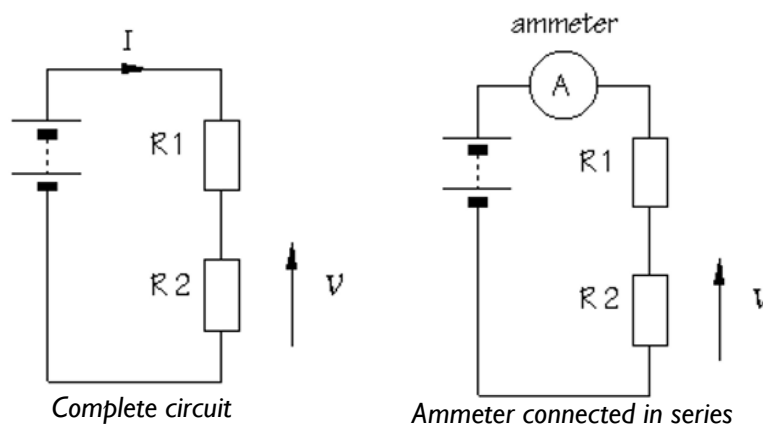


Figure 6.22

Always remember the changes to be made to a practical circuit in order to include the ammeter. To start, the circuit must be broken so the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behaviour of the circuit, or at least not significantly, and it follows that an ammeter must have a very LOW resistance.

Measuring Voltages

To measure voltages, it isn't necessary to break the circuit as in the case of current measurement. The procedure is as follows

1. Insert the black lead jack of the meter into the port marked 'COM'
2. Insert the red lead jack into the port marked 'VΩ'.
3. Select the appropriate voltage range on the meter depending on whether it is ac (ACV) or dc (DCV). The caution here is that a voltage range must be selected that is higher than the estimated voltage of the circuit.
4. Connect the probes of the meter parallel to the circuit. Note that the polarity of the probes does not matter when measuring AC voltages. However, if it is DC, the red probe must be on the positive side of the power source and the black on the negative side.
5. Read the measurement on the meter.

The following figures show the same dc circuit before and after connecting a voltmeter:

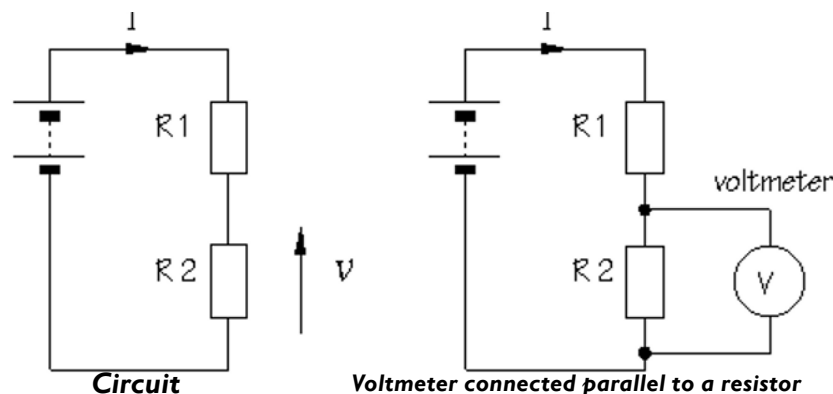


Figure 6.23

Points to Note

To measure potential difference (voltage), the circuit is not changed: the voltmeter is connected in parallel. Note that voltmeters must have HIGH resistance. This time, it isn't necessary to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible. In other words, a voltmeter should have a very HIGH resistance. Voltage measurements have advantages over current measurements: they are easier to make, the meter probes are connected simply by touching them to the points of interest. The original circuit does not also have to be changed. Voltage measurements are used much more often than current measurements since the processing of electronic signals is usually thought of in terms of voltage.

Measuring Resistance

To measure resistance, switch over to the Ohms side of the meter. This implies that an Ohmmeter is now being used. Before going through the procedure for measuring resistance remember that an ohmmeter does not function with a circuit connected to a power supply. If the resistance of a particular component is to be measured, it must be taken out of the circuit altogether and tested separately.

The procedure is as follows

1. Insert the black lead jack of the meter into the port marked 'COM'
2. Insert the red lead jack into the port marked 'VΩ'.
3. Select the appropriate resistance range on the meter. The caution here to select a range that is higher than the estimated resistance of the circuit or component.
4. Switch off power to the circuit or in the case of electronic components, remove the component from the circuit
5. Connect the probes of the meter to the two points of the circuit or the component whose resistance is to be measured. Note that the polarity of the probes does not matter when measuring resistance.
6. Read the measurement on the meter.

The following diagram shows how the resistance of a resistor is measured. Note that the resistor is removed from the circuit and tested as shown in fig 6.24 r.

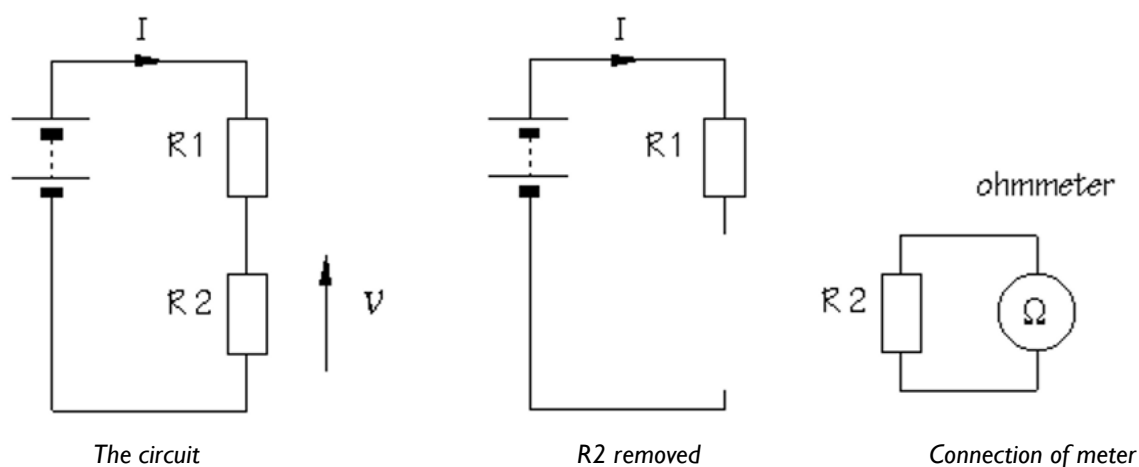


Figure 6.24

Points to Note

When measuring resistance, the **component must be removed from the circuit altogether**. Ohmmeters work by passing a small current through the component and measuring the voltage produced. If this is tried with the component connected into a circuit with a power supply, the most likely result is that the meter will be damaged. Most multimeters have a fuse to help protect against misuse.

Measuring h_{FE} of a transistor

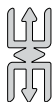
The h_{FE} is the current gain of a transistor. It has no unit. To measure the h_{FE} , first be sure of the type of transistor being tested, whether it is an NPN or PNP.

You should then follow these steps:

1. Turn the knob of the meter to the portion marked ' h_{FE} '
2. Insert the pins of the transistor into the h_{FE} ports ensuring that the base pin goes into the base port, the collector pin goes into the collector port and emitter pin into the emitter port.
3. Read the h_{FE} directly on the LCD

Learning Tasks

1. Differentiate between the CRO and the LCD
2. How does the LCD produce a trace?
3. Explain how the oscilloscope is used to take measurements

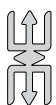


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain how a trace is produced in a CRO and LCD or LED, explain the terms SWEEP and FLYBACK. They should also state 3 advantages of LCD.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to Explain how the oscilloscope is used to take measurements. Encourage learners to pool their knowledge and skills to brainstorm and research and come up with the differences between CRO and LCD.



Note

Through this group work, learners not only enhance their understanding of protective measures but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

Experiential Learning: Engage learners in an experiential learning process by inviting them to measure voltage, current and resistance using the multimeter. Through active participation in these activities, learners will gain first-hand experience and understanding of typical applications of measuring instruments.

Additionally, they should watch videos on YouTube to see how the oscilloscope operates. They should collaboratively describe the differences between CRO and LCD, bringing out the differences between them. This experience will reinforce understanding of measuring instruments. This experiential learning approach not only enhances learners' practical knowledge but also fosters critical thinking skills as they analyse and apply their knowledge of electrical measuring instruments in real-world contexts.

KEY ASSESSMENT

Level 1: Define the following terms as they relate to measuring instruments

- a. Oscilloscope
- b. Multimeter

Level 2

1. What are the functions of the following as they relate to multimeters
 - a. OHM
 - b. DCA
 - c. ACA
 - d. DCV
 - e. ACV
2. Describe the procedure in measuring Resistance and hFE with a multimeter.

Level 3: Input a signal with the following characteristics into an oscilloscope

1. 1 volt (2v peak-to-peak) signal. In other words, it has a peak of 1 volt and a negative "peak" at -1 volt.
2. A frequency of 1000 Hz (i.e., 1 KHz).
3. A sinusoidal signal. In other words, it looks like a familiar sine wave.



HINT

*The recommended mode of assessment for week 23 is **portfolio presentation**.*

UNIT 23 REVIEW

This unit introduced learners to measuring instruments and specifically, moving iron meter, the oscilloscope and the multimeter. The unit discusses the definition of these instruments, terms associated with them, their functions, and advantages. The discussion also included a comparison of CRO and LCD and how to take various measurements with them. Various pedagogical approaches and assessment methods have been carried out to facilitated active learning and engagement among learners with diverse learning needs and abilities

Resources

The following resources will be required *Digital multimeters, Oscilloscope, Computers installed with multism software, Internet source, Cells and circuit components*

UNIT 24

STRAND: ELECTRICAL AND ELECTRONICS TECHNOLOGY

Sub-Strand: Electronic Devices and Circuits

Learning Outcome: *Demonstrate knowledge and understanding of electronic components and use them to design and construct electronic circuits.*

Content Standard: *Apply knowledge and understanding of electronic components in designing electronic circuits*

INTRODUCTION AND SECTION SUMMARY

This section looks at transistors as part of electronic devices and circuits. It is geared towards equipping the learner with the knowledge, understanding, skills and techniques in electronics components through exposure to the following: Construction, principles of operation and application of the various type of electronic components and be able to design electronic circuits with them.

The unit covers only week 24: Apply knowledge of electronic components in designing circuits

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this section to be accomplished learners are to be actively engaged in practical demonstration on the various aspect of electronic components through a wide range of pedagogical exemplars such as Talk for learning, Collaborative learning, Experiential learning, Project – based learning, Research and collaboration.

ASSESSMENT SUMMARY

The concepts involved in this section requires learners' ability to demonstrate the understanding relating to real life situation hence the assessment should cover all the levels. Teachers should therefore employ a variety of formative assessment strategies both oral and written to collect data from learner's progress and give prompt feedback to them. Teacher can consult Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 24

Learning Indicator: *Apply knowledge of electronic components in designing circuits*

Focal Area 24: Designing Electronic Circuits

Building a Fire Alarm Circuit (Project one)

Materials and components needed

Components

1. Thermistor
2. Transistor (NPN BC547)
3. L.E.D
4. A 9V Battery
5. Toggle switch

Materials

1. Bread board
2. Connecting wires
3. Matrix board
4. Soldering Iron
5. Solder
6. Solder sucker.

Circuit Diagram of Fire Alarm

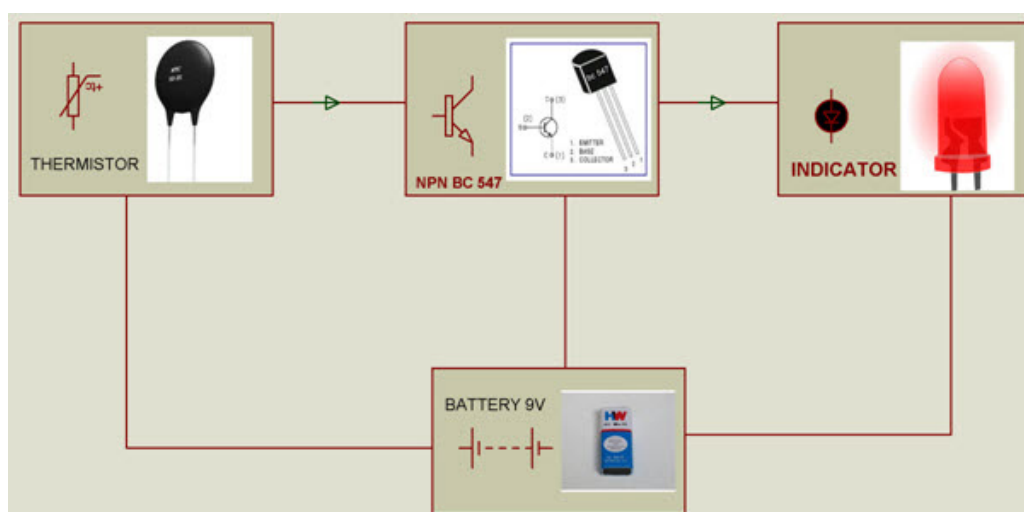


Figure 6.25: *Fire Alarm*

Procedure/Steps in building fire alarm circuit

5-Simple Steps to Build Fire Alarm Project

- **Step 1:** Fire Alarm Circuit Block Diagram Estimation.
- **Step 2:** Gathering Required Components for Fire Alarm Circuit.
- **Step 3:** Estimating the Fire Alarm Circuit Diagram.
- **Step 4:** Connecting & Soldering Circuit.
- **Step 5:** Fire Alarm Working Principle.

Building an F.M Transmitter Circuit (Project Two)

Materials and components needed

Components

1. Resistor (R1) = $15K\Omega$
2. Resistor (R2) = $1K\Omega$
3. Capacitor (C1) = $0.001\mu F$
4. Variable Capacitor (C2) = 10-40 PF
5. Capacitor (C3) = 4.7 PF
6. Inductor (L) = wire coil
7. Antenna = 15 inch
8. Audio jack pin/headphone jack pin.

Materials

1. Bread board
2. Connecting wires
3. Matrix board
4. Soldering Iron
5. Solder
6. Solder sucker.

Circuit Diagram of An FM Transmitter

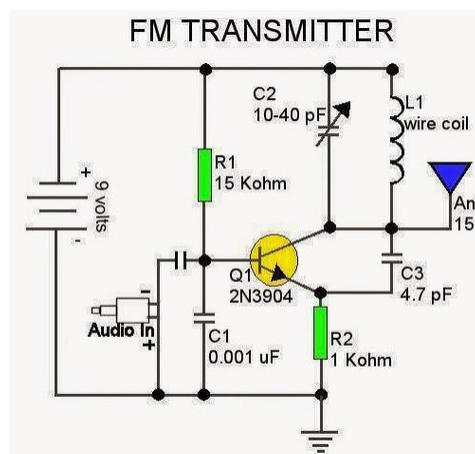


Figure 6.26: FM Transmitter

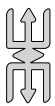
Procedure/Steps in building An FM Transmitter circuit

5-Simple Steps to Build an FM Transmitter Project

- **Step 1:** FM Transmitter Circuit Block Diagram Estimation.
- **Step 2:** Gathering Required Components for FM Transmitter Circuit.
- **Step 3:** Estimating the Circuit FM Transmitter Diagram.
- **Step 4:** Connecting & Soldering Circuit.
- **Step 5:** FM Transmitter Working Principle.

Learning Tasks

1. Explain the concept of electronic circuit design.
2. Identify at least three components and materials needed to build a fire alarm circuit.
3. Describe the importance of at least four electronic components used in building the fire alarm circuit.

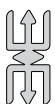


Note

1. Learners with additional support needs should be given more time to complete a given task.
2. During presentations, ensure that all learners are encouraged to present on behalf of the groups as well as becoming a group leader.

PEDAGOGICAL EXEMPLARS

1. **Talk for Learning:** Engage the entire class in a discussion aimed at encouraging learners to actively participate and collectively brainstorm to explain the concept of electronic circuit design.
2. **Group Work/Collaborative Learning:** In small mixed-ability groups, task learners to identify components and materials needed to build the fire alarm circuit and the FM transmitter circuit and guide them through the steps in building the projects.



Note

Through this group work, learners not only enhance their understanding of electronic circuit design but also develop teamwork and communication skills. Each group member can contribute their unique perspectives, fostering a collaborative learning environment where everyone learns from each other's experiences and insights.

KEY ASSESSMENT

1. **Level 1:** Explain the concept of electronic circuit design.
2. **Level 2:** Identify at least three components and materials needed to build a fire alarm circuit.
3. **Level 3:** Describe the importance of at least four electronic components used in building the fire alarm circuit.

HINT



*The recommended mode of assessment for week 24 is **end of semester examination**. Refer to Appendix G at the end of this section for Table of specification.*

UNIT 24 REVIEW

This unit introduced learners to the concept of electronic circuit design thus bringing the knowledge and understanding of various electronic components together to form or build one complete circuit to perform a specific task. Various pedagogical approaches and assessment methods have been carried out to facilitate active learning and engagement among learners with diverse learning needs and abilities.



APPENDIX G: END OF SEMESTER TWO EXAMINATION

STRUCTURE OF EXAMINATION

- **30 Multiple Choice Questions (MCQ)** all should be answered within 45 minutes. Questions cover DoK level 1 to 3
- 10 essay type questions, 7 to be answered within 2 hours. Questions cover DoK level 1 to 3

RESOURCES

Scannable sheets, A4 paper, answer booklets, class list, etc.

SAMPLE QUESTIONS

Multiple Choice- 45 mins

SECTION A

1. How should a company respond to a safety incident to prevent future occurrences?
 - a. Blame the employee involved and issue a warning.
 - b. Ignore incident if no one was seriously injured.
 - c. Increase the workload to make up for lost time.
 - d. Investigate and implement corrective actions.

SECTION B: Essay

Explain the concept of house wiring, etc.

MARKING SCHEME

Multiple Choice- 30 marks at 1 mark each

SECTION A

1. How should a company respond to a safety incident to prevent future occurrences?
 - a. Blame employee involved and issue a warning.
 - b. Ignore the incident if no one was seriously injured.
 - c. Increase the workload to make up for lost time.
 - d. **Investigate and implement corrective actions.**

SECTION B

Essay- 70 marks (7 questions to be answered out of 10)

Question: a) Explain the concept of house wiring, etc.

Expected Answer:

An explanation of the concept with relevant technical words such as, protection, cables and wires, switches, earthing, etc. **5 marks**

TABLE OF SPECIFICATION FOR END OF SEMESTER TWO EXAMINATION

Weeks	Learning Indicators	Item	DoK Level			TOTAL
			1	2	3	
13	Describe types of resistors as passive electronic components.	MCQ	1	1	1	4
		Essay	1			
14	Describe types of resistors as passive electronic components.	MCQ	1	1	1	4
		Essay		1		
15	Describe types of resistors as passive electronic components.	MCQ	1	1	1	4
		Essay			1	
16	Illustrate the construction and operation of bipolar junction transistors.	MCQ	1	1	1	4
		Essay			1	
17	Illustrate the principles of operation of the various transistors (FET).	MCQ	1	1	1	4
		Essay	1			
18	Analyse DC circuits and solve problems on them by applying various circuit laws.	MCQ	1	1	1	4
		Essay		1		
19	Explain the effects of alternating current on RLC circuits.	MCQ	1	1		3
		Essay	1			
20	Describe the types of control systems and give practical examples.	MCQ		1	1	3
		Essay			1	
21	Solve problems on Binary operations.	MCQ		1	1	3
		Essay		1		
22	Explain the operation of electrical measuring instruments through Principles of electromagnetism. Convert moving coil instrument into voltmeter and ammeter.	MCQ	1	1		3
		Essay		1		
23	Convert moving iron instrument into voltmeter and ammeter and use it with other meters to take measurements.	MCQ	1	1		2
		Essay				
24	Apply knowledge of electronic components in designing circuits.	MCQ		1	1	2
		Essay				
TOTAL			12	16	12	40

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ONLINE IMAGES

No	Name of Image	Reference (link)
1	Surface conduit wiring	https://th.bing.com/th?id=OIP.7gH--xXU58q8mrOFE3ua7gHaEK&w=333&h=187&c=8&rs=1&qlt=90&o=6&pid=3.1&rm=2
2	Concealed wiring	https://th.bing.com/th/id/OIP.s4iKF9wonpcQPRHNrpYAtQHFT?pid=ImgDet&w=191&h=137&c=7
3	Trunking system	https://th.bing.com/th/id/OIP.NioCVQ8T5SgVUgyOuhI46gHaFj?w=232&h=180&c=7&r=0&o=5&pid=1.7
4	Various sizes of trunking	https://th.bing.com/th/id/OIP.fK8Ws0wPeHi8_fpa2wjh2wAAAA?pid=ImgDet&w=194&h=198&c=7

5		www.electricaltechnology.org
6		https://www.diydoctor.org.uk/projects/consumer_unit.htm
7	Wiring of light bulb controlled from two locations	https://www.electricaltechnology.org/wp-content/uploads/2012/11/Staircase-wiring-diagram-How-to-control-a-lamp-from-two-different-places-by-two-2-way-switches.png
8	Wiring of socket outlets in ring circuit	https://www.designingbuildings.co.uk/w/images/1/17/RingCircuit.jpg
9	Mains switch in off position	https://static.wixstatic.com/media/d99b00_89a556ef908a4b9bb6c2524db0228edf~mv2.png/v1/fit/w_570%2Ch_427%2Cal_c/file.png
10	Testing of a circuit	https://th.bing.com/th/id/OIP.Afe8fyjGycLinGCmnHPZOAHaFI?pid=ImgDet&w=194&h=134&c=7
11	Wiring of socket outlets in a radial circuit	https://th.bing.com/th/id/OIP.OaFfotCxV7yY7rPBwt1XNQAAAA?rs=1&pid=ImgDetMain
12	Earthing of an Electrical System	https://electricalapprentice.co.uk/wp-content/uploads/2018/07/Earthing-Bonding.png
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15	Lattice-Copper-Earth-Mat	https://kingsmillindustries.com/wp-content/uploads/2020/08/Lattice-Copper-Earth-Mats-b.jpg
16	Marconite Earthing Compound	https://5.imimg.com/data5/VK/UG/YP/SELLER-7685381/marconite-1000x1000.jpg
17	Copper Earthing Strip	https://i.ebayimg.com/images/g/ax0AAOSwReVh5qm3/s-l1200.jpg
16	Plate Earthing	https://cdn.thepipingmart.com/wp-content/uploads/2023/05/Advantages-and-Disadvantages-of-Plate-Earthing.png
19	Components of an Earthing/Grounding System	https://www.electricaltechnology.org/wp-content/uploads/2015/05/Components-of-Earthing-System.-Complete-Grounding-System1.jpg
20	Continuity test using a multimeter	https://th.bing.com/th/id/OIP.Vu04q6F3bUTll6heUvFmeAHaEW?pid=ImgDet&w=194&h=114&c=7
21	Continuity testing of a lighting circuit	https://th.bing.com/th/id/OIP.IYghmg8bduUWnuTsAfhKRwAAAA?rs=1&pid=ImgDetMain
22	Setting the meter	https://th.bing.com/th?id=OIP.IvK-guZGmnef8ZRIZR9ttwHaHa&w=119&h=104&c=7&bgcl=c604fb&r=0&o=6&pid=13.1

23	Conducting continuity test	https://blogger.googleusercontent.com/img/b/R29vZ2xl/AVvXsEjCUMwrXJl1K-FYJbsue2lzn30o5X7zSkRr7Yg1Epdd3F0ZDze0IjkMujGERBw9hAcU6hcKFwM-7F0aUkn6kdNvJePXjPI_Xi26NiwnQNqNq0ABOwFVY4OaT0k3deMnie0Veg-1BB-wxb1R2uu/s640/cont.JPG
24	Polarity test on a lighting circuit	https://th.bing.com/th/id/OIP.7xiP-z-8XjcFX6xwHPE8qAHaF8?pid=ImgDet&w=191&h=153&c=7
25	Polarity test on a radial circuit	https://www.tlc-direct.co.uk/Figures/8.9b.gif
26	Polarity test	https://blogger.googleusercontent.com/img/b/R29vZ2xl/AVvXsEgN0cqVC-HCLf7cxZURP5GNSSahIPuYJJ0juBx-2y7hpsl2SMNUME17MyOX0k12_VGEDHSbNf3HkPQJYrIvlpPpOpXvZ5C-vP_oWdUoCspUEsk7Yl_J8FCpCrwP4ij-XGoO5sE6wCQo_S9qMQ/s640/test.JPG
27	Polarity test using Test lamp	https://th.bing.com/th/id/OIP.XihjQGZ8Tvw4nemyTOrMwAAAA?w=246&h=180&c=7&r=0&o=5&pid=1.7
28	Insulation resistance Test	https://th.bing.com/th/id/OIP.ExxsDumsuQaLVqEMuZpCyAAAAA?rs=1&pid=ImgDetMain
29	Double pole MCB	https://n1.sdlcdn.com/imgs/i/6/9/Schneider-MCB-Two-Pole-16-SDL023236694-1-4a05d.jpeg
30	Single phase RCCB	https://5.imimg.com/data5/MF/IB/EU/SELLER-91440790/havells-rccb-500x500.jpg
31	Wiring diagram of consumer control unit	https://th.bing.com/th/id/OIP.wZoPEWizijZ77hVnUm590gHaDt?pid=ImgDet&w=191&h=95&c=7
32	Double pole MCB	https://n1.sdlcdn.com/imgs/i/6/9/Schneider-MCB-Two-Pole-16-SDL023236694-1-4a05d.jpeg
33	Single phase RCCB	https://5.imimg.com/data5/MF/IB/EU/SELLER-91440790/havells-rccb-500x500.jpg
34	Wiring diagram of consumer control unit	https://th.bing.com/th/id/OIP.wZoPEWizijZ77hVnUm590gHaDt?pid=ImgDet&w=191&h=95&c=7
35	Wiring of the final circuits	https://i1.wp.com/smartsciencepro.com/wp-content/uploads/2018/02/House-Circuit-Full-Size.png
36	Carbon Resistors	https://media.sciencephoto.com/c0/30/82/66/c0308266-800px-wm.jpg
37	Wire-wound Resistor	https://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/passive-components/resistors/images/wirewoundresistor.png
38	Thermistors	https://www.allaboutcircuits.com/uploads/thumbnails/Davis_temperature_sensors_eatured.jpg
39	Light Dependent Resistor	https://www.elprocus.com/wp-content/uploads/2016/01/Light-Dependent-Resistor.jpg
40	Varistors	https://m.media-amazon.com/images/I/31zBSzC9GuL._AC_UF1000,1000_QL80_.jpg
41	A Fixed Resistor	https://res.cloudinary.com/rsc/image/upload/bo_1.5px_solid_white,b_auto,c_pad,dpr_2,f_auto,h_399,q_auto,w_710/c_pad,h_399,w_710/F4777928-01?pgw=1

42	Variable Resistors	https://www.shutterstock.com/image-photo/variable-resistor-on-white-background-260nw-1904372290.jpg
43	Resistor Colour Chart	https://www.amazon.com/uxcell-50pcs-Carbon-Resistor-Tolerance/dp/B07GN3RH99
44	Capacitor with dielectric	https://th.bing.com/th/id/OIP.7JZo9Vfl_OVbWYlMP5mtQAAAA?pid=ImgDet&w=191&h=208&c=7
45	Capacitor with air as dielectric	https://www.watelectrical.com/wp-content/uploads/simple-form-of-capacitor-diagram.jpg
46	Capacitor symbols	https://www.watelectrical.com/wp-content/uploads/capacitor-symbols.jpg
47	Types of capacitor	https://th.bing.com/th?id=OIP.CKNWgY189SOKmorAtK5_dwHaE8&w=306&h=204&c=8&rs=1&qtl=90&o=6&pid=3.1&rm=2
48	Picture of polarized capacitors	https://th.bing.com/th/id/OIP.ByEiVIdEvN2up6T-nz5bAgAAAA?pid=ImgDet&w=178&h=144&c=7
49	Some examples of non-polarized capacitors	https://th.bing.com/th/id/OIP.ChPZm0s8BcKEaMSxxJz4RAHaFd?pid=ImgDet&w=194&h=143&c=7
50	Capacitor colour code chart	https://www.elprocus.com/wp-content/uploads/2013/01/colour-chart1.jpg
51	Picture of cells and a battery	https://th.bing.com/th/id/OIP.FChTQmYmhsbGqTsb7S5WDQAAAA?rs=1&pid=ImgDetMain
52	Picture of cells and battery	https://th.bing.com/th/id/OIP.IKfPQpBfYPJB5J2Hgm0eQwHaEk?pid=ImgDet&w=191&h=117&c=7
53	Cells in series and in parallel	https://th.bing.com/th/id/OIP.O6wa6sd90d1vm2ZhH7O9CAAAAA?rs=1&pid=ImgDetMain
54	Structure of NPN transistor	https://th.bing.com/th/id/OIP.3udT9VPqovNg-eEdpAYTEQHAEK?pid=ImgDet&w=191&h=107&c=7
55	Structure of PNP transistor	https://th.bing.com/th/id/OIP.rI_cKJwj2weTHITTZBDVywHaDs?pid=ImgDet&w=191&h=95&c=7
56	NPN and PNP configurations	https://th.bing.com/th?q=Bipolar+Junction+Transistor+Ce+Circuit&w=120&h=120&c=1&rs=1&qtl=90&cb=1&pid=InlineBlock&mkt=en-WW&cc=GH&setlang=en&adlt=moderate&t=1&mw=247
57	A typical BJ transistor	https://th.bing.com/th/id/OIP.CjKFeFJDj5ou7Qdtj_pyyQAAAA?pid=ImgDet&w=194&h=194&c=7
58	Cross section of the field effect transistor	https://upload.wikimedia.org/wikipedia/commons/4/49/JFET_cross_section.svg
59	Block diagram of open loop control system	https://media.geeksforgeeks.org/wp-content/uploads/20240124122835/Block-diagram-of-CONTROL-SYSTEM-660.webp
60	Block diagram of a closed loop control system	https://www.geeksforgeeks.org/components-of-control-systems/?ref=lbp

61	Irrigation sprinkler	https://2.bp.blogspot.com/-K4oO6juT3kg/VQB2vt4PfoI/AAAAAAAAAADE/smlr7-lKAZU/s1600/Impact_Sprinkler_Mechanism_2.jpg
62	A Traffic light system	https://images.squarespace-cdn.com/content/v1/5ac5efa845776e0c941a574a/1570189445029
63	An Air conditioner	https://www.91-cdn.com/pricebaba-blogimages/wp-content/uploads/2018/01/air-conditioner-india-feature.jpg
64	A smoke detector	https://ashbusterscharleston.com/wp-content/uploads/2019/11/Depositphotos_64015179_s-2019-1.jpg
65	Analogue oscilloscope	https://store.cdn-krs.com/fileadmin/_processed_/0/b/csm_mixed-signal-oscilloscope-15-ghz-4-analog-plus-16--msox4154a-e2490585-02_3dca23df23.jpg
66	Digital multimeter	https://th.bing.com/th/id/OIP.YNfhvmdJEjEE2D-BIVawdQHaMM?pid=ImgDet&w=191&h=314&c=7
67	An analogue multimeter	https://th.bing.com/th/id/OIP.S7ngfNVgoHeihAmPspLoiAHaHa?pid=ImgDet&w=191&h=191&c=7
68	An AC signal being displayed by an oscilloscope	https://th.bing.com/th/id/OIP.0eth8QmgZ098fghal4fSwQHaDt?pid=ImgDet&w=194&h=97&c=7
69	Circuit Diagram of Fire Alarm	https://www.elprocus.com/wp-content/uploads/2016/01/Fire-Alarm-System-Block-Diagram-by-www.edgefxkits.com_.jpg
70	Circuit Diagram of An FM Transmitter	https://i.pinimg.com/564x/bf/26/51/bf2651ee26d6e81d243f89addfb8e334.jpg
71	Earthing of an Electrical System	https://electricalapprentice.co.uk/wp-content/uploads/2018/07/Earthing-Bonding.png
72	Copper Rod Electrode Earthing System	https://www.electricaltechnology.org/wp-content/uploads/2023/11/Ground-Rod-in-the-Grounding-System.png
73	Types of Earthing	https://solarismypassion.com/wp-content/uploads/2023/07/types-of-earthing.webp
74	Lattice-Copper-Earth-Mat	https://kingsmillindustries.com/wp-content/uploads/2020/08/Lattice-Copper-Earth-Mats-b.jpg
75	Marconite Earthing Compound	https://5.imimg.com/data5/VK/UG/YP/SELLER-7685381/marconite-1000x1000.jpg
76	Copper Earthing Strip	https://i.ebayimg.com/images/g/ax0AAOSwReVh5qm3/s-l1200.jpg
77	Plate Earthing	https://cdn.thepipingmart.com/wp-content/uploads/2023/05/Advantages-and-Disadvantages-of-Plate-Earthing.png
78	Components of an Earthing/Grounding System	https://www.electricaltechnology.org/wp-content/uploads/2015/05/Components-of-Earthing-System.-Complete-Grounding-System1.jpg
79	Wiring of supply-control equipment	www.marshflattsfarm.org.uk
80	A Typical 12-way DB	www.youtube.com

81	Some basic hand tools	<i>Draper tool kit</i>
82	Some power tools	https://th.bing.com/th/id/OIP.YFd0waLTczCS11NsdZ4yKgHaHa?pid=ImgDet&w=194&h=194&c=7
83	Testing and measuring equipment	https://th.bing.com/th/id/OIP.jtwHtku9xQmzZjt1v4tJWQAAAA?pid=ImgDet&w=194&h=221&c=7
84	Safety equipment	https://th.bing.com/th/id/OIP.jtwHtku9xQmzZjt1v4tJWQAAAA?pid=ImgDet&w=194&h=221&c=7
85	A typical cut-out fuse	https://th.bing.com/th/id/OIP.O438WEwqfyqRyRiAUFTpYAAAA?rs=1&pid=ImgDetMain
86	A single-phase meter	https://th.bing.com/th/id/OIP.GtWFHtKiWPTUrZt7kz0J_QHaG4?pid=ImgDet&w=194&h=180&c=7
87	A single-phase isolator	https://th.bing.com/th/id/OIP.DX0WPmQqmeGn5pPaiSANYQAAAA?pid=ImgDet&w=194&h=194&c=7
88	Single Phase Distribution Board wiring/ distribution board wiring	https://th.bing.com/th/id/OIP.K0aZUND3Lbt12H44tDtDAgHaDt?pid=ImgDet&w=194&h=97&c=7
89	Picture of a DB	https://th.bing.com/th/id/OIP.Ht7L4jVvOKqf6k7tWGXCgQHaHa?pid=ImgDet&w=194&h=194&c=7
90	Sequence of Supply-Control Equipment	https://th.bing.com/th/id/OIP.nnnumxAb7dZTVudUftNz6gAAAA?pid=ImgDet&w=194&h=194&c=7
91	Wiring	https://www.hp.com/us-en/printers/site-print/automation-best-practices-electrical-engineers-construction.html
92	Copper Strip	https://www.ebay.com/itm/323722990585
93	Testing Polarity	https://www.electronicclinic.com/methods-of-testing-electrical-installations/
94	Air core conductors	https://www.iqsdirectory.com/articles/electric-coil/inductors-and-inductor-coils.html

