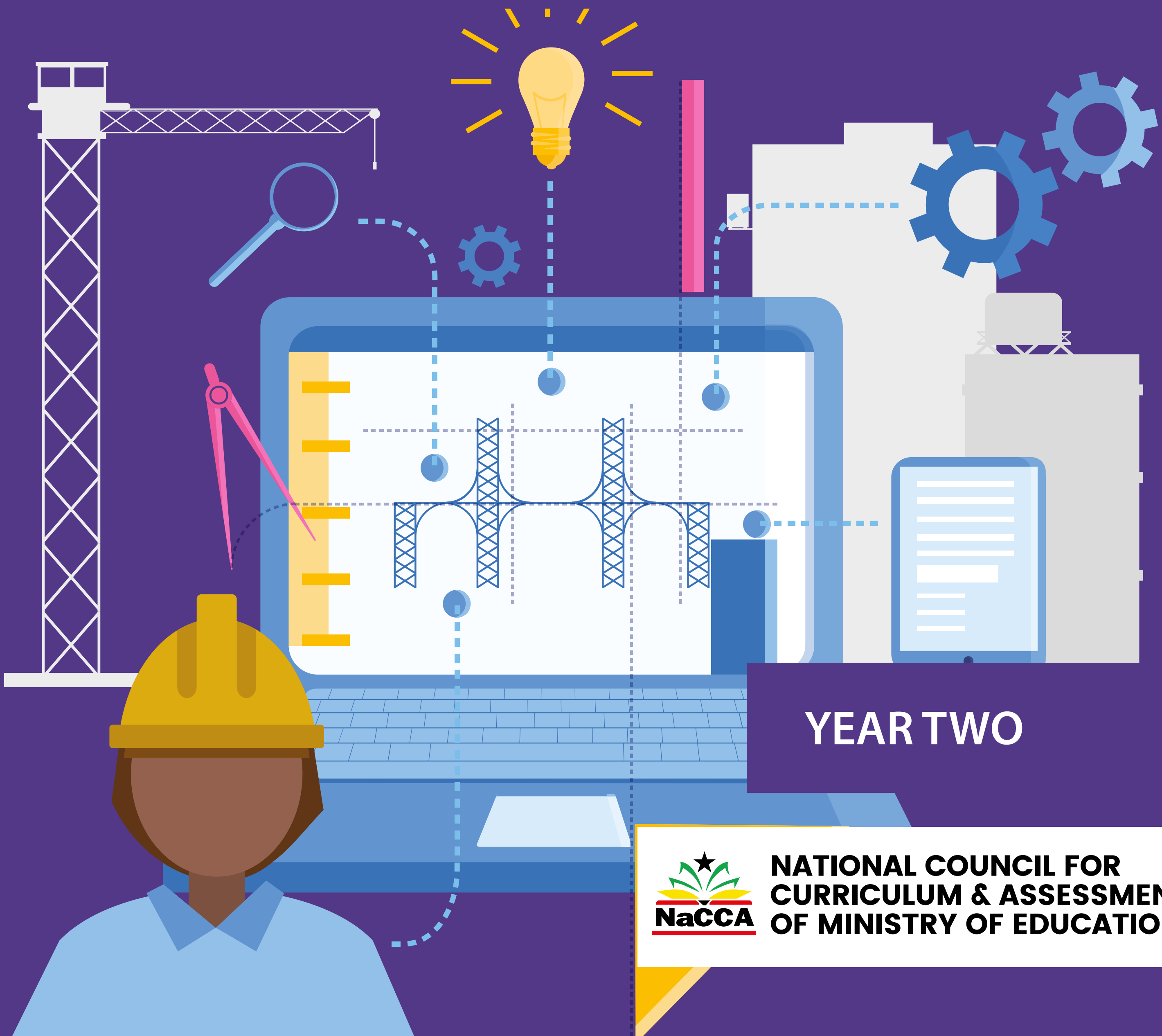
MINISTRY OF EDUCATION

Engineering

for Senior High Schools

TEACHER MANUAL



YEAR TWO

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Engineering

for Senior High Schools

Teacher Manual

Year Two

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

ENGINEERING 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 Engineering 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.

ACKNOWLEDGEMENTS

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SECTION 1: ENGINEERING PRACTICE IN SOCIETY

Strand: Engineering Practice

Sub-Strand: Engineering in society

Learning Outcome: *Use systematic investigation to identify and provide solutions to problems.*

Content Standard: Demonstrate understanding of systematic investigation and model construction

Hint

Learners should be assigned their group projects in week 2 and given a prompt to submit it by week 9. See Appendix A at the end of this session for more information on the group project

INTRODUCTION AND SECTION SUMMARY

In this section, learners will explore systematic research as a crucial aspect of engineering practice. They'll learn to address specific issues by employing a methodical strategy for data analysis. Understanding the processes involved in Systematic investigation ensures precision and replicable results, fostering core principles like problem-solving, critical thinking, creativity, and innovation as well as collaboration across engineering domains. An engineer who excels in one area can adapt their skills to address challenges in other fields, fostering interdisciplinary collaboration and accelerating innovation.

The weeks covered by the section are:

Week 1: Systematic investigation and its relevance in engineering professional practice

Week 2: Processes for systematic investigation

SUMMARY OF PEDAGOGICAL EXEMPLARS

Effective teaching involves selecting diverse approaches tailored to the varied backgrounds, learning capacities, and preferred styles of learners. Strategies like managing talk for learning, building on others' contributions, and collaborative learning enhance the teaching process. During moderated discussions, learners share experiences related to research challenges and methods. Learners engage in cognitive processes, contemplating, collaborating, and communicating their perspectives on systematic research. Teachers can use concept maps or webbing to organise thoughts. Encourage pairs to discuss the efficacy of methodical inquiry. Employ visual aids such as flowcharts to provide concise overviews. Learners can work in groups, collectively devising systematic approaches to explore problems and presenting their methodologies to the class for feedback

ASSESSMENT SUMMARY

It is important to examine different types of assessment methods to give all categories of learners the chance to demonstrate their comprehension of the main ideas in the section. During class discussions after outlining the processes involved in systematic investigation, learners can be prompted to provide oral responses to questions. Marks may be allocated for the individual or group presentation as part of formative assessment. Additionally, learners can be asked to provide written responses at different levels of difficulty, which are suitable for the class, based on the main topics covered in this section. Learners can participate in a project during their vacation, where they visit their communities and observe or conduct surveys to identify the most significant problems requiring solutions. They can then outline the specific engineering skills and competencies needed to address these problems. These factors should contribute to the evaluation of learners' progress and development. Learners can also be motivated to develop their answers to the identified problems and deliver a written, oral, or PowerPoint presentation in class, which can contribute to their formative assessment.

Refer to Teacher Assessment Manual and Toolkits (NaCCA, 2023) for more examples

WEEK 1: SYSTEMATIC INVESTIGATION AND ITS RELEVANCE IN ENGINEERING PROFESSIONAL PRACTICE

Learning Indicator: *Explain systematic investigation and its relevance in engineering professional practice.*

FOCAL AREA 1: SYSTEMATIC INVESTIGATION AND ITS RELEVANCE

An essential component of engineering professional practice is systematic investigation. In order to proffer a solution to a particular problem, it is essential to use an organised and methodical approach to the collection, analysis, and interpretation of data or information. Here is why this matters:

1. **Problem-solving:** Fundamentally, engineering involves problem-solving. Systematic investigation provides engineers with a framework to methodically define, analyse, and identify problems, enabling them to develop practical solutions. It helps engineers break down complex problems into manageable components and evaluate viable solutions rationally.
2. **Data-driven decision-making**: Ideally, in engineering, judgements should be supported by facts rather than just gut feeling. A systematic study entails gathering pertinent data and applying it to guide decisions. This data might be obtained by observations, simulations, or experiments. By using this method, errors are less likely to occur and engineering solutions are more accurate, practical and directly applicable.
3. **Risk management:** Engineering projects frequently entail inherent risks, encompassing technical, financial, and safety aspects. Systematic research enables engineers to methodically discover and evaluate potential risks. Engineers can assure project success by conducting a comprehensive investigation of elements that may affect the project's outcome or safety. This allows them to devise methods to minimise these risks.
4. **Quality assurance:** Ensuring the quality of products or constructions is crucial in sectors such as manufacturing and construction. Systematic research is crucial in quality assurance since it allows engineers to methodically assess processes, materials, and products. Engineers can utilise statistical analysis and quality control measures to detect faults or deviations from norms and subsequently conduct remedial activities to uphold or enhance quality.
5. **Innovation and optimisation:** Engaging in systematic study motivates engineers to delve into novel concepts, technologies, and procedures. Through a methodical examination of various methodologies and assessing their efficacy, engineers have the capacity to stimulate originality and enhance the efficiency, effectiveness, and sustainability of designs, processes, and systems. Systematic research also enables a decision on variables that affect designs, and ultimately a determination of the values of such variables that minimises or maximises certain outcomes such as cost, profit, manufacturing time, etc. within a given constraint. Such a procedure is known as optimisation.

6. **Compliance and regulation**: Numerous engineering projects must adhere to regulatory criteria and norms. Conducting a methodical examination guarantees that engineers have a comprehensive understanding of and adhere to applicable norms and standards. Engineers can guarantee that their projects fulfil legal and ethical standards by methodically examining regulatory requirements and performing compliance assessments.

Learning Task

1. In moderated discussions, guide learners to share experiences related to problems (research challenges) within their community and contribute to discussions on the methods to solve them.
2. Use concept maps or webbing to organise the thoughts of learners and guide learners to understand how systematic investigation can help in solving such problems effectively.
3. Work with learners to identify five (5) key components of a systematic investigation from the foregoing discussions.
4. Discuss with learners and help them appreciate how systematic investigation ensures precision in the identification of problems and the provision of accurate solutions?
5. Have learners working in groups make presentations on how systematic investigation contributes to the innovation and optimisation of engineering solutions?

Pedagogical Exemplars

Managing Talk for Learning

1. In a moderated discussion, learners share experiences on any problem they have encountered that required investigation and how they went about the investigation.
2. Learners think, pair, and share their views on what systematic investigation is in their own words. Others are encouraged to add to the content presented by each individual in a respectful manner. Learners should be encouraged to tolerate others' views.
3. Organise/summarise their thoughts using concept maps/webbing. In pairs, let them mention the usefulness of systematic investigation. Monitor learner progress and adjust your approach as needed. For example, if a pair is struggling, you could provide additional support or modify the activity.

Enquiry-Based Learning

1. Guide learners to research the systematic investigation in engineering practice and share their findings with their class.
2. Support an individual or group working at a slower pace whilst the rest of the class completes more activities

Key Assessment

Level 2 Skills of conceptual understanding

1. How does a systematic investigation differ from an ad-hoc or informal investigation?
2. Discuss the main objectives of conducting a systematic investigation in engineering.
3. How does a systematic investigation contribute to the advancement of engineering knowledge and practice?
4. How does systematic investigation help to optimise products and services?

Level 3 Strategic Reasoning

Outline steps you would take to conduct a systematic investigation of a problem in your community and discuss why your approach will yield the necessary solution.

Hint

The recommended mode of assessment for week 1 is **questioning.** Refer to level 2 question 4 as a sample question.

WEEK 2: PROCESSES OF SYSTEMATIC INVESTIGATION

Learning Indicator: *Explain the processes for systematic investigation*

FOCAL AREA 1: PROCESSES FOR SYSTEMATIC INVESTIGATION

Systematic investigation in engineering involves a structured approach to research and problem-solving, ensuring thoroughness, accuracy, and repeatability. The key steps in this process are:

1. **Problem Definition**
   - **a.** Identify the Problem: Clearly define the issue or challenge to be addressed.
   - **b.** Set Objectives: Determine the goals and what you aim to achieve through the investigation, and break the goals into smaller achievable objectives.
   - **c.** Constraints and Requirements: Establish the limitations and requirements for the solution, such as budget, time, materials, and regulatory constraints.

2. **Literature Review and Background Research**
   - **a.** Gather Information: Collect relevant information from existing sources such as books, academic papers, technical reports, patents, and industry standards.
   - **b.** Analyse Previous Work: Understand the current state of knowledge and identify gaps or areas for improvement.

3. **Hypothesis Formulation**

Propose Hypotheses: Based on the problem definition and background research, propose potential solutions or explanations that can be tested.

4. **Experimental Design**
   - **a.** Design Experiments: Plan experiments to test the hypotheses. This includes selecting the variables to be measured, control variables, and determining the methods and equipment to be used.
   - **b.** Develop Procedures: Create detailed procedures for conducting experiments to ensure consistency and repeatability.

5. **Data Collection**
   - **a.** Conduct Experiments: Perform the experiments as per the designed procedures, carefully collecting data.
   - **b.** Use Appropriate Tools: Utilise proper tools and instruments to ensure accurate data collection.

6. **Data Analysis**
   - **a.** Process Data: Organise and process the collected data using appropriate statistical and analytical methods.
   - **b.** Interpret Results: Analyse the results to determine if they support or refute the hypotheses. Look for patterns, trends, and anomalies.

7. **Validation and Verification**
   a. Repeat Experiments: Conduct repeated trials to verify the results and ensure they are consistent and reproducible.
   b. Compare with Standards: Compare the results with established standards, benchmarks, or simulations.

8. **Conclusion and Recommendations**
   a. Draw Conclusions: Summarise the findings and determine whether the hypotheses were correct.
   b. Provide Recommendations: Based on the conclusions, make recommendations for practical applications, further research, or improvements.

9. **Documentation and Reporting**
   a. Prepare Reports: Document the entire investigation process, including the problem definition, methodology, data, analysis, and conclusions.
   b. Publish Findings: Share the results with the engineering community through reports, papers, presentations, or other appropriate means.

10. **Review and Feedback**
    a. Peer Review: Submit the work for peer review to get feedback and validation from other experts in the field.
    b. Incorporate Feedback: Refine the investigation and its conclusions based on the feedback received.

Best Practices in Systematic Investigation

a. Maintain Objectivity: Avoid bias and ensure the investigation is conducted objectively.

b. Ensure Accuracy: Use precise measurement tools and techniques to ensure data accuracy.

c. Ethical Considerations: Follow ethical guidelines, ensuring the integrity of the research and the safety of all participants and environments.

d. Continuous Improvement: Regularly review and improve the processes and methodologies used in the investigation.

Learning Task

1. Moderate discussions reviewing the importance of systematic investigation in engineering practice, focusing on innovation, problem solving and optimisation.
2. Apply the listed pedagogical exemplars to discuss the role of problem identification, literature review, data collection, hypothesis formulation, experimental design, validation and verification, among others, in a systematic investigation.
3. Have learners work in groups to brainstorm how systematic investigation contributes to the reliability and validity of engineering solutions?
4. Guide learners, working in groups, to build the systematic investigation process into a flow chart and present to class for feedback.

Pedagogical Exemplars

Managing Talk for Learning

a. In a moderated discussion, learners outline general processes for systematic investigation.

b. Use flowcharts to illustrate the process and summarise their views.

Building on what others say

a. Allow a learner to outline the general processes for systematic investigation then another continues from there, in a respectful and tolerant manner.

b. The facilitator fine-tunes the processes outlined by learners by adding on.

Collaborative Learning

a. Learners sit in groups, and each group is presented with a problem for the group to brainstorm and come up with a process to investigate it.

b. Support a group working at a slower pace whilst the rest of the class completes more activities.

c. Each group presents their process to the entire class for comments.

Key Assessment

Level 2 Skills of Conceptual Understanding

1. Discuss the main processes involved in conducting a systematic investigation.

2. Explain the significance of each of the steps in systematic investigation.

Level 3 Strategic Reasoning

3. How can the skills learned from systematic investigations be applied to everyday engineering tasks?

4. Provide an example of a real-world engineering problem where systematic investigation was crucial.

5. How did the systematic investigation help in solving the problem effectively?

Level 4 Extended Reasoning

1. Propose an alternative approach to the systematic investigation process and discuss your proposal with the teacher, and then make a presentation to the class.

2. Using systematic investigations, research challenges within your school communities, and find possible solutions. Identify some specific problems in the school community to use for this investigation, such as Water Conservation and Usage, Waste Management and Recycling, Student Access to Healthy Food Options, Bullying and Student Well-being, Noise Pollution and Its Impact on Learning.

Hint

The recommended mode of assessment for week 2 is a **group project.** Refer to level 4 question 2 as sample question for the group project.

SECTION 1 REVIEW

1. Would learners be able to establish how a systematic investigation contributes to the innovation and optimisation of engineering solutions?
2. Can learners discuss the role of literature review in a systematic investigation?
3. Would learners be able to establish how the systematic investigation helps in solving the problem effectively?
4. Would learners be able to discuss the importance of systematic investigation in engineering practice?
5. Can learners mention five (5) key components of a systematic investigation?
6. Would learners be able to establish how a systematic investigation contributes to the reliability and validity of engineering solutions?

Additional Reading

1. Hacker, M, Barden B., *Living with Technology*, 2nd edition. Albany NY: Delmar Publishers, 1993.

2. *(PDF) Action Research as 'Systematic Investigation of Experience'*. Available from: https://www.researchgate.net/publication/315468164_Action_Research_as_'Systematic_Investigation_of_Experience' [accessed Jun 19 2024].

APPENDIX A: GROUP PROJECT

Prompts for the group project should be given to learners in week 2. The final submission of the group project should be in the 9th week of the academic year.

Task

E.g.,

Project Topic

Using systematic investigations, research challenges within your school communities and find possible solutions. Learners should identify some specific problems in their school community to use for this investigation such as Water Conservation and Usage, Waste Management and Recycling, Student Access to Healthy Food Options, Bullying and Student Well-being, Noise Pollution and Its Impact on Learning, etc

Submission Requirements

1. Problem Identification

Learners must identify a specific problem within their school community (e.g., Water Conservation and Usage, Waste Management and Recycling, Student Access to Healthy Food Options, Bullying and Student Well-being, Noise Pollution and Its Impact on Learning).

A brief description of the identified problem (100-150 words).

2. Research Plan

Outline the systematic investigation process, including

- Research objectives.
- Methods of data collection (e.g., surveys, interviews, observations).
- Timeline for data collection and analysis.
- Sources of data and expected outcomes.

3. Investigation Report

Detailed report (3-5 pages) outlining

- Introduction to the problem.
- Methodology (How the data was collected).
- Analysis and findings (What the investigation revealed).
- Proposed solutions (Possible solutions based on findings).

4. Solution Proposal

Learners must present at least two viable solutions to address the identified problem.

Solutions should include:

- Feasibility assessment (e.g., cost, time, resources).
- Potential impact on the school community.

5. Visual Presentation

Learners should create a visual presentation (e.g., PowerPoint) that summarizes the investigation and proposed solutions.

6. Group Collaboration (If in groups)

Each group must submit a brief collaboration log detailing the roles and contributions of each member.

7. References

Learners must provide a list of sources and references used during the investigation (books, websites, interviews, etc.).

How to Administer

1. Introduce the Concept of Systematic Investigation

Begin by explaining what systematic investigation is and how it is used in research and problem-solving.

Highlight the importance of investigating issues systematically to find effective solutions.

2. Present the Scope of Community Challenges

Discuss the range of potential challenges in the school community (e.g., Water Conservation, Bullying, Waste Management).

Encourage students to choose a topic that resonates with them or affects their community.

3. Guide Learners Through the Research Process

Provide instruction on how to develop a research plan, including forming research questions and selecting data collection methods.

Teach data analysis techniques and help students make sense of their findings.

4. Facilitate Group Work

Organise students into groups, ensuring each group has a clear division of responsibilities.

Monitor group progress through check-ins and offer feedback on their research plan and findings.

5. Encourage Solution-Oriented Thinking

After data collection, guide students in brainstorming practical solutions.

Discuss the feasibility of their proposed solutions (consider cost, resources, time, and sustainability).

6. Assess and Provide Feedback

Use rubrics to evaluate submissions based on problem identification, research process, clarity of report, and the viability of proposed solutions.

Provide constructive feedback on both the investigation process and the proposed solutions.

7. Presentation

Schedule a presentation day where learners showcase their findings and solutions.

Encourage peer review and open discussion on the solutions proposed by different groups.

Marking Scheme for scoring the group project task

a) *Problem Identification such as "Waste Management and Recycling" as the most pressing issue due to excessive waste accumulation and low recycling rates within the school.*

- *Identifies five problems – (5 marks)*
- *Identifies four problems – (4 marks)*
- *Identifies three problems – (3 marks)*
- *Identifies two problems – (2 marks)*
- *Identifies one problem – (1 mark)*

b) *Research and Data Collection such as for waste management, the group could track how much waste is generated daily in the cafeteria, classroom, kitchen, dormitories and how many bins are used, and if waste is being correctly sorted into recycling and non-recycling.*

- *5 research and data collected – (5 marks)*
- *4 research and data collected – (4 marks)*
- *3 research and data collected – (3 marks)*
- *2 research and data collected – (2 marks)*
- *1 research and data collected – (1 mark)*

c) *Analysis of Problem, upon analysing the data, the group might discover that although there are sufficient recycling bins, students are unclear on how to use them, leading to waste mismanagement.*

- *5 insightful analyses of the problem such as root causes, relevance of data, time, budget, sustainability. – (5 marks)*
- *4 insightful analyses of the problem such as root causes, relevance of data, time, budget, sustainability. - (4 marks)*
- *3 insightful analyses of the problem such as root causes, relevance of data, time, budget, sustainability. – (3 marks)*
- *2 insightful analyses of the problem such as root causes, relevance of data, time, budget, sustainability. - (2 marks)*
- *1 insightful analyse of the problem such as root causes, relevance of data, time, budget, sustainability. - (1 mark)*

d) *Proposed Solutions such as for waste management, could include creating a school-wide recycling awareness campaign, redesigning the layout of waste bins for better visibility, and having "recycling monitors" from the student body.*

- *5 skills exhibited such as Innovative, creative, sustainable, practical, and clear steps for implementation. - (5 marks)*
- *4 skills exhibited such as Innovative, creative, sustainable, practical, and clear steps for implementation. - (4 marks)*

- *3 skills exhibited such as Innovative, creative, sustainable, practical, and clear steps for implementation. – (3 marks)*
- *2 skills exhibited such as Innovative, creative, sustainable, practical, and clear steps for implementation. - (2 marks)*
- *1 skill exhibited such as Innovative, creative, sustainable, practical, and clear steps for implementation. - (1 mark)*

e) *Group Collaboration and Organization, such as one group member may be responsible for designing the survey, another for conducting interviews, and others for analyzing the data and preparing visuals for the presentation.*

- *Group collaborates effectively with all members actively involved – (5 marks)*
- *Group collaborates effectively with one member not actively involved. – (4 marks)*
- *Group collaborates effectively with two members not actively involved. - (3 marks)*
- *Group collaborates effectively with three members not actively involved. - (2 marks)*
- *Group collaborates effectively with four members not actively involved – (1 mark)*

f) *Presentation of Findings, the group presents their findings on waste management in a school assembly, highlighting the problem with improper waste disposal and suggesting new bin layouts and awareness programs. Visual aids, such as infographics, can make the message more impactful.*

- *With five well-organised visual aids and five findings on waste management. – (5 marks)*
- *With four well-organised visual aids and four findings on waste management. -(4 marks)*
- *With three well-organised visual aids and three findings on waste management. -(3 marks)*
- *With two well-organised visual aids and two findings on waste management. - (2 marks)*
- *With one well-organised visual aid and one finding on waste management. – (1 mark)*

g) *Creativity and Innovation, for the waste management problem, the group could suggest using a mobile app to track recycling efforts or organize a school-wide competition where the class that recycles the most wins eco-friendly prizes.,*

- *Demonstrates five skills such as creativity, originality, practicality, resourcefulness, sustainability. - (5 marks)*
- *Demonstrates four skills such as creativity, originality, practicality, resourcefulness, sustainability. - (4 marks)*
- *Demonstrates three skills such as creativity, originality, practicality, resourcefulness, sustainability. - (3 marks)*

- *Demonstrates two skills such as creativity, originality, practicality, resourcefulness, sustainability. - (2 marks)*
- *Demonstrate one skill such as creativity, originality, practicality, resourcefulness, sustainability. – (1 mark)*

Feedback

Give specific written or oral feedback on exact areas that went well, those areas needing improvement, etc.

SECTION 2: HEALTH AND SAFETY

Strand: Engineering Practice

Sub-Strand: Health and Safety in Engineering Practice

Learning Outcomes

1. *Explain risk assessment*
2. *Perform risk assessment*

Content Standard: Demonstrate understanding of risk assessment

Hint

Portfolio should be assigned to learners in week 3 which should be submitted at the end of the academic year by week 23. See Appendix B at the end of this session for more information on the portfolio

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to risk assessment in engineering. Risk assessment in engineering is a systematic method for identifying, investigating, and evaluating potential risks in engineering projects. This section helps learners to understand how engineers and project managers make informed decisions to manage and reduce these risks. Additionally, learners will be introduced to different methodologies that exist, each with its own advantages and disadvantages. Learners will understand the importance of implementing control mechanisms, such as engineering controls, administrative controls, and Protective Personal Equipment (PPEs), which is crucial for a secure working environment. This section emphasises the importance of the risk assessment matrix as it is an effective tool for assessing and prioritising hazards according to their probability and consequences. As a Facilitator, keep in mind that safety is of utmost importance when working with tools, so always make sure to refer to the specific guidelines and instructions provided by the tool manufacturer and your local safety regulations. The lessons in this section equip learners to demonstrate general competence in conducting risk assessment in engineering using case studies as it is a crucial practice for comprehending potential dangers, assessing their effects, and devising solutions to reduce risks.

The weeks covered by the section are:

Week 3: Risk assessment and its relevance

Week 4: Procedure for risk assessment and control measures for various hazards

Week 5: Risk assessment matrix

SUMMARY OF PEDAGOGICAL EXEMPLARS

Individuals with intersecting identities, such as gender, race, and socio-economic background, may encounter many types of prejudices. The notion of gender roles might restrict the involvement of girls in workshop activities and the use of tools and machinery, which are traditionally associated with male-dominated professions. Variances in culture can impact the communication methods and reactions of learners during talk-for-learning exercises. Therefore, as a Facilitator, it is important to employ a diverse range of instructional approaches and strategies that promote the engagement of all learners, regardless of their cultural, gender, or cognitive differences. In this section, learners discuss their experiences with risks and their methods for assessing them through managing talk for learning. They analyse and collaborate on risk assessment concepts to enhance their understanding. They can conduct research on various risk assessment categories and present their findings; this will promote collaborative learning. Consider using mind maps, flowcharts, and question and answer sessions to enable learners illustrate the process of risk assessment. Allow learners to discuss hazards and propose control strategies through initiating talk for learning. Encourage learners to collaborate on examining the risk assessment matrix and its components, and build upon their ideas. Through mixed ability groupings with varying competencies, each group can be given a risk scenario to conduct a thorough risk assessment and proposed control measures.

ASSESSMENT SUMMARY

It is important to examine different types of assessment methods to give all types of learners the chance to demonstrate their comprehension of the main ideas in the section. In mixed ability grouping, provide learners with a case to examine the risk assessment matrix and its components, each group makes a presentation in a written or oral form for which marks will be awarded for formative assessment. Learners can use concept- or mind-mapping to illustrate the process of risk assessment which can be used for formative assessment. Provide learners with examples of risk assessment matrix and prompt them to identify the main components. Present learners with scenarios describing engineering hazards and ask them to identify the primary contributing factors. Additionally, learners can be motivated to develop their own strategies for addressing the listed issues and provide a presentation in written, oral, or PowerPoint format during class. This activity can be included as part of the learners' final evaluation.

WEEK 3: RISK ASSESSMENT AND ITS RELEVANCE

Learning Indicators

1. *Describe risk assessment and outline its relevance.*
2. *Explain the types of risk assessment*

FOCAL AREA 1: RISK ASSESSMENT AND ITS RELEVANCE

Risk assessment in engineering is a systematic method of detecting, analysing, and evaluating potential hazards that may occur during the design, construction, operation, or maintenance of engineering projects. This approach facilitates the comprehension of potential hazards and uncertainties linked to projects by engineers and project managers. It empowers them to make well-informed decisions to successfully manage and mitigate these risks.

1. **Hazard**
   a. A hazard is a potential source of harm or adverse health effect on a person or persons.
   b. It represents something with the inherent capacity to cause damage or negative impact.
   c. Examples include toxic chemicals, machinery, electricity, extreme weather events, etc.

2. **Risk**
   a. Risk is the likelihood that a person may be harmed or suffer adverse health effects if exposed to a hazard.
   b. It is a function of both the likelihood (probability) of the occurrence of the hazard and the severity (impact) of the harm that can result from the hazard.
   c. It is often expressed as a combination of the probability of an event happening and the consequences if it does happen.

3. **Relationship between Hazard and Risk**
   a. **Hazard Identification**: The first step in risk assessment is identifying the hazard. Without a hazard, there is no risk.
   b. **Risk Assessment** Once a hazard is identified, the next step is to evaluate the risk associated with it. This involves estimating how likely it is that the hazard will cause harm and how severe that harm could be.
   c. **Risk Management**: Based on the assessment, steps are taken to manage or mitigate the risk. This can involve removing the hazard, reducing the likelihood of the hazard causing harm, or minimising the severity of the potential harm.

The relevance of risk assessment in engineering is significant, and here are some key aspects:

1. **Safety**: Prioritising the safety of staff, the public, and the environment is of utmost importance in engineering projects. Risk assessment is a process that aids in the identification and reduction of potential hazards that have the potential, or "risk" of causing accidents, injuries, or harm to the environment.

2. **Compliance**: Engineering projects must adhere to multiple norms and requirements. Risk assessment is a process that helps guarantee project compliance with legal obligations by identifying and resolving potential hazards that may occur.
3. **Cost Management**: Risk assessment facilitates the identification of potential hazards that may result in exceeding the budget. Through early identification of these risks, engineers may formulate strategies to effectively manage and mitigate them, hence reducing the impact on project costs.
4. **Schedule Management**: Risks identified through risk assessment can impact project schedules. By identifying and mitigating these risks, engineers can help ensure that projects are completed on time.
5. **Quality Assurance**: Risk assessment aids in the identification of potential hazards that may impact the overall quality of the end product or service. Engineers can mitigate these risks to guarantee that projects adhere to the necessary quality standards.
6. **Resource Optimisation**: Risk assessment can help optimise the use of resources by identifying potential risks that could lead to resource wastage. By mitigating these risks, engineers can help ensure that resources are used efficiently.
7. **Reputation Management**: Engineering initiatives can greatly influence an organisation's reputation. Engineers can safeguard the organisation's reputation and bolster stakeholder confidence by recognising and managing risks.
8. **Innovation**: Risk assessment facilitates innovation by detecting potential dangers linked to novel technology or methodologies. Engineers can promote the acceptance of novel ideas by effectively dealing with these hazards.

Learning Task

1. Have learners work in groups to brainstorm the difference between qualitative and quantitative risk assessment methods.
2. Work with learners to describe a scenario where risk assessment could have prevented a major engineering disaster.
3. Learners think, pair and share their views on how risk assessment contributes to the overall safety of engineering projects.
4. Moderate discussions review, the importance of considering both probability and severity in risk assessment.
5. Moderate discussions reviewing the role of risk assessment in regulatory compliance for engineering projects.
6. Work with learners to identify how engineers communicate the results of a risk assessment to stakeholders effectively.

Pedagogical Exemplars

Managing Talk for Learning

1. In a moderated discussion, learners share experiences on any risk they or others encountered and how they evaluated it.

2. Learners think, pair and share views on what risk assessment is and explain its benefits. Learners should be encouraged to be respectful and to tolerate others' views

Build on what others say

1. Build on the understanding of learners, provide an enhanced definition of risk assessment. Individuals add to what others have said respectfully. Learners should be encouraged to tolerate others' views.
2. Fine-tune the understanding of its significance.

Key Assessment

Level 2 Skills of conceptual understanding

1. Discuss risk assessment in the context of engineering.
2. Why is it important to conduct a risk assessment before starting an engineering project?
3. Identify and describe the main components of a risk assessment.

Level 3 Strategic reasoning

1. How would you prioritise risks identified in an engineering project?
2. How does risk assessment contribute to decision-making processes?
3. Explain how risk assessment can help in prioritising risk mitigation measures.
4. Describe the relationship between risk assessment and insurance in engineering projects.
5. Discuss the limitations of risk assessment and how engineers can address them.

FOCAL AREA 2: TYPES OF RISK ASSESSMENT

In engineering, there are several types of risk assessment methods used to identify, analyse, and manage risks associated with projects. These methods vary in complexity and application, and each has its own strengths and weaknesses. Here are some common types of risk assessment in engineering:

1. **Qualitative Risk Assessment** This method uses descriptive terms to assess the likelihood and impact of risks. It is often based on expert judgment and experience rather than quantitative data. Qualitative risk assessments are useful for quickly identifying and prioritising risks but may lack precision.
2. **Quantitative Risk Assessment** This method uses numerical values to assess the likelihood and impact of risks. It often involves statistical analysis and modelling to estimate the probability of risk occurrence and its potential consequences. Quantitative risk assessments provide more precise and detailed risk information but may require more time and resources to conduct.
3. **Fault Tree Analysis (FTA)**: FTA is a deductive method used to analyse the various combinations of events that can lead to a specific undesired event, known as the top event. It is useful for understanding the causes of complex system failures and identifying critical pathways that could lead to failure.

4. **Failure Mode and Effects Analysis (FMEA)**: FMEA is a systematic method for evaluating potential failure modes of components or processes and their effects on system performance. It is often used in product design and manufacturing to identify and prioritise potential failure modes based on their severity, frequency, and detectability.
5. **Hazard and Operability Study (HAZOP)**: HAZOP is a structured method used to identify and evaluate potential hazards and operability issues in process systems. It involves a systematic review of process parameters to identify deviations from design intent that could lead to hazardous conditions.
6. **Event Tree Analysis (ETA)**: ETA is a method used to analyse the possible outcomes of an event or series of events. It is often used in risk assessment to model the sequence of events that could lead to a specific consequence and estimate the likelihood of each outcome.
7. **Risk Matrix**: A risk matrix is a tool used to assess and prioritise risks based on their likelihood and impact. It is often used in qualitative risk assessments to visually represent risks and their severity levels.
8. **Scenario Analysis**: Scenario analysis involves the development of alternative future scenarios to assess how different risks may impact a project. It is useful for understanding the potential range of outcomes and developing contingency plans.

Learning Task

1. Discuss with learners and help them appreciate the role of a qualitative risk matrix in assessing and prioritising risks.
2. Work with learners to compare and contrast the strengths and weaknesses of qualitative and quantitative risk assessment.
3. Provide examples of when qualitative risk assessment would be more appropriate than quantitative risk assessment.
4. Work with learners to describe a scenario where a combination of qualitative and quantitative risk assessment methods would be beneficial.
5. Have learners work in groups to brainstorm on how engineers ensure that the data used in quantitative risk assessment is accurate and reliable.
6. Learners think, pair and share their views on how engineers incorporate feedback from stakeholders into the risk assessment process.

Pedagogical Exemplars

Initiate Talk for Learning

1. Learners research the various types of risk assessments and share them with the class.
2. Support learners working at a slower pace whilst the rest of the class completes more activities

Collaborative Learning

1. In small, mixed-ability groups, learners discuss when to use the various types of risk assessment for different tasks and share them with the class.
2. Support a group working at a slower pace whilst the rest of the class completes more activities
3. Summarise learners' views using mind maps.

Key Assessment

Level 1 Recall

1. List six (6) primary types of risk assessments used in engineering practice.
2. Discuss five (5) common types of risk assessment processes in engineering.

Level 2 Skills of conceptual understanding

1. What distinguishes qualitative risk assessment from quantitative risk assessment in engineering?
2. What is the purpose of a detailed hazard and operability study (HAZOP) in risk assessment?
3. Explain the differences between deterministic and probabilistic risk assessment approaches.
4. Explain the difference between qualitative and quantitative risk assessment methods.
5. How does a hazard analysis contribute to risk assessment in engineering projects?

Level 3 Strategic reasoning

1. Discuss the role of fault tree analysis (FTA) in identifying and analysing risks in engineering systems.
2. Discuss the importance of risk matrix in risk assessment for engineering systems.
3. How can engineers use the results of a risk assessment to inform decision-making and risk management strategies?
4. Discuss the Role of Risk Assessment in Enhancing Safety in Engineering Projects: Exploring Different Types of Risk Assessment.

Hint

The recommended mode of assessment for week 3 is **discussion.** Use level 3 question 4 as sample question for the discussion.

WEEK 4. PROCEDURE FOR RISK ASSESSMENT AND CONTROL MEASURES FOR VARIOUS HAZARDS

Learning Indicators

1. *Explain the procedure for risk assessment*
2. *Explain control measures for various hazards*

FOCAL AREA 1: PROCEDURE FOR RISK ASSESSMENT

Risk assessment in engineering is a systematic process to identify, evaluate, and manage risks associated with engineering projects, processes, or systems. The procedure typically involves several steps:

1. **Identify Hazards**
   a. **Gather Information**: Collect data on the processes, activities, and environments involved. This can include technical documents, process flow diagrams, safety data sheets, and historical incident records.
   b. **Identify Potential Hazards**: Recognise and list all potential hazards that could cause harm. Hazards can be physical, chemical, biological, ergonomic, or psychosocial.

2. **Assess Risks**
   a. **Determine Likelihood**: Estimate the probability of each identified hazard occurring. Factors influencing likelihood include frequency of exposure, history of similar events, and existing controls.
   b. **Assess Severity**: Evaluate the potential impact or consequences if the hazard were to occur. Consider health effects, environmental damage, financial losses, and reputational impact.
   c. **Risk Matrix**: Use a risk matrix to combine likelihood and severity, classifying risks into categories (e.g., low, medium, high, critical).

3. **Evaluate and Prioritise Risks**
   a. **Risk Tolerance**: Compare the assessed risks against predefined risk criteria or tolerance levels.
   b. **Prioritise**: Rank risks based on their potential impact and likelihood. Focus on addressing higher-priority risks first.

4. **Control Measures**
   a. **Identify Controls**: Determine possible control measures to mitigate identified risks. Controls can be engineering controls (e.g., redesigning processes), administrative controls (e.g., training, procedures), or personal protective equipment (PPE).
   b. **Implement Controls**: Put the chosen controls into practice, ensuring they are feasible, effective, and sustainable.

5. **Monitor and Review**
   a. **Monitor**: Continuously observe the effectiveness of implemented controls. This can involve regular inspections, audits, and incident reporting.
   b. **Review**: Periodically review the risk assessment to account for changes in processes, new hazards, or after incidents occur. Update the assessment and controls as necessary.
6. **Document and Communicate**
   a. **Documentation**: Record all findings, decisions, and actions taken during the risk assessment process. This includes hazard identification, risk evaluations, control measures, and monitoring results.
   b. **Communication**: Share the risk assessment outcomes and control measures with all relevant stakeholders, including employees, management, and contractors.
7. **Continuous Improvement**
   a. **Feedback Loop**: Encourage feedback from employees and stakeholders to identify areas for improvement.
   b. **Training and Education**: Provide ongoing training to ensure that everyone understands the risks and their roles in mitigating them.
   c. **Review and Update**: Regularly revisit the risk assessment process to incorporate new knowledge, technologies, and practices to continually improve safety and risk management.

Learning Task

1. Have learners work in groups to brainstorm on the key steps in conducting a comprehensive risk assessment in an engineering project.
2. Learners think, pair and share their views on how the identification of hazards initiates the risk assessment process.
3. Have learners work in groups to explain the role of risk analysis, in the overall risk assessment procedure.
4. Moderate discussion learners describe the methods used to evaluate the likelihood and impact of identified risks.
5. Work with learners on how risk matrices are used to prioritise risks during the risk assessment procedure.
6. Work with learners to identify the typical tools and techniques used in the risk assessment process for engineering projects.

Pedagogical Exemplars

Managing talk for learning

1. Put learners in small mixed-ability groups
2. Assign roles: leader, scribe, someone in charge of keeping the group on task and focused on the objective, someone to present the group's work. Assign specific roles to learners to ensure that all learners fully participate in the group work. Let learners decide on the mode

of presentation such as written reports, oral presentation or video presentations and receive feedback.

3. Present various case studies and various risk scenarios for learners to discuss how to assess them
4. Support a group working at a slower pace whilst the rest of the class completes more activities
5. Groups share the findings with the class. Encourage learners to simply and clearly articulate their points and listen to others during the discussions. Make room for non-vocal learners to contribute to the group discussions through writing.

Initiate Talk for Learning

1. The Facilitator explains to learners the broad approaches to risk assessment and encourages them to ask questions for clarification.
2. Organise views using flowcharts to illustrate procedures for risk assessment.
3. Encourage learners to tolerate each other.

Key Assessment

Level 2

1. What are the key steps in engineering risk assessment?
2. How does engineering risk assessment contribute to project success?
3. What tools are commonly used in engineering risk assessment procedures?

Level 3

1. Explain the importance of risk mitigation strategies in engineering.
2. How do engineers prioritise risks during the assessment process?

FOCAL AREA 2: CONTROL MEASURES FOR HAZARDS

Control measures for hazards in engineering are essential for ensuring a safe working environment. These measures can be categorised into several types, including engineering controls, administrative controls, and personal protective equipment (PPE). Here are some common hazards in engineering and their corresponding control measures:

1. Physical Hazards

Noise

a. **Engineering Controls:** Install sound-dampening materials, use quieter machinery, and implement noise barriers.

b. **Administrative Controls:** Limit the duration of exposure, schedule regular breaks, and rotate workers to minimise exposure.

c. **PPE:** Provide earplugs or earmuffs.

Vibration

a. **Engineering Controls:** Use vibration-damping mounts, maintain equipment to reduce vibration, and design equipment to minimise vibration.

b. **Administrative Controls:** Limit exposure time and rotate workers.

c. **PPE:** Use anti-vibration gloves.

Radiation

a. **Engineering Controls:** Shield sources of radiation, use remote handling tools, and install radiation monitors.

b. **Administrative Controls:** Implement safety protocols and provide radiation safety training.

c. **PPE:** Provide lead aprons and other radiation shielding garments.

2. Chemical Hazards

Toxic Chemicals

a. **Engineering Controls:** Use fume hoods, ventilation systems, and enclosed processes.

b. **Administrative Controls:** Implement proper labelling, storage, and handling procedures. Conduct regular training and emergency drills.

c. **PPE:** Provide gloves, goggles, and respirators.

Flammable Chemicals

a. **Engineering Controls:** Use explosion-proof equipment, install proper ventilation, and store chemicals in fire-resistant cabinets.

b. **Administrative Controls:** Enforce strict handling and storage procedures, and provide training on fire safety.

c. **PPE:** Provide flame-resistant clothing and fire extinguishers.

3. Biological Hazards

Infectious Agents

a. **Engineering Controls:** Use biological safety cabinets, proper ventilation, and sanitation facilities.

b. **Administrative Controls:** Implement protocols for handling biological materials and provide training on biosafety.

c. **PPE:** Provide gloves, masks, lab coats, respirators and face shields.

4. Ergonomic Hazards

Repetitive Strain Injuries

a. **Engineering Controls:** Design workstations ergonomically, provide adjustable furniture, and use tools that reduce strain.

b. **Administrative Controls:** Implement job rotation, enforce breaks, and conduct ergonomic assessments.

c. **PPE:** Provide ergonomic aids like wrist supports and anti-fatigue mats.

5. Electrical Hazards

Electric Shock and Arc Flash

a. **Engineering Controls:** Install proper grounding and insulation, use circuit breakers, and conduct regular maintenance.

b. **Administrative Controls:** Implement lockout/tagout procedures and provide electrical safety training.

c. **PPE:** Provide insulated gloves, face shields, and flame-resistant clothing.

6. Mechanical Hazards

Moving Machinery

a. **Engineering Controls:** Install guards and barriers, use automatic shut-off systems, and ensure proper maintenance.

b. **Administrative Controls:** Enforce safe operating procedures, provide training, and implement a lockout/tag out system.

c. **PPE:** Provide safety goggles, gloves, and protective clothing.

Falling Objects

a. **Engineering Controls:** Install nets, barriers, and guardrails.

b. **Administrative Controls:** Implement proper storage and stacking procedures, and conduct regular safety inspections.

c. **PPE:** Provide hard hats and safety boots.

7. Environmental Hazards

Extreme Temperatures

a. **Engineering Controls:** Use insulation, heating, and cooling systems.

b. **Administrative Controls:** Schedule work during cooler periods, enforce breaks, and provide acclimatisation programs.

c. **PPE:** Provide thermal clothing and cooling vests.

Confined Spaces

a. **Engineering Controls:** Ensure proper ventilation and use remote monitoring systems.

b. **Administrative Controls:** Implement entry and exit procedures, conduct atmospheric testing, and provide training.

PPE: Provide respirators, harnesses, and communication devices.

Learning Task

1. Have learners work in groups to explain the importance of risk evaluation in the risk assessment procedure.
2. Discuss with learners and help them appreciate how effective risk control measures are assessed during the risk assessment process.
3. Work with learners to describe the process of documenting and communicating risk assessment findings to stakeholders.

4. Discuss with learners and help them appreciate how risk assessment results are integrated into the decision-making process in engineering projects.
5. Discuss with learners and help them appreciate the role of continuous monitoring and review in the risk assessment procedure.
6. Work with learners to explain how risk assessment procedures differ for new engineering projects versus existing systems.

Pedagogical Exemplars

Initiate Talk for Learning

1. Through questions and answers, learners mention hazards they know in pairs.
2. Learners think and share views on control measures that can be adopted to overcome various hazards.
3. Encourage learners to listen to others contribution and ask questions for clarification in a respectful and inclusive manner.

Key Assessment

Level 1 Recall

1. How can control measures differ for chemical hazards?
2. What are effective control measures for biological hazards?
3. What are the key control measures for psychological hazards?

Level 3 Strategic reasoning

1. Explain control measures for physical hazards in workplaces.
2. How do control measures vary for ergonomic hazards?
3. Use Figure 1 to answer the following questions.
   a. What work is being done? Understanding the kind of work being done is an important step to being able to identify the potential hazards associated with the work.
   b. What kind of possible injury, damage, or danger can occur?
   c. List all the potential hazards that can occur depending on the nature of the work being done.
   d. What can or has to be done to avoid the potential hazard?
   e. After listing all the possible hazards that can occur, write down all the precautions that can be taken to avoid such hazards or to reduce risk if the hazard should occur.

Figure 1: *An image of a workplace*

4. Use Figure 2 to answer the following questions.
   a. What work is being done? Understanding the kind of work being done is an important step to being able to identify the potential hazards associated with the work.
   b. What kind of possible injury, damage or danger can occur?
   c. List all the potential hazards that can occur depending on the nature of the work being done.
   d. What can or has to be done to avoid the potential hazard?
   e. After listing all the possible hazards that can occur, write down all the precautions that can be taken to avoid such hazards or to reduce risk if the hazard should occur.

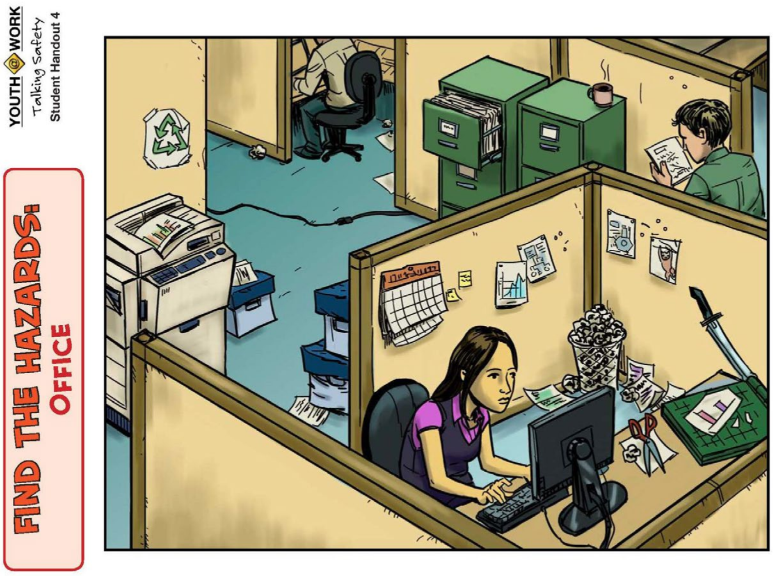

Figure 2. *An image of an Office*

Hint

The recommended mode of assessment for week 4 is **homework.** Use level 1 question 3 as sample question for the homework.

WEEK 5: RISK ASSESSMENT MATRIX

Learning Indicators

1. *Apply the risk assessment matrix to a given risk scenario*
2. *Perform risk assessment through the use of case studies*

FOCAL AREA 1: RISK ASSESSMENT MATRIX IN RISK SCENARIOS

The risk assessment matrix is a useful tool for evaluating and prioritising risks based on their likelihood and impact. Here's a step-by-step example of how to apply the risk assessment matrix to a given risk scenario in engineering.

Scenario: Designing an Automated Conveyor Belt System in a Manufacturing Plant

Context: An engineering team is designing an automated conveyor belt system for a manufacturing plant. The system will transport heavy materials between different stages of production. The primary concerns are the safety of workers, potential mechanical failures, and operational downtime.

Figure 3: *An image of packed goods and books on conveyor belt*

Steps to Apply the Risk Assessment Matrix

1. **Identify Potential Hazards**
   a. **Mechanical Failure of the Conveyor Belt**
      i. Cause: Wear and tear, lack of maintenance.
      ii. Consequence: Production stoppage, potential injuries to workers.

b. Electrical Faults in the Control System

i. Cause: Short circuits, power surges.

ii. Consequence: System malfunction, risk of fire.

c. Worker Injuries Due to Moving Parts

i. Cause: Lack of proper guarding, loose clothing, human error.

ii. Consequence: Serious injuries, and possible fatalities.

2. Determine the Likelihood and Severity

For each hazard, estimate the likelihood and severity:

a. Mechanical Failure of the Conveyor Belt

i. Likelihood: Medium (3)

ii. Severity: High (4)

b. Electrical Faults in the Control System

i. Likelihood: Low (2)

ii. Severity: Critical (5)

c. Worker Injuries Due to Moving Parts

i. Likelihood: Medium (3)

ii. Severity: Critical (5)

3. Construct the Risk Assessment Matrix

The risk assessment matrix is a tool that helps visualise the risk levels by plotting the likelihood against the severity. Below is an example of a 5x5 matrix:

Table 1: 5x5 Matrix of Likelihood and Severity

Severity / Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	High (4)	Critical (5)
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	1
Likely (4)	4	8	12	16	20
Almost Certain (5)	5	10	15	20	25

4. Assign Risk Levels

Using the matrix, assign a risk level to each hazard

a. Mechanical Failure of the Conveyor Belt

i. Likelihood: Medium (3)

ii. Severity: High (4)

iii. Risk Level: 12 (Possible, High)

b. Electrical Faults in the Control System

i. Likelihood: Low (2)

ii. Severity: Critical (5)

iii. Risk Level: 10 (Unlikely, Critical)

c. Worker Injuries Due to Moving Parts

i. Likelihood: Medium (3)

ii. Severity: Critical (5)

iii. Risk Level: 15 (Possible, Critical)

5. Evaluate and Mitigate Risks

Based on the risk levels, prioritise mitigation strategies

a. Mechanical Failure of the Conveyor Belt (Risk Level: 12)

Mitigation: Implement regular maintenance schedules, use high-quality materials, and install sensors to detect wear and tear.

b. Electrical Faults in the Control System (Risk Level: 10)

Mitigation: Install surge protectors, use circuit breakers, and conduct regular electrical inspections.

c. Worker Injuries Due to Moving Parts (Risk Level: 15)

Mitigation: Install proper guarding around moving parts, implement safety training programs, PPE coveralls to cover any loose clothing, and use emergency stop mechanisms.

Learning Task

1. Discuss with learners and help them appreciate how the risk assessment matrix helps in prioritising risks?
2. Work with learners to identify four (4) key components of a risk assessment matrix.
3. Have learners work in groups to discuss how risk assessment matrices help in decision-making
4. Work with learners to identify three (3) factors that contribute to assessing risk likelihood effectively.

Pedagogical Exemplars

Initiate Talk for Learning

1. Learners watch videos or pictures on the risk assessment matrix and individually share their views on what it is.

2. Guide learners to individually mention the importance of the matrix.
3. Through questions and answers, learners discuss the elements of the matrix and how it can be applied.
4. Add on what learners say to fine-tune their thoughts and encourage learners to embrace tolerance and empathy amongst each other.

Key Assessment

Level 1 Recall

1. What is the risk assessment matrix?
2. What are the various components of the risk assessment matrix?

Level 2 Skills of conceptual understanding

1. How would you use a risk assessment matrix to evaluate the risk of slipping on a wet floor in an office?
2. If there is a risk of a minor spill in a laboratory, how would you apply the risk assessment matrix to evaluate this risk?
3. Explain how risk matrices are used in qualitative risk assessment.

Level 3 Strategic reasoning

1. If there is a risk of a minor injury from using a machine, how would you rate the severity and likelihood on a risk assessment matrix?
2. Given the risk of a minor vehicle breakdown during a road trip, how would you use the risk assessment matrix to evaluate this risk?
3. Given the risk of a small fire in a kitchen, how would you use the risk assessment matrix to assess the risk?
4. How would you use a risk assessment matrix to assess the risk of minor flooding in a basement during heavy rain?
5. How would you use a risk assessment matrix to prioritise risks in a water treatment plant with potential equipment corrosion issues?
6. Discuss how to use a risk assessment matrix to prioritise risks in a construction project where multiple safety hazards have been identified?

FOCAL AREA 6: PERFORMING RISK ASSESSMENT USING CASE STUDIES

Performing risk assessment through the use of case studies in engineering is an essential practice to understand potential hazards, evaluate their impacts, and develop strategies to mitigate risks. Here's a structured approach to conducting such assessments:

1. Identify the Case Study

Choose a relevant engineering case study that provides detailed information about a specific project or incident. The case study should include background information, project scope, technical details, and any incidents or challenges encountered.

2. Define Objectives and Scope

Clearly outline the objectives of the risk assessment. Determine the scope, including the specific aspects of the project or incident to be analysed. For instance, focus on safety, financial risks, environmental impact, or technical failures.

3. Gather Data

Collect all necessary data from the case study. This includes project specifications, timelines, stakeholder information, historical data, and any recorded incidents or near misses.

4. Identify Hazards

Identify potential hazards associated with the project or incident. These could be related to technical failures, human errors, environmental conditions, regulatory compliance, or financial uncertainties.

5. Assess Risks

Evaluate the identified hazards by analysing the likelihood and potential impact of each risk. Use qualitative or quantitative methods to assess the risks. Common techniques include:

- **a.** Hazard and Operability Study (HAZOP)
- **b.** Failure Mode and Effects Analysis (FMEA)
- **c.** Fault Tree Analysis (FTA)
- **d.** Risk Matrices

6. Prioritise Risks

Rank the risks based on their assessed likelihood and impact. This helps in identifying which risks require immediate attention and which ones can be monitored over time.

7. Develop Mitigation Strategies

Propose mitigation strategies to manage the identified risks. Strategies can include:

- **a.** **Engineering Controls:** Design modifications, safety features, redundancy systems
- **b.** **Administrative Controls:** Training programs, standard operating procedures, maintenance schedules
- **c.** **Personal Protective Equipment (PPE):** Safety gear for workers
- **d.** **Contingency Plans:** Emergency response plans, insurance coverage

8. Implement Mitigation Measures

Detail how the proposed mitigation strategies will be implemented. Assign responsibilities, allocate resources, and set timelines for the implementation of these measures.

9. Monitor and Review

Establish a monitoring and review process to track the effectiveness of the mitigation measures. Regularly review the risk assessment to incorporate any new data or changes in the project scope.

10. Document and Report

Document the entire risk assessment process, including the identified hazards, assessed risks, proposed mitigation strategies, and monitoring plans. Prepare a comprehensive report to communicate the findings to stakeholders.

Case Study 1: Construction Site Safety

Scenario

A construction company is building a multi-story office complex. The site involves various high-risk activities such as working at heights, operating heavy machinery, and handling hazardous materials. The company aims to perform a risk assessment to ensure the safety of its workers.

Figure 4: *An image of a construction site*

Risk Assessment Steps

a. **Identify Hazards**
   i. Working at heights
   ii. Heavy machinery operation
   iii. Handling hazardous materials (e.g., chemicals, asbestos)
   iv. Slips, trips, and falls
   v. Electrical hazards

b. **Determine Likelihood and Consequence**:

Table 2: 5x5 Matrix of Likelihood and Consequence

Consequence /Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	High (4)	Critical (5)
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Almost Certain (5)	5	10	15	20	25

i. Working at heights: Likelihood (3 - Possible), Consequence (5 - Catastrophic)

ii. Heavy machinery: Likelihood (4 - Likely), Consequence (4 - Major)

iii. Hazardous materials: Likelihood (2 - Unlikely), Consequence (5 - Catastrophic)

iv. Slips, trips, and falls: Likelihood (5 - Almost Certain), Consequence (3 - Moderate)

v. Electrical hazards: Likelihood (3 - Possible), Consequence (4 - Major)

c. **Calculate Risk Ratings**:

i. Working at heights: 3 × 5 = 15 (High)

ii. Heavy machinery: 4 × 4 = 16 (High)

iii. Hazardous materials: 2 × 5 = 10 (Medium)

iv. Slips, trips, and falls: 5 × 3 = 15 (High)

v. Electrical hazards: 3 × 4 = 12 (High)

d. **Use Risk Assessment Matrix**:

i. Plot each risk on the matrix to determine priority levels.

ii. High risks: Working at heights, Heavy machinery, Slips, trips, and falls, Electrical hazards

iii. Medium risk: Hazardous materials

e. **Implement Control Measures**:

i. Working at heights: Install guardrails, provide safety harnesses, conduct training.

ii. Heavy machinery: Ensure proper maintenance, provide operator training, establish exclusion zones.

iii. Hazardous materials: Provide PPE, proper storage, and handling procedures.

iv. Slips, trips, and falls: Maintain clean work areas, provide appropriate footwear, install warning signs.

v. Electrical hazards: Regular equipment inspections, proper grounding, and use of GFCIs.

Case Study 2: Manufacturing Plant Machinery

Scenario

A manufacturing plant uses automated machinery to produce consumer electronics. There is a risk of machinery malfunction leading to worker injuries and production downtime. The plant management decides to perform a risk assessment.

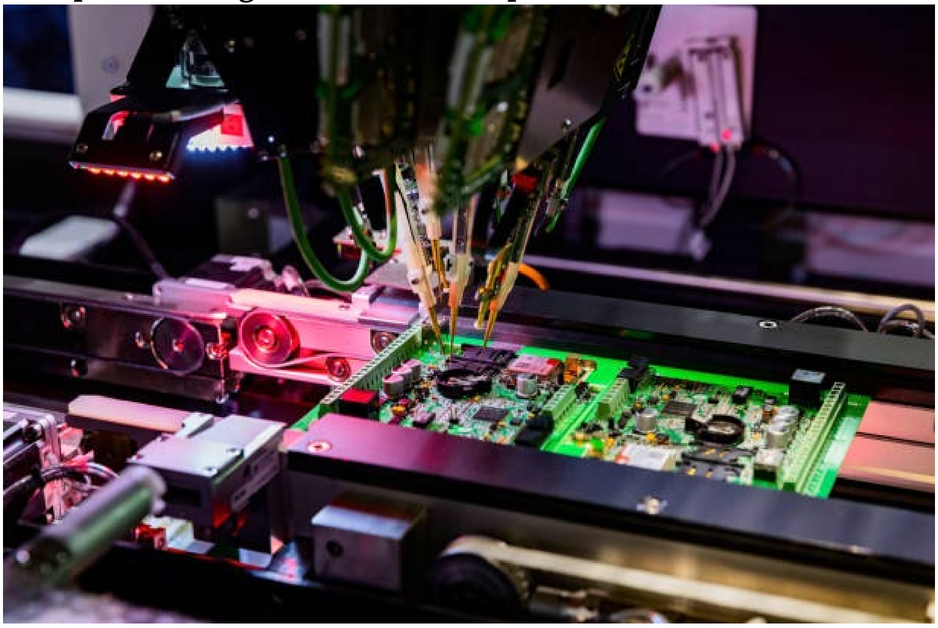

Figure 5: *An image of electronic circuit board production and computer chip fly test by robotic automated*

Risk Assessment Steps

a. **Identify Hazards**
   i. Machinery malfunction
   ii. Contact with moving parts
   iii. Electrical hazards
   iv. Exposure to noise

b. **Determine the Likelihood and Consequence using Table 2 above**
   i. Machinery malfunction: Likelihood (4 - Likely), Consequence (3 - Moderate)
   ii. Moving parts: Likelihood (3 - Possible), Consequence (4 - Major)
   iii. Electrical hazards: Likelihood (2 - Unlikely), Consequence (5 - Catastrophic)
   iv. Noise exposure: Likelihood (5 - Almost Certain), Consequence (2 - Minor)

c. **Calculate Risk Ratings**
   i. Machinery malfunction: $4 \times 3 = 12$ (High)
   ii. Moving parts: $3 \times 4 = 12$ (High)
   iii. Electrical hazards: $2 \times 5 = 10$ (Medium)
   iv. Noise exposure: $5 \times 2 = 10$ (Medium)

d. **Use Risk Assessment Matrix**

i. High risks: Machinery malfunction, Moving parts

ii. Medium risks: Electrical hazards, Noise exposure

e. **Implement Control Measures**

i. Machinery malfunction: Regular maintenance, real-time monitoring systems.

ii. Moving parts: Install safety guards, emergency stop mechanisms, training on safe operation.

iii. Electrical hazards: Implement LOTO procedures, regular inspections, training.

iv. Noise exposure: Provide ear protection, soundproofing, regular hearing checks.

Case Study 3: Chemical Processing Plant

Scenario

A chemical processing plant handles toxic and flammable substances. There is a risk of chemical spills, fires, and worker exposure to hazardous substances. The plant management undertakes a risk assessment to enhance safety protocols.

Figure 6: *An image of industrial zone equipment oil refining close pipelines*

Risk Assessment Steps

a. **Identify Hazards**

i. Chemical spills

ii. Fire and explosion

iii. Worker exposure to toxic substances

iv. Equipment failure

b. **Determine Likelihood and Consequence using table 2 above**

i. Chemical spills: Likelihood (3 - Possible), Consequence (4 - Major)

ii. Fire and explosion: Likelihood (2 - Unlikely), Consequence (5 - Catastrophic)

iii. Worker exposure: Likelihood (4 - Likely), Consequence (4 - Major)

iv. Equipment failure: Likelihood (3 - Possible), Consequence (4 - Major)

c. **Calculate Risk Ratings**

i. Chemical spills: $3 \times 4 = 12$ (High)

ii. Fire and explosion: $2 \times 5 = 10$ (Medium)

iii. Worker exposure: $4 \times 4 = 16$ (High)

iv. Equipment failure: $3 \times 4 = 12$ (High)

d. **Use Risk Assessment Matrix**

i. High risks: Chemical spills, Worker exposure, Equipment failure

ii. Medium risk: Fire and explosion

e. **Implement Control Measures**

i. Chemical spills: Spill containment systems, training on spill response, regular inspections.

ii. Fire and explosion: Install fire suppression systems, proper storage of flammable materials, emergency response plans.

iii. Worker exposure: Use of PPE, proper ventilation, regular health monitoring.

iv. Equipment failure: Regular maintenance, real-time monitoring, proper training on equipment use.

Learning Task

Facilitators put learners in mixed ability groups and present the following case studies to them to perform the risk assessment. The groups take turns to present their work to the class for critiquing.

1. **Case Study: Construction Site Safety**

   a. Given a case study of a construction site, what are the major hazards present?

   b. How would you perform a risk assessment to ensure worker safety on this site?

2. **Case Study: Chemical Spill in a Laboratory**

a. From a case study involving a chemical spill in a laboratory, what steps would you take to assess the risks to lab personnel?

b. How would you rate the severity and likelihood of exposure to harmful chemicals?

3. **Case Study: Factory Floor Hazard**

   a. What potential risks can be identified from a case study of a factory floor where workers frequently move heavy machinery?

   b. How would you assess the severity and likelihood of a worker injury in this scenario?

4. **Case Study: Electrical Safety in a Workshop**

   a. Based on a case study of a workshop with faulty electrical wiring, what risks need to be assessed?

   b. How would you prioritise these risks using a risk assessment matrix?

Pedagogical Exemplars

Collaborative and Problem-based Learning

1. Learners sit in mixed-ability groups. Group learners based on their readiness, interests, and learning styles. For example, you could group learners who have a strong interest in engineering together, or group learners who learn best through hands-on activities together.
2. The groups are presented with the same risk situation for each group to perform a comprehensive risk assessment and recommend control measures.
3. Support groups working at a slower pace whilst the rest of the class completes more activities.
4. The groups take turns to present their work to the class for critiquing in a respectful manner.

Key Assessment

Level 3 Strategic reasoning

1. **Case:** A school's untidy workshop is equipped with various tools, such as soldering irons, drills, and electrical testing devices without PPEs. During a practical lesson, a learner accidentally touches an exposed wire, receiving an electric shock.

   Questions:

   a. Identify the hazards present in this scenario.

   b. What are the potential risks associated with each identified hazard?

   c. Propose control measures to mitigate the risks.

   d. How would you assess the severity and likelihood of injury from the exposed wire?

   e. What steps should be taken to prevent a similar incident in the future?

2. Case Study: Construction site

Figure 7: *An image of a construction site*

a. From a case study of a construction site, what potential safety hazards can be identified?

b. How would you use a risk assessment matrix to evaluate these hazards?

3. Case Study: Food Safety in a Restaurant

Figure 8: *An image of a fast food restaurant.*

a. Based on a case study of a restaurant with recent food contamination issues, what risks need to be assessed?

b. How would you use a risk assessment matrix to address food safety concerns?

Hint

The recommended mode of assessment for week 5 is **case study.** Use level 3 question 1 as sample question for the case study.

SECTION 2 REVIEW

1. Can learners discuss risk assessment in the context of engineering practice?
2. Can explain why risk assessment is important in engineering projects?
3. Would learners be able to explain how risk assessment can help in prioritising resources in an engineering project?
4. Could learners outline the key steps in engineering risk assessment?
5. Would learners be able to suggest how engineering risk assessment contributes to project success?
7. Can learners suggest tools commonly used in engineering risk assessment procedures?
8. Would learners be able to explain the importance of risk mitigation strategies in engineering?
9. Can learners explain how engineers prioritise risks during the assessment process?

Additional Reading

1. Learners watch a short video on how to create a risk assessment matrix https://youtu.be/-E-jfcoR2W0?si=Fb089vzzrelYa2Eh	
2. The Ethical Engineer, available at Https://ethicalengineer.ttu.edu/articles/engineering-ethics-and-its-impact-on-society, [accessed on 10th July 2024].	
3. Matt Osborne, Richard Hawkins, Mark Nicholson, and Rob Alexander, "Understanding safety engineering practice: Comparing safety engineering practice as desired, as required, and as observed", Elsevier Safety Science, https://doi.org/10.1016/j.ssci.2024.106424	

APPENDIX B: PORTFOLIO BUILDING

Prompt for building the portfolio should be given in week 1 and final submission date for the portfolio should be by the 22nd week of academic year.

1. Task example

Build a portfolio which includes the following items:

a) Exercises
   i. Case study
   ii. Presentation/Poster
   iii. Homework

b) Project works
   i. Individual project work- submitted in week 20
   ii. Group project- submitted in week 9

c) Reports on
   i. Practical exercises.
   ii. Research

d) Results for
   i. Mid-semester examinations
   ii. End-of-first semester examinations

e) Awards.

1. Organisation of the portfolio

A file with all collected items should have the following components:

a) Cover page: Subject name, Full name, Class, and Academic Year (for example 2024/2025 Academic Year).

b) A brief 50-word introduction to what the portfolio is about (summary of portfolio).

c) A glossary on the last page with new terminologies learnt throughout the year.

All items may be placed in a clear file bag.

2. Administration

a) Give clear instructions on the purpose of the portfolio and the items to be included.

b) Provide and discuss the marking scheme/ rubrics with learners.

c) Remind and prompt learners throughout the academic year which exercises should be included in the portfolio (*reminders have been provided at various sessions in the PLC handbook, to help prompt learners as well*).

3. Marking scheme/Scoring Rubrics for scoring Portfolio task

Criteria	4 marks	3 marks	2 marks	1 mark
Content Completeness	*All required items (exercises, project works, reports, results for mid semester examinations, end of semester examination, etc.) are included*	*Provide items except 1 document.*	*Provide items except 2 documents.*	*Provide items except 3 documents.*
Organisation of Portfolio and Creativity	*The portfolio is exceptionally organised, with a professional cover page, a clear introduction, and a well-structured glossary.*	*Well-organised except 1 document*	*Well-organised except 2 documents*	*Well-organised except 3 documents*
Introduction and Glossary	*Introduction provides summary of the portfolio; glossary includes all relevant terms learned*	*Introduction is clear; glossary excluding 1 relevant term learned*	*Introduction is vague; glossary excluding 2 relevant terms learned*	*Introduction is missing; glossary excluding 3 relevant terms learned*

Submission of portfolio on the due date: 4 marks

Total marks = 12 marks

Feedback

Appreciate all learners for significant effort in presenting their portfolio and commend those with exceptionally organised portfolios while encouraging those whose overall organisation needs improvement; Entreat learners to continue keeping portfolios even outside class due to its importance, etc.

The marking scheme/rubrics for scoring the discussion task

Criteria	3 marks	2 marks	1 mark
Understanding of Risk Assessment	*Explains what risk assessment is with three key elements such as hazard identification, risk analysis, risk evaluation, control measures, etc.*	*Explains what risk assessment is with two key elements such as hazard identification, risk analysis, risk evaluation, control measures, etc.*	*Explains what risk assessment is with one key element such as hazard identification, risk analysis, risk evaluation, control measures, etc.*
Types of Risk Assessment (Qualitative, Quantitative, FTA, FMEA, HAZOP, ETA)	*Explains three types of risk assessment*	*Explains two types of risk assessment*	*Explain one type of risk assessment*
Safety Enhancement in Engineering	*Gives three explanations on how risk assessment enhances safety.*	*Gives two explanations on how risk assessment enhances safety*	*Gives one explanation on how risk assessment enhances safety*

Participation in Discussion	*Participates and contributes to the discussion by asking or answering questions.*	*Participates in the discussion with some contributions.*	*Minimal participation or contributions to the discussion.*
Clarity and Communication	*With three clear ideas*	*With two clear ideas*	*With one clear idea*

Total = 15 marks

The marking scheme/rubrics for scoring the Case Study task

Look out for:

a. *Exposed electrical wires, Lack of PPE, Untidy workshop, etc. - (4 marks)*

b. *Exposed electrical wires, Improper storage of tools, etc. - (4 marks)*

c. *Immediate Repair, Insulation, Signage, etc. - (4 marks)*

d. *Severity, Likelihood, High risk, etc. - (4 marks)*

e. *Provide Safety Training, implement a Workshop Safety Protocol, Maintain Equipment, etc. – (4 marks)*

Total Marks – 20 Marks

SECTION 3: PROFESSIONAL ETHICS

Strand: Engineering Practice

Sub-Strand: Ethics and Professional Practice

Learning Outcomes

1. *Explain the need for professionalism in engineering practice*
2. *Identify professional behaviour in engineering practice*

Content Standard: Demonstrate understanding of professionalism and unprofessionalism in engineering practice.

Hint

- Mid-Semester Examination for the first semester is in Week 6. Refer to Appendix C for the Table of Specification to guide you to set the questions. Set questions to cover all the indicators covered for at least 1 to 5.
- Remind learners to submit their group project in week 9.

INTRODUCTION AND SECTION SUMMARY

Professionalism in engineering involves ethical, responsible, and competent conduct. This section is a continuation of the year's sub-strand ethics and professional practice. Learners will be introduced to how engineers are being perceived as trustworthy and proficient by peers, clients, and the public. Additionally, learners will be introduced to the importance of engaging in professional conduct that benefits individuals, organisations, and society. A successful engineering workplace is characterised by integrity, respect, and excellence. Learners will understand the professional ethical behaviour that engineers must possess such as diverse technical, interpersonal, and professional abilities through formal education, specialised training, and practical experience. Unprofessional conduct can have significant repercussions which learners will be introduced to in this section.

The weeks covered by the section are:

Week 6: Professionalism in Engineering Practice

Week 7: Characteristics of an ethical and professional workplace

Week 8: Attributes of an engineer

Week 9: Unprofessional behaviour

SUMMARY OF PEDAGOGICAL EXEMPLARS

The section outlines how managing talk for learning and initiating talk for learning are used to solicit learners' views on characteristics of an ethical and unprofessional workplace, attributes of an engineer and unprofessional behaviour. The teacher can explain the concept of professionalism in engineering, using illustrative examples and concept cartoons. Consider learners discussing the advantages of exhibiting professional behaviour and the traits of work environments that display unethical behaviour through managing talk for learning. Learners can watch a video or movie then work in pairs to identify desirable attributes of an engineer and discuss how to instil these qualities using initiating talk for learning. Their discussion also includes small groups discussing the repercussions of unprofessional conduct and the impact on individuals, organisations, and the nation.

ASSESSMENT SUMMARY

Class discussions can be used to elicit oral answers after watching a movie that explores ethical and immoral behaviours in daily life. Students can also be motivated to identify the difficulties that engineers encounter in their careers, which frequently entail managing conflicting interests, technical limitations, and ethical deliberations. They can then provide a presentation in class, either in written, oral, or PowerPoint format on characteristics of an ethical and unprofessional workplace, attributes of an engineer and unprofessional behaviour. Present the learners with a carefully chosen case study or set of scenarios and allocate them sufficient time to read and assess each circumstance. Allow learners to discern the ethical concerns and possible quandaries inherent in each situation. These factors should enhance learners' formative assessment.

WEEK 6: PROFESSIONALISM IN ENGINEERING PRACTICE

Learning Indicators

1. *Explain professionalism in Engineering practice*
2. *Explain professional behaviour*

FOCAL AREA 1: PROFESSIONALISM IN ENGINEERING

Professionalism in engineering practice encompasses a range of behaviours and attitudes that are expected from engineers to ensure they conduct themselves in an ethical, responsible, and competent manner. Here are some key aspects:

1. **Ethical Conduct**
   a. **Integrity**: Engineers should act with honesty and integrity, avoiding deceptive acts and ensuring their work is accurate and truthful.
   b. **Confidentiality**: Respecting the confidentiality of sensitive information encountered in the course of their work.
   c. **Public Safety**: Prioritising the health, safety, and welfare of the public in their work, and reporting any concerns that might endanger public welfare.

2. **Competence**
   a. **Continuous Learning**: Engaging in lifelong learning to keep skills and knowledge current with technological advancements and industry standards.
   b. **Qualification**: Only undertaking tasks for which they are qualified by education, training, or experience.

3. **Accountability**
   a. **Responsibility**: Taking responsibility for their work and the work of those they supervise, including acknowledging and correcting mistakes.
   b. **Transparency**: Being open and transparent in their communications and reporting, especially when it comes to potential risks and issues.

4. **Respect and Fairness**
   a. **Respect for Others**: Treating colleagues, clients, and the public with respect and consideration.
   b. **Non-Discrimination**: Acting without bias or discrimination and promoting diversity and inclusion within the workplace and the profession.

5. **Professional Development**
   a. **Mentorship**: Contributing to the development of the next generation of engineers through mentorship and sharing knowledge.

b. **Professional Organisations**: Participating in professional organisations and contributing to the advancement of the engineering profession.

6. **Regulatory Compliance**
   a. **Adherence to Laws**: Complying with all relevant laws, regulations, and standards that govern engineering practice.
   b. **Professional Licensure**: Maintaining any required professional licensure and adhering to the associated codes of conduct and continuing education requirements.

Learning Task

1. Have learners work in groups to discuss the importance of integrity and honesty in engineering practice
2. Discuss with learners and help them appreciate how respecting diversity and inclusion contribute to professionalism in engineering
3. Work with learners to define professionalism in engineering and provide an example of professional behaviour.
4. Work with learners to discuss why integrity is important in engineering practice, and how engineers demonstrate it
5. Have learners work in groups to discuss the role of ethical behaviour in engineering and its impact on public trust.
6. Moderate discussions reviewing how continuous professional development contributes to an engineer's career
7. Have learners work in groups to explain the importance of teamwork and collaboration in maintaining professionalism in engineering.

Pedagogical Exemplars

Initiating Talk for Learning

1. In a moderated discussion, have learners comment on the quality of civil and construction of works around them.
2. Provide cases and different scenarios for learners to determine what is professional or not. Remember to consider socio-emotional learning by encouraging respectful and open communication among learners. Promote gender equality and social inclusion by ensuring that all learners, regardless of gender or social background, are given equal opportunities to participate in the discussion. Lastly, incorporate national core values in your teaching by relating the discussion to real-life scenarios or issues relevant to Ghana.
3. The facilitator explains professionalism in engineering, drawing partly from the comments passed by learners. Facilitators should steer discussions, and be mindful to stay off biases, stereotypes, and prejudices and place efforts to provide well-balanced examples.

Key Assessment

Level 2 Skills of conceptual understanding

1. Why is it important for engineers to engage in lifelong learning and continuous professional development?
2. Describe one way engineers can demonstrate accountability in their work.

Level 3 Strategic Reasoning

1. How does ethical decision-making impact public trust in engineering projects?
2. Discuss the consequences of unprofessional behaviour in engineering and provide examples of how it can affect projects and public safety.
3. Discuss how effective communication skills contribute to the success of engineering projects and influence team dynamics. Provide examples to support your explanation.

FOCAL AREA 2: PROFESSIONAL BEHAVIOUR IN ENGINEERING

Professional behaviour in engineering refers to the conduct and demeanour that engineers are expected to exhibit in their professional interactions and duties. This behaviour ensures that engineers are seen as trustworthy, reliable, and competent by their colleagues, clients, and the public. Here are some key elements of professional behaviour in engineering:

1. **Integrity and Honesty**
   a. **Truthfulness**: Always provide accurate and honest information in reports, communications, and professional dealings.
   b. **Ethical Decisions**: Make decisions based on ethical considerations, even when it might be difficult or when cutting corners seems easier.

2. **Accountability and Responsibility**
   a. **Ownership of Work**: Take responsibility for your work, including any mistakes or errors, and take steps to correct them.
   b. **Dependability**: Follow through on commitments and deliver work on time and to the best of your ability.

3. **Respect and Fair Treatment**
   a. **Collegial Respect**: Treat colleagues, clients, and all stakeholders with respect and courtesy, valuing their contributions and perspectives.
   b. **Non-Discrimination**: Foster an inclusive work environment by avoiding any form of discrimination based on race, gender, age, religion, or other personal characteristics.

4. **Confidentiality and Privacy**
   a. **Sensitive Information**: Respect and protect the confidentiality of client information, proprietary data, and sensitive project details.
   b. **Data Security**: Ensure that all data is handled securely and responsibly, following best practices for data protection.

5. **Communication and Collaboration**
    a. **Clear Communication**: Communicate clearly, concisely, and professionally in all forms of communication, whether written, verbal, or electronic.
    b. **Teamwork**: Collaborate effectively with team members, valuing their input and working towards common goals.
6. **Professional Competence and Development**
    a. **Continuous Improvement**: Engage in lifelong learning and continuous professional development to stay current with industry standards and technological advancements.
    b. **Competence**: Only undertake tasks and projects for which you are qualified and seek assistance or training when necessary.
7. **Ethical Practices**
    a. **Public Welfare**: Always consider the impact of your work on public health, safety, and welfare, and strive to minimise any negative impacts.
    b. **Fair Practice**: Avoid conflicts of interest and disclose any potential conflicts to relevant parties.
8. **Adherence to Standards and Regulations**
    a. **Regulatory Compliance**: Follow all applicable laws, regulations, and standards governing the practice of engineering.
    b. **Quality Standards**: Adhere to best practices and standards to ensure the quality and safety of engineering work.

Learning Task

1. Discuss with learners and help them appreciate what it means to behave professionally in a workplace
2. Work with learners to discuss why ethical behaviour is important in a professional setting
3. Learners think, pair and share their views on how clear communication demonstrates professional behaviour
4. Work with learners to discuss one way an individual can show respect in the workplace
5. Learners think, pair and share their views on why professionals should engage in continuous learning and development

Pedagogical Exemplars

Initiating Talk for Learning

1. Through questions and answers, learners identify what professional behaviour is by giving examples. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
2. Fine-tune learners' understanding by explaining professional behaviour further and embracing tolerance and empathy amongst each other.

Managing Talk for Learning

1. Use concept cartoons to reflect ethical/unethical behaviour and professional behaviour.
2. Learners debate the difference between them and examine what constitutes ethical and professional behaviour. Individuals add to what others have said respectfully. Learners should be encouraged to tolerate others' views.

Key Assessment

Level 2 Skills of conceptual understanding

1. Define professional behaviour and explain why it is important in the workplace.
2. How can professionals demonstrate professionalism in their communication with colleagues and clients?

Level 3 Strategic Thinking

1. Discuss the role of ethics in professional behaviour and its impact on decision-making.
2. How does professional behaviour contribute to a positive organisational culture?
3. Describe a scenario where maintaining professional behaviour could resolve a workplace conflict.

Hint

The recommended mode of assessment for week 6 is **Mid Semester.**

Refer to table of specification C for first mid- semester examination for more details.

WEEK 7: CHARACTERISTICS OF AN ETHICAL AND PROFESSIONAL WORKPLACE

Learning Indicators

1. *Spell out the benefits of professional behaviour*
2. *Explain the characteristics of an ethical and professional workplace*

FOCAL AREA 1: THE BENEFITS OF PROFESSIONAL BEHAVIOUR

Professional behaviour in engineering offers numerous benefits that extend to individuals, organisations, and society as a whole. Here are some key benefits:

1. **Enhanced Reputation and Trust**
   a. **Public Confidence**: Professional behaviour builds trust with the public, clients, and stakeholders, leading to greater confidence in the engineering profession.
   b. **Professional Credibility**: Engineers who consistently act professionally are seen as reliable and trustworthy, enhancing their personal and organisational reputation.
2. **Higher Quality of Work**
   a. **Accuracy and Reliability**: Ethical and professional conduct leads to higher quality, more accurate, and reliable engineering work.
   b. **Consistency**: Adherence to standards and best practices ensures consistent quality across projects.
3. **Improved Safety and Welfare**
   a. **Public Safety**: Prioritising ethical considerations and public welfare helps prevent accidents and failures, protecting the health and safety of the public.
   b. **Risk Mitigation**: Professional behaviour includes thorough risk assessment and management, reducing the likelihood of negative outcomes.
4. **Career Advancement and Opportunities**
   a. **Professional Growth**: Demonstrating professional behaviour can lead to career advancement, recognition, and increased opportunities within the field.
   b. **Networking**: Ethical and respectful conduct fosters positive relationships and networking opportunities with colleagues and industry leaders.
5. **Legal and Regulatory Compliance**
   a. **Reduced Legal Risks**: Adhering to laws and regulations minimises the risk of legal issues, penalties, and liabilities.
   b. **Regulatory Adherence**: Professional behaviour ensures compliance with industry standards and regulatory requirements.

6. **Organisational Benefits**
   a. **Reputation Management**: Companies with a culture of professional behaviour enjoy better reputations, which can attract clients and top talent.
   b. **Efficiency and Productivity**: Professionalism in the workplace promotes a positive work environment, leading to increased efficiency, productivity, and job satisfaction.
7. **Ethical and Moral Satisfaction**
   a. **Personal Fulfilment**: Acting with integrity and professionalism provides personal and ethical satisfaction, contributing to a sense of pride and fulfilment in one's work.
   b. **Positive Impact**: Knowing that one's work contributes positively to society and adheres to ethical standards can be highly rewarding.
8. **Enhanced Collaboration and Teamwork**
   a. **Effective Communication**: Professional behaviour fosters clear and respectful communication, leading to better teamwork and collaboration.
   b. **Mutual Respect**: A professional environment encourages mutual respect among team members, improving morale and cooperation.
9. **Innovation and Continuous Improvement**
   a. **Commitment to Learning**: Professional behaviour includes a commitment to continuous learning and improvement, fostering innovation and staying current with technological advances.
   b. **Knowledge Sharing**: Engaging in mentorship and knowledge sharing helps develop the next generation of engineers and promotes a culture of continuous improvement.

Learning Task

1. Discuss with learners and help them appreciate some benefits of professional behaviour in teamwork and collaboration
2. Have learners work in groups to discuss how professional behaviour can contribute to a positive work culture
3. Work with learners to discuss how professional behaviour can impact the success of projects.
4. Work with learners to discuss the role of professional behaviour in building trust with clients and colleagues.
5. Learners think, pair and share their views on how professional behaviour can help individuals achieve their career goals

Pedagogical Exemplars

Initiating Talk for Learning

1. Through questions and answers class discusses the benefits of professional behaviour.
2. Encourage individuals to share their thoughts and use webbing to organise their views. Allow learners to demonstrate their understanding in different ways. For example, some

learners could present their findings to the class, while others could create a report or a mind map.

Key Assessment

Level 2 Skills of conceptual understanding

1. What are some benefits of professional behaviour in teamwork and collaboration?
2. How can professional behaviour contribute to a positive work culture?
3. Describe how professional behaviour can impact the success of projects.
4. Explain how professional behaviour helps build trust with clients and colleagues.
5. Describe ways in which professional behaviour can contribute to achieving career goals.

FOCAL AREA 2: CHARACTERISTICS OF AN ETHICAL AND PROFESSIONAL WORKPLACE

An ethical and professional workplace in engineering is characterised by various attributes that foster a culture of integrity, respect, and excellence. Here are some key characteristics:

1. **Commitment to Ethics**
   a. **Clear Ethical Guidelines**: The organisation has well-defined ethical standards and codes of conduct that guide employees in their professional activities.
   b. **Ethical Leadership**: Leaders and managers demonstrate ethical behaviour and set a positive example for employees to follow.
2. **Integrity and Accountability**
   a. **Transparency**: Open and honest communication is encouraged, and information is shared transparently with all stakeholders.
   b. **Responsibility**: Employees take responsibility for their actions and decisions, and there is a culture of acknowledging and correcting mistakes.
3. **Respect and Fair Treatment**
   a. **Diversity and Inclusion**: The workplace promotes diversity and inclusion, ensuring equal opportunities for all employees regardless of their background.
   b. **Respectful Interactions**: All employees treat each other with respect and courtesy, fostering a positive and collaborative work environment.
4. **Focus on Public Welfare and Safety**
   a. **Safety Standards**: The organisation prioritises the health, safety, and welfare of the public and employees by adhering to strict safety standards and regulations.
   b. **Risk Management**: There are robust procedures for identifying, assessing, and mitigating risks to ensure the safety and reliability of engineering projects.
5. **Continuous Professional Development**
   a. **Lifelong Learning**: Employees are encouraged and supported to engage in continuous learning and professional development to stay current with industry advancements.

b. **Skill Enhancement**: Regular training and development programs are offered to enhance employees' skills and knowledge.

6. **Quality and Excellence**

a. **Adherence to Standards**: The organisation follows industry standards and best practices to ensure high-quality work.

b. **Commitment to Excellence**: There is a strong focus on delivering excellent results and continuously improving processes and products.

7. **Effective Communication and Collaboration**

a. **Open Dialogue**: There is an open dialogue between employees at all levels, promoting effective communication and collaboration.

b. **Teamwork**: Collaborative efforts are encouraged, and team achievements are recognised and celebrated.

8. **Fair and Transparent Decision-Making**

a. **Objective Criteria**: Decisions are made based on objective criteria, data, and thorough analysis, ensuring fairness and impartiality.

b. **Employee Involvement**: Employees are involved in decision-making processes, particularly those that affect their work and the organisation's direction.

9. **Supportive and Safe Work Environment**

a. **Work-Life Balance**: The organisation promotes a healthy work-life balance, recognising the importance of employees' well-being.

b. **Safe Workplace**: A safe and healthy work environment is maintained, with measures in place to prevent accidents and injuries.

10. **Ethical Business Practices**

a. **Fair Competition**: The organisation engages in fair competition and avoids any practices that could be considered deceptive or unfair.

b. **Sustainable Practices**: There is a commitment to sustainability and environmental responsibility in business operations and engineering practices.

11. **Compliance with Laws and Regulations**

a. **Legal Adherence**: The organisation complies with all relevant laws, regulations, and industry standards, ensuring that all activities are legally compliant.

b. **Regulatory Updates**: There are processes in place to stay updated with regulatory changes and ensure continuous compliance.

Learning Task

1. Work with learners to discuss some characteristics of an ethical and professional workplace
2. Discuss with learners and help them appreciate how an ethical and professional workplace can handle conflicts effectively

3. Have learners work in groups to discuss the role of transparency in promoting ethics and professionalism in the workplace.
4. Learners think, pair and share their views on how an ethical and professional workplace supports employee well-being
5. Have learners work in groups to discuss why it is important for leaders to set an example of ethical behaviour in the workplace

Pedagogical Exemplars

Initiating Talk for Learning

1. In pairs, think and share views on the characteristics of workplaces where workers exhibit ethics and professionalism. Encourage all learners to contribute to the discussion while ensuring that a few learners do not dominate the discussion session. Develop communication and discussion skills to facilitate learning.
2. Conversely, learners discuss the characteristics of workplaces where unethical and unprofessional conduct are exhibited.
3. Provide various scenarios for learners to say whether the environment will promote ethical and professional behaviour or not.
4. Facilitators should steer the discussions, and be mindful to stay off biases, stereotypes, and prejudices and place efforts to provide well-balanced examples.

Key Assessment

Level 2 Skills of conceptual understanding

1. What are some key characteristics of an ethical and professional workplace?
2. Explain how clear communication supports an ethical workplace environment.

Level 3 Strategic Reasoning

1. How can leaders promote and maintain an ethical workplace culture?
2. Describe a situation where an ethical workplace successfully resolved a conflict of interest.
3. Why is it important for employees to feel empowered to speak up about ethical concerns in the workplace?
4. Act out a role-play on the benefits of professional behaviour and the importance of leaders setting examples of ethical behaviour at the workplace.

    a. The CEO, Mr. Kofi Mensah, calls a meeting with the project team, including Supervisor Mrs. Afriyie, junior employees Kojo and Adwoa, to discuss the delay caused by the cement shortage.

    Mr. Mensah: (Calmly) Team, we have hit a roadblock. The cement shortage in the market will delay the project. Hiding this from the client is not an option. We must be transparent and work together to find a solution.

    Mrs. Afriyie: (Concerned) Sir, don't you think being upfront about this might make the client doubt our capability?

Mr. Mensah: (Firmly) Trust is our foundation. Nana values honesty, and we will show them we are committed to completing the project without compromising quality.

b. Later, in the Supervisor's office, Kojo suggests an unethical shortcut to avoid the delay.

Kojo: (Eagerly) Mrs. Afriyie, I have been thinking. We could mix more sand with less cement; we must meet the deadline. It will save time, and the client will not know.

Adwoa: (Shocked) Kojo, that is wrong! Cutting corners will harm the building's quality and our reputation.

Mrs. Afriyie: (Pausing) Kojo, I understand your frustration, but compromising quality goes against everything we stand for. I have seen how Mr. Mensah leads with integrity, and I cannot betray that example.

Kojo: (Reluctantly) I thought I was helping. I did not think about the long-term impact.

c. The team meets with Mr. Mensah again to finalize their plan. Adwoa proposes a suggestion.

Adwoa: Sir, what if we reorganize the project schedule and focus on other tasks until the cement arrives? It will reduce idle time and keep the client informed of our progress.

Mr. Mensah: (Smiling) That is an excellent idea, Adwoa. Let us prepare an updated schedule for the client.

d. Mr. Mensah meets with Nana, the client, to explain the situation.

Mr. Mensah: Nana, I want to update you on the project. Due to the cement shortage in the market, we are experiencing a delay. However, we are committed to delivering quality, and we have adjusted our schedule to minimize the impact.

Nana: (Thoughtfully) Thank you for your honesty, Mr. Mensah. Delays happen, but integrity like this is why I trust your company.

e. Back at the office, the team reflects on the situation.

Kojo: (Sincerely) I was wrong to suggest cutting corners. Seeing how you handled this, Mrs. Afriyie, and Mr. Mensah's example, I realize that doing the right thing builds trust.

Adwoa: (Encouragingly) Exactly, Kojo. Upholding our values ensures long-term success.

Mrs. Afriyie: (Smiling) This was a tough situation, but we showed that professionalism and ethics guide our actions.

Mr. Mensah: (Addressing the team) Remember, ethical leadership is not just about making the right decision—it is about inspiring others to do the same. I am proud of how we handled this.

The team exchanges determined smiles, ready to move forward.

Hint

The recommended mode of assessment for week 7 is **drama.** Use level 3 question 4 as sample question for the drama. The duration of the drama exercise is between 5 – 6 minutes.

WEEK 8: ATTRIBUTES OF AN ENGINEER

Learning Indicator: *Outline the desired attributes of an engineer and explain how those attributes could be developed*

FOCAL AREA 1: DESIRED ATTRIBUTES OF ENGINEERS AND HOW TO DEVELOP THEM

The desired attributes of an engineer encompass a range of technical, interpersonal, and professional skills that are essential for success in the field. These attributes can be developed through a combination of education, training, and hands-on experience. Here are some key attributes of an engineer and how they can be developed:

Desired Attributes of an Engineer and How to Develop Them

1. **Technical Proficiency**
   a. **Attributes**
      i. Strong foundation in engineering principles.
      ii. Proficiency with industry-specific tools and technologies.
      iii. Continuous learning to keep up with technological advancements.
   b. **Development**
      i. **Education**: Obtain a degree in engineering from an accredited institution.
      ii. **Certifications**: Pursue relevant certifications and attend workshops.
      iii. **Experience**: Gain hands-on experience through internships, co-ops, and project-based learning.
      iv. **Continuing Learning**: Stay updated with the latest advancements by reading journals, attending webinars, and participating in professional development courses.

2. **Problem-Solving Skills**
   a. **Attributes**
      i. Ability to identify, analyse, and solve complex problems.
      ii. Creative and critical thinking.
      iii. Analytical skills to evaluate solutions and make decisions.
   b. **Development**
      i. **Practical Exercises**: Engage in real-world projects and case studies that challenge problem-solving abilities.
      ii. **Mentorship**: Learn from experienced engineers and mentors who can provide guidance and insights.
      iii. **Simulations and Challenges**: Participate in simulations, competitions, and hackathons.

3. **Communication Abilities**

   a. **Attributes**

      i. Effective verbal and written communication.

      ii. Ability to explain technical concepts to non-technical stakeholders.

      iii. Strong presentation and documentation skills.

   b. **Development**

      i. **Technical Writing Courses**: Take courses focused on technical writing and documentation.

      ii. **Public Speaking**: Practice public speaking and presenting technical information.

      iii. **Collaborative Projects**: Work in teams to improve communication and interpersonal skills.

4. **Ethical Behaviour**

   a. **Attributes**

      i. Strong understanding of professional and ethical standards.

      ii. Integrity and honesty in professional conduct.

      iii. Commitment to public safety and welfare.

   b. **Development**

      i. **Ethics Education**: Enrol in courses on engineering ethics and professional standards.

      ii. **Case Studies**: Study real-world cases involving ethical dilemmas in engineering.

      iii. **Professional Organisations**: Join organisations that emphasise ethical behaviour and provide resources and training on ethics.

5. **Teamwork and Collaboration**

   a. **Attributes**

      i. Ability to work effectively in multidisciplinary teams.

      ii. Respect for diverse perspectives and contributions.

      iii. Strong interpersonal skills.

   b. **Development**

      i. **Group Projects**: Participate in team-based projects and collaborative assignments.

      ii. **Team-building Activities**: Engage in activities that promote teamwork and cooperation.

      iii. **Feedback**: Seek and provide feedback to improve teamwork skills.

6. **Adaptability and Lifelong Learning**

   a. **Attributes**

      i. Openness to change and new ideas.

ii. Willingness to learn and adapt to new technologies and methodologies.

iii. Resilience in the face of challenges and setbacks.

b. Development

i. **Learning Mindset**: Foster a growth mindset and remain curious and open to new experiences.

ii. **Professional Development**: Regularly engage in professional development activities, such as attending seminars and taking online courses.

iii. **Exposure to Diverse Roles**: Take on various roles and responsibilities to build adaptability and resilience.

7. Attention to Detail

a. Attributes

i. Thoroughness in completing tasks.

ii. Precision and accuracy in work.

iii. Vigilance in identifying and correcting errors.

b. Development

i. **Quality Control**: Participate in quality control and assurance activities.

ii. **Practice**: Regularly practice detailed work and double-checking outputs.

iii. **Tools and Techniques**: Use tools and techniques that enhance precision and accuracy.

8. Innovation and Creativity

a. Attributes

i. Ability to think outside the box.

ii. Willingness to explore unconventional solutions.

iii. Openness to experimenting with new ideas and technologies.

b. Development

i. **Creative Workshops**: Attend workshops and courses that encourage creative thinking and innovation.

ii. **Cross-Disciplinary Projects**: Engage in projects that involve multiple disciplines to gain diverse perspectives.

iii. **Brainstorming Sessions**: Participate in brainstorming sessions and innovation challenges.

9. Project Management

a. Attributes

i. Ability to plan, execute, and oversee projects effectively.

ii. Strong organisational and time management skills.

iii. Capability to manage resources and meet deadlines.

b. Development

i. **Project Management Courses**: Enrol in courses on project management methodologies and tools.

ii. **Practical Experience**: Lead or participate in projects to gain hands-on experience.

iii. **Certification**: Obtain certifications like PMP (Project Management Professional).

10. Leadership

a. Attributes

i. Ability to inspire and motivate team members.

ii. Strong decision-making and conflict-resolution skills.

iii. Visionary thinking and strategic planning.

b. Development

i. **Leadership Training**: Attend leadership development programs and workshops.

ii. **Mentoring and Coaching**: Seek opportunities for mentorship and coaching.

iii. **Leadership Roles**: Take on leadership roles in projects, teams, or professional organisations.

Learning Task

1. Discuss with learners and help them appreciate some desired attributes of an engineer
2. Learners think, pair and share their views on how engineers can develop their leadership skills
3. Have learners work in groups to discuss a scenario where effective communication was crucial for an engineer.
4. Learners think, pair and share their views on how engineers can demonstrate their commitment to continuous learning
5. Have learners work in groups to discuss why ethical behaviour important for engineers

Pedagogical Exemplars

Managing Talk for Learning

1. Individually, learners describe the desired characteristics of an engineer, embracing tolerance and empathy amongst each other.
2. In pairs, learners discuss how engineers could instil certain desired values in themselves.
3. Learners share their thoughts with the whole class. Encourage learners to share their findings with each other to promote collaborative learning. Let advanced learners find more complex examples relating to each concept.
4. Use webbing to summarise their views.

Key Assessment

Level 1 Recall

1. List five desired attributes of an engineer.
2. Name the attribute that relates to an engineer's ability to generate new ideas and solutions.
3. Which attribute of an engineer involves the ability to work effectively in a team?
4. What is the importance of analytical skills for engineers?

Level 2 Skills of conceptual understanding

1. Explain how technical competence contributes to an engineer's effectiveness.
2. How do communication skills benefit engineers in their professional practice?
3. How can engineers stay updated with the latest developments in their field to maintain their technical competence?
4. How can engineers develop their problem-solving abilities?

Level 3 Strategic Reasoning

1. Discuss the role of teamwork in engineering projects and how engineers can enhance their teamwork skills.
2. Provide examples of ethical dilemmas engineers might face and how professionalism and ethics play a role in resolving them.
3. Outline a plan for an engineer to improve their communication skills.
4. Describe a situation where creativity and innovation could lead to a breakthrough in engineering.
5. Explain the importance of self-reflection in the development of an engineer's attributes.
6. Describe a scenario where an engineer's analytical skills are crucial to the success of a project.
7. Discuss the impact of continuous learning and development on an engineer's career growth and attribute development.
8. Research on the desired attributes of an engineer, explain how those attributes could be developed and make presentations to the whole class.

Hint

- The recommended mode of assessment for week 8 is **group research.** Use level 3 question 8 as sample question for the group research.
- Remind learners to submit their group project in week 9.

WEEK 9: UNPROFESSIONAL BEHAVIOUR

Learning Indicator: *Describe the consequences of unprofessional behaviour*

FOCAL AREA 1: CONSEQUENCES OF UNPROFESSIONAL BEHAVIOUR

Unprofessional behaviour in engineering can have serious and far-reaching consequences, impacting individuals, organisations, projects, and society as a whole. Here are some key consequences:

1. **Safety Risks**
   a. **Public Safety**: Unprofessional behaviour, such as negligence or cutting corners, can lead to design flaws or failures in engineering projects, posing significant risks to public safety. This can result in accidents, injuries, or fatalities.
   b. **Environmental Impact**: Poor adherence to safety and environmental standards can lead to environmental damage, such as pollution, resource depletion, and ecological harm.
2. **Legal and Regulatory Consequences**
   a. **Legal Liability**: Engineers and their employers may face legal action, including lawsuits, fines, and penalties, for failing to comply with laws, regulations, and industry standards.
   b. **Loss of Licensure**: Engineers can lose their professional licence and certifications if found guilty of unethical or unprofessional conduct, severely affecting their careers.
3. **Financial Losses**
   a. **Project Failures**: Unprofessional behaviour can lead to project delays, cost overruns, and failures, resulting in significant financial losses for clients and employers.
   b. **Reputation Damage**: Organisations known for unprofessional conduct may lose business opportunities and clients, leading to reduced revenue and profitability.
4. **Reputation and Trust**
   a. **Loss of Trust**: Unethical or unprofessional behaviour erodes trust among clients, colleagues, and the public, damaging the reputation of the individual engineer and their organisation.
   b. **Brand Damage**: Companies associated with unprofessional conduct can suffer brand damage, making it difficult to attract top talent, secure contracts, and maintain customer loyalty.
5. **Impact on Team and Workplace**
   a. **Decreased Morale**: Unprofessional behaviour, such as poor communication, lack of respect, or unethical actions, can lead to decreased morale and job satisfaction among team members.

b. **Increased Turnover**: A toxic work environment resulting from unprofessional conduct can result in higher employee turnover, leading to increased recruitment and training costs.

6. **Ethical and Social Implications**

   a. **Erosion of Ethical Standards**: Widespread unprofessional behaviour can erode ethical standards within the profession, leading to a culture where unethical practices become normalised.

   b. **Negative Social Impact**: Engineers hold a significant responsibility to society. Unprofessional behaviour can undermine the social and ethical responsibilities of the engineering profession, affecting societal welfare and progress.

7. **Personal Consequences**

   a. **Career Damage**: Engineers found engaging in unprofessional behaviour can face career setbacks, including demotion, job loss, and difficulty finding new employment.

   b. **Personal Reputation**: Individual engineers can suffer long-term damage to their personal and professional reputation, making it challenging to rebuild trust and credibility.

Examples of Unprofessional Behaviour and Consequences

a. **Negligence**: An engineer neglecting safety standards in construction projects can lead to structural failures, resulting in legal action and loss of licensure.

b. **Fraud**: Falsifying test results or project data can result in severe legal penalties, project failures, and long-term damage to professional credibility.

c. **Conflict of Interest**: Failing to disclose a conflict of interest can compromise project integrity and lead to loss of client trust and legal repercussions.

d. **Discrimination**: Engaging in discriminatory practices can lead to legal consequences, loss of team cohesion, and damage to the organisation's reputation.

Learning Task

1. Have learners work in groups to discuss unprofessional behaviour
2. Learners think, pair and share their views on some examples of unprofessional behaviour in an engineering context.
3. Discuss with learners and help them appreciate why maintaining a professional demeanour is important in engineering practice.
4. Learners think, pair and share their views on a scenario where unprofessional behaviour led to project delays or failures.
5. Discuss with learners and help them appreciate how unprofessional behaviour can affect the safety of engineering projects
6. Have learners work in groups to discuss the impact of unprofessional behaviour on the morale of a project team.

Pedagogical Exemplars

Managing Talk for Learning

1. In small groups, learners discuss and share thoughts on the consequences of unprofessional behaviour considering individual, organisational, and national dimensions. Encourage all learners to contribute to the discussion while ensuring that a few learners do not dominate the discussion session. Develop communication and discussion skills to facilitate learning.
2. Groups add to what others have said in a polite manner.
3. Encourage learners to tolerate each other.

Key Assessment

Level 1 Recall

1. List 5 ways an unprofessional behaviour affect the reputation of an engineer
2. Name one consequence of unprofessional behaviour in a team setting.
3. List 5 ways an unprofessional behaviour impact client relationships

Level 2 Skills of conceptual understanding

1. Outline steps that can be taken to prevent unprofessional behaviour in the workplace.
2. How can unprofessional behaviour affect an engineer's career advancement opportunities?
3. Explain how effective communication can help mitigate unprofessional behaviour.

Level 3 Strategic Reasoning

1. How can unprofessional behaviour affect an engineer's career advancement opportunities?
2. Describe the role of professional codes of conduct in discouraging unprofessional behaviour.
3. Discuss the responsibility of senior engineers in addressing unprofessional behaviour among their team members.
4. How can continuing education and professional development help reduce instances of unprofessional behaviour in the engineering field?

Hint

The recommended mode of assessment for week 9 is **class exercise.** Use level 3 question 1 as sample question for the class exercise.

SECTION 3 REVIEW

1. Can learners explain the importance of integrity and honesty in engineering practice?
2. Can learners define professionalism in engineering and provide an example of professional behaviour.

3. Would learners be able to describe the role of ethical behaviour in engineering and its impact on public trust?
4. Can learners explain the importance of teamwork and collaboration in maintaining professionalism in engineering?
5. Would learners be able to describe how professional behaviour can impact the success of projects?
6. Would learners be able to discuss the role of professional behaviour in building trust with clients and colleagues?
7. Can learners explain how professional behaviour help individuals achieve their career goals?

Additional Reading

1. The Ethical Engineer, available at Https://ethicalengineer.ttu.edu/articles/engineering-ethics-and-its-impact-on-society, [accessed on 10th July 2024].	
2. D. L. Evans, G. C. Beakley, P. E. Crouch, G. T. Yamaguchi, Attributes of Engineering Graduates and Their Impact on Curriculum Design, *Journal of Engineering Education*, https://doi.org/10.1002/j.2168-9830.1993.tb01075.x, October 1993	

APPENDIX C: FIRST MID-SEMESTER EXAMINATION

Structure of Mid-semester Examinations: 15 multiple choice questions (MCQs) and three (3) essay questions covering focal areas weeks 1-5 for first semester as in the table of specifications.

a. Paper 1: 15 MCQs.

b. Paper 2: PART A and PART B

i. Part A: 1 compulsory question

ii. Part B: 2 questions.

Materials Needed: Printer, A4 sheets, etc. **Duration:** One Hour

Marking Scheme/Rubrics

i. MCQs: 1 mark for each option. Total marks: 15 marks

ii. Essay type question: 5 marks for Part A and 10 marks for Part B (5 marks per question)

Total marks: 30 marks

How to administer assessment task

a) Preparation: Inform learners about the structure of examination including the number of questions, duration of the examinations and scoring rubrics, etc.

b) State clear instructions on the paper such as how to select the option, etc.

c) Examination day: Ensure a controlled environment to avoid cheating. Learners sit independently in well supervised, calm atmosphere; each learner should be given a printed hard copy of the question papers. e-Assessment can also be used if available, etc.

Table of Specification for Mid-Semester Examination

The specification for the number of questions for each week are indicated in the table below

Content /week		DoK (Number of questions)			
		Level 1	Level 2	Level 3	Total
1. Systematic investigation and its relevance in engineering practice	Objectives	1	2		3
	Essay	-	-	-	
2. Processes for systematic investigation	Objectives	1	1	1	4
	Essay	-	1	-	
3. Risk assessment and its relevance	Objectives	1	1	1	4
	Essay	-	-	1	

4. Procedure for risk assessment and control measures for various hazards	*Objectives*	*1*	*1*	*1*	*4*
	Essay	*1*	*-*	*-*	
5. Risk assessment matrix	*Objectives*	*-*	*2*	*1*	*3*
	Essay	*-*	*-*	*-*	
Total		*5/18 x 100 =27.8%*	*8/18 x100= 44.4%*	*5/18 x100 = 27.8%*	*18/18 x 100=100%*

Feedback

After marking, discuss the questions with learners, appreciate those who did well and encourage those who need improvement, etc.

The marking scheme/rubrics for scoring the Drama task

	4 marks	*3 marks*	*2 marks*	*1 mark*
Content relevance	*With four ethical behaviours exhibited such as integrity and honesty, accountability and responsibility, respect and fairness, confidentiality and privacy, communication and collaboration, etc.*	*With three ethical behaviours exhibited such as integrity and honesty, accountability and responsibility, respect and fairness, confidentiality and privacy, communication and collaboration, etc.*	*With two ethical behaviours exhibited such as integrity and honesty, accountability and responsibility, respect and fairness, confidentiality and privacy, communication and collaboration, etc.*	*With one ethical behaviour exhibited such as integrity and honesty, accountability and responsibility, respect and fairness, confidentiality and privacy, communication and collaboration, etc.*
Acting and Delivery	*Showing four of acting skills such as Body language, movement to enhance storytelling, emotional expression, timing*	*Showing three of acting skills such as Body language, movement to enhance storytelling, emotional expression, timing*	*Showing two of acting skills such as Body language, movement to enhance storytelling, emotional expression, timing*	*Showing one of acting skill such as Body language, movement to enhance storytelling, emotional expression, timing*
Communication	*Showing four of the skills e.g. Audible voice, Keeping eye contact Pay attention to audience Engaging the audience with interaction Use of gesture*	*Showing three of the skills e.g. Audible voice, Keeping eye contact Pay attention to audience Engaging the audience with interaction Use of gesture*	*Showing two of the skills e.g. Audible voice, Keeping eye contact Pay attention to audience Engaging the audience with interaction Use of gesture*	*Showing one of the skills e.g. Audible voice, Keeping eye contact Pay attention to audience Engaging the audience with interaction Use of gesture*

Creativity	*Showing four skills of originality, imagination, flexibility, curiosity, etc.*	*Showing three skills of originality, imagination, flexibility, curiosity, etc.*	*Showing two skills of originality, imagination, flexibility, curiosity, etc.*	*Showing one skill of originality, imagination, flexibility, curiosity, etc.*
Stage performance	*Showing four skills of acting and characterisation, dialogue delivery, facial expressions, costumes, and makeup*	*Showing three skills of acting and characterisation, dialogue delivery, facial expressions, costumes, and makeup*	*Showing two skills of acting and characterisation, dialogue delivery, facial expressions, costumes, and makeup*	*Showing one skill of acting and characterisation, dialogue delivery, facial expressions, costumes, and makeup*

Total = 20 marks

The marking scheme/rubrics for scoring the Group Research task

Desired attributes of an engineer (Technical Proficiency, Problem Solving, Communication abilities, Ethical behaviour, etc.)	**4 marks**	**3 marks**	**2 marks**	**1 mark**
	Four desired attributes of an engineer	Three desired attributes of an engineer	Two desired attributes of an engineer	One attribute of an engineer
Explanation of the attributes	Four explanations of attributes	Three explanations of attributes	Two explanations of attributes	One explanation of attributes
Development of attributes	Four ways of developing attributes	Three ways of developing attributes	Two ways of developing attributes	One way of developing attributes
Group collaboration	Four members actively involved	Three members actively involved	Two members actively involved	One member actively involved
Presentation Skills	Four skills of Content preparation, structure and organisation, clarity and simplicity, delivery techniques	Three skills of Content preparation, structure and organisation, clarity and simplicity, delivery techniques	Two skills of Content preparation, structure and organisation, clarity and simplicity, delivery techniques	One skill of Content preparation, structure and organisation, clarity and simplicity, delivery techniques
Visual Aids	Showing four skills of slides, videos, graphs, handling technical difficulties to support delivery.	Showing three skills of slides, videos, graphs, handling technical difficulties to support delivery.	Showing two skills of slides, videos, graphs, handling technical difficulties to support delivery.	Showing one skill of slides, videos, graphs, handling technical difficulties to support delivery.

Total – 24 marks

SECTION 4: ELECTRICAL AND ELECTRONIC CIRCUIT

Strand: Energy Systems

Sub-Strand: Circuit and Machines

Learning Outcomes

1. *Explain the use of basic analogue electronic circuit components*
2. *Apply the design process to simple electronic circuits*

Content Standard: Develop an understanding of the design and construction processes for basic analogue electronic circuits

INTRODUCTION AND SECTION SUMMARY

In this section, learners will be introduced to analogue electronic circuits which consist of different fundamental components, each having distinct functions that collectively determine the circuit's behaviour. Learners will understand how a resistor affects the current and voltage in a circuit. Learners will understand the role and indispensability of analogue electronic circuits in modern electronics. Designing electrical circuits requires a comprehensive grasp of the functions and properties of different electronic components. CAD tools are often employed in the design and analysis of analogue electronic circuits which find application in everyday consumer electronics as well as specialised industrial and medical equipment. These analogue electronic circuits are essential for processing real-world signals and ensuring the proper functioning of a wide range of devices and systems. The knowledge acquired by learners will help them to be able to design a power supply circuit, an astable multivibrator circuit and more. The lessons in this section equip learners to demonstrate general competence in designing simple analogue electronic circuits.

The weeks covered by the section are:

Week 10: Functions of the basic components of analogue electronic circuits

Week 11: The use of CAD tools for the design and analysis of simple analogue electronic circuits

SUMMARY OF PEDAGOGICAL EXEMPLARS

This section outlines how Initiating Talk for Learning, Experiential Learning, Problem-based- and Collaborative-Learning can be used to support learning. Facilitators can put learners in different task groups, then each group researches the functions of a number of basic components of analogue electronic circuits. Learners share findings with the class and take comments and criticisms in a tolerant manner. Learners can watch videos on the uses of basic analogue electronic circuit components and share observations with the whole class. Guide learners to design a power supply, an astable multivibrator circuit or light activated switch if materials are available. This will help learners build their competence in design and curiosity. Learners can work in groups to design the circuits if materials are not enough for individual designs. Guide Learners to practically use CAD tools (e.g., Proteus software) to design and analyse simple analogue circuits. In mixed ability groupings, learners search online for basic analogue electronic circuits to simulate and analyse circuits which can be a problem-based learning. Learners can build and test the circuits they had simulated. Other groups observe and comment.

ASSESSMENT SUMMARY

It is crucial to analyse various assessment methods to provide all types of learners with the opportunity to showcase their understanding of the key concepts in the section. In mixed ability grouping, design power supply, astable multivibrator circuits and simple water level indicator circuits, each group makes a presentation in a written or oral form in which marks will be awarded for formative assessment. Learners search online for basic analogue electronic circuits to simulate and analyse the results. Learners can present their findings in the form of written or oral statement which can be used for formative assessment. Additionally, learners can be motivated to design their own power supply circuit and provide a presentation in written, oral, or PowerPoint format during class. This activity can be included as part of the learners' term project.

WEEK 10: FUNCTIONS OF THE BASIC COMPONENTS OF ANALOGUE ELECTRONIC CIRCUITS

Learning Indicators

1. *Explain the functions of the basic components of analogue electronic circuits*
2. *Apply knowledge of electronic components in designing electronic circuits*

FOCAL AREA 1: FUNCTIONS OF BASIC ELECTRONIC COMPONENTS

Analogue electronic circuits are composed of various basic components, each with specific functions that contribute to the overall behaviour of the circuit. Here's an overview of some common components and their functions:

1. **Resistors**
   a. **Function:** Resistors limit the flow of electric current and divide voltage. They are used to control the voltage and current in a circuit.
   b. **Applications**: Voltage dividers, current limiting, biasing circuits.
   c. **Behaviour**: Resistors follow Ohm's Law (V = IR). They dissipate power as heat and their resistance value determines the amount of current flowing through a circuit for a given voltage.

2. **Capacitors**
   a. **Function:** Capacitors store and release electrical energy. They can filter out signals, block direct current (DC) while allowing alternating current (AC) to pass, and smooth out fluctuations in power supply.
   b. **Application:** Filtering in power supplies, timing circuits, coupling and decoupling signals.
   c. **Behaviour**: Capacitors store and release energy in the form of an electric field. They block DC and allow AC signals to pass. The capacitance value determines how much charge it can store. Since the impedance (reactance) of a capacitor is inversely proportional to the frequency, a capacitor will present an open-circuit (infinite impedance) to a dc (frequency, f=0), a pass to low frequency (e.g. 50 Hz) and a short-circuit (zero impedance) to very high frequency (e.g. 100 GHz).

3. **Inductors**
   a. **Function:** Inductors store energy in a magnetic field when electric current flows through them. They oppose changes in current and are used to filter signals and store energy in power supplies.
   b. **Application:** Chokes in power supplies, filters in audio and radio frequency applications.

c. **Behaviour**: Inductors store energy in a magnetic field and resist changes in current. They pass DC and block high-frequency AC signals. The inductance value affects how much energy it can store and its reactance at different frequencies. Since the impedance (reactance) of an inductor is directly proportional to the frequency, an inductor will present a short-circuit (zero impedance) to a dc (frequency, f=0), a pass to low frequency (e.g. 50 Hz) and an open-circuit (infinite impedance) to very high frequency (e.g. 100 GHz).

4. **Diodes**
   a. **Function:** Diodes allow current to flow in one direction only, acting as a one-way valve. They are used for rectification (converting AC to DC), protection, and signal demodulation.
   b. **Application:** Power rectifiers, signal demodulators, voltage protection.
   c. **Behaviour**: Diodes allow current to flow in one direction only, with a characteristic forward voltage drop (typically 0.7V for silicon diodes). They block reverse current until the breakdown voltage is reached.

5. **Transistors**
   a. **Function:** Transistors act as amplifiers or switches. They can amplify signals or turn the current on and off in a circuit.
   b. **Application:** Signal amplification, switching in digital circuits, voltage regulation.
   c. **Behaviour**: Transistors control current flow between the collector and emitter terminals based on the base current (BJT) or gate voltage (MOSFET). They can amplify signals or act as electronic switches.

6. **Operational Amplifiers (Op-Amps)**
   a. **Function:** Op-amps are used to amplify voltage signals. They have high input impedance and low output impedance, making them ideal for a variety of signal processing tasks.
   b. **Application:** Signal amplification, filtering, mathematical operations (addition, subtraction, integration, differentiation).
   c. **Behaviour**: Op-amps amplify the voltage difference between their input terminals. They have high input impedance and low output impedance, making them ideal for signal conditioning and processing.

7. **Transformers**
   a. **Function:** Transformers transfer electrical energy between circuits through electromagnetic induction. They can step up or step down voltage levels.
   b. **Application:** Power supply voltage conversion, impedance matching in communication systems.
   c. **Behaviour**: Transformers transfer energy between two or more windings through electromagnetic induction. The voltage ratio between the primary and secondary windings is determined by the turn's ratio. The turns ratio is the ratio of the number of turns in the primary (Np) to the number of turns in the secondary (Ns), Np/Ns. A step-up transformer increases voltage and decreases current, whereas a step-down transformer decreases voltage and increases current.

8. Voltage Regulators

a. **Function:** Voltage regulators maintain a constant output voltage regardless of variations in input voltage or load conditions. They are used to provide a stable power supply to circuits.

b. **Application:** Power supplies for electronic devices, and battery chargers.

c. **Behaviour:** A voltage regulator generates a fixed output voltage of a preset magnitude that remains constant regardless of changes to its input voltage or load conditions. There are two types of voltage regulators: linear and switching. Switching regulators use high-frequency switching components (typically transistors) to convert and regulate input voltage to a stable output voltage. A linear regulator compares the output voltage with a precise reference voltage and adjusts the pass device to maintain a constant output voltage.

9. Relays

a. **Function:** Relays are electromechanical switches that use a small current to control a larger current. They provide electrical isolation between control and output circuits.

b. **Application:** Switching high-power devices, protecting circuits, automating systems.

c. **Behaviour**: Relays use an electromagnet to mechanically switch contacts. They can control large currents with a small input signal, providing electrical isolation between control and output circuits. A relay as an electromagnetic switch opens and closes circuits electromechanically or electronically. A relatively small electric current that can turn on or off a much larger electric current operates a relay.

10. Light Emitting Diodes (LEDs)

a. **Function:** LEDs emit light when an electric current passes through them. They are used as indicators and for illumination.

b. **Application:** Status indicators, display panels, lighting.

c. **Behaviour:** The voltage drops across the LED when it is forward-biased and conducting current.

11. Photodiodes and Light Dependent Resistors (LDRs)

a. **Function:** Photodiodes and LDRs change their electrical properties in response to light. Photodiodes generate current when exposed to light, while LDRs change their resistance based on light intensity.

b. **Application:** Light sensing in automatic lighting systems, opto-isolators, and light meters.

c. **Behaviour**: Photodiodes generate current proportional to the light intensity they receive. They can be used in reverse bias mode to detect light.

Learning Task

1. Learners watch video on the distinction between analogue and digital electronic circuits from the link below

   https://youtu.be/G0iSEDyJKDo

2. Have learners work in groups to brainstorm on how a resistor affects the current and voltage in a circuit.
3. Moderate discussions on how a capacitor stores and releases energy in an analogue circuit.
4. Learners think, pair and share their views on what the function of an inductor is in an analogue circuit.
5. Work with learners to describe the role of capacitors in filtering and smoothing voltage fluctuations.
6. Guide Learners to design, build and test simple analogue electronic circuits such as *power supply, astable multivibrator or* simple water level indicator circuits.

Pedagogical Exemplars

Initiating Talk for Learning

1. In different task groups, each group researches the functions of basic components of analogue electronic circuits. Group learners based on their readiness, interests, and learning styles. For example, you could group learners who have a strong interest in electronics together, or group learners who learn best through hands-on activities together.
2. Learners share findings with the class and take comments and criticisms in a tolerant manner.

Experiential Learning

1. Learners apply various voltages to selected basic analogue electronic circuit components. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
2. Share their observations with the whole class. Allow learners to demonstrate their understanding in different ways. For example, some students could present their findings to the class, while others could create a report or a model.

Problem-Based Learning

1. Learners work in group to design various electronic circuits such as power supply, water level indicators, etc.
2. Share their experiences with the class. Encourage learners to simply and clearly articulate their points and listen to others during the discussions. Make room for non-vocal learners to contribute to the group discussions through writing.

Key Assessment

Level 1 Recall

1. What is an operational amplifier?
2. List the basic functions of an operational amplifier in analogue circuits.

Level 2 Skills of conceptual understanding

1. Explain the function and behaviour of a diode in an analogue circuit.
2. Describe how a diode can be used for rectification.
3. What is the role of a transistor in analogue circuits?
4. Explain how a transistor can be used as a switch and as an amplifier.
5. How does a transformer change voltage levels?
6. Describe how a transformer steps up or steps down voltage.

Level 3 Strategic Thinking

1. Explain why a transformer is required in four (4) identified analogue electronic circuit.

FOCAL AREA 2: APPLYING KNOWLEDGE IN DESIGNING ELECTRONIC CIRCUITS

Designing electronic circuits involves understanding the roles and characteristics of various electronic components and how they interact with each other. Here are the key steps and considerations in the design process:

Steps in Designing Electronic Circuits

1. **Define the Purpose and Requirements**
   a. Clearly outline what the circuit needs to do (e.g., amplify a signal, regulate voltage, switch loads).
   b. Determine the input and output specifications (voltage, current, frequency, etc.).

2. **Select Components**
   a. **Resistors**: Control current flow and divide voltages.
   b. **Capacitors**: Store and release energy, filter signals, and stabilise voltage.
   c. **Inductors**: Store energy in a magnetic field, filter signals, and provide impedance.
   d. **Diodes**: Allow current to flow in one direction only, used for rectification and protection.
   e. **Transistors**: Amplify or switch electronic signals.
   f. **Operational Amplifiers**: Used for amplification, filtering, and other analogue signal processing.
   g. **Microcontrollers (e.g., Arduino)**: Control digital operations and interface with sensors and actuators.

h. **Relays**: Electrically operated switches used for controlling high power devices.

i. **Sensors (e.g., LDRs, IR sensors)**: Detect environmental changes and convert them into electrical signals.

j. **Actuators (e.g., motors, LEDs)**: Convert electrical signals into physical actions.

3. **Create a Schematic Diagram**

   a. Use CAD tools (e.g., Proteus, LTspice, CircuitLab) to draw the circuit.

   b. Connect components logically according to their roles.

4. **Simulate the Circuit**

   a. Use simulation tools to test the circuit's behaviour.

   b. Identify and correct any issues (e.g., incorrect voltage levels, unexpected current flow).

5. **Prototype the Circuit**

   a. Build the circuit on a breadboard or a prototyping board.

   b. Test the physical prototype to ensure it meets the design specifications.

6. **Optimise and Finalise the Design**

   a. Make any necessary adjustments to improve performance.

   b. Design a PCB (Printed Circuit Board) if needed for the final product.

Practical Examples

Designing circuits for *power supply, astable multivibrators and* simple water level indicators involves understanding the specific requirements of each application and the behaviour of various electronic components. Here's an overview of how you can approach designing each of these circuits:

1. Power Supply Circuit

A simple regulated power supply can be designed using a transformer, bridge rectifier, filter capacitor, and voltage regulator IC.

Components:

a. Transformer (e.g., 230V to 12V step-down)

b. Bridge rectifier (e.g., 1N4007 diodes)

c. Filter capacitors (e.g., C1= 2200µF, C2=330nF, C3= 100nF)

d. Voltage regulator IC (e.g., 7809 for 9V output)

e. LEDs (optional for power indication)

Steps

1. **Step-Down Transformer:** Use the transformer to step down the AC mains voltage to a lower AC voltage (e.g., 9V or 12V AC).
2. **Bridge Rectifier:** Convert the AC voltage to pulsating DC using the bridge rectifier.
3. **Filter Capacitor:** Smooth the pulsating DC using the filter capacitor.

4. **Voltage Regulator:** Regulate the smoothed DC voltage to a stable output voltage using the voltage regulator IC.

Circuit Diagram

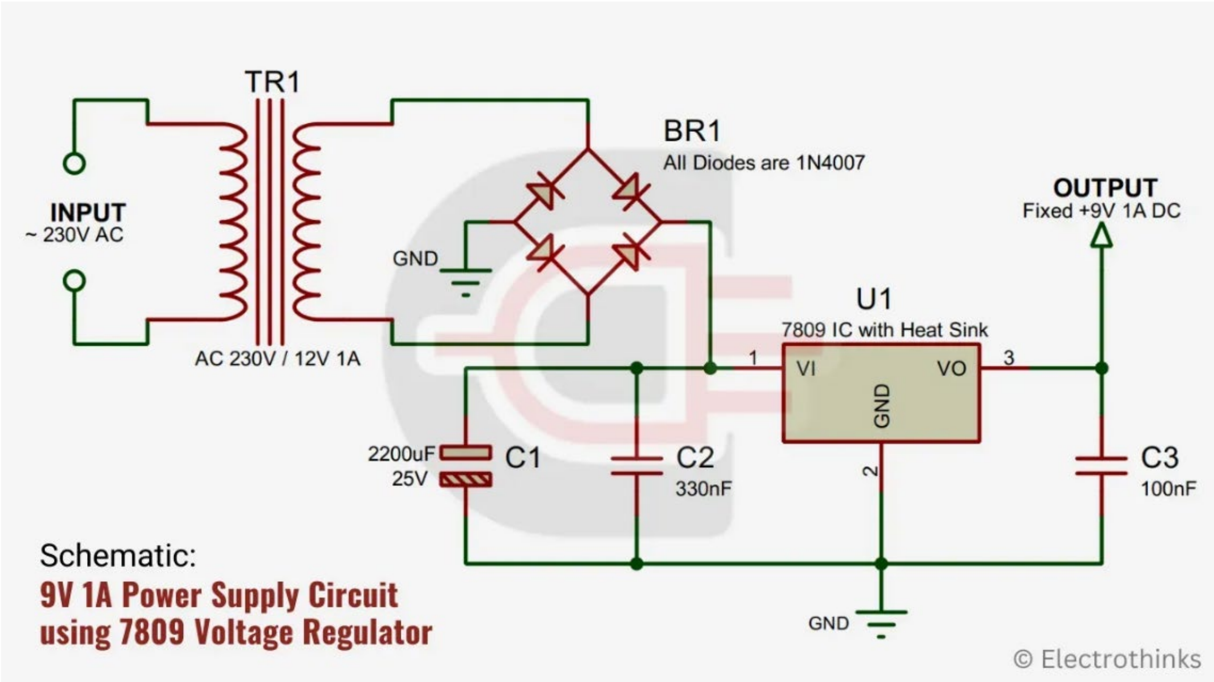

Figure 9: *A Circuit diagram of DC Power Supply*

2. Design an astable multivibrator

Designing an LED blinking circuit using transistors, such as the BC548B, involves creating an astable multivibrator circuit. This circuit uses two transistors to alternately switch the LED on and off, creating the blinking effect.

Components Needed

a. **Transistors**: 2 x BC548B NPN transistors
b. **LEDs**: 2 x LEDs (any colour)
c. **Resistors**: R1, R4: 22 kΩ

R2, R3: 1 kΩ

d. **Capacitors**: C1, C2: 100µF (electrolytic)
e. **Power Supply**: 9V to 12V battery
f. **Breadboard**: For prototyping the circuit
g. **Connecting Wires**: For making connections on the breadboard

Steps to Design the Circuit

Understand the Circuit

The astable multivibrator circuit has no stable state; it continuously oscillates between two states, causing the LEDs to blink alternately.

Circuit Diagram:

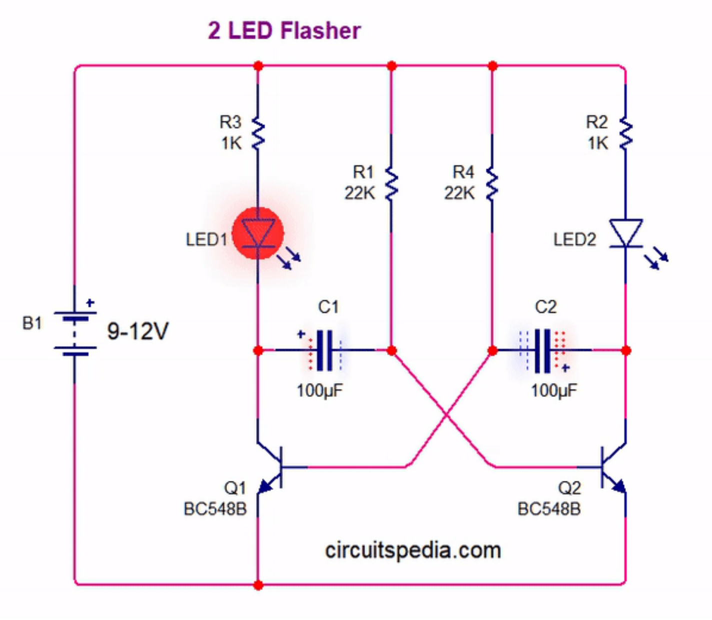

Figure 10: *A circuit diagram of an astable multivibrator*

Connections

a. Transistor Connections

i. Connect the collector of the first BC548B transistor (Q1) to the positive rail of the power supply through a 1 kΩ resistor (R3).

ii. Connect the emitter of Q1 to ground.

iii. Connect the collector of the second BC548B transistor (Q2) to the positive rail of the power supply through another 1 kΩ resistor (R2).

iv. Connect the emitter of Q2 to ground.

b. Base Connections

i. Connect the base of Q1 to the positive rail of the power supply through a 22 kΩ resistor (R4).

ii. Connect the base of Q2 to the positive rail of the power supply through another 22 kΩ resistor (R1).

c. Capacitor Connections

i. Connect a 100 µF capacitor (C2) between the collector of Q2 and the base of Q1, ensuring the correct polarity (negative terminal to the base of Q1).

ii. Connect another 100 µF capacitor (C1) between the collector of Q1 and the base of Q2, ensuring the correct polarity (negative terminal to the base of Q2).

d. Power Supply

i. Connect the positive terminal of the power supply to the positive rail of the breadboard.

ii. Connect the negative terminal of the power supply to the ground rail of the breadboard.

Testing the Circuit

Power Up: Connect the power supply to the circuit.

Observe the LEDs: The LEDs should start blinking alternately. The frequency of the blinking depends on the values of the capacitors C1 and C2, and the resistors R1 and R2.

Adjusting the Blink Rate

The frequency (f) of the blinking LEDs in an astable multivibrator circuit can be approximated using the formula: $f = 1.44 / (R_1 + 2R_2)C$

Where R is the resistance in ohms and C is the capacitance in farads. By changing the values of the resistors and capacitors, you can adjust the blink rate of the LEDs.

3. Simple Water Level Indicator

Components

a. Two probes (e.g., metal rods)

b. NPN Transistor (e.g., 2N2222)

c. Resistor (1 kΩ)

d. LED

e. Battery (9V)

f. Breadboard and jumper wires

Circuit Diagram

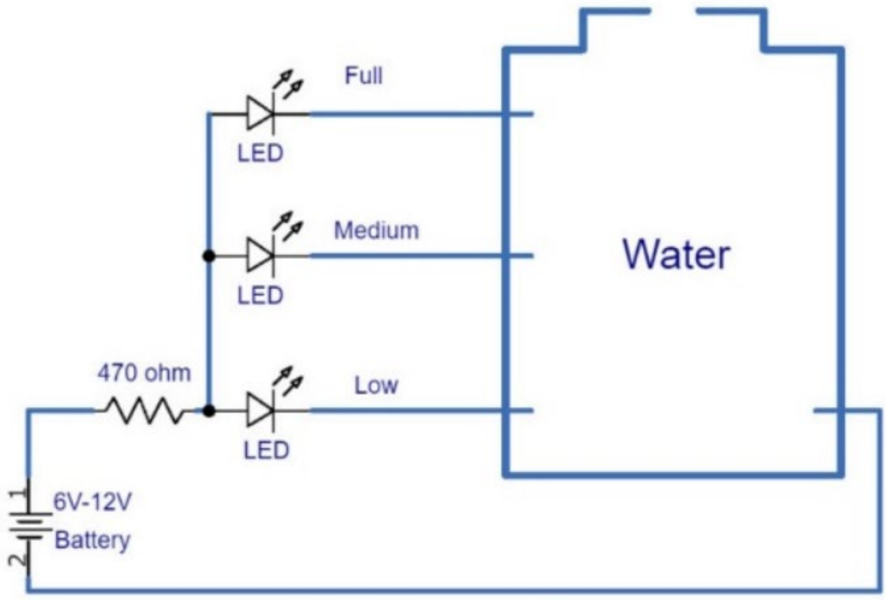

Figure 11: *A picture of the electrical circuit of water tank indicator circuit.*

How it Works

a. **Probes:** Placed at the desired water level.

b. **NPN Transistor:** Acts as a switch.

c. **Resistor (1 kΩ):** Limits current to the base of the transistor.

d. **LED:** Indicates water level.

Operation

1. When water connects the probes, a small current flows from Probe 1 to Probe 2.
2. This small current is enough to turn on the NPN transistor.
3. The transistor then allows current to flow from the collector to the emitter, lighting up the LED.

Building the Circuits

a. Place the transistor, resistor, and LED on the breadboard.
b. Connect the collector of the transistor to the positive terminal of the LED.
c. Connect the emitter of the transistor to the negative terminal of the battery.
d. Connect one probe to the base of the transistor through the resistor.
e. Connect the other probe to the positive terminal of the battery.
f. When water connects the probes, the LED will light up.

4. Motion-Activated Light

Components

- PIR (Passive Infrared) sensor
- Transistor (NPN)
- Resistor (10kΩ)
- Relay
- Diode (1N4007)
- LED
- Power source

Circuit Diagram

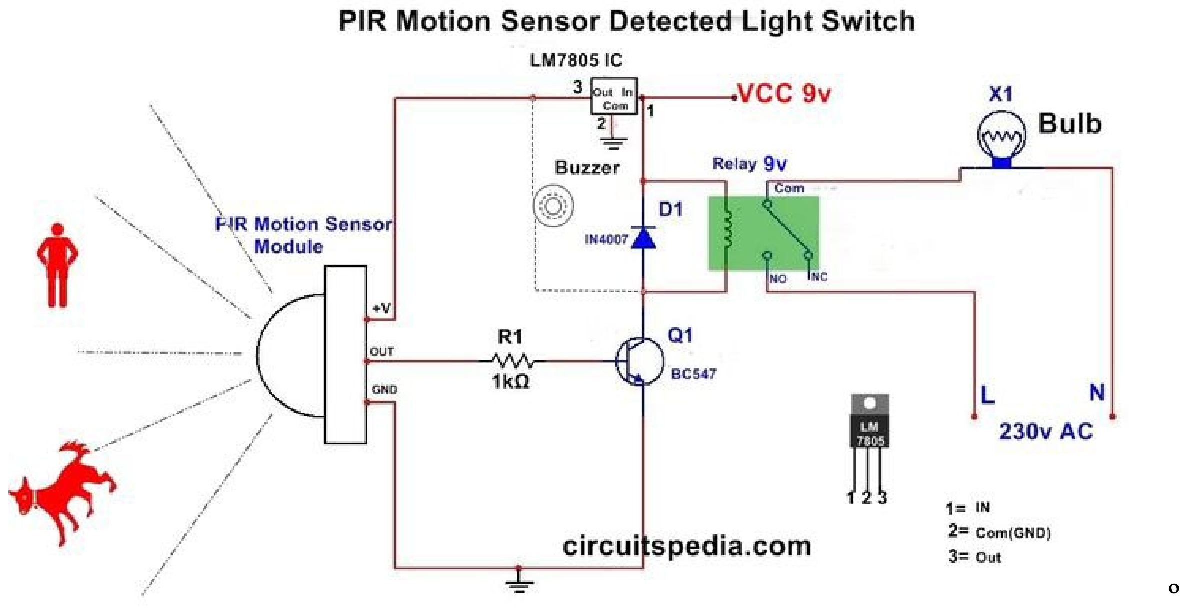

Figure 12: *A picture of the electrical circuit of motion sensor light switch*

- Connect the output pin of the PIR sensor to the base of the NPN transistor through a 1kΩ resistor.
- Connect the collector of the transistor to the negative terminal of the relay coil.
- Connect the emitter of the transistor to the ground.
- Connect the positive terminal of the relay coil to the power source.
- Place a diode across the relay coil to protect against back EMF.
- Connect the relay's NO contact to the LED and the power source.

Explanation

- When the PIR sensor detects motion, it outputs a high signal, allowing current to flow through the base of the transistor, turning it on.

This activates the relay, closing the NO contact and turning on the LED

Learning Task

1. Work with learners to explain how a bridge rectifier converts AC to DC.
2. Have learners work in groups to brainstorm on why a filter capacitor is used in a power supply circuit.
3. Guide learners to discuss the role the voltage regulator plays in a power supply circuit.
4. Learners think, pair and share their views on how to design a 9V power supply circuit using a transformer, bridge rectifier, filter capacitor, and voltage regulator.
5. Work with learners to explain what an astable multivibrator is, and how it differs from other types of multivibrators.
6. Work with learners to explain the effectiveness of using a water level indicator in preventing water wastage.

Pedagogical Exemplars

Experiential Learning

1. Learners test various electronic components and share their observations with the whole class. Group learners based on their readiness, interests, and learning styles. For example, you could group learners who have a strong interest in electrical science together, or group learners who learn best through hands-on activities together
2. The facilitator guides learners to design power supplies, astable multivibrators and water level indicator circuits. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.

Collaborative Learning

1. Put learners in groups to design power supply, astable multivibrators and water level indicator circuits
2. Support a group working at a slower pace whilst the rest of the class completes more activities

Key Assessment

Level 2 Skills of conceptual understanding

1. Describe the basic components required to build an astable multivibrator using transistors.
2. Explain the role of capacitors in an astable multivibrator circuit.
3. Explain how you can use an oscilloscope to measure the output waveform of an astable multivibrator.
4. How does the water level indicator determine the different levels of water in a tank?
5. Describe the role of an LED in a water level indicator circuit.
6. Why is it important to use resistors in a water level indicator circuit?
7. What would happen if there is no resistor connected to the LED in a water level indicator circuit?

Level 3 Strategic reasoning

1. How would you choose the resistor and capacitor values to achieve a specific frequency in an astable multivibrator?
2. Describe how you would test an astable multivibrator circuit to ensure it is working correctly.
3. Discuss the effect of changing the power supply voltage on the operation of an astable multivibrator circuit.
4. How would you connect multiple LEDs to indicate different water levels in a tank?

Level 4 Extended Reasoning

1. Design an astable multivibrator circuit that operates at a frequency of 1kHz. Provide the values of the resistors and capacitors used.
2. If one of the transistors in an astable multivibrator fails, how would you diagnose the issue and what steps would you take to troubleshoot and repair the circuit?
3. Propose a modification to a basic water level indicator circuit to integrate an advanced alarm system with multiple stages of alert (e.g., different alarms for different water levels). Develop a detailed implementation plan, including the rationale for the chosen alarm system, the integration process, and how the modifications will impact the circuit's overall functionality.
4. An experiment session should be carried out in the laboratory, consisting of two parts.
   a. For the first part, given an array of electronic components which they must identify and write their functions. (e.g., resistors, capacitors, regulators, diodes, transistors, LEDs), etc.
   b. For the second session, build simple circuits such as power supply circuits, water level indicator circuits, etc.

Hint

The recommended mode of assessment for week 10 is **experiment.** Use level 4 question 4 as sample question for the experiment.

WEEK 11: THE USE OF CAD TOOLS FOR THE DESIGN AND ANALYSIS OF SIMPLE ANALOGUE ELECTRONIC CIRCUITS

Learning Indicator: *Use CAD tools for the design and analysis of simple analogue electronic circuits*

FOCAL AREA 1: USING CAD TOOLS TO DESIGN AND ANALYSE ELECTRONIC CIRCUITS

Using CAD tools for the design and analysis of simple analogue electronic circuits involves several steps. Below is a guide to get you started with three popular CAD tools: Proteus, LTspice, and CircuitLab.

1. Proteus

Designing a Circuit in Proteus

a. **Launch Proteus**: Open the Proteus software on your computer.

b. **Create a New Project**: Select "New Project" and follow the wizard to set up your project.

c. **Schematic Capture**
   i. Go to the "Schematic Capture" mode.
   ii. Use the component library to find and place components like resistors, capacitors, transistors, etc., onto the schematic.
   iii. Connect the components using wires.

d. **Simulation Setup**
   i. Place a ground reference and power sources if needed.
   ii. Add probes or virtual instruments (oscilloscope, voltmeter) to measure circuit parameters.

e. **Run Simulation**: Click the "Run" button to start the simulation and observe the behaviour of your circuit.

Analysing the Circuit

a. **Monitor Outputs**: Use the virtual instruments to measure voltage, current, and other parameters.

b. **Adjust Parameters**: Modify component values and observe the changes in the circuit behaviour.

c. **Troubleshoot**: Identify and fix any issues in the circuit based on the simulation results.

2. LTspice

Designing a Circuit in LTspice

a. **Launch LTspice**: Open LTspice on your computer.

b. **Create a New Schematic**: Go to "File" > "New Schematic".

c. **Add Components**
   i. Use the "Component" button to place components on the schematic.
   ii. Connect components using wires.

d. **Set Up Simulation**
   i. Add voltage sources and ground.
   ii. Configure the type of analysis (transient, AC sweep, DC operating point) using the ".op" button.

e. **Run Simulation**: Click the "Run" button to start the simulation.

Analysing the Circuit

a. **View Results**: Use the waveform viewer to see the simulation results.

b. **Parameter Sweep**: Perform parameter sweeps to analyse how changes in component values affect the circuit.

c. **FFT Analysis**: Use FFT (Fast Fourier Transform) for frequency domain analysis if needed.

3. CircuitLab

Designing a Circuit in CircuitLab

a. **Access CircuitLab**: Open CircuitLab in your web browser (no download needed).

b. **Create a New Circuit**: Click on "New Circuit".

c. **Place Components**
   i. Use the component toolbar to drag and drop components onto the canvas.
   ii. Connect components with wires.

d. **Simulation Setup**
   i. Add power sources and ground.
   ii. Use the simulation menu to set up the type of analysis (DC, AC, transient).

Analysing the Circuit

a. **Run Simulation**: Click the "Simulate" button to run the analysis.

b. **Observe Outputs**: View the results in the plot window.

c. **Modify and Re-simulate**: Change component values and re-run the simulation to see the effects.

Tips for Effective Use of CAD Tools

a. **Learn the Interface**: Spend some time learning the interface and features of each tool.

b. **Component Libraries**: Make use of the extensive component libraries available in these tools.

c. **Documentation and Tutorials**: Refer to the official documentation and online tutorials for advanced features and tips.

d. **Save Regularly**: Regularly save your work to avoid data loss.

e. **Experiment**: Don't hesitate to experiment with different components and circuit configurations to deepen your understanding.

Examples: Use CAD tools to design and analyse the following circuits

1. D.C Power Supply

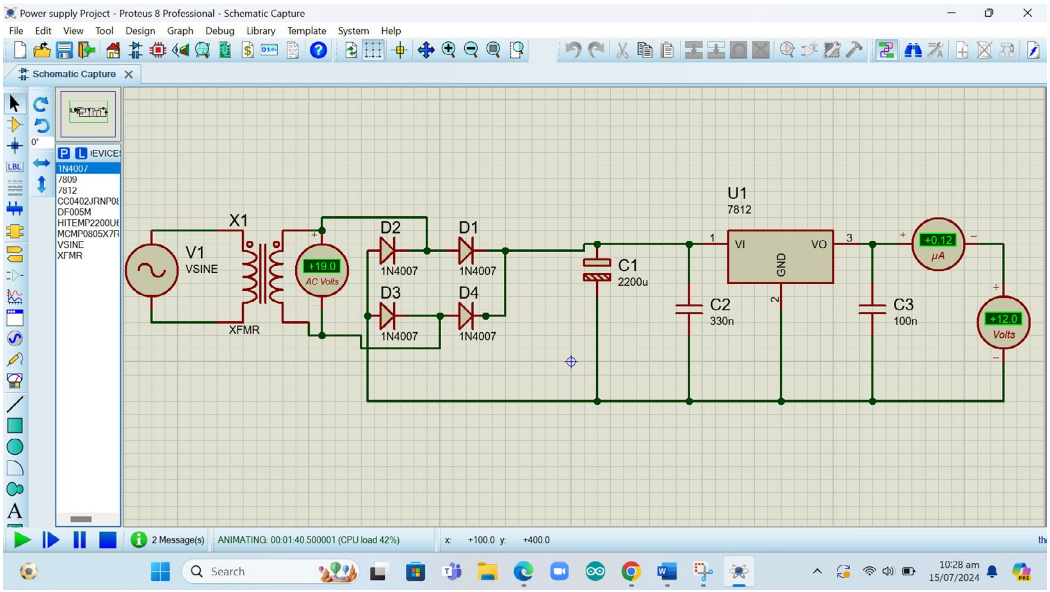

Figure 13: *A picture of D.C Power Supply simulation in Proteus*

2. Astable Multivibrator

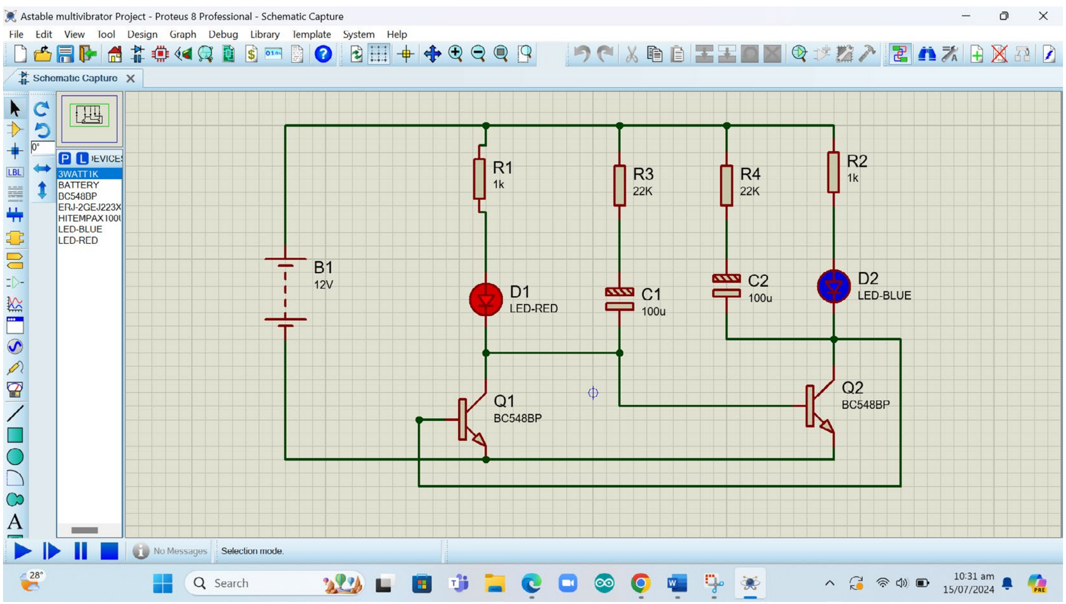

Figure 14: *A picture of An Astable Multivibrator simulation in Proteus*

3. Simple Water Level Indicator

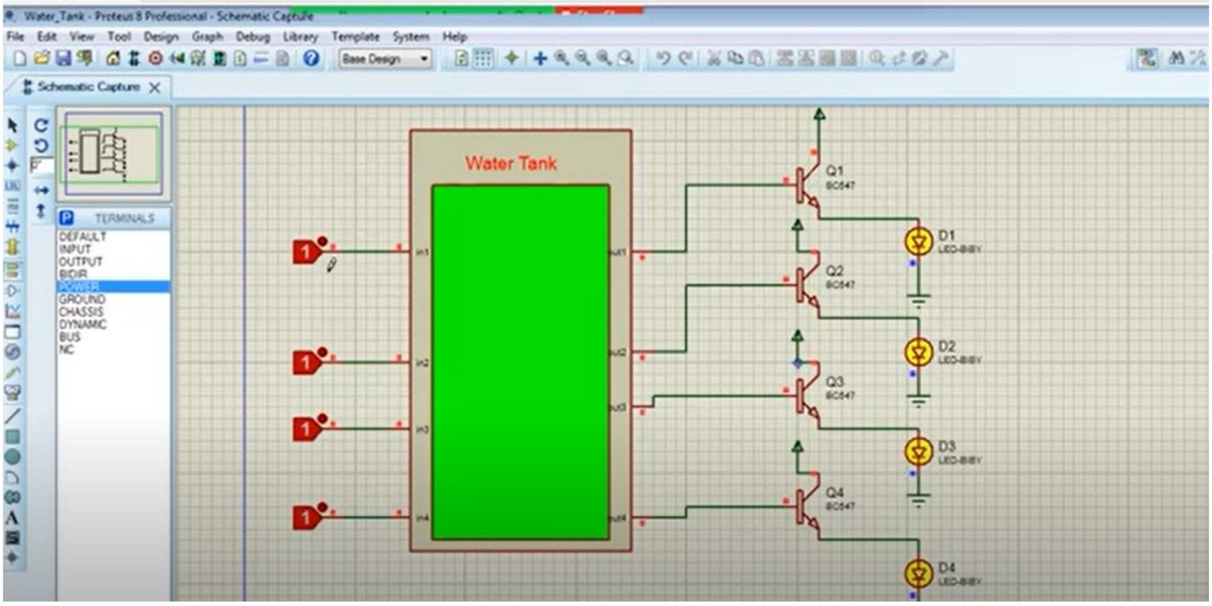

Figure 15: *A picture of Simple Water Level Indicator simulation in Proteus*

Learning Task

1. Learners watch video on proteus for beginners from the links below

a. https://youtu.be/Oo_2J2traQc?si=vllCdB0VH0pm7v3L	
b. https://youtu.be/tYDsZu7pW2U?si=NF5F03GWGM5Z-ERi	
c. https://youtu.be/TWcUqqos1Po?si=SjgP9bBgozYKNi9L	
d. https://youtu.be/0KsJfP74OKQ?si=sjbUYcCqRK6LnHY7	

2. Discuss with learners and help them appreciate the purpose of using CAD tools in electronic circuit design.
3. Work with learners to create a new project in Proteus for designing an analogue circuit
4. Guide learners to describe the steps to place and connect components in LTspice for a basic RC (resistor-capacitor) circuit.
5. Learners think, pair and share their view on how to simulate a circuit in CircuitLab to observe the voltage across a capacitor in an RC circuit.

Pedagogical Exemplars

Experiential Learning

1. At the computer lab, the facilitator explains to learners how to use CAD tools (e.g., Proteus software) to design and analyse simple analogue circuits.
2. The facilitator guides learners to design and simulate simple analogue circuits.
3. Support those working at a slower pace whilst the rest of the class completes more activities

Problem-based and collaborative Learning: In groups, learners search online for basic analogue electronic circuits to simulate and analyse.

Problem-based, Collaborative and Experiential Learning: At the workshop, learners build and test the circuits they had simulated. Support an individual or group working at a slower pace whilst the rest of the class completes more activities.

1. Other groups observe and comment. Encourage learners to share their findings with each other to promote collaborative learning. Let advanced learners find more complex examples relating to each concept.

Key Assessment

Level 1 Recall

1. What are CAD tools like Proteus and LTspice used for in electronic circuit design?
2. What is the first step to run a basic simulation in LTspice for a DC circuit?

Level 2 Skills of Conceptual Understanding

1. How can you use a CAD tool to observe the voltage across a resistor in a simple voltage divider circuit?
2. How would you change the value of a resistor in Proteus to see its effect on the circuit performance?

Level 3 Strategic Reasoning

1. If your circuit simulation in Proteus does not run, what are some basic checks you can perform to identify the issue?
2. Use CAD tools to design and analyse Power Supply circuit, Water Level Indicator.

Hint

The recommended mode of assessment for week 11 is **simulation.** Use level 3 question 2 as sample question for the simulation.

SECTION 4 REVIEW

1. Can learners explain how a resistor affects the current and voltage in a circuit?
2. Can learners explain how a capacitor stores and releases energy in an analogue circuit?
3. Would learners be able to appreciate the purpose of using CAD tools in electronic circuit design?
4. Can learners create a new project in Proteus for designing an analogue circuit?
5. Would learners be able to think, pair and share their view on how to simulate a circuit in CircuitLab to observe the voltage across a capacitor in an RC circuit?
6. Can Learners design, build and test simple analogue electronic circuits?

Additional Reading

1. All about circuits, [online] available at https://www.allaboutcircuits.com/textbook/direct-current/, [accessed on 11th July 2024]

Teaching/Learning Resources

1. Projector

2. Laptop

3. Assorted basic components of analogue electronic circuits and videos on the components of analogue electronic circuits

The marking scheme and rubrics for scoring the Experiment task

a)

	4 marks	3 marks	2 marks	1 mark
Component Identification	Identifies four components such as resistors, capacitors, transistors, diodes	Identifies three components such as resistors, capacitors, transistors, diodes	Identifies two components such as resistors, capacitors, transistors, diodes	Identifies one of these components such as resistors, capacitors, transistors, diodes

Function Description	Describe four functions of the components such as opposing charges, storing charges, amplifying signals, rectifier, etc.	Describe three functions of the components such as opposing charges, storing charges, amplifying signals, rectifier, etc.	Describe two functions of the components such as opposing charges, storing charges, amplifying signals, rectifier, etc.	Describe one function of the components such as opposing charges, storing charges, amplifying signals, rectifier, etc.
Practical Application	Explains four practical uses such as voltage divider, timing circuits, voltage protection	Explains three practical uses such as voltage divider, timing circuits, voltage protection	Explains two practical uses such as voltage divider, timing circuits, voltage protection	Explains one practical use such as voltage divider, timing circuits, voltage protection

Total - 12 marks

b)

	4 marks	*3 marks*	*2 marks*	*1 mark*
Circuit design	*Shows four skills such as problem definition, specification and requirements, schematic design, layout design*	*Shows three skills such as problem definition, specification and requirements, schematic design, layout design*	*Shows two skills such as problem definition, specification and requirements, schematic design, layout design*	*Shows one skill such as problem definition, specification and requirements, schematic design, layout design*
Component Assembly	*Shows four skills such as component placement, identifying components, securing components, testing during assembly.*	*Shows three skills such as component placement, identifying components, securing components, testing during assembly*	*Shows two skills such as component placement, identifying components, securing components, testing during assembly*	*Shows one skill such as component placement, identifying components, securing components, testing during assembly*
Functionality	*Shows four skills such as component functionality, circuit behaviour, reliability, and stability*	*Shows three skills such as component functionality, circuit behaviour, reliability, and stability*	*Shows two skills such as component functionality, circuit behaviour, reliability, and stability*	*Shows one skill such as component functionality, circuit behaviour, reliability, and stability*
Problem-solving skills	*Shows four skills such as analysing the circuit design, logical thinking, verification, and validation*	*Shows three skills such as analysing the circuit design, logical thinking, verification, and validation*	*Shows two skills such as analysing the circuit design, logical thinking, verification, and validation*	*Shows one skill such as analysing the circuit design, logical thinking, verification, and validation*

Total – 16 marks

The marking scheme and rubrics for scoring the Simulation task

	4 marks	3 marks	2 marks	1 mark
Use CAD tools to design and analyse electronic circuits using any of the CAD tools (Proteus, LT Spice and CircuitLab)	*Designing with four components values correctly assigned*	*Designing with three components values correctly assigned*	*Designing with two components values correctly assigned*	*Designing with one component value correctly assigned*
	Connects four measuring instruments correctly	*Connects three measuring instruments correctly*	*Connects two measuring instruments correctly*	*Connects one measuring instrument correctly*

Ability to simulate and read the circuit values (current and voltage) - (2 marks)

Total Mark = 10 marks

Strand: Energy Systems

Sub-Strand: Renewable Energy Systems

Learning Outcome: *Apply operating principles of Photovoltaic and Solar Thermal Systems to design a simple Photovoltaic and Solar Thermal Energy System.*

Content Standard: Demonstrate understanding of basic concepts in Photovoltaic and Solar Thermal Systems through the design of simple renewable energy systems.

Hint

- End of Semester Examination for the first semester is in Week 12. Refer to Appendix D for the Table of Specification to guide you to set the questions. Set questions to cover all the indicator covered.
- Give learners individual projects in week 13 that will be collected in week 23 after the presentation. See Appendix E at the end of this session for further information on the individual project.
- Remind learners to include copies of responses to the individual project in their portfolios.

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to the functions of the basic components of photovoltaic and solar thermal systems, operation and maintenance of simple photovoltaic and solar thermal systems and the design and installation of simple photovoltaic and solar thermal systems. Learners will understand that photovoltaic (PV) systems harness the energy from sunlight and convert it into electrical energy by utilising semiconductor materials. They will appreciate the role of the various components in the PV System, including capture of solar energy, transformation into usable electrical power, storage if required, and distribution to the desired electrical loads or back into the grid. Learners should understand the importance of consistent maintenance and prompt troubleshooting which are crucial for optimising the efficiency and reliability of solar energy system.

The weeks covered by the section are:

Week 12: Functions of the basic components of photovoltaic and solar thermal systems

Week 13: Operation and maintenance simple photovoltaic and solar thermal systems

Week 14: Design and install simple photovoltaic and solar thermal systems

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section, teachers may consider using Experiential Learning, Collaborative Learning, and Managing Talk for Learning. Through experiential learning, learners may watch videos of photovoltaic and solar thermal systems and identify their basic components. Learners may watch videos on the installation of the two systems and share their observations with the whole class. Learners can inspect basic components of photovoltaic and solar thermal systems and discuss their features. Through collaborative learning, put learners in mixed-ability groups to discuss the functions of the basic components of photovoltaic and solar thermal systems and share their findings with the whole class. Allow other groups to critique and add their views. Through managing talk for learning, moderate discussion, on how to operate and maintain photovoltaic and solar thermal systems. Finally, where components are available, support learners to build a simple PV system to power lights in a given location. Teacher may use webbing to summarise learners' views.

ASSESSMENT SUMMARY

Consider using all the assessment modes that encourage learners to express their understanding of the focal areas in this section. Teachers may allow learners to watch videos of photovoltaic and solar thermal systems and identify their basic components. Learners may present their findings orally or in written. Allow learners to watch videos on the installation of the two systems and share their observations with the whole class. Marks may be allocated which may be part of their formative assessment. Learners can inspect basic components of photovoltaic and solar thermal systems and discuss their features. Learners may present their findings orally or written. Put learners in mixed-ability groups, different groups to discuss the functions of the basic components of photovoltaic and solar thermal systems and share their finding with the whole class. This can be used for their formative assessment.

Refer to Teacher Assessment Manual and Toolkits (NaCCA, 2023) for more examples.

WEEK 12: FUNCTIONS OF THE BASIC COMPONENTS OF PHOTOVOLTAIC AND SOLAR THERMAL SYSTEMS

Learning Indicators

1. *Identify the basic components of photovoltaic and solar thermal systems*
2. *Explain the functions of the basic components of photovoltaic and solar thermal systems*

FOCAL AREA 1: BASIC COMPONENTS OF PHOTOVOLTAIC AND SOLAR SYSTEMS

Basic Components of Photovoltaic (PV) Systems

1. **Solar Panels (PV Modules)**: Convert sunlight directly into electricity using semiconductor materials.
2. **Inverters**: Convert the direct current (DC) output from the solar panels into alternating current (AC) used by most household appliances and the electrical grid.
3. **Mounting Systems**: Structures to mount the solar panels on rooftops or the ground.
4. **Charge Controllers**: Regulate the voltage and current coming from the solar panels to the batteries, preventing overcharging and prolonging battery life.
5. **Batteries**: Store excess energy generated by the solar panels for use when sunlight is not available.
6. **Combiner Boxes**: Combine the output of multiple solar strings into a single output for the inverter.
7. **Disconnect Switches**: Safety devices that allow for manual disconnection of the PV system from the grid or the load.
8. **Cabling and Wiring**: Conductors that connect the various components of the PV system.
9. **Monitoring Systems**: Track the performance of the solar power system, often providing data on energy production, system status, and alerts for maintenance.

Basic Components of Solar Thermal Systems

1. **Solar Collectors**: Absorb solar radiation and convert it into heat. Common types include flat-plate collectors and evacuated tube collectors.
2. **Heat Transfer Fluid**: Fluid that carries heat from the solar collectors to the storage tank or heat exchanger. Common fluids include water, glycol mixtures, or special thermal oils.
3. **Heat Exchangers**: Transfer heat from the heat transfer fluid to the water or air that will be used for heating.
4. **Storage Tanks**: Store the heated water or heat transfer fluid for later use.
5. **Pumps**: Circulate the heat transfer fluid between the solar collectors and the storage tank or heat exchanger.

6. **Controllers**: Manage the operation of the solar thermal system, including the pumps and valves, to optimise performance and ensure safety.
7. **Expansion Tanks**: Accommodate the expansion of the heat transfer fluid as it heats up and prevents pressure build-up in the system.
8. **Piping and Insulation**: Transport the heat transfer fluid between the components and minimise heat loss.
9. **Valves and Fittings**: Control the flow of fluids within the system and allow for maintenance and safety operations.
10. **Temperature Sensors and Gauges**: Monitor the temperatures of the heat transfer fluid, storage tanks, and other critical points in the system to ensure proper operation.
11. **Backup Heating Systems**: Provide additional heat when solar energy is insufficient to meet the demand, typically using electric or gas heaters.

Learning Task

1. Learners watch video on photovoltaic and solar thermal systems
   https://youtu.be/__63nFqe1__dc?si=Eb__uArKKFeezsSxh
2. In moderated discussions, guide learners to identify the primary function of a photovoltaic (PV) cell.
3. Discuss with learners and help them appreciate the main materials used in the construction of PV cells
4. Have learners work in groups to brainstorm the role of a solar charge controller in a PV system
5. Work with learners to discuss the main purpose of a solar thermal collector

Pedagogical Exemplars

Experiential Learning

1. Learners watch videos of photovoltaic and solar thermal systems and identify their basic components.
2. Learners inspect basic components of photovoltaic and solar thermal systems and discuss their features. Encourage learners to share their findings with each other to promote collaborative learning. Let advanced learners find more complex examples relating to each concept.

3. Further, learners watch videos on the installation of the two systems and share their observations with the whole class.
4. Support learners working at a slower pace whilst the rest completes more activities.
5. Guide Learners to assemble and build a simple photovoltaic system. Create a peer-to-peer mentoring system to help learners having difficulties receive help from colleagues

Key Assessment

Level 1 Recall

1. Name the component that is responsible for converting the DC electricity generated by PV panels into AC electricity.
2. Identify the component used to store the electricity generated by PV panels for later use.
3. Name the two primary types of solar thermal collectors.
4. What component is used to mount and orient PV panels?
5. Which device in a PV system ensures the panels operate at their maximum power point?
6. Identify the component used to store the heat collected in a solar thermal system.
7. What type of fluid is commonly used in solar thermal systems to transfer heat?

Level 2 Skills of conceptual understanding

1. Discuss the function of a combiner box in a PV system?
2. What is the role of a pump in a solar thermal system?

FOCAL AREA 2: FUNCTIONS OF PHOTOVOLTAIC AND SOLAR SYSTEMS COMPONENTS

Functions of Basic Components of Photovoltaic (PV) Systems

1. Solar Panels (PV Modules)

Function: Convert sunlight directly into electricity through the photovoltaic effect, where semiconductor materials generate a flow of electrons when exposed to sunlight.

2. Inverters

Function: Convert the direct current (DC) output from the solar panels into alternating current (AC), which is the standard form of electricity used by most household appliances and for grid distribution.

3. Mounting Systems

Function: Provide structural support for the solar panels, ensuring they are securely attached to rooftops or ground-based structures and positioned for optimal sunlight exposure.

4. **Charge Controllers**

Function: Regulate the voltage and current coming from the solar panels to the batteries, preventing overcharging and excessive discharging, thereby protecting and prolonging battery life.

5. **Batteries**

Function: Store excess energy generated by the solar panels during sunny periods, which can then be used when sunlight is not available, ensuring a consistent power supply.

6. **Combiner Boxes**

Function: Combine the electrical output from multiple solar panel strings into a single, manageable output that feeds into the inverter, simplifying wiring and enhancing system safety.

7. **Disconnect Switches**

Function: Allow for the manual disconnection of the PV system from the electrical grid or load for maintenance, safety, or emergency purposes, ensuring the safety of technicians and equipment.

8. **Cabling and Wiring**

Function: Conduct electricity between the various components of the PV system, ensuring efficient and safe transmission of power from the solar panels to the inverter, batteries, and the grid.

9. **Monitoring Systems**

Function: Track and report on the performance of the solar power system, providing data on energy production, system efficiency, and operational status. They help identify issues and optimise system performance.

Functions of Basic Components of Solar Thermal Systems

1. **Solar Collectors**

Function: Absorb solar radiation and convert it into heat. Flat-plate collectors and evacuated tube collectors are designed to maximise heat absorption and minimise heat loss, efficiently capturing solar energy.

2. **Heat Transfer Fluid**

Function: Circulate through the solar collectors to absorb heat and then transport this heat to the storage tank or heat exchanger. Common fluids include water, glycol mixtures, or specialised thermal oils.

3. **Heat Exchangers**

Function: Transfer heat from the heat transfer fluid to the water or air used in the heating system, enabling the efficient delivery of solar-generated heat to the end-use application.

4. **Storage Tanks**

Function: Store heated water or heat transfer fluid, allowing the system to provide hot water or heat even when there is no sunlight. This ensures a continuous supply of thermal energy.

5. **Pumps**

Function: Circulate the heat transfer fluid between the solar collectors and the storage tank or heat exchanger, maintaining a consistent flow and efficient heat transfer throughout the system.

6. **Controllers**

Function: Manage the operation of the solar thermal system, including the pumps and valves, to optimise performance, maximise energy capture, and ensure system safety. They adjust the flow of the heat transfer fluid based on temperature and system demand.

7. **Expansion Tanks**

Function: Accommodate the expansion of the heat transfer fluid as it heats up, preventing excessive pressure build-up in the system and ensuring safe and reliable operation.

8. **Piping and Insulation**

Function: Transport the heat transfer fluid between the components of the solar thermal system and minimise heat loss during transfer, enhancing overall system efficiency.

9. **Valves and Fittings**

Function: Control the flow of fluids within the system, allowing for isolation of components, regulation of fluid flow, and facilitating maintenance and safety operations.

10. **Temperature Sensors and Gauges**

Function: Monitor the temperatures of the heat transfer fluid, storage tanks, and other critical points in the system, ensuring proper operation and providing data for system control and optimisation.

11. **Backup Heating Systems**

Function: Provide additional heat when solar energy is insufficient to meet the demand, typically using electric or gas heaters to ensure a consistent and reliable supply of hot water or heat.

Learning Task

1. Facilitate the visit of learners to a PV system installation and interact with the operators; in the absence of that, have learners watch a video of the installations.
2. Discuss with learners what the function of a photovoltaic (PV) cell is.
3. Moderate discussions on the role of an inverter in a PV system.
4. Moderate discussions on the purpose of a solar charge controller in a PV system
5. Have learners work in groups to brainstorm on the purpose of a combiner box in a PV system.

Pedagogical Exemplars

Experiential Learning

1. Learners visit a PV and Solar Thermal installations or watch videos to understand the functions of the basic components of photovoltaic and solar thermal systems, as well as the installation of the two systems and share their observations.

2. Give clear instructions as learners watch the video.
3. Fine-tune learners' views and summarise their thoughts.
4. Support learners working at a slower pace whilst the rest of the class completes more activities

Collaborative Learning

1. In mixed-ability groups, different groups discuss the functions of the basic components of photovoltaic and solar thermal systems and share their finding with the whole class.
2. Other groups critique and add their views in a tolerant and respectful manner.
3. The teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently

Key Assessment

Level 2 Skills of conceptual understanding

1. Explain how photovoltaic (PV) cells convert sunlight into electricity.
2. Why is a solar charge controller essential for battery-based PV systems?
3. Explain the function of a storage tank in a solar thermal system
4. Describe the process by which solar thermal collectors capture and transfer solar energy.

Level 3 Strategic reasoning

1. Discuss the importance of inverters in PV systems and how they affect overall system efficiency.
2. What factors should be considered when selecting an inverter for a residential PV system?

Hint

The recommended mode of assessment for week 12 is **End of semester examination.** Refer to the appendix D at the end of this session for guidance in setting questions for the end-of-semester examination

WEEK 13: OPERATE AND MAINTAIN SIMPLE PHOTOVOLTAIC AND SOLAR THERMAL ENERGY SYSTEMS

Learning Indicator: *Operate and maintain simple photovoltaic and solar thermal energy systems*

FOCAL AREA 1: OPERATION AND MAINTENANCE OF PHOTOVOLTAIC AND SOLAR SYSTEMS

Operating and Maintaining Simple Photovoltaic (PV) Systems

Operation

1. **Initial Setup**
   a. Ensure the solar panels are installed at the optimal angle and orientation to maximise sunlight exposure.
   b. Verify that all electrical connections are secure and properly insulated.
   c. Turn on the system using the main disconnect switch.
   d. Check the inverter to ensure it is functioning correctly and converting DC to AC power.

2. **Daily Operation**
   a. Monitor the system's performance through the monitoring system, noting any significant deviations in energy production.
   b. Ensure that the inverter is operating within normal parameters (usually indicated by green lights or specific operational codes).

3. **Energy Storage**
   a. If batteries are used, monitor their charge levels to ensure they are not overcharged or excessively discharged.
   b. Check the charge controller to ensure it is regulating the charging and discharging cycles properly.

Maintenance

1. **Regular Inspections**
   a. Visually inspect the solar panels for dirt, debris, or damage. Clean the panels with water and a soft brush or cloth if necessary.
   b. Check all wiring and electrical connections for signs of wear, corrosion, or damage.

2. **Inverter Maintenance**
   a. Periodically check the inverter for any error messages or fault codes.
   b. Ensure adequate ventilation around the inverter to prevent overheating.

   c. Verify the integrity of the inverter's connections and settings.

3. **Battery Maintenance**
   a. If using lead-acid batteries, check electrolyte levels and top up with distilled water if necessary.
   b. Inspect battery terminals for corrosion and clean them as needed.
   c. Perform periodic capacity tests to ensure the batteries are holding a charge.

4. **System Monitoring**
   a. Regularly review data from the monitoring system to identify any trends or issues in performance.
   b. Set up alerts for significant deviations in energy production or system faults.

5. **Safety Checks**
   a. Ensure all safety disconnects are easily accessible and properly labelled.
   b. Test the operation of disconnect switches periodically.
   c. Keep the area around electrical components free of obstructions.

Operating and Maintaining Simple Solar Thermal Systems

Operation

1. **Initial Setup**
   a. Ensure solar collectors are installed at the optimal angle and orientation for maximum solar gain.
   b. Fill the system with the appropriate heat transfer fluid, ensuring there are no air pockets.
   c. Set the controller to regulate the operation of pumps and valves based on temperature settings.

2. **Daily Operation**
   a. Monitor the temperature sensors to ensure the system is reaching the desired temperature levels.
   b. Check the flow rate of the heat transfer fluid to confirm proper circulation.
   c. Verify that the controller is functioning correctly and responding to temperature changes.

3. **Heat Storage**
   a. Ensure the storage tank is maintaining the correct temperature and pressure.
   b. Monitor the heat exchanger for efficient transfer of heat to the domestic water supply or heating system.

Maintenance

1. **Regular Inspections**
   a. Visually inspect solar collectors for dirt, debris, or damage. Clean collectors with water and a soft brush or cloth if necessary.
   b. Check all piping and insulation for leaks, damage, or degradation.
2. **Pump Maintenance**
   a. Periodically check the operation of the pumps to ensure they are running smoothly and quietly.
   b. Inspect pump seals and connections for leaks.
3. **Fluid Maintenance**
   a. Test the heat transfer fluid for proper concentration and chemical balance, especially if using glycol mixtures.
   b. Replace the heat transfer fluid periodically according to manufacturer recommendations.
4. **System Monitoring**
   a. Regularly review data from the system controller to ensure it is operating within expected parameters.
   b. Set up alerts for significant deviations in temperature or flow rates.
5. **Safety Checks**
   a. Ensure all safety valves and pressure relief mechanisms are functioning correctly.
   b. Test expansion tanks for proper operation and pressure settings.
   c. Maintain clear access to all system components for easy inspection and maintenance.

Learning Task

1. Learners watch a video on the operation and maintenance of photovoltaic and solar thermal systems
   https://youtu.be/8Yg4hklILxE
2. Discuss with learners and help them identify the steps involved in safely starting up a photovoltaic (PV) system.
3. Moderate discussions on how to monitor the performance of a PV system to ensure it is operating efficiently

4. Learners think, pair and share their views on the procedure for safely shutting down a PV system.
5. Moderate discussions with learners on the routine maintenance tasks performed on a PV system to ensure its longevity.
6. Have learners work in groups to brainstorm on some safety precautions to be taken into consideration when performing maintenance on a PV system

Pedagogical Exemplars

Experiential Learning

1. Learners visit a PV System and Solar Thermal System installations to interact with operators the operation and maintenance of photovoltaic and solar thermal systems.
2. Where not possible, learners may watch videos on the operation and maintenance of photovoltaic and solar thermal systems.
3. Teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently

Managing Talk for Learning

1. In a moderated discussion, learners discuss how to operate and maintain photovoltaic and solar thermal systems. Individuals add to what others have said respectfully. Learners should be encouraged to tolerate others' views.
2. Use webbing to summarise learners' views.
3. Support learners with special needs whilst the rest of the class completes more activities. Create a peer-to-peer mentoring system to help learners having difficulties receive help from colleagues.

Key Assessment

Level 1 Recall

1. What are the main components of a solar thermal energy system?
2. What personal protective equipment (PPE) is recommended when installing solar panels?

Level 2 Skills of conceptual understanding

1. What is the primary difference between photovoltaic and solar thermal energy systems?
2. How does a photovoltaic cell generate electricity?
3. How do you determine the maximum power point of a PV system?
4. What is the function of an inverter in a PV system?
5. What safety precautions should be taken when performing maintenance on a PV system?

Level 3 Strategic reasoning

1. Discuss the common causes of reduced efficiency in solar panels?

2. How should a leaking solar thermal collector be handled?

3. Explain five (5) factors needed to be considered when designing a solar thermal system for domestic hot water supply.

Hint

The recommended mode of assessment for week 13 is **individual homework.** Use level 3 question 3 as sample question for the individual homework.

WEEK 14: DESIGN AND INSTALL SIMPLE PHOTOVOLTAIC AND SOLAR THERMAL SYSTEMS

Learning Indicator: *Design and install simple photovoltaic and solar thermal systems*

FOCAL AREA 1: TO DESIGN AND INSTALL PHOTOVOLTAIC AND SOLAR THERMAL SYSTEMS

Designing and Installing Simple Photovoltaic (PV) Systems

Design

1. **Assess Energy Needs**
   - **a.** Calculate the total energy consumption of the household or building by reviewing past electricity bills or consider the power rating of the gadgets (loads) in the household to determine the possible consumption. Make provision for variation in the load.
   - **b.** Determine the peak energy usage and the total daily energy requirement.
2. **System Sizing**
   - **a.** Estimate the number of solar panels needed by dividing the total daily energy requirement by the average solar insolation (sunlight) for your location.
   - **b.** Choose the appropriate wattage of solar panels to meet your energy needs.
3. **Component Selection**
   - **a.** **Solar Panels**: Select high-efficiency panels suitable for your location and budget.
   - **b.** **Inverter**: Choose an inverter that can handle the total power output of your solar panels.
   - **c.** **Mounting System**: Select a mounting system that is compatible with your roof type or ground installation.
   - **d.** **Batteries (Optional)**: If using batteries, choose the appropriate type (e.g., lead-acid, lithium-ion) and capacity based on your energy storage needs.
   - **e.** **Charge Controller**: If batteries are used, select a charge controller that matches the system voltage and battery type.
4. **Site Survey**
   - **a.** Evaluate the installation site for shading, orientation, and structural integrity.
   - **b.** Determine the optimal tilt angle for the solar panels to maximise sunlight exposure.

Installation

1. **Mounting System Installation**
   a. Secure the mounting brackets to the roof or ground structure, ensuring they are properly aligned and anchored.
   b. Attach the rails to the mounting brackets, making sure they are level and secure.
2. **Solar Panel Installation**
   a. Mount the solar panels onto the rails, securing them with the appropriate clamps or fasteners.
   b. Connect the solar panels in series or parallel as per the design requirements.
3. **Electrical Connections**
   a. Run the DC wiring from the solar panels to the inverter, ensuring all connections are properly insulated and weatherproofed.
   b. Connect the inverter to the main electrical panel or grid tie-in point, following local electrical codes and regulations.
4. **Battery Installation (if applicable)**
   a. Install the batteries in a well-ventilated and secure location.
   b. Connect the batteries to the charge controller and inverter, ensuring proper polarity and secure connections.
5. **System Commissioning**
   a. Double-check all electrical connections and ensure all components are securely mounted.
   b. Turn on the system and verify the inverter is operational and converting DC to AC power.
   c. Test the system under load to ensure it meets the expected performance parameters.

Designing and Installing Simple Solar Thermal Systems

Design

1. **Assess Hot Water Needs**
   a. Calculate the daily hot water usage of the household or building, typically in gallons or litres.
   b. Determine the peak hot water demand.
2. **System Sizing**
   a. Estimate the number of solar collectors needed by dividing the total daily hot water requirement by the average solar insolation and collector efficiency.
   b. Choose the appropriate type and size of solar collectors based on your hot water needs.

3. **Component Selection**
   a. **Solar Collectors**: Select flat-plate or evacuated tube collectors based on efficiency and budget.
   b. **Heat Transfer Fluid**: Choose a suitable heat transfer fluid (e.g., water, glycol mixture) for your climate.
   c. **Storage Tank**: Select a storage tank with the appropriate capacity to meet your hot water demand.
   d. **Heat Exchanger**: Choose a heat exchanger that can handle the heat load and is compatible with your system design.
   e. **Pumps and Controllers**: Select pumps and controllers that match the flow rates and control requirements of your system.

4. **Site Survey**
   a. Evaluate the installation site for shading, orientation, and structural integrity.
   b. Determine the optimal tilt angle for the solar collectors to maximise sunlight exposure.

Installation

1. **Mounting System Installation**
   a. Secure the mounting brackets to the roof or ground structure, ensuring they are properly aligned and anchored.
   b. Attach the rails to the mounting brackets, making sure they are level and secure.

2. **Solar Collector Installation**
   a. Mount the solar collectors onto the rails, securing them with the appropriate clamps or fasteners.
   b. Connect the solar collectors in series or parallel as per the design requirements.

3. **Plumbing Connections**
   a. Run the piping from the solar collectors to the storage tank and heat exchanger, ensuring all connections are properly insulated and weatherproofed.
   b. Connect the heat transfer fluid loop to the solar collectors, storage tank, and heat exchanger.

4. **Pump and Controller Installation**
   a. Install the pumps and controllers in accessible locations, ensuring they are securely mounted and properly connected to the system.
   b. Set up the controller to regulate the operation of the pumps based on temperature settings.

5. **System Commissioning**
   a. Double-check all plumbing connections and ensure all components are securely mounted.
   b. Fill the system with the heat transfer fluid, ensuring there are no air pockets.

c. Turn on the system and verify the pumps are operational and circulating the fluid.

d. Test the system under load to ensure it meets the expected performance parameters and that the hot water is being efficiently heated and stored.

Learning Task

1. Learners watch videos on the installation of photovoltaic and solar thermal system

   https://youtu.be/MZ_vRUknhzw?si=UjDIUS3EHWLDHbbo

2. Guide learners to discuss the principle of operation of a photovoltaic system.
3. Moderate discussions with learners to describe the basic components of a solar thermal system.
4. Discuss with learners and help them identify the factors that influence the efficiency of a solar PV panel
5. Help learners identify the personal protective equipment (PPE) recommended when installing solar thermal collectors.

Pedagogical Exemplars

Experiential Learning

1. Learners watch videos on the design and installation of the two systems.
2. In a moderated discussion, learners share their observations and discuss how photovoltaic and solar thermal systems are designed and installed. Other groups add to the content presented by each group in a respectful manner. Groups should be encouraged to tolerate others' views.

Managing Talk for Learning

1. Use question and answer technique for learners to discuss the design and installation of the two systems
2. Use a flowchart to illustrate the approach or processes for the basic design and installation of such systems. Differentiation can be incorporated by allowing learners to express their understanding in various ways. For instance, some learners prefer to draw diagrams, while others prefer to write a paragraph or give a verbal explanation.
3. The teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently.

Experiential and Problem-based Learning

1. Learners visit a facility of installed photovoltaic and solar thermal systems to interact with engineers/technicians about the installations.
2. Learners are given group assignments to design photovoltaic and solar thermal systems for a facility. Assign specific roles to learners to ensure that all learners participate in the project and are challenged according to their understanding and skills.
3. Learners display for colleagues to observe and critique.
4. The teacher support a group working at a slower pace whilst the rest of the class completes more activities.

Key Assessment

Level 2 Skills of conceptual understanding

1. What are the basic steps involved in installing a solar thermal collector?
2. Why is insulation important in the installation of a solar thermal system?
3. What are the environmental benefits of using solar energy systems compared to conventional energy sources?

Level 3 Strategic reasoning

1. What factors need to be considered when designing a solar thermal system for domestic hot water supply?
2. How do you determine the size of a solar thermal system required for a given household?
3. Design and install simple prototype photovoltaic and solar thermal systems with features suitable for use in households using CAD tools and components,

Hint

The recommended mode of assessment for week 14 is **Experiment.** Use level 3 question 3 as sample question for the experiment.

SECTION 5 REVIEW

1. Can learners explain the primary function of a photovoltaic (PV) cell?
2. Can learners identify the main materials used in the construction of PV cells
3. Would learners be able to explain the role of a solar charge controller in a PV system?
4. Would learners be able to discuss the main purpose of a solar thermal collector?
5. Can learners describe the principle of operation of a photovoltaic cell?
6. Would learners be able to identify the factors that influence the efficiency of a solar PV panel?

7. Would learners be able to identify the personal protective equipment (PPE) recommended when installing solar thermal collectors?

8. Can Learners install a simple PV system under supervision?

Additional Reading

1. Science Buddies, [available online] at https://www.sciencebuddies.org/science-fair-projects/science-projects/use-solar-energy/high-school; [accessed on 11th July 2024].

Teaching/Learning Resources

1. Projector
2. Laptop and Videos on the design and installation of photovoltaic and solar thermal systems
3. Visit facilities with installed photovoltaic and solar thermal systems.

APPENDIX D: END OF FIRST SEMESTER EXAMINATION

Structure of End of semester Examination

1. Examination will cover focal areas covered in each table of specification (weeks 1-12 for semester 1)

   a. Paper 1: 30 MCQs.

   b. Paper 2: PART A and PART B

      i. Part A: One (1) compulsory question,

      ii. Part B: Four (4) questions from which learners will answer only Three (3) questions.

2. **Duration**: 2 hours

3. **Materials Needed**: Printer, A4 sheets, A large exam room, answer booklets, stationery, timers; for e-Assessment, consider a stable internet, computer, or tablet as well, etc.

4. **Marking Scheme/Rubrics**

   a. MCQs: 1 mark for each option. Total marks: 30 marks

   b. Essay type question: 10 marks for Part A and 30 marks for Part B (10 marks per question)

Total = 70 Marks

SAMPLE OF TABLE OF SPECIFICATIONS FOR END-OF-SEMESTER EXAMS

The specifications for the number of questions for each week are indicated in the table below

Content /week		DoK (Number of questions)				
		Level 1	Level 2	Level 3	Level 4	Total
1. Systematic investigation and its relevance in engineering practice	Objectives	1	-	1	-	2
	Essay	-	-	-	-	
	Case study	-	-	-	-	
2. Processes for systematic investigation	Objectives	-	-	1	-	3
	Essay	-	1	-	-	
	Case study	-	-	-	1	
3. Risk assessment and its relevance	Objectives	1	-	-	-	3
	Essay	-	1	-	-	
	Case study	-	-	-	1	
4. Procedure for risk assessment and control measures for various hazards	Objectives	1	-	-	-	2
	Essay	-	1	-	-	
	Case study	-	-	-	-	

5. Risk assessment matrix	*Objectives*	*1*	*–*	*–*	*–*	*3*
	Essay	*–*	*1*	*–*	*–*	
	Case study	*–*	*–*	*–*	*1*	
6. Professionalism in engineering practice	*Objectives*	*–*	*1*	*1*	*–*	*2*
	Essay	*–*	*–*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
7. Characteristics of an ethical and professional workplace	*Objectives*	*1*	*1*	*1*	*–*	*4*
	Essay	*–*	*1*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
8. Attributes of an engineer	*Objectives*	*1*	*1*	*1*	*–*	*3*
	Essay	*–*	*–*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
9. Unprofessional behaviour	*Objectives*	*1*	*1*	*–*	*–*	*3*
	Essay	*–*	*1*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
10. Functions of the basic components of analogue electronic circuits	*Objectives*	*1*	*1*	*–*	*–*	*3*
	Essay	*–*	*1*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
11. The use of CAD tools for the design and analysis of analogue electronic circuits	*Objectives*	*1*	*1*	*1*	*–*	*4*
	Essay	*–*	*1*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
12. Functions of the basic components of photovoltaic and solar thermal systems	*Objectives*	*1*	*1*	*1*	*–*	*3*
	Essay	*–*	*–*	*–*	*–*	
	Case study	*–*	*–*	*–*	*–*	
Total		*10/35x 100 =28.5%*	*15/35 x100= 42.9%*	*7/35 x 100 = 20%*	*3/35 x100 =8.5%*	*35/35 x 100=100%*

APPENDIX E: INDIVIDUAL PROJECT

Prompts for the individual project should be given to learners in week 13. The final submission of the individual project should be by the 23rd week of the academic year.

Task

E.g.,

Project Topics: Design a mini project into a functional system such as Home Automation System, Smart Irrigation System, Weather Station, Smart Parking System, Automated Greenhouse, Intruder Alert System, Smart Door Lock, Energy Monitoring Systems, Automated Pet Feeder, Smart Waste Management System, Environmental Monitoring System, Home Security System, Personal Fitness Tracker, Automated Aquarium, Voice-Controlled Home Automation, Smart Garden, Automated Curtain System, *etc.*

Submission Requirements

1. **Define Clear Project Objectives**
   - **a.** Project Scope: Clearly define what students are expected to achieve. The goal is for each student to design and build a functional system, such as a Home Automation System, Smart Irrigation System, or Weather Station.
   - **b.** Expected Outcomes:
     - A fully functional prototype.
     - A report detailing the design, components used, and implementation process.
     - A demonstration of the system in action.
   - **c.** Required Skills: The project should include components like programming, electronics, sensors, and communication systems.
2. **Provide Detailed Project Guidelines**
   - **a.** Project Proposal: Have students submit a brief project proposal outlining the system they will design (e.g., Home Automation, Smart Irrigation, Weather Station). The proposal should include:
     - Problem statement and objectives.
     - System architecture (block diagram of components and their functions).
     - List of components (e.g., microcontrollers, sensors, relays, etc.).
     - Estimated timeline and plan for development.
   - **b.** Functional Requirements: Define specific requirements for each type of project. For example:
     - Home Automation System: Must control multiple appliances or systems remotely (e.g., lights, fans, or security).
     - Smart Irrigation System: Must monitor soil moisture levels and control water flow based on environmental conditions.

- Weather Station: Must collect weather data (e.g., temperature, humidity, pressure) and display or record it.

3. **Allocate Time and Resources**

   a. Set a Timeline: Provide a clear project timeline with key milestones, such as:

   - Week 14: Project proposal submission.
   - Week 15: System design and component selection.
   - Week 18: System assembly, programming, and troubleshooting.
   - Week 22: Final testing and report preparation.
   - Week 23: Demonstration and presentation.

   b. Access to Resources: Ensure students have access to:

   - Hardware components: Microcontrollers (e.g., Arduino, Raspberry Pi), sensors, relays, actuators, etc.
   - Software: Programming tools and software platforms (e.g., Arduino IDE, Python, cloud services).
   - Workspace: Access to labs or tools to build and test their systems.

4. **Conduct Regular Checkpoints**

   a. Weekly Progress Reports: Have students submit short progress reports at set intervals. Reports should cover:

   - Tasks completed.
   - Challenges faced and solutions.
   - Upcoming tasks.

   b. Meetings/Consultations: Conduct one-on-one or group consultations during the project's development phase to review progress and address any technical challenges.

Marking Scheme/Rubrics

Criteria	*4 marks*	*3 marks*	*2 marks*	*1 mark*
Design and Conceptualization	*The design shows creativity and organisation of any four of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.*	*The design shows creativity and organisation of any three of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.*	*The design shows creativity and organisation of any two of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.*	*The design shows creativity and organisation of any one of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.*

Component Selection and Integration	*Selects and integrates four components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.*	*Selects and integrates three components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.*	*Selects and integrates two components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.*	*Selects and integrates one component (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.*
System Functionality	*Demonstrates four intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security*	*Demonstrates three intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security*	*Demonstrates two intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security*	*Demonstrates one intended feature and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security*
Programming and Code Efficiency	*With four constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)*	*With three constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)*	*With two constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)*	*With one constituent of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)*
Report and Documentation	*Shows four items such as functions of components used, circuit diagrams, explanations, and pictures*	*Shows three items such as functions of components used, circuit diagrams, explanations, and pictures*	*Shows two items such as functions of components used, circuit diagrams, explanations, and pictures*	*Shows one item such as functions of components used, circuit diagrams, explanations, and pictures*
Presentation and Demonstration	*Shows four items such as final design, installation process, demonstration, functionality*	*Shows three items such as final design, installation process, demonstration, functionality*	*Shows two items such as final design, installation process, demonstration, functionality*	*Shows one item such as final design, installation process, demonstration, functionality*

Total – 24 marks

Feedback

Encourage learners to reflect on their project, including the challenges they faced and how they might improve or expand their system in the future, etc.

The marking scheme and rubrics for scoring the Individual homework task

Correctly listing some factors needed to be considered when designing solar panel systems such as

Solar Resource Availability: Factors such as latitude, climate, and shading (from trees, buildings, or other obstacles) influence the system's performance.

Hot Water Demand: Considering the number of occupants and their usage habits, including the storage tank and collector area.

System Orientation and Tilt: The solar collector should be oriented to maximize exposure to sunlight.

Type of Solar Collector: Select the appropriate type of solar collector based on efficiency and cost.

Backup Heating System: This could be an electric heater, or a gas-powered system integrated into the design, etc.

(2 marks each)

Total = 10 marks

The marking scheme and rubrics for scoring the Experiment task

Criteria	4 marks	3 marks	2 marks	1 mark
Design phase	Design shows four areas such as understanding household needs, energy demand calculation, solar resource assessment, roof space and orientation	Design shows three areas such as understanding household needs, energy demand calculation, solar resource assessment, roof space and orientation	Design shows two areas such as understanding household needs, energy demand calculation, solar resource assessment, roof space and orientation	Design shows one area such as understanding household needs, energy demand calculation, solar resource assessment, roof space and orientation
CAD tool application	Demonstrates four proficiencies such as creating CAD models, Wiring/ Piping layout, Simulation and Analysis.	Demonstrates three proficiencies such as creating CAD models, Wiring/ Piping layout, Simulation and Analysis.	Demonstrates two proficiencies such as creating CAD models, Wiring/ Piping layout, Simulation and Analysis.	Demonstrates one proficiency such as creating CAD models, Wiring/Piping layout, Simulation and Analysis.
Installation planning	Demonstrates four skills such as site analysis, component assembly, electrical or plumbing connections, sizing of components	Demonstrates three skills such as site analysis, component assembly, electrical or plumbing connections, sizing of components	Demonstrates two skills such as site analysis, component assembly, electrical or plumbing connections, sizing of components	Demonstrates one skill such as site analysis, component assembly, electrical or plumbing connections, sizing of components

Prototyping and Testing	*Shows four skills such as connecting solar panels to the inverter and battery then system testing for PV*	*Shows skill three such as connecting solar panels to the inverter and battery then system testing for PV*	*Shows two skills such as connecting solar panels to the inverter and battery then system testing for PV*	*Shows one skill such as connecting solar panels to the inverter and battery then system testing for PV*
Documentation and Analysis	*Shows four skills in specifications of documents, installation steps, performance evaluation, cost, and sustainability*	*Shows three skills in specifications of documents, installation steps, performance evaluation, cost, and sustainability*	*Shows two skills in specifications of documents, installation steps, performance evaluation, cost, and sustainability*	*Shows one skill in specifications of documents, installation steps, performance evaluation, cost, and sustainability*
Presentation	*Shows four items such as final design, installation process, demonstration, suitability to households*	*Shows three items such as final design, installation process, demonstration, suitability to households*	*Shows two items such as final design, installation process, demonstration, suitability to households*	*Shows one item such as final design, installation process, demonstration, suitability to households*

Total = 24 marks

SECTION 6: ENERGY EFFICIENCY AND CONSERVATION

Strand: Energy Systems

Sub-Strand: Energy Efficiency and Conservation

Learning Outcomes
1. *Design energy management plan and basic energy audit plan*
2. *Explain energy-saving methods for electrical and thermal systems*

Content Standard: Demonstrate an understanding of energy management principles

INTRODUCTION AND SECTION SUMMARY

In this section learners will be introduced to the Energy Management Plan and basic Energy Audit Plan. Learners will understand energy saving methods for electrical and thermal systems. Learners will understand that creating an energy management plan involves several steps to ensure efficient use of energy, reduce costs, and minimise environmental impact. Learners will be able to perform a walk-through energy audit which involves a systematic inspection of a facility to identify areas where energy is being wasted. Learners will also be introduced to some energy-saving tips, for various types of electrical equipment, which can significantly reduce energy consumption, leading to cost savings and a lower environmental impact. The knowledge acquired by learners in this section will enable them to implement an energy-saving plan for electrical and thermal equipment leading to significant reductions in energy consumption, lower utility bills, and a smaller environmental footprint.

The weeks covered by the section are:

Week 15: Energy Management Plan and basic Energy Audit Plan

Week 16: Energy saving methods for electrical and thermal systems

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section facilitators may consider using Problem-based, Experiential, Collaborative Learning, and Managing Talk for Learning. In a moderated discussion, allow learners to discuss energy conservation measures for electrical and thermal equipment. Furthermore, learners may compare various measures to achieve common energy saving goals in various equipment and systems. Through experiential Learning, Facilitators may put learners in groups to assess facilities in the school to know the energy-saving measures in place and those that could be deployed. The groups present their findings to the class. In pairs, learners think and share views on what they understand about energy management. In moderated discussions, allow learners to discuss the importance of energy management in facilities as well as the benefits of developing a plan for it. Through questions and answers, learners explain the key components of an energy management plan and the processes involved in developing a plan for a facility. In small groups, guide learners to sketch energy management plans with the aid of a sample. Groups share their sketches with the whole class for comments and additions. Encourage learners to share views respectfully and tolerate the opinions of others.

ASSESSMENT SUMMARY

It is important to analyse various assessment methods in order to provide all types of learners with the opportunity to demonstrate their understanding of the key concepts in the section. Learners can make a presentation on energy conservation measures for electrical and thermal equipment. Furthermore, learners can be required to compare various measures to achieve common energy saving goals for various equipment and systems and share their findings with the whole class. The scores for this task can form part of their formative assessment. Put learners into mixed-ability groupings to assess facilities in the school to know the energy-saving measures in place and those that could be deployed and present a report. Through questions and answers, learners explain the key components of an energy management plan and the processes involved in developing a plan for a facility. This can be an oral or written presentation.

Refer to the Teacher Assessment Manual and Toolkits (NaCCA, 2023) for more examples.

WEEK 15: ENERGY MANAGEMENT PLAN AND BASIC ENERGY AUDIT PLAN

Learning Indicators

1. *Develop energy management plans*
2. *Perform a walk-through energy audit of a facility and identify sources of energy wastage*

FOCAL AREA 1: DEVELOPING ENERGY MANAGEMENT PLANS

Creating an energy management plan involves several steps to ensure efficient use of energy, reduce costs, and minimise environmental impact. Here's a step-by-step guide to developing an effective energy management plan:

Step 1: Establish a Baseline

1. **Audit Energy Usage**
    a. Conduct a comprehensive energy audit to identify where and how energy is being used.
    b. Collect data on energy consumption for different facilities, equipment, and processes over a specific period.

2. **Analyse Energy Bills**
    a. Review past energy bills to understand consumption patterns and costs.
    b. Identify peak usage times and rates.

Step 2: Set Goals and Objectives

1. **Define Clear Goals**
    a. Set specific, measurable, achievable, relevant, and time-bound (SMART) goals for energy reduction.
    b. Examples include reducing energy consumption by a certain percentage or improving energy efficiency in specific areas.

2. **Establish Objectives**
    a. Identify key performance indicators (KPIs) to track progress.
    b. Objectives might include implementing renewable energy sources, upgrading equipment, or improving insulation.

Step 3: Develop Action Plans

1. **Identify Opportunities for Improvement**
    a. Based on the audit, identify areas with the most significant potential for energy savings.
    b. Prioritise actions based on cost-effectiveness and potential impact.

2. **Implement Energy Efficiency Measures**
    a. Upgrade to energy-efficient lighting, HVAC systems, and appliances.

   b. Implement automated systems for lighting and temperature control.
   c. Improve insulation and weatherisation.

3. **Incorporate Renewable Energy**
   a. Explore the feasibility of solar, wind, or other renewable energy sources.
   b. Consider power purchase agreements (PPAs) or on-site generation.

Step 4: Engage Stakeholders

1. **Involve Employees**
   a. Educate and train employees on energy conservation practices.
   b. Encourage a culture of energy efficiency through incentives and recognition programs.

2. **Collaborate with Suppliers**
   a. Work with suppliers to source energy-efficient products and services.
   b. Explore opportunities for shared energy-saving initiatives.

Step 5: Monitor and Review

1. **Track Progress**
   a. Use energy management software to monitor energy usage in real-time.
   b. Compare actual consumption against goals and KPIs.

2. **Regularly Review and Update**
   a. Conduct regular reviews of the energy management plan to assess progress.
   b. Update the plan based on new technologies, changing goals, or regulatory requirements.

Step 6: Report and Communicate

1. **Document Results**
   a. Maintain detailed records of energy consumption, savings, and improvements.
   b. Prepare regular reports for internal and external stakeholders.

2. **Communicate Achievements**
   a. Share successes and lessons learned with employees, management, and the public.
   b. Highlight the environmental and financial benefits achieved through the plan.

Example of an Energy Management Plan Outline

1. **Introduction**
   a. Purpose of the plan
   b. Overview of current energy usage

2. **Goals and Objectives**
   a. Specific energy reduction targets
   b. Key performance indicators

3. **Baseline Data**
   a. Results of the energy audit
   b. Historical energy consumption data
4. **Action Plan**
   a. Energy efficiency measures
   b. Renewable energy initiatives
   c. Timeline and responsibilities
5. **Stakeholder Engagement**
   a. Employee training and involvement
   b. Supplier collaboration
6. **Monitoring and Review**
   a. Methods for tracking progress
   b. Schedule for regular reviews
7. **Reporting and Communication**
   a. Documentation of results
   b. Communication strategy

Learning Task

1. Work with learners to discuss the key components of an energy management plan.
2. Learners think, pair and share their views on how an energy audit contributes to an energy management plan.
3. Discuss with learners and help them appreciate the common goals of an energy management plan.
4. Have learners visit facilities in the school and report on energy saving mechanisms in place, evaluate same and give a recommendation.
5. Moderate discussions with learners on how to set measurable objectives for energy management.
6. Guide learners to develop their own energy management plan for their households.

Pedagogical Exemplars

Managing Talk for Learning

1. In pairs, learners think and share views on what they understand by energy management.
2. In moderated discussions, learners discuss the energy management being practiced in their household and the importance of energy management in facilities as well as the benefits of developing a plan for it. Remember to consider socio-emotional learning by encouraging respectful and open communication among learners. Promote gender equality and social inclusion by ensuring that all learners, regardless of gender or social background, are given equal opportunities to participate in the discussion. Lastly, incorporate national core values in your teaching by relating the discussion to real-life scenarios or issues relevant to Ghana.

Initiating Talk for Learning

1. Through questions and answers, learners explain the key components of an energy management plan and the processes involved in developing a plan for a facility. Differentiation can be incorporated by allowing learners to express their understanding in various ways. For instance, some learners prefer to draw diagrams, while others prefer to write a paragraph or give a verbal explanation.
2. In small groups, guide learners to sketch energy management plans with the aid of a sample.
3. Groups share their sketches with the whole class for comments and additions. Other groups add to the content presented by each group in a respectful manner. Groups should be encouraged to tolerate others' views.
4. The teacher support a group working at a slower pace whilst the rest of the class completes more activities.
5. Encourage learners to share views in a respectful manner and tolerate the opinions of others.

Key Assessment

Level 1 Recall

1. What are some examples of energy efficiency measures that can be included in an energy management plan?
2. What are the components of an energy management plan?

Level 2 Skills of conceptual understanding

1. What steps are involved in conducting an energy audit?

Level 3 Strategic Thinking

1. How do you identify energy-saving opportunities during an energy assessment?
2. How do you develop strategies to reduce energy consumption?
3. What factors should be considered when prioritising energy efficiency projects?

FOCAL AREA 2: WALK-THROUGH ENERGY AUDIT

Performing a walk-through energy audit involves a systematic inspection of a facility to identify areas where energy is being wasted. This type of audit is often the first step in developing an energy management plan. Here's a guide to conducting a walk-through energy audit:

Preparation

1. **Gather Information**
   a. Obtain floor plans and layout of the facility.
   b. Collect historical energy consumption data (electricity, gas, water, etc.).
   c. Understand the operation schedule and occupancy patterns.

2. **Assemble Tools**
    a. Clipboards, notepads, and pens
    b. Flashlight
    c. Infrared thermometer
    d. Light meter
    e. A digital camera or smartphone for photos
    f. Personal protective equipment (PPE) as needed

3. **Create a Checklist**
    a. Develop a checklist to ensure all areas and equipment are inspected.
    b. Include categories such as lighting, HVAC, insulation, equipment, and processes.

Conducting the Walk-through

1. **Lighting**
    a. Inspect all lighting fixtures for type and condition (incandescent, fluorescent, LED, etc.).
    b. Check for unnecessary lighting in unoccupied areas.
    c. Measure light levels and compare them to standards (over-lighting can waste energy).
    d. Identify opportunities for day lighting or occupancy sensors.

2. **HVAC (Heating, Ventilation, and Air Conditioning)**
    a. Examine thermostats for proper settings and functionality.
    b. Check for blocked vents and registers.
    c. Inspect HVAC equipment for maintenance issues (dirty filters, worn belts, etc.).
    d. Look for opportunities to use programmable thermostats or zone controls.

3. **Insulation and Building Envelope**
    a. Inspect doors and windows for air leaks (drafts).
    b. Check insulation levels in walls, ceilings, and floors.
    c. Look for gaps in weather stripping and sealant.

4. **Equipment and Appliances**
    a. Assess the condition and efficiency of major equipment and appliances.
    b. Check for equipment running unnecessarily or left on when not in use.
    c. Identify older, less efficient equipment that may need upgrading.

5. **Processes and Operations**
    a. Observe industrial or commercial processes for energy-intensive practices.
    b. Look for opportunities to optimise operational schedules and processes.
    c. Identify areas where heat recovery or process optimisation could save energy.

6. **Other Areas**
   a. Check for leaking faucets or toilets that waste water (and energy if hot water is involved).
   b. Inspect for any electrical equipment that may be left in standby mode.

Documentation and Analysis

1. **Document Findings**
   a. Take detailed notes and photos of issues identified.
   b. Record temperature readings, light levels, and any other relevant measurements.
2. **Analyse Data**
   a. Compare findings against energy consumption data to identify significant sources of waste.
   b. Calculate potential savings from addressing each identified issue.
3. **Prioritise Actions**
   a. Rank opportunities based on potential energy savings, cost, and ease of implementation.
   b. Develop a list of recommended actions.

Reporting and Recommendations

1. **Create a Report**
   a. Summarise findings, including photos and notes from the walk-through.
   b. Highlight areas of significant energy waste and potential improvements.
2. **Provide Recommendations**
   a. Suggest specific actions to reduce energy consumption (e.g., replacing incandescent bulbs with LEDs, sealing air leaks, upgrading HVAC systems).
   b. Include estimated costs and savings for each recommendation.
3. **Present the Report**
   a. Share the report with facility management and relevant stakeholders.
   b. Discuss the findings and recommended actions to gain support for implementation

Learning Task

1. Help learners discuss the purpose of conducting a walk-through energy audit.
2. Moderate discussion in which learners identify the tools and equipment commonly used during a walk-through energy audit.
3. Guide learners to discuss why it is important to have access to the facility's historical energy consumption data.
4. Guide learners to perform a walk-through energy audit for a school facility.

Pedagogical Exemplars

Initiate Talk for Learning

1. In a moderated discussion, learners discuss what an audit (in general) is, its importance, and processes.
2. From the general understanding, learners explain what an energy audit is.
3. The teacher support learners working at a slower pace whilst the rest of the class completes more activities.
4. Share with learners the procedure for performing a walk-through energy audit of a facility and how to prepare a report. Offer multiple ways to learn, such as hands-on practice, instructional videos, and step-by-step guides. Allow learners to demonstrate their understanding through different formats, such as written reports, oral presentations, or practical demonstrations.

Problem-based, experiential and collaborative Learning

1. Learners grouped and tasked to perform a walk-through energy audit of a selected facility in their school, e.g. classroom, offices, dormitories, etc. in their school.
2. The groups present their report to the class for questions and observations.
3. Encourage learners to tolerate each other's views.

Key Assessment

Level 1 Recall

1. What are common signs of energy wastage in lighting systems?
2. What types of electrical equipment should be inspected during an energy audit
3. What are common indicators of energy wastage in a facility?
4. What are some examples of behavioural changes that can reduce energy consumption?

Level 2 Skills of conceptual understanding

1. How can you identify inefficient lighting systems during a walk-through audit?
2. What should you look for when inspecting heating, ventilation, and air conditioning (HVAC) systems?
3. How can poor insulation contribute to energy wastage?
4. How can employee behaviour contribute to energy wastage?
5. Name two components responsible for converting the DC electricity generated by PV panels into AC electricity

Level 3 Strategic reasoning

1. How can you identify energy wastage in HVAC systems during an audit?
2. How can you determine if electrical equipment is consuming more energy than necessary

Hint

The recommended mode of assessment for week 15 is **Class exercise.** Use level 2 question 5 as sample question for the class exercise.

WEEK 16: ENERGY SAVING METHODS FOR ELECTRICAL AND THERMAL SYSTEMS

Learning Indicators

1. *Identify energy-saving tips for electrical equipment*
2. *Identify appropriate energy-saving tips for thermal equipment*

FOCAL AREA 1: ENERGY-SAVING TIPS FOR ELECTRICAL EQUIPMENT

Here are some energy-saving tips for various types of electrical equipment whereby implementing these tips can significantly reduce energy consumption, leading to cost savings and a lower environmental impact:

General Tips

1. **Turn off When Not in Use:** Always switch off electrical devices and equipment when they are not in use. This includes lights, computers, printers, and other office equipment.
2. **Unplug Devices:** Unplug chargers, appliances, and other electronics when not in use, as they can still consume energy in standby mode.
3. **Use Power Strips:** Use power strips to easily turn off multiple devices at once, reducing phantom loads.

Lighting

1. **Switch to LED Bulbs:** Replace incandescent and fluorescent bulbs with energy-efficient LED bulbs, which consume less energy and have a longer lifespan.
2. **Use Natural Light:** Utilise natural daylight whenever possible to reduce the need for artificial lighting.
3. **Install Motion Sensors:** Use motion sensors or timers to ensure lights are only on when needed.

Heating and Cooling

1. **Programmable Thermostats:** Install programmable thermostats to automatically adjust the temperature when you're away or sleeping.
2. **Maintain HVAC Systems:** Regularly clean and maintain heating, ventilation, and air conditioning (HVAC) systems to ensure they run efficiently.
3. **Seal Leaks:** Seal windows, doors, and ducts to prevent air leaks that can cause heating and cooling systems to work harder.

Appliances

1. **Energy-Efficient Models:** Purchase Energy Star-rated appliances, which are designed to consume less energy.

2. **Use Appropriate Settings:** Use appliances on their most energy-efficient settings, such as washing clothes in cold water and air-drying dishes.
3. **Full Loads:** Run dishwashers and washing machines with full loads to maximise efficiency.

Office Equipment

1. **Energy-Saving Modes:** Enable energy-saving modes on computers, printers, and other office equipment to reduce power consumption when not in use.
2. **Upgrade to Laptops:** Consider using laptops instead of desktop computers, as they typically consume less energy.
3. **Optimise Printing:** Reduce paper use and energy consumption by printing double-sided and in draft mode when possible.

Electronics

1. **Energy-Efficient Electronics:** Choose energy-efficient electronics, such as televisions and audio systems.
2. **Lower Brightness:** Lower the brightness on screens and use power-saving modes on devices.
3. **Smart Power Management:** Use smart power management settings on electronics to reduce energy consumption when idle.

Kitchen Equipment

1. **Efficient Cooking Methods:** Use microwaves, slow cookers, and toaster ovens, which typically consume less energy than conventional ovens.
2. **Proper Refrigeration:** Keep refrigerator and freezer doors closed as much as possible and ensure they are set to the appropriate temperatures (3-4°C for refrigerators and -18°C for freezers).
3. **Maintain Appliances:** Regularly clean and defrost refrigerators and freezers to ensure they operate efficiently.

Industrial Equipment

1. **Variable Speed Drives:** Use variable speed drives (VSDs) on motors to adjust the speed according to the load, reducing energy consumption.
2. **Regular Maintenance:** Conduct regular maintenance on industrial equipment to ensure they are operating at peak efficiency.
3. **Energy Audits:** Perform energy audits to identify areas where energy can be saved and implement recommendations.

Learning Task

1. Learners watch video on energy savings in electrical equipment from the link
   https://youtu.be/lmQ6QvZPtj0

2. Work with learners to discuss the significance of saving energy when using electrical equipment.
3. Work with learners to discuss how energy efficiency contributes to cost savings and environmental sustainability.
4. Guide learners to discuss how you can determine the energy consumption of a particular piece of electrical equipment.
5. Moderate discussions with learners on some common indicators for identifying energy inefficient electrical equipment.

Pedagogical Exemplars

Managing Talk for Learning

1. In a moderated discussion, learners discuss energy conservation measures for electrical equipment. Individuals add to what others have said respectfully. Learners should be encouraged to tolerate others' views.
2. Furthermore, learners compare various measures to achieve common energy saving goals in various equipment and systems.
3. The teacher support learners working at a slower pace whilst the rest of the class completes more activities.

Experiential Learning

1. Learners interact with facility managers in their school on energy saving methods being employed in their school.
2. Learners watch videos on energy savings in electrical equipment. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
3. The teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently

Problem-based, Experiential and Collaborative Learning

1. In groups, learners assess selected facilities in their school to know the energy-saving measures in place and those that could be deployed.
2. The groups present their findings to the class for comments. Allow learners to present their findings in a way that suits their strengths. Options could include a group written report, a collaborative digital mind map, or a short video explaining key characteristics.

Key Assessment

Level 1 Recall

1. Name five (5) energy-saving tips for using household appliances like refrigerators and washing machines?

Level 2 Skills of conceptual understanding

1. How can turning off equipment when not in use contribute to energy savings?
2. What are the benefits of unplugging devices that are not frequently used?
3. How can the use of energy-efficient appliances impact overall energy consumption?
4. What are some simple behavioural changes that can lead to significant energy savings?

Level 3 Strategic reasoning

1. How can educating employees or household members about energy-saving practices reduce energy consumption?

Level 4 Extended Thinking

1. Prepare an energy saving poster for your household, stating clearly what your assumptions are.

FOCAL AREA 2: ENERGY-SAVING TIPS FOR THERMAL EQUIPMENT

Here are some appropriate energy-saving tips specifically for thermal equipment. Implementing these energy-saving tips for thermal equipment can lead to significant reductions in energy consumption, lower utility bills, and a smaller environmental footprint.

Heating Systems

1. **Programmable Thermostats:** Install programmable thermostats to automatically reduce heating when it's not needed, such as during the night or when the house is empty.
2. **Insulation:** Improve insulation in your home or building to retain heat better, reducing the workload on your heating system.
3. **Seal Leaks:** Seal any leaks around windows, doors, and ducts to prevent heat from escaping.
4. **Regular Maintenance:** Regularly service and clean heating systems to ensure they operate efficiently.
5. **Efficient Heating Systems:** Upgrade to energy-efficient heating systems, such as condensing boilers or heat pumps.

Water Heaters

1. **Lower Temperature Settings:** Set your water heater to 49°C (120°F) to save energy and prevent scalding.
2. **Insulate Water Heater and Pipes:** Use insulating blankets for water heaters and insulate hot water pipes to reduce heat loss.
3. **Reduce Hot Water Usage:** Install low-flow showerheads and faucets to reduce the amount of hot water used.

4. **Tankless Water Heaters:** Consider installing tankless (on-demand) water heaters, which can be more energy-efficient than traditional storage tank water heaters.

Cooking Equipment

1. **Efficient Appliances:** Use energy-efficient cooking appliances such as convection ovens, which cook food faster and more evenly.
2. **Properly Sized Pots and Pans:** Use pots and pans that match the size of your stove burners to maximise heat transfer and reduce energy waste.
3. **Lid Use:** Cover pots and pans with lids while cooking to retain heat and cook food faster.
4. **Microwaves and Toaster Ovens:** Use microwaves, toaster ovens, and slow cookers for smaller meals, as they use less energy than conventional ovens.

Industrial Thermal Equipment

1. **Waste Heat Recovery:** Implement waste heat recovery systems to capture and reuse excess heat from industrial processes.
2. **Insulation:** Insulate pipes, tanks, and other equipment to minimise heat loss in industrial settings.
3. **Process Optimisation:** Optimise thermal processes to operate at the most efficient temperatures and pressures.
4. **Regular Inspections:** Conduct regular inspections and maintenance of thermal equipment to identify and repair inefficiencies.

Space Heaters

1. **Energy-Efficient Models:** Use energy-efficient space heaters with features like timers, thermostats, and safety shut-offs.
2. **Zoning:** Use space heaters to heat only occupied areas instead of the entire building.
3. **Smart Usage:** Turn off space heaters when leaving the room or going to sleep.

Boilers and Furnaces

1. **High-Efficiency Models:** Upgrade to high-efficiency boilers and furnaces, which use less energy to produce the same amount of heat.
2. **Regular Maintenance:** Schedule regular maintenance to ensure boilers and furnaces are running efficiently.
3. **Optimised Operation:** Use weather-compensating controls and modulating burners to optimise the operation of boilers and furnaces.

Solar Thermal Systems

1. **Maximise Solar Gain:** Position solar thermal collectors to maximise exposure to sunlight.
2. **Regular Cleaning:** Keep solar thermal panels clean and free of debris to ensure maximum efficiency.

3. **Storage Systems:** Use efficient storage systems to retain heat collected by solar thermal systems for use when needed.

Learning Task

1. Discuss with learners and help them understand how setting thermostats to appropriate temperatures save energy in heating systems.
2. Facilitate learners' discussion on the benefits of using programmable thermostats for thermal equipment.
3. Moderate discussion among learners on how educating users about energy-saving practices reduces energy consumption for thermal equipment.
4. Moderate discussions among learners on some simple behavioural changes that can lead to significant energy savings with thermal equipment.

Pedagogical Exemplars

Managing Talk for Learning

1. In a moderated discussion, learners discuss energy conservation measures for thermal equipment.
2. Furthermore, learners compare various measures to achieve common energy saving goals in various equipment and systems.
3. Encourage learners to share views in a respectful manner and tolerate the opinions of others.

Experiential Learning

1. Learners watch videos on energy savings in thermal equipment.
2. Give clear instructions on what learners should lookout for in the video. Support an individual or group working at a slower pace whilst the rest of the class completes more activities
3. Learners discuss their observations with the rest of the class. Individuals add to what others have said respectfully. Learners should be encouraged to tolerate others' views.
4. The teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently

Experiential and Collaborative Learning

1. In groups, learners assess facilities in the school to know the energy-saving measures in place and those that could be deployed. To ensure differentiation, the teacher can form groups considering the learners' readiness, interests, and learning styles. The complexity of the task can be varied based on the group's readiness level. For instance, advanced groups can be given additional facilities to evaluate or asked to explain why certain energy saving measures fit better than others.
2. The teacher supports a group working at a slower pace whilst the rest of the class completes more activities.

3. The groups present their findings to the class. Allow learners to demonstrate their understanding in different ways. For example, some learners could present their findings to the class, while others could create a report or a mind map.
4. Encourage learners to support each other

Key Assessment

Level 1 Recall

What tools can be used to monitor the energy consumption of thermal equipment?

Level 2 Skills of conceptual understanding

1. How can the use of natural light reduce energy consumption in a facility?
2. What is the importance of saving energy when using thermal equipment?
3. What are the benefits of using smart thermostats and other smart devices for managing thermal equipment?

Level 3 Strategic reasoning

1. How can the use of energy management systems help monitor and reduce energy consumption of thermal equipment?
2. How does improving the energy efficiency of thermal equipment contribute to cost savings and environmental sustainability?
3. A school with multiple classrooms, labs, and offices. The electricity bills have been increasing, and the Head of the school has asked the engineering students to help find ways to save energy. The goal is to reduce electricity usage by 10% over the next six months.

Scenario

The school uses several types of electrical equipment, including:

- **a.** Lighting: Fluorescent lights in classrooms, hallways, and the gym.
- **b.** Computers: Desktops and laptops in the computer lab and classrooms.
- **c.** Air Conditioners: Units in classrooms and offices to keep the temperature comfortable.
- **d.** Projectors and Interactive Whiteboards: Used by teachers for lessons.

Task

Identify simple ways to reduce electricity usage for these electrical devices and develop practical tips that students and staff can easily implement.

Hint

The recommended mode of assessment for week 16 is **Case study.** Use level 3 question 3 as sample question for the case study.

SECTION 6 REVIEW

1. Can learners state the benefits of using programmable thermostats for thermal equipment?
2. Can learners mention some simple behavioural changes that can lead to significant energy savings with thermal equipment?
3. Would learners be able to discuss the significance of saving energy when using electrical equipment?
4. Can learners discuss how energy efficiency contributes to cost savings and environmental sustainability?
6. Would learners be able to determine the energy consumption of a particular piece of electrical equipment?
7. Can learners discuss the purpose of conducting a walk-through energy audit?
8. Would learners be able to mention the tools and equipment commonly used during a walk-through energy audit?
9. Can learners discuss why it is important to have access to the facility's historical energy consumption data?
10. Can learners conduct a walk-through energy audit?

Additional Reading

Science Buddies, [available online] at https://www.sciencebuddies.org/science-fair-projects/science-projects/use-solar-energy/high-school; [accessed on 11th July 2024].

Teaching/Learning Resources

- Projector
- Laptop and videos on energy-saving measures for thermal equipment
- Videos on energy-saving measures for electrical equipment

The marking scheme and rubrics for scoring the Case study task

1. Conduct a School Energy Walk,

2. Identify Energy-Saving Tips etc. (2 marks each)

Total Mark = 10 marks

SECTION 7: ENGINEERING DESIGN AND PROTOTYPING

Strand: Systems Design and Prototyping

Sub-Strand: Engineering Design

Learning Outcomes

1. *Consider all possible solutions and select the most suitable solution(s) based on a set of constraints.*
2. *Design prototypes based on given solution requirements*

Content Standard: Demonstrate the ability to select an optimal solution from a given set of solutions to a problem.

Hint

Mid-Semester Examination for the second semester is in Week 18. Refer to Appendix F for the Table of Specification to guide you to set the questions. Set questions to cover all the indicators covered for at least 13 to 17.

INTRODUCTION AND SECTION SUMMARY

The section introduces learners to Engineering design and prototyping. To thoroughly evaluate a range of alternative solutions to a particular problem and provide a rationale for selecting the most effective answer, it is advisable to adopt a systematic approach. This technique entails recognising the problem at hand, creating a variety of possible solutions, assessing these solutions based on certain criteria, and ultimately choosing the most favourable option. This will enable learners to understand the process of generating basic 3D objects through a functional prototype. This entails a series of steps: establishing the design specifications, strategising the prototype, choosing the appropriate tools and materials, conceptualising the 3D object, fabricating the product, and enhancing the design. Additionally, this section will enable learners to appreciate the importance of prototyping in Engineering. It bridges the gap between conceptual design and final production, allowing engineers to test, refine, and validate their ideas

The weeks covered by the section are:

Week 17: Solutions and suitable solution(s) based on a set of constraints

Week 18: Prototypes based on given solution requirements

SUMMARY OF PEDAGOGICAL EXEMPLARS

Initiating Talk for Learning, Problem-Based learning and Collaborative learning are some suggested pedagogical exemplars for this section. Through Initiating Talk for Learning, Commence a discussion on the assessment of resolutions to an intricate real-life issue. Take into consideration priority standards and compromises that consider many limitations, such as expenses, safety, dependability, and aesthetics, as well as potential social, cultural, and environmental consequences. In Problem-Based learning, students are assigned a case study to thoroughly examine and evaluate potential alternatives. They are then required to create a report justifying their chosen solution(s) taking into account many factors such as cost, safety, reliability, aesthetics, as well as potential social, cultural, and environmental consequences. Students collaborate in teams and provide presentations to the entire class, showcasing their proposed resolution to a given scenario, in order to receive feedback.

ASSESSMENT SUMMARY

Provide learners with application questions focusing on this section's focal areas. For instance, gutters are choked in our communities, making drainage difficult and breeding mosquitoes. What are the underlying principles behind each solution? Request learners to compare the possible solutions regarding cost, feasibility and sustainability. Based on your analysis, which solution do you consider the most optimal? A case study mode of assessment is recommended for this section which will enhance learners critical thinking and creativity among learners. Consider using research as an assessment mode in this section. Learners can work in groups on a selected research topic and present their findings in weeks ahead. This will promote collaboration and teamwork among learners. Individual class exercises and homework are also recommended for this section where learners can work on why it is important to consider the orientation of a model on the print bed. They can also discuss the factors that should be considered when choosing a material for a 3D-printed prototype. Learners may submit a written exercise or do an oral presentation.

WEEK 17: SOLUTIONS AND SUITABLE SOLUTION(S) BASED ON A SET OF CONSTRAINTS

Learning Indicator: *Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution*

FOCAL AREA 1: TO ANALYSE POSSIBLE SOLUTIONS TO A PROBLEM

To critically analyse a set of possible solutions to a given problem and justify the choice of an optimal solution, follow a structured approach that includes identifying the problem, generating potential solutions, evaluating these solutions against specific criteria, and selecting the best option, follow these steps:

1. Define the Problem Clearly

Begin with a precise and comprehensive definition of the problem. Understand the requirements, constraints, and objectives. This helps to ensure that all potential solutions are evaluated against the same criteria.

2. Identify Possible Solutions

Generate a list of potential solutions. These could be based on brainstorming, research, past experiences, or expert opinions. Ensure that all viable options are considered.

3. Establish Evaluation Criteria

Determine the criteria for evaluating each solution. Common criteria include:

a. **Effectiveness**: How well does the solution solve the problem?

b. **Cost**: What are the financial implications of each solution?

c. **Feasibility**: Can the solution be implemented within the constraints (time, resources, technology)?

d. **Risks**: What are the potential risks and how can they be mitigated?

e. **Sustainability**: How does the solution impact the environment or society in the long term?

f. **Scalability**: Can the solution be scaled if needed?

4. Analyse Each Solution

Evaluate each solution against the established criteria:

a. **Effectiveness**: Assess the solution's ability to meet the problem's objectives. Consider if it addresses the root cause and delivers the desired outcomes.

b. **Cost**: Compare the costs of implementation, including initial investment, ongoing expenses, and potential savings or revenue generation.

c. **Feasibility**: Examine the practicality of implementing the solution, considering available resources, technology, and expertise.

d. **Risks**: Identify potential risks associated with each solution and evaluate the likelihood and impact of these risks. Consider mitigation strategies.

e. **Sustainability**: Evaluate the long-term impact of the solution on the environment and society.

f. **Scalability**: Consider if the solution can be expanded or adapted to larger or different contexts if needed.

5. Compare Solutions

Create a matrix or table to compare the solutions based on the evaluation criteria. Assign weights to each criterion based on its importance and score each solution accordingly.

6. Select the Optimal Solution

Analyse the scores and identify the solution that best meets the criteria. Justify the choice by explaining why this solution is optimal based on the analysis. Highlight how it effectively solves the problem, its cost-effectiveness, feasibility, risk management, sustainability, and scalability.

7. Justify the Choice

Provide a detailed justification for the chosen solution:

a. **Effectiveness**: Explain how the solution effectively addresses the problem.

b. **Cost**: Justify the cost, considering the budget and potential return on investment.

c. **Feasibility**: Discuss the practicality of implementation and the availability of resources.

d. **Risks**: Explain how the risks are manageable and the mitigation strategies in place.

e. **Sustainability**: Highlight the long-term benefits and minimal negative impacts.

f. **Scalability**: Demonstrate how the solution can adapt to future needs or growth.

Example Scenario

Problem: Reducing energy consumption in a manufacturing plant.

Possible Solution

1. Implementing energy-efficient lighting.
2. Upgrading to energy-efficient machinery.
3. Installing a solar power system.
4. Implementing a comprehensive energy management system.

Evaluation Criteria

1. Effectiveness
2. Cost
3. Feasibility
4. Risks
5. Sustainability

6. Scalability

Analysis

1. **Energy-efficient lighting**: Effective in reducing lighting energy consumption, low cost, highly feasible, minimal risks, sustainable, but limited scalability.
2. **Energy-efficient machinery**: Significant reduction in energy use, high initial cost, feasible with a phased approach, moderate risks, sustainable, and scalable.
3. **Solar power system**: High potential for reducing energy bills, high initial investment, feasible with subsidies, risks include weather dependency, highly sustainable, scalable.
4. **Energy management system**: Comprehensive reduction in energy use, moderate cost, feasible with training, low risks, sustainable, scalable.

Criteria	Lighting	Machine	Solar Power	Energy Management
Effectiveness	Medium	High	High	High
Cost	Low	High	High	Medium
Feasibility	High	Medium	Medium	High
Risks	Low	Medium	Medium	Low
Sustainability	Medium	High	High	High
Scalability	Low	High	High	High

Optimal Solution: Implementing an energy management system.

Justification

1. **Effectiveness**: The energy management system provides a comprehensive approach to reducing energy consumption across the entire plant.
2. **Cost**: While not the cheapest option, it is more cost-effective in the long term compared to high initial investments in machinery or solar power.
3. **Feasibility**: Highly feasible with proper training and resources.
4. **Risks**: Low risks associated with implementation.
5. **Sustainability**: High sustainability, reducing overall energy consumption and carbon footprint.
6. **Scalability**: Can be scaled and adapted as the plant grows or as new technologies become available.

This structured approach ensures a thorough evaluation and a well-justified choice of the optimal solution.

Learning Task

1. Guide learners to analyse possible solutions to the wastage of electricity in our households
2. In moderated discussions, guide learners to analyse possible ways to dispose of waste (liquid and solid) to avoid spreading diseases.

3. Discuss with learners and help them analyse the causes of frequent road accidents on our roads and how to mitigate them.
4. Put learners in groups to identify problems in the school dining hall, kitchen, store, staff bungalow, dormitories, and classrooms and analyse possible solutions to the problem. Present their findings to the whole class.

Pedagogical Exemplars

Initiating Talk for Learning: Initiate a discussion on the evaluation of solutions to a complex real-world problem based on prioritised criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics, as well as possible social, cultural, and environmental impacts. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.

Problem-based Learning: Learners are given a case study to critically analyse the possible solutions and make a report on the justification of selected solution(s) based on a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Offer differentiated instruction sheets with step-by-step guides for evaluation of energy saving measures for approaching proficiency learners, while encouraging proficient and highly proficient learners to explore advanced techniques.

Collaborative Learning: Learners work in groups and make presentations on their solution to a case study to the whole class for comments. Allow learners to present their findings in a way that suits their strengths. Options could include a group written report, a collaborative digital mind map, or a short video explaining key characteristics.

Key Assessment

Level 2 Skills of conceptual understanding

Scenario

In our communities, gutters are choked, making drainage very difficult and breeding mosquitoes.

1. What are the possible solutions to the problem?
2. Can you describe the key features of each solution?

Level 3 Strategic reasoning

1. How would you implement the solutions suggested in the scenario?
2. What potential outcomes can you predict from implementing each solution?
3. How would you measure the success of each solution?
4. What challenges might you face when implementing each solution?

Level 4 Extended critical thinking and reasoning

1. What are the underlying principles behind each solution?
2. How do the possible solutions compare in terms of cost, feasibility and sustainability?
3. Based on your analysis, which solution do you consider the most optimal?

4. Discuss reducing Energy Consumption in a Manufacturing Plant: A Critical Analysis of Potential Solutions and Justification of the Optimal Approach.

Hint

The recommended mode of assessment for week 17 is **Discussion.** Use level 4 question 4 as sample question for the discussion.

WEEK 18: PROTOTYPES BASED ON GIVEN SOLUTION REQUIREMENTS

Learning Indicator: *Design a working prototype based on design requirements*

FOCAL AREA 1: TO DESIGN 3D WORKING PROTOTYPES

Designing a working prototype for creating simple 3D objects involves several steps: defining the design requirements, planning the prototype, selecting the tools and materials, designing the 3D object, printing the object, and refining the design. Here's a step-by-step guide to help you through the process:

1. Define the Design Requirements

The design requirements for this project might include:

- **a.** Use a 3D printer to create simple 3D objects.
- **b.** The 3D object should be designed using CAD software.
- **c.** The design should include basic geometric shapes like cubes, spheres, and cylinders.
- **d.** The object should be functional or decorative.

2. Plan the Prototype

Create a plan that includes the design concept, the software tools needed, and the 3D printing process:

Design Concept

- **a.** Create a simple 3D object, such as a keychain, a small box, or a figurine.

Software Tools

- **a.** CAD software (e.g., Tinkercad, Fusion 360, Blender) for designing the 3D object.
- **b.** Slicing software (e.g., Cura, PrusaSlicer) to prepare the design for 3D printing.

3D Printing Process

- **a.** Design the object in CAD software.
- **b.** Export the design as an STL file.
- **c.** Import the STL file into the slicing software.
- **d.** Configure print settings (e.g., layer height, infill density).
- **e.** Print the object using a 3D printer.

3. Select Tools and Materials

- **a.** **3D Printer**: Choose a reliable 3D printer (e.g., Creality Ender 3, Prusa i3 MK3S).
- **b.** **Filament**: Select the appropriate filament type (e.g., PLA, ABS) and color.
- **c.** **CAD Software**: Tinkercad for beginners, Fusion 360 for more advanced users.
- **d.** **Slicing Software**: Cura, PrusaSlicer.

e. **Additional Tools**: Spatula, tweezers, and calipers for post-processing.

4. **Design the 3D Object**
   a. **Open CAD Software**: Start with Tinkercad for simplicity.

   b. **Create Basic Shapes**
      i. Drag and drop basic shapes (cube, sphere, cylinder) from the toolbar.
      ii. Resize and position the shapes as needed.
      iii. Combine shapes to form the desired 3D object.

   c. **Refine the Design**
      i. Add details (e.g., holes, text) to make the object functional or decorative.
      ii. Ensure the design is manifold (no gaps or intersecting faces).

   Example: Designing a simple keychain

   - Drag a rectangle (base of the keychain).
   - Add a small hole (cylinder) for the keyring.
   - Add text or logo using the text tool.
   - **Export the Design**:

   Export the design as an STL file for 3D printing.

5. **Prepare for 3D Printing**
   a. **Open Slicing Software**: Use Cura or PrusaSlicer.
   b. **Import the STL File**: Load the exported STL file into the slicer.

   c. **Configure Print Settings**
      i. Set the layer height (e.g., 0.2 mm for a balance of quality and speed).
      ii. Choose the infill density (e.g., 20% for moderate strength).
      iii. Adjust other settings like print speed and support structures if needed.

   d. **Generate G-code**: Slice the model and save the G-code file.

6. **Print the Object**

   a. **Prepare the 3D Printer**
      i. Load the filament into the 3D printer.
      ii. Ensure the print bed is level.

   b. **Start the Print**
      i. Transfer the G-code file to the printer (via SD card or USB).
      ii. Begin the print and monitor the initial layers to ensure proper adhesion.

   c. **Post-Processing**
      i. Once printing is complete, carefully remove the object from the print bed.

ii. Remove any support structures and clean up the edges if necessary.

7. **Test and Refine the Design**

   a. **Evaluate the Print**

      i. Check for dimensional accuracy and overall quality.

      ii. Test the functionality if it's a functional object.

   b. **Make Adjustments**

      i. Return to the CAD software to make any necessary design changes.

      ii. Reprint the object if significant changes were made.

   c. **Documentation**

      i. **Design Files**: Include the final STL and CAD files.

      ii. **Print Settings**: Document the slicing settings used.

      iii. **Testing Results**: Record observations, issues, and solutions.

      iv. **User Manual**: Write a brief guide on how to use and modify the design.

Learning Task

1. Guide learners to create a 3D model of a simple **keychain** and discuss the steps and considerations involved in the design process.
2. Have learners work in groups to design a simple 3D printed **phone stand** and record the key dimensions and features they considered.
3. Assign learners to design a simple **pen stand** to hold at least five (5) pens or pencils and give the considerations involved in the design process. Present their design to the class.

Pedagogical Exemplars

Initiate Talk for Learning

Show learners how a 3D printer works (using a 3D printer, software, or a digital model) and walk the class through the process of creating simple objects.

Experiential Learning

1. Have learners design and print their own objects.
2. Give learners a project in which they have to design and print their own objects using 3D modelling software. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
3. These could be simple objects like a keychain, the power button of a laptop, a phone housing, etc.
4. Have learners design and print their own objects and award the best 3 designs.

Collaborative Learning

1. Work in groups and discuss learner's observations on the strengths and weaknesses of 3D printing as well as the future of 3D printing. Create a peer-to-peer mentoring system to help learners having difficulties receive help from colleagues.
2. Groups should make presentations on their observations.
3. Support groups working at a slower pace whilst the rest of the class completes more activities.

Key Assessment

Level 2 Skills of conceptual understanding

1. Explain the importance of infill density in 3D-printed prototypes
2. Describe the role of support structures in 3D printing

Level 3 Strategic reasoning

1. How does layer height affect the quality and print time of a 3D-printed object
2. Why is it important to consider the orientation of a model on the print bed?

Level 4 Extended critical thinking and reasoning

1. Discuss the factors that should be considered when choosing a material for a 3D-printed prototype.

Hint

The recommended mode of assessment for week 18 is **Mid-semester examination.** Refer to Appendix F for table of specifications on how to develop assessment items for mid-semester examinations.

SECTION 7 REVIEW

1. Can learners analyse possible solutions to the wastage of electricity in our households?
2. Can learners analyse possible ways to dispose of waste (liquid and solid) to avoid spreading diseases?
3. Would learners analyse the causes of frequent road accidents on our roads and how to mitigate them?
4. Would learners be able to identify problems in the school dining hall, kitchen, store, staff bungalow, dormitories, and classrooms and analyse possible solutions to the problem?
5. Can learners create a 3D model of a simple keychain and discuss the steps and considerations involved in the design process?
6. Can learners work in groups to design a simple 3D-printed phone stand and record the key dimensions and features they considered?

7. Can learners design a simple pen stand to hold at least five (5) pens or pencils and give the considerations involved in the design process?

Additional Reading

Watch a video on 3D printing using tinkercad from the link below: https://www.youtube.com/watch?v=zIwrW4kcHTU,

1. CETE: Report Incorporating Engineering Design Challenges into STEM Courses, National Center for Engineering and Technology Education (2012)

2. Wesley L. Stone and Hugh Jack, "Project-Based Learning: Integrating Engineering Technology and Engineering," in American Society of Engineering Education Annual Conference, Columbus, Ohio, 2017.

3. *Engineering Design and Manufacturing Education through Research Experience for High School Teachers*. Available from: https://www.researchgate.net/publication/326822347_Engineering_Design_and_Manufacturing_Education_through_Research_Experience_for_ High_School_Teachers [accessed Apr 16, 2024].

Teaching/Learning Resources

- 3D Modelling Software, example Autodesk Fusion 360, Tinkercad and SketchUp 3D Printer, Online Tutorials on 3D printers and modelling software.
- Case Studies: Case studies of real-world applications of 3D printing and rapid prototyping
- Textbooks

The marking scheme and rubrics for scoring the Discussion task

	4 marks	3 marks	2 marks	1 mark
Identification of inefficiencies	Identifies four inefficiencies such as outdated equipment, inefficient lighting, lack of automation, inefficient HVAC	Identifies three inefficiencies such as outdated equipment, inefficient lighting, lack of automation, inefficient HVAC	Identifies two inefficiencies such as outdated equipment, inefficient lighting, lack of automation, inefficient HVAC	Identifies one inefficiency such as outdated equipment, inefficient lighting, lack of automation, inefficient HVAC
Proposal of solutions	Identifies four solutions such as upgrade of energy efficient machinery, replace incandescent bulbs, introduce, upgrade HVAC automation technology,	Identifies three solutions such as upgrade of energy efficient machinery, replace incandescent bulbs, introduce, upgrade HVAC automation technology	Identifies two solutions such as upgrade of energy efficient machinery, replace incandescent bulbs, introduce, upgrade HVAC automation technology	Identifies one solution such as upgrade of energy efficient machinery, replace incandescent bulbs, introduce, upgrade HVAC automation technology
Justification of solution	With four solution justifications such as Upgrading to energy-efficient machinery reduces the overall energy consumption of equipment.	With three solution justifications such as Upgrading to energy-efficient machinery reduces the overall energy consumption of equipment	With two solution justifications such as Upgrading to energy-efficient machinery reduces the overall energy consumption of equipment	With one solution justification such as Upgrading to energy-efficient machinery reduces the overall energy consumption of equipment
Uses of Data and metrics	With four uses of data and matrices such as energy consumption, monitor and track the frequency of machine, track the amount of waste from raw materials, monitor HVAC and water usage	With three uses of data and matrices such as energy consumption, monitor and track the frequency of machine, track the amount of waste from raw materials, monitor HVAC and water usage	With two uses of data and matrices such as energy consumption, monitor and track the frequency of machine, track the amount of waste from raw materials, monitor HVAC and water usage	With one use of data and matrices such as energy consumption, monitor and track the frequency of machine, track the amount of waste from raw materials, monitor HVAC and water usage

Total - 16 marks

APPENDIX F: SECOND MID-SEMESTER EXAMINATION

Structure of Mid-semester Examinations: 15 multiple choice questions (MCQs) and three (3) essay questions covering focal areas weeks 13-17 for first semester as in the table of specifications.

a. Paper 1: 15 MCQs.

b. Paper 2: PART A and PART B

i) Part A: 1 compulsory question

ii) Part B: 2 questions.

Materials Needed: Printer, A4 sheets, etc. **Duration:** One Hour

Marking Scheme/Rubrics

Award 1 mark for each correct answer. **Total marks**: 30 marks

How to administer assessment task

a. Preparation: Inform learners about the structure of examination including the number of questions, duration of the examinations and scoring rubrics, etc.

b. State clear instructions on the paper such as how to select the option, etc.

c. Examination day: Ensure a controlled environment to avoid cheating. Learners sit independently in well supervised, calm atmosphere; each learner should be given a printed hard copy of the question papers. e-Assessment can also be used if available, etc.

Table of Specification for Mid-Semester Examination

The specification for the number of questions for each week are indicated in the table below

Content /week		DoK (Number of questions)			
		Level 1	Level 2	Level 3	Total
1. Operate and maintain simple photovoltaic and solar thermal energy systems	Objectives	1	1	1	4
	Essay	1	–	–	
2. Design and install simple photovoltaic and solar thermal systems	Objectives	–	2	1	4
	Essay	–	1	–	
3. Energy management plan and basic energy audit plan	Objectives	1	1	1	4
	Essay	–	–	1	
4. Energy-saving methods for electrical and thermal systems	Objectives	1	2	–	3
	Essay	–	–	–	
5. Solutions and suitable solution(s) based on a set of constraints.	Objectives	1	1		3
	Essay	–	–	1	

Total		*5/18 x 100 =27.8%*	*8/18 x100= 44.4%*	*5/18 x100 = 27.8%*	*18/18 x 100=100%*

Feedback

After marking, discuss the questions with learners, appreciate those who did well and encourage those who need improvement, etc.

SECTION 8: ENGINEERING PROTOTYPING

Strand: Systems Design and Prototyping

Sub-Strand: Rapid Prototyping

Learning Outcomes

1. *Navigate the CAD tools and perform basic operations and functions associated with model design.*
2. *Implement CAD models using 3D printing systems*

Content Standard: Demonstrate understanding of the use of CAD tools for the design of models.

INTRODUCTION AND SECTION SUMMARY

This section will introduce learners' implementation of CAD models using a 3D printing system. The process of utilising CAD tools for model creation entails a series of steps: software selection, comprehension of fundamental functionalities, model design, and preparation for 3D printing or alternative manufacturing procedures. Learners will understand some basic operations and functions associated with model design. The process of establishing, adjusting, and employing a 3D printer to manufacture CAD prototype models encompasses multiple stages will be introduced to learners in this section.

The weeks covered by the section are:

Week 19: The use of CAD tools for the design of models

Week 20: Implement CAD models using 3D printing systems

SUMMARY OF PEDAGOGICAL EXEMPLARS

In the section, some pedagogical exemplars recommended are Talk for learning, Experiential learning, Self-directed learning and Project-based learning. To teach CAD, start by familiarising learners with basic concepts like user interface, drawing and modelling skills, and layers. Provide practical examples and encourage independent design production. Utilise online resources like tutorials, instructional videos, and forums for guidance. Integrate practical projects to enhance problem-solving abilities and design methodology. Demonstrate the function of a 3D printer and guide students in creating basic objects. Assign tasks to create and produce products using 3D modelling software. Let learners collaborate in teams to tackle design challenges using computer-aided design and manufacturing tools. Structure roles based on industry roles to enhance teamwork and collaboration skills. Support individuals or groups working at a slower pace whilst the rest work on more activities,

ASSESSMENT SUMMARY

Written or PowerPoint presentations can be used to elicit learners' observations on basic operations and functions associated with model design. Let learners watch a video and use it to explain CAD software, and its primary functions in the design and modelling process Oral presentation is encouraged for this exercise. Let learners predict how to create basic geometric shapes (e.g., rectangle, circle, and triangle) in CAD software. These should contribute to learners' formative assessment. In this section, Research, debate and homework are recommended as modes of assessment. Learners may research how to transfer the sliced model file to the 3D printer and some common methods for doing this. Support learners working at a slower pace whilst the rest work on more activities.

WEEK 19: THE USE OF CAD TOOLS FOR THE DESIGN OF MODELS

Learning Indicator: *Apply CAD tools to create models*

FOCAL AREA 1: TO CREATE 3D MODELS

Applying CAD tools to create models involves several steps: selecting the right software, understanding the basic features, designing a model, and preparing it for 3D printing or other manufacturing processes. Here's a detailed guide to help you through the process using a popular CAD tool like Tinkercad for beginners and Fusion 360 for more advanced users.

Step-by-Step Guide: Using Tinkercad

1. **Create an Account and Start a New Design**
   a. **Sign Up**: Go to the Tinkercad website and create an account.
   b. **New Design**: Once logged in, click on "Create new design" to start a new project.

2. **Understand the User Interface**
   a. **Workplane**: The grid where you place and manipulate shapes.
   b. **Shapes Library**: A collection of basic geometric shapes, text, and more complex models.
   c. **Toolbar**: Tools for grouping, aligning, and modifying shapes.

3. **Design a Simple 3D Model (Example Keychain)**
   a. **Drag Shapes**: Drag a rectangle (parallelepiped) from the shapes library to the work plane.
   b. **Resize Shape**: Click on the shape and use the white handles to resize it (e.g., 50mm x 20mm x 3mm).
   c. **Add Text**: Drag the "Text" shape to the workplane, resize, and position it on the rectangle.
   d. **Create a Hole**: Drag a cylinder shape, resize it to a small circle (e.g., 5mm diameter), and position it near the edge of the rectangle. Set it as a hole using the "Hole" option in the inspector.
   e. **Group Shapes**: Select all shapes (rectangle, text, and cylinder), then click the "Group" button to merge them into a single model.

4. **Export the Model**

Export as STL: Click on the "Export" button and choose ".STL" format to save your design for 3D printing.

Step-by-Step Guide: Using Fusion 360

1. **Install and Set Up Fusion 360**
   a. **Download**: Get Fusion 360 from the Autodesk website.
   b. **Install and Launch**: Follow the installation instructions and launch the application.
   c. **Sign In**: Use your Autodesk account to sign in.

2. **Understand the User Interface**
   a. **Toolbar**: Contains tools for creating and modifying sketches, features, and assemblies.
   b. **Browser**: Lists the components and sketches of your project.
   c. **Canvas**: The main area where you create and view your model.
   d. **Timeline**: Shows the history of operations performed on the model.

3. **Design a Simple 3D Model (Example Simple Box)**

   a. **Create a Sketch**
      i. Click on "Create Sketch" and select a plane (e.g., XY plane).
      ii. Use the rectangle tool to draw a 50mm x 50mm square.
      iii. Finish the sketch.

   b. **Extrude the Sketch**
      i. Select the sketch and click on "Extrude".
      ii. Enter a height (e.g., 30mm) and click "OK".

   c. **Add Features**
      i. To add a hole, create another sketch on one of the faces of the box.
      ii. Draw a circle in the desired location.
      iii. Finish the sketch and use the "Extrude" tool to cut through the box.

   d. **Fillet Edges**
      i. Select edges to be rounded.
      ii. Click on "Fillet" and specify the radius.

4. **Assemble Components (if necessary)**
   a. **Insert Components**: Use the "Insert" menu to add multiple components.
   b. **Joint Tool**: Use the "Joint" tool to define relationships between components.

5. **Export the Model**

Save as STL: Right-click the body or component in the browser, select "Save As STL".

3D Printing Preparation

1. **Open Slicing Software**: Use Cura, PrusaSlicer, or any preferred slicer.
2. **Import the STL File**: Load the STL file exported from your CAD tool.

3. **Configure Print Settings**: Set parameters such as layer height, infill density, print speed, and support structures.
4. **Generate G-code**: Slice the model and save the G-code file.

Testing and Refinement

1. **Print the Object**: Transfer the G-code to your 3D printer and start the print.
2. **Evaluate the Print**: Check for accuracy, surface finish, and functionality.
3. **Make Adjustments**: Return to the CAD software to make any necessary design changes and repeat the printing process.

Documentation

1. **Design Files**: Save and organise your CAD files (.f3d, .stl).
2. **Print Settings**: Document the slicing settings used for each print.
3. **Testing Results**: Record observations, issues, and solutions.
4. **User Guide**: Write a brief guide on how to use and modify the design.

By following these steps, you will be able to create simple 3D models using CAD tools and prepare them for 3D printing. This process covers the basics of 3D modelling, slicing, and printing, essential for prototyping and manufacturing.

Learning Task

1. Guide learners to create a 3D model of a **wall hook** that must support the weight of common items like coats or bags, be easy to mount on a wall, and have a decorative design.
2. Help learners to design a **customised nameplate** that clearly displays a name or message, able to stand on a desk or hang on a wall and can include decorative elements or company logos.
3. In mixed ability groups assign learners to design **bottle opener** that must be strong enough to open bottles, compact and easy to carry.
4. Assign learners to design **plant pot** that must hold soil and a small plant, should have drainage holes to prevent waterlogging and aesthetic design to complement home décor.

Pedagogical Exemplars

Talk for Learning: Begin by introducing learners to the fundamental concepts and principles of CAD, such as the user interface, basic drawing and modelling techniques, and the use of layers.

Experiential Learning

1. Provide learners with examples of real-world designs and have them practice creating similar designs on their own.

2. This will help them understand how to apply the concepts they are learning in a practical setting. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.

Self-Directed Learning: Explore online resources

1. There are many online resources available that can help learners learn more about CAD and how to use it.
2. Some good options include online tutorials, instructional videos, and forums where learners can ask questions and get feedback from experts. Develop a peer mentoring system in the mixed-ability groups to encourage more advanced learners to support their colleagues in understanding and effectively applying these concepts
3. Learners learn additional knowledge and experiences of 3D printing and present individual reports.
4. Support learners with special needs whilst the rest perform more activities.

Project-based Learning

1. Incorporate hands-on projects that allow learners to apply their CAD skills to real-world design challenges. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
2. This can help them develop their problem-solving skills and better understand the design process.

Key Assessment

Level 2 Skills of conceptual understanding

1. Explain what is CAD software, and its primary functions in the design and modelling process.
2. Discuss some commonly used CAD software programs and briefly describe their main features.
3. How do you create basic geometric shapes (e.g., rectangle, circle, triangle) in CAD software?

Level 3 Strategic reasoning

1. Explain the process of modifying a shape by using tools such as fillet, chamfer, and offset. Provide an example for each.
2. How do you ensure that the keychain model is suitable for 3D printing, particularly in terms of size and thickness?

Level 4 Extended critical thinking and reasoning

1. Discuss the steps involved in designing a keychain with a custom shape and text using CAD software.2. Use CAD tool like Tinkercad for beginners to design and create models of choice, such as keyholder, bottle opener, phone cover

Hint

- The recommended mode of assessment for week 19 is **e-assessment.** Use level 4 question 2 as sample question for the e-assessment.
- Ensure you have a stable internet connection on a compatible device (computer, tablet, or smartphone) and write clearly /print out your responses on a one-page paper.

WEEK 20: IMPLEMENT CAD MODELS USING 3D PRINTING SYSTEMS

Learning Indicator: *Set up configure and utilise a 3D printer to produce CAD prototype models*

FOCAL AREA 1: TO PRODUCE CAD PROTOTYPES

Setting up, configuring, and utilising a 3D printer to produce CAD prototype models involves several detailed steps. Here's a comprehensive guide to help you through the process:

1. **Choose the Right 3D Printer**

   Select a 3D printer that meets your needs. Consider factors such as build volume, material compatibility, resolution, and price.

2. **Set Up the 3D Printer**

   Unbox and Assemble

   a. **Unbox the Printer**: Carefully remove the printer and all its components from the packaging.

   b. **Assemble the Printer**: Follow the manufacturer's instructions to assemble the 3D printer. This typically includes assembling the frame, attaching the print bed, and connecting the extruder and other components.

   Level the Print Bed

   a. **Initial Levelling**: Many printers come with manual levelling knobs. Adjust these to ensure the bed is as level as possible.

   b. **Use a Piece of Paper**: Place a piece of paper between the nozzle and the print bed. Adjust the height so the nozzle just touches the paper, providing slight resistance when moving the paper.

   c. **Auto-Levelling**: If your printer has an auto-levelling feature, run the auto-levelling procedure as per the printer's instructions.

   Load the Filament

   a. **Heat the Nozzle**: Preheat the nozzle to the recommended temperature for the filament (e.g., 200°C for PLA).

   b. **Insert Filament**: Feed the filament into the extruder until you see it coming out of the nozzle.

3. **Configure the 3D Printer**

   Connect to the Printer

   a. **Via USB or SD Card**: Connect your computer to the printer using a USB cable or transfer files via an SD card.

   b. **Install Printer Drivers**: If necessary, install the appropriate drivers for your 3D printer.

Use Slicing Software

a. **Install Slicing Software**: Download and install slicing software such as Cura, PrusaSlicer, or Simplify3D.

b. **Add Printer Profile**:
   i. Open the slicing software and add your 3D printer model from the list of supported printers.
   ii. Configure the basic settings like print bed size, nozzle diameter, and filament type.

4. **Prepare CAD Models for Printing**

Create or Import CAD Models

a. **Design in CAD Software**: Use Tinkercad, Fusion 360, or any other CAD software to create your 3D model.

b. **Export as STL**: Once the design is complete, export the model as an STL file.

Slice the Model

a. **Open the STL File**: Import the STL file into your slicing software.

b. **Configure Print Settings**
   i. **Layer Height**: Set the layer height (e.g., 0.2 mm).
   ii. **Infill Density**: Set the infill percentage (e.g., 20%).
   iii. **Print Speed**: Adjust the print speed based on the filament and model complexity.
   iv. **Supports**: Enable supports if your model has overhangs.
   v. **Temperature Settings**: Set the nozzle and bed temperature according to the filament (e.g., 200°C for PLA nozzle, 60°C for bed).

c. **Generate G-code**: Slice the model and generate the G-code file.

5. **Utilise the 3D Printer**

Transfer and Start the Print

a. **Transfer G-code**: Transfer the G-code file to the 3D printer via SD card or USB connection.

b. **Start Printing**: Begin the print job from the printer's control panel.

Monitor the Print

a. **Initial Layers**: Watch the first few layers to ensure they adhere correctly to the print bed.

b. **Ongoing Monitoring**: Periodically check the print to ensure it's progressing smoothly without issues like warping or layer shifting.

6. **Post-Processing**

Remove the Print

a. **Cool Down**: Allow the print bed and model to cool down before removing it.

b. **Careful Removal**: Use a spatula or scraper to gently remove the model from the print bed.

Clean Up

a. **Remove Supports**: Carefully remove any support structures using pliers or cutters.

b. **Sand and Polish**: Sand the surface to remove any rough edges and achieve a smooth finish.

Documentation and Refinement

a. **Document Settings**: Record the print settings used, such as temperature, print speed, and infill.

b. **Evaluate the Print**: Check the printed model for accuracy and quality. Note any issues encountered.

c. **Refine the Design**: If necessary, return to the CAD software to make adjustments to the model and repeat the printing process.

Learning Task

1. Demonstrate to learners how to transfer the sliced model file to the 3D printer and show them some common methods used for doing this.
2. Work with learners to identify the file formats that are typically used for 3D printing, and how to export a CAD model into one of these formats.
3. Work with learners to identify the pre-print checks that should be performed before starting a 3D print.
4. Moderate discussions on processes of starting a print on a 3D printer and how to monitor the progress of the print.

Pedagogical Exemplars

Initiate Talk for Learning

Show learners how a 3D printer works (using a 3D printer, software, or a digital model) and walk the class through the process of creating simple objects.

Support individuals working at a slower pace whilst the rest of the class completes more activities.

Experiential Learning

1. Have learners design and print their own objects. Give learners a project in which they have to design and print their own objects using 3D modelling software. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learner
2. These could be simple objects like a keychain, the power button of a laptop, a phone housing, etc.
3. Have learners design and print their own objects and award the best 3 designs.

Collaborative Learning

1. Work in groups on a design challenge. Groups will compete the design and produce models using the suite of CAD/CAM tools available according to design requirements or constraints given by the facilitator. Use your knowledge of your learners and your creativity to adapt the activity as needed. For example, you could incorporate elements of gamification or use technology tools to enhance learning.
2. Each group should assign a specific role(s) to members towards the solution of the challenge. Assign specific roles to learners to ensure that all learners participate in the project and are challenged according to their understanding and skills.
3. Roles may, for example may, be modelled after typical design and production teams in the industry to give them relevant exposure and develop team and collaborative skills in them.

Key Assessment

Level 1 Recall

1. List four (4) essential components of a 3D printer, and what role each play in the printing process.
2. List two (2) file formats that are typically used for 3D printing.

Level 2 Skills of conceptual understanding

1. Describe the steps involved in the initial setup of a 3D printer. What safety precautions should be taken?
2. Describe three (3) pre-print checks that should be performed before starting a 3D print.
3. How do you transfer the sliced model file to the 3D printer? What are some common methods for doing this?
4. How do you export a CAD model into file formats?

Level 3 Strategic reasoning

1. Explain slicing software, and why it's necessary for 3D printing.
2. How do you level the print bed on a 3D printer, and why is this step important for successful printing?
3. Explain how to load and unload filament in a 3D printer. What types of filaments are commonly used, and how do you choose the right one for your project?
4. Describe the process of starting a print on a 3D printer. How do you monitor the progress of the print?

Level 4 Extended critical thinking and reasoning

1. Describe the process of preparing a CAD model for 3D printing using slicing software. What key settings are configured, such as layer height, infill density, and print speed?
2. Demonstrate the process of setting up and configuring a 3D printer to produce a CAD prototype model. Your demonstration should include:
   a. Proper setup and calibration of the 3D printer (e.g., bed leveling, nozzle/extruder temperature, material loading).

b. Importing and preparing a CAD model in slicing software, adjusting print settings (e.g., layer height, infill density, and print speed).

c. Starting and monitoring the 3D print, explaining key steps during the printing process.

d. Discussing the choice of printing material (e.g., PLA, ABS) for the prototype and the rationale behind the selection

Hint

The recommended mode of assessment for week 20 is **Demonstration.** Use level 4 question 2 as sample question for the demonstration.

SECTION 8 REVIEW

1. Can learners demonstrate how to transfer the sliced model file to the 3D printer and some common methods used for doing this?
2. Would learners be able to identify the file formats that are typically used for 3D printing, and how to export a CAD model into one of these formats?
3. Would learners be able to identify the pre-print checks that should be performed before starting a 3D print?
4. Can learners create a 3D model of a wall hook that must support the weight of common items like coats or bags, be easy to mount on a wall, and have a decorative design?
5. Would learners be able to design a customised nameplate that displays a name or message, able to stand on a desk or hang on a wall and can include decorative elements or company logos?
6. Would groups be able to design bottle openers that must be strong enough to open bottles, compact and easy to carry?
7. Can learners design plant pot that must hold soil and a small plant, should have drainage holes to prevent waterlogging and aesthetic design to complement home décor?

Additional Reading

1. Watch video on how to get started with 3D printing from the link https://youtu.be/m12bX1eEVDM?si=DakY7dOlRccMiR1X	
2. Watch video on 3D printing https://www.youtube.com/watch?v=Kb0egLiolbo	

Teaching/Learning Resources

1. Computers with CAD Software installed (Sketchup, Solid Works)
2. Video Tutorials for Self-Directed Learning
3. Textbooks and Design manuals for CAD practice assignments
4. Integrated 3D printing machines with CAM functionality

The marking scheme and rubrics for scoring the e-assessment task

Criteria	4 marks	3 marks	2 marks	1 mark
Basic Shape Creation	Creates 4 shapes accurately with proper dimensions.	Creates 3 shapes accurately with proper dimensions.	Creates 2 shapes accurately with proper dimensions.	Creates 1 shape accurately with proper dimensions.
Design Completeness	4 models (key-holder, bottle opener, phone cover, pen holder) are completed.	3 models completed	2 models completed	1 model completed
Use of CAD Tools	Demonstrates effective use of 4 CAD tools like align, group, and rotate.	Demonstrates effective use of 3 CAD tools like align, group, and rotate.	Demonstrates effective use of 2 CAD tools like align, group, and rotate.	Demonstrates effective use of 1 CAD tool like align, group, and rotate.
Proportions and Scale	4 models are well-proportioned and scaled for real-world use.	3 models are well-proportioned and scaled for real-world use.	2 models are well-proportioned and scaled for real-world use.	1 model is well-proportioned and scaled for real-world use.
Creativity	4 designs show creativity and originality beyond basic requirements.	3 designs show creativity and originality beyond basic requirements	2 designs show creativity and originality beyond basic requirements	1 design show creativity and originality beyond basic requirements
Neatness of Design	The 4 models are neat, with clean edges and precise alignments.	The 3 models are neat, with clean edges and precise alignments.	The 2 models are neat, with clean edges and precise alignments.	The 1 model is neat, with clean edges and precise alignments.
Submission Format	4 files are correctly named and submitted in the right format.	3 files are correctly named and submitted in the right format.	2 files are correctly named and submitted in the right format.	1 file is correctly named and submitted in the right format.

Total = 28 marks

The marking scheme and rubrics for scoring the Demonstration task

Criteria	*3 marks*	*2 marks*	*1 mark*
Printer Setup and Calibration	*Properly sets up the 3D printer (i.e., Connecting the printer to the power supply), demonstrates accurate bed leveling (i.e., Verifying the correct gap between the nozzle and the print bed), correct extruder settings, and material loading with no errors (i.e. Ensuring the extruder is calibrated to release the correct amount of filament)*	*Properly sets up the 3D printer (i.e., Connecting the printer to the power supply), demonstrates accurate bed leveling (i.e., Verifying the correct gap between the nozzle and the print bed)*	*Properly sets up the 3D printer (i.e., Connecting the printer to the power supply)*
Use of Slicing Software	*Accurately imports CAD model into slicing software, configures print settings (layer height, infill, speed) correctly, with clear explanation.*	*Imports CAD model and configures most print settings correctly but lacks a clear explanation of choices.*	*Struggles to configure slicing settings properly, with incorrect or missing details in key areas.*
Material Selection and Application	*Selects the appropriate material (e.g., PLA, ABS) for the prototype with clear reasoning based on project requirements.*	*Selects a suitable material but provides limited reasoning behind the choice.*	*Selects material but does not provide sufficient explanation or chooses less appropriate material.*
Print Monitoring and Troubleshooting	*Actively monitors the print process, identifies, and addresses potential issues (e.g., print quality, filament feed) with clear explanations.*	*Monitors the print and addresses some issues, but with minor lapses in judgment or response.*	*Monitors the print with limited understanding of potential issues or troubleshooting steps.*
Explanation and Presentation	*Provides a clear, organized, and detailed explanation of each step, with strong confidence and understanding of the process.*	*Provides a clear explanation of most steps but lacks detail or confidence in some areas.*	*Provides a basic explanation, but the process is unclear or lacks key details in multiple areas.*
Safety Practices	*Demonstrates excellent awareness of 3D printer safety protocols (e.g., handling heated elements, material safety).*	*Demonstrates good awareness of safety protocols but overlooks minor safety considerations.*	*Demonstrates minimal safety awareness or neglects some important safety protocols.*

Total = 18 marks

SECTION 9: AUTOMATION AND EMBEDDED SYSTEMS

Strand: Automation and Embedded Systems

Sub-Strand: Automation Technologies

Learning Outcome: *Utilise basic electronic components for simple automation tasks.*

Content Standard: Demonstrate understanding of basic electronics for automation systems

Hint

Remind learners of the presentation and submission of their Individual project work and portfolio in week 23, end of semester examination in week 24.

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to how to create uncomplicated automation systems using fundamental electrical components, one must comprehend the purposes of each component and how they might be combined to execute a particular function. Learners will understand how to write code in C/C++. When working with Arduino, you utilise the Arduino IDE to write code in C/C++. Learners will appreciate the fundamental guide that explains how to declare variables and constants and execute control actions and loops. Learners will be able to write functions and test and debug code using the Arduino IDE. Creating uncomplicated Arduino-based embedded systems entails connecting the Arduino to several hardware components to accomplish specific functionality. Additionally, this section introduces learners to illustrative examples showcasing the integration of Arduino with various components such as switches, LEDs, LCDs, relays, IR sensors, seven-segment displays, and other digital sensors. Facilitators may organised the students into groups of varying abilities to create and build one of the listed projects. The tasks include choosing components, designing circuits, using CAD tools for simulation, creating 3D models for enclosures, and utilising Arduino for control.

The weeks covered by the section are:

Week 21: Basic electronic components for simple automation tasks

Week 22: The use of IDE of Arduino to write simple programmes

Week 23: The design of simple Arduino-based embedded systems

Week 24: Design a mini project into a functional system

SUMMARY OF PEDAGOGICAL EXEMPLARS

The recommended pedagogical exemplars for this section are experiential learning, self-directed learning, project-based learning and collaborative learning. The facilitator put learners in small groups to construct basic automated circuits using electronic components on a breadboard, such as a streetlight using a Light Dependent Resistor (LDR). They are then tasked with enhancing the circuit's functionality by incorporating timed functions or motion sensors. Learners are provided with schematics of common automation circuits for assembly and practice, this can be a project for the semester. Learners are encouraged to design and execute an electronic circuit to solve an automation issue. Students collaborate in teams to devise, execute, evaluate, and record an electrical circuit for an automation challenge. Roles are structured based on traditional design and production teams to develop teamwork and collaborative abilities. Students are encouraged to use internet resources to explore additional tutorials and programming projects involving Arduino-embedded kits. Examples of projects include displaying the current date and time on LCD screens, creating intelligent traffic signal displays, designing stopwatches and countdown timers, developing intelligent street lighting, and implementing display and scrolling of names on multi-segment displays.

ASSESSMENT SUMMARY

Assess learners based on their understanding of key concepts, participation in hands-on activities, and successful completion of project tasks. Written and Oral responses can be elicited in class discussions following a talk from a guest speaker. Learners can be encouraged to describe the operation of a motor control circuit using a relay. Allow learners to discuss the significance of memory alignment and padding in structures. Learners can give oral presentations which can be used for their formative assessment. Allow learners to write a program to control the speed of a DC motor using a potentiometer and PWM on an Arduino. Research, project, portfolio and homework are recommended as assessment mode for this section.

WEEK 21: BASIC ELECTRONIC COMPONENTS FOR SIMPLE AUTOMATION TASK

Learning Indicator: *Design and build automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc*

FOCAL AREA 1: TO DESIGN AND BUILD AUTOMATION SYSTEMS

Designing and building simple automation systems using basic electronic components involves understanding the functions of each component and how they can be integrated to perform a specific task. Here's a guide to get you started with a few example projects:

1. Design Light-Activated Switch

A light-activated switch is an electronic device that automatically turns on or off an electrical load (such as a light bulb or a motor) based on the ambient light level. It uses a light-sensitive component, typically a Light Dependent Resistor (LDR), to detect the level of light in the environment.

Components Needed

Light Dependent Resistor (LDR)

NPN Transistor (e.g., BC547)

Resistors: Various values (e.g., 1kΩ, 330Ω)

Relay Module

Diode (e.g., 1N4007)

Power Supply: Suitable voltage for your relay and transistor (e.g., 6V battery)

Connecting Wires

Breadboard or PCB for assembling the circuit

Load (e.g., a bulb or LED) to be switched on/off

Circuit diagram

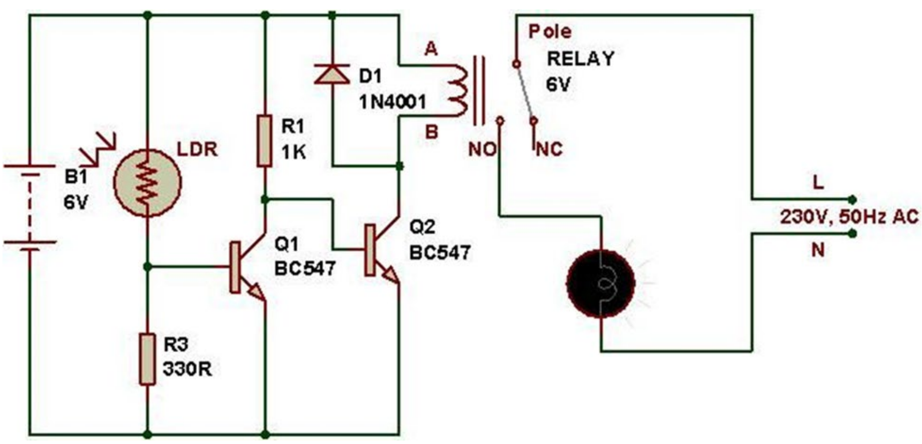

Figure 16: *A picture of the electrical circuit of light-activated switch*

Circuit Design

1. LDR and Voltage Divider

a. Connect one end of the LDR to the positive terminal of the power supply.

b. Connect the other end to a resistor (10kΩ) and then to the ground. The junction between the LDR and the resistor will be the input to the transistor's base.

2. Transistor Switching

a. Connect the base of the NPN transistor (BC547) to the junction between the LDR and the resistor through another resistor (330Ω).

b. Connect the emitter of the transistor to the ground.

c. Connect the collector of the transistor to one end of the LED, and the other end of the LED to the positive terminal of the power supply through a current-limiting resistor (330Ω).

Operation

a. When it's dark, the resistance of the LDR increases, causing a voltage drop across the LDR that is high enough to turn on the transistor. This allows current to flow through the LED, turning it on.

b. In daylight, the LDR resistance decreases, causing the voltage drop to be insufficient to turn on the transistor, keeping the LED off.

2. Motor Control with Relay

Components

a. Relay module

b. Normally Close Push Button

c. Normally Open Push Button

d. DC Motor

e. Power supply (e.g., 12V for motor)

Circuit Design

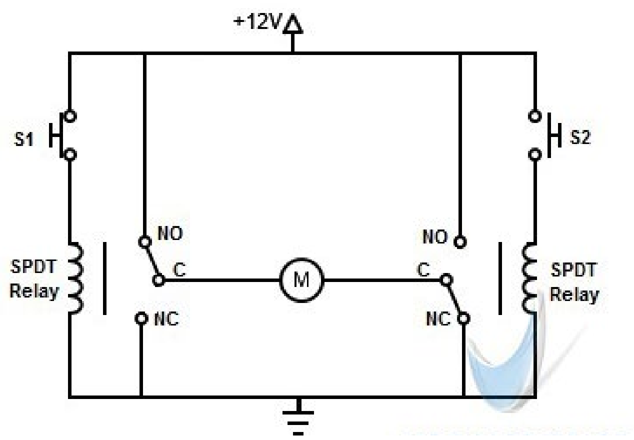

Figure 17: *A picture of the electrical circuit of motor control with relay*

3. Temperature-Controlled Fan

Components

- **a.** NTC Thermistor (20k)
- **b.** Capacitor (0.1μ)
- **c.** NPN Transistor (e.g., BD139)
- **d.** Resistors (20kΩ, 1kΩ)
- **e.** IC (NE555)
- **f.** DC Fan (12V)
- **g.** Diode (1N4007)
- **h.** Power supply (e.g., 12V for fan, 5V for control circuit)

Circuit Design

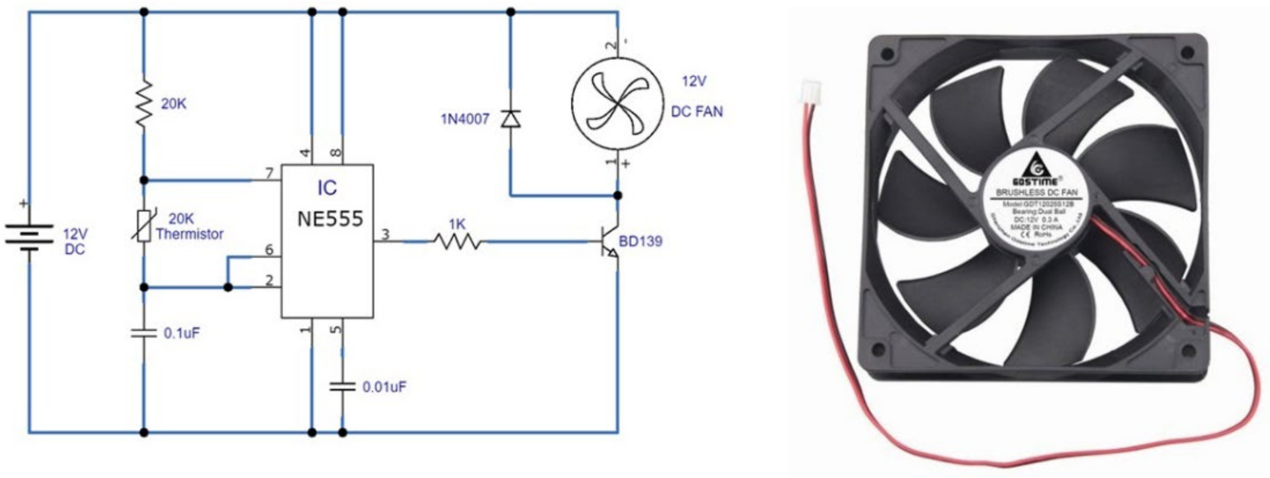

Figure 18: *A picture of the electrical circuit of a temperature-controlled fan*

Learning Task

1. Work with learners to design a complete automation system that includes a light-activated switch, motor control, and temperature-controlled fan.
2. Discuss with learners to propose a method to improve the sensitivity of a light-activated switch using an LDR.
3. Work with learners to create a circuit diagram for a motor control system that uses both relay contacts and transistor switching.

Pedagogical Exemplars

Experiential Learning

1. The facilitator guides learners to assemble electronic components on a breadboard to build a simple automated circuit, such as an automated streetlight with LDR and explains the functions of each component in the circuit.

2. Learners are then left to modify the circuit to increase its functionality and complexity by adding timing functions or motion sensors, for example. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
3. Learners should be given schematics of common automation circuits to assemble and practice with them by modifying components to vary performance

Project-based Learning

Learners work on a project that involves designing and implementing an electronic circuit for an automation problem, given the requirements. Provide different levels of activities based on learners' readiness. For example, some learners could work on simple circuits wheras more advanced circuits could be given to more advanced learners.

Self-Directed Learning

1. Learners are given access to online resources to explore further electronic automation circuits for implementation and experimentation.
2. Learners should be motivated to individually build and test at least three (3) of such circuits on their own. Monitor learner progress and adjust your approach as needed. For example, if a learner is struggling, you could provide additional support or modify the activity.

Collaborative Learning

1. Learners work in groups to design, implement, test and document an electronic circuit for an automation problem.
2. Each group should assign a specific role(s) to members towards the solution of the challenge.
3. Roles may, for example, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop team and collaborative skills in them.

Key Assessment

Level 1 Recall

1. What is the function of a transistor in an electronic circuit?
2. Name three types of components commonly used to build automation systems.
3. What does LDR stand for and what is its function in a circuit?
4. Describe the purpose of a relay in an automation system.
5. How does a capacitor function in a circuit?
6. What is the role of an LED in a circuit?

Level 2 Skills of conceptual understanding

1. Explain the role of the transistor in a light-activated switch circuit.
2. Describe the operation of a motor control circuit using a relay.
3. What happens when the contacts of a relay are activated in a motor control circuit?

4. How does a temperature-controlled fan circuit work?
5. Explain the function of relay contacts in an automation system.

Level 3 Strategic reasoning

1. How would you select the resistor values for the voltage divider in a light-activated switch to ensure proper operation?
2. Describe how you would adjust the sensitivity of a light-activated switch to different light levels.
3. Describe how you would control a motor using a relay and a transistor.
4. How would you integrate an LED into a light-activated switch circuit to indicate when the circuit is active?
5. Outline the steps to build a temperature-controlled fan circuit using a thermistor and a transistor.

Level 4 Extended critical thinking and reasoning

1. Construct a light-activated switch circuit using an LDR, a 2N2222 transistor, and a relay. Include a detailed circuit diagram and component values.
2. Discuss potential issues that could arise in a light-activated switch circuit and how you would troubleshoot them.
3. Explain how you could modify a basic light-activated switch circuit to include a delay so that the load stays on for a few seconds after the light level drops below the threshold.
4. What are the potential issues that could arise in a motor control circuit using a relay?
5. Evaluate the performance of a temperature-controlled fan circuit at different temperature settings.
6. Design and build automation systems such as Light-Activated switch, Temperature control fan, etc.
   - **a.** Identify an array of electronic components needed for practical work.
   - **b.** Build the circuits using circuit diagrams

Hint

The recommended mode of assessment for week 21 is **Practical work.** Use level 4 question 6 as sample question for the practical work.

WEEK 22: THE USE OF IDE OF ARDUINO TO WRITE SIMPLE PROGRAMMES

Learning Indicator: *Declare variables and constants, perform control actions and loops, write functions in C, test and debug programmes within the Arduino IDE*

FOCAL AREA 1: ARDUINO PROGRAMMING IN C; BASICS

When programming with Arduino, you write code in C/C++ using the Arduino IDE. Here's a basic guide on declaring variables and constants, performing control actions and loops, writing functions, and testing/debugging within the Arduino IDE.

1. Declaring Variables and Constants

Variables can be declared globally (outside any function) or locally (inside functions). Constants are declared using #define or the const keyword.

```
// Global variable
int ledPin = 13;  // LED connected to digital pin 13

// Constant using #define
#define BUTTON_PIN 2  // Button connected to digital pin 2

// Constant using const keyword
const int sensorPin = A0;  // Sensor connected to analog pin A0
```

Figure 19: *A picture of Declaring Variables and Constants Code*

2. Control Actions and Loops

Control actions include conditional statements (if, else, switch) and loops (for, while, do-while).

```
void setup() {
  pinMode(ledPin, OUTPUT);  // Set pin 13 as an output
  pinMode(BUTTON_PIN, INPUT);  // Set pin 2 as an input
}

void loop() {
  int buttonState = digitalRead(BUTTON_PIN);  // Read the button state

  if (buttonState == HIGH) {  // If button is pressed
    digitalWrite(ledPin, HIGH);  // Turn on the LED
  } else {
    digitalWrite(ledPin, LOW);  // Turn off the LED
  }

  // Loop with a delay
  for (int i = 0; i < 10; i++) {
    digitalWrite(ledPin, HIGH);
    delay(100);  // Wait for 100 milliseconds
    digitalWrite(ledPin, LOW);
    delay(100);
  }
}
```

Figure 20: *A picture of Control Actions and Loops code*

3. Writing Functions

Functions in C/C++ are defined with a return type, function name, and parameters.

```
// Function to turn on LED for a specified duration
void turnOnLED(int duration) {
  digitalWrite(ledPin, HIGH);  // Turn on the LED
  delay(duration);  // Wait for the specified duration
  digitalWrite(ledPin, LOW);  // Turn off the LED
}

void loop() {
  if (digitalRead(BUTTON_PIN) == HIGH) {
    turnOnLED(1000);  // Turn on LED for 1000 milliseconds
  }
}
```

Figure 21: *A picture of Writing Functions code*

4. Testing and Debugging

The Arduino IDE includes a Serial Monitor for debugging.

```
void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(BUTTON_PIN, INPUT);
  Serial.begin(9600);  // Initialize serial communication at 9600 baud
}

void loop() {
  int buttonState = digitalRead(BUTTON_PIN);
  Serial.print("Button state: ");
  Serial.println(buttonState);  // Print button state to Serial Monitor

  if (buttonState == HIGH) {
    turnOnLED(1000);
  }
}
```

Figure 22: *A picture of Testing and Debugging code*

Example Project Traffic Light Control System

This project uses an Arduino to control a simple traffic light system with red, yellow, and green LEDs.

Components

1. Arduino Uno
2. Red, Yellow, and Green LEDs

3. Resistors (220Ω for each LED)
4. Breadboard and jumper wires

Wiring

1. Connect the red LED to pin 8 through a 220Ω resistor
2. Connect the yellow LED to pin 9 through a 220Ω resistor
3. Connect the green LED to pin 10 through a 220Ω resistor

Code

```
const int redLedPin = 8;
const int yellowLedPin = 9;
const int greenLedPin = 10;

void setup() {
  pinMode(redLedPin, OUTPUT);
  pinMode(yellowLedPin, OUTPUT);
  pinMode(greenLedPin, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  // Red light for 5 seconds
  digitalWrite(redLedPin, HIGH);
  Serial.println("Red LED ON");
  delay(5000);
  digitalWrite(redLedPin, LOW);
  Serial.println("Red LED OFF");
  // Yellow light for 2 seconds
  digitalWrite(yellowLedPin, HIGH);
  Serial.println("Yellow LED ON");
  delay(2000);
  digitalWrite(yellowLedPin, LOW);
  Serial.println("Yellow LED OFF");

  // Green light for 5 seconds
  digitalWrite(greenLedPin, HIGH);
  Serial.println("Green LED ON");
  delay(5000);
  digitalWrite(greenLedPin, LOW);
  Serial.println("Green LED OFF");
}
```

Figure 23: *A picture of Traffic Light Control System Code*

Testing and Debugging

1. **Upload the code** to the Arduino board.
2. **Open the Serial Monitor** from the Arduino IDE (Tools > Serial Monitor) to observe the status messages.
3. **Verify the LEDs** light up in the correct sequence (red, yellow, green) and the delays match the specified durations.

Learning Task

1. Work with learners to write a program to implement a state machine using switch-case statements.
2. Work with learners to learn how to write a loop that handles multiple tasks using a non-blocking approach.
3. Work with learners to write a function that implements a binary search algorithm on a sorted array.
4. Guide learners on how to implement callback functions in C.

Pedagogical Exemplars

Experiential Learning

1. Guide learners through the basics of navigating the Arduino microcontroller and IDE through hands-on exercises. Offer differentiated instruction sheets with step-by-step guides for the Arduino microcontroller for approaching proficiency learners, while encouraging proficient and highly proficient learners to explore advanced techniques.
2. The facilitator should guide the learners to implement simple concepts in C programming like variable and constant declarations, loops, if else decisions, functions and debugging within the Arduino IDE.
3. Simple hardware interfacing with LEDs and switches should be employed to demonstrate these concepts.

Project-based Learning

Learners work on a simple mini project like a traffic light where they apply their programming skills to solve the given problem.

Support individuals or groups working at a slower pace whilst the rest of the class completes more activities.

Digital Learning

Learners are encouraged to use the available online resources to explore more tutorials and programming projects involving Arduino-embedded kits.

Collaborative Learning

1. Learners work in groups on a mini project.
2. Each group should assign a specific role(s) to members towards the solution of the challenge. Assign specific roles to learners to ensure that all learners participate in the project and are challenged according to their understanding and skills.
3. Roles may, for example may, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop team and collaborative skills.

Key Assessment

Level 1 Recall

1. What is a variable in C?
2. How do you declare an integer variable named count in C?
3. What is a constant, and how do you declare one in C using #define?
4. Declare a float variable named temperature.
5. How do you declare a character variable in C?

Level 2 Skills of conceptual understanding

1. What is the difference between global and local variables in C?
2. Declare a constant integer named MAX_LIMIT with a value of 100.
3. Explain the scope of a variable with an example.
4. How do you declare an array of integers with 5 elements?
5. What is the purpose of the constant keyword in C?

Level 3 Strategic reasoning

1. Explain the difference between static and extern keywords in C.
2. Declare a pointer to an integer and assign it the address of a variable.
3. How do you define and initialise a structure in C?
4. What are enumerations in C, and how do you declare one?
5. Explain typecasting in C with an example.

Level 4 Extended critical thinking and reasoning

1. How do you declare and use unions in C?
2. Discuss the significance of memory alignment and padding in structures.
3. How can you declare and initialise a multidimensional array?
4. Explain the use of const with pointers in C.
5. Use Arduino IDE to declare variables and constants, perform control actions and loops, test, and debug programmes within.

Hint

The recommended mode of assessment for week 22 is **Simulation.** Use level 4 question 5 as sample question for the simulation.

WEEK 23: THE DESIGN OF SIMPLE ARDUINO-BASED EMBEDDED SYSTEMS

Learning Indicator: *Design simple Arduino-based embedded systems which interface with basic hardware like switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays, as well as other digital sensors.*

FOCAL AREA 1: TO DESIGN SIMPLE ARDUINO-BASED EMBEDDED SYSTEMS

Designing simple Arduino-based embedded systems involves interfacing the Arduino with various hardware components to achieve desired functionality. Below are a few example projects that demonstrate how to interface the Arduino with switches, LEDs, LCDs, relays, IR sensors, seven-segment displays, and other digital sensors.

Example 1: LED Control with a Push Button

Components

1. Arduino Uno
2. Push Button
3. LED
4. Resistors (10kΩ for pull-down, 220Ω for LED)
5. Breadboard and jumper wires

Circuit Diagram

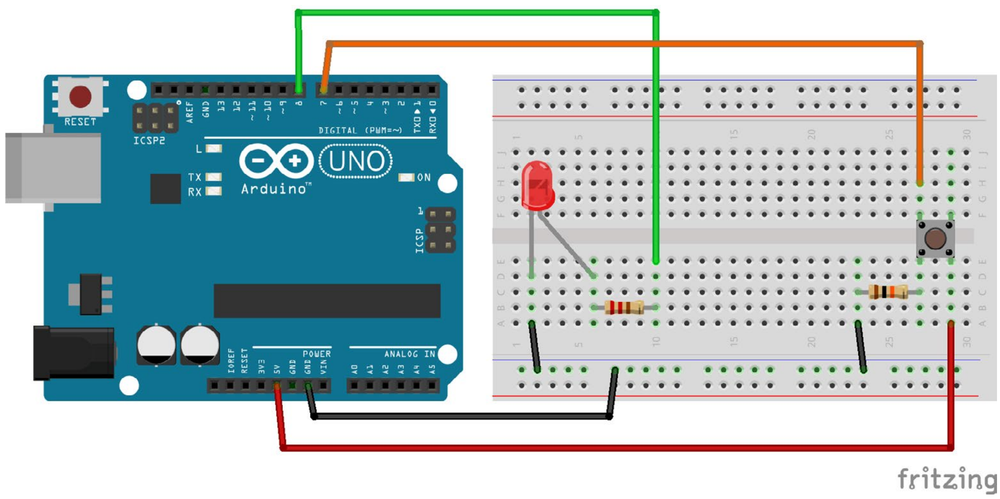

Figure 24: *A picture of Arduino connected to LED and a Push Button*

1. Connect one end of the push button to the 5V pin of the Arduino.
2. Connect the other end to digital pin 2 and ground through a 10kΩ resistor (pull-down resistor).

3. Connect the LED to digital pin 13 through a 220Ω resistor, with the other end of the LED connected to the ground.

Code

```
const int buttonPin = 2;
const int ledPin = 13;
int buttonState = 0;

void setup() {
  pinMode(buttonPin, INPUT);
  pinMode(ledPin, OUTPUT);
}

void loop() {
  buttonState = digitalRead(buttonPin);
  if (buttonState == HIGH) {
    digitalWrite(ledPin, HIGH);
  } else {
    digitalWrite(ledPin, LOW);
  }
}
```

Figure 25: *A picture of LED control with a Push Button Code*

Example 2: Displaying Text on an LCD

Components

1. Arduino Uno
2. 16x2 LCD
3. Potentiometer (for LCD contrast adjustment)
4. Breadboard and jumper wires

Circuit Diagram

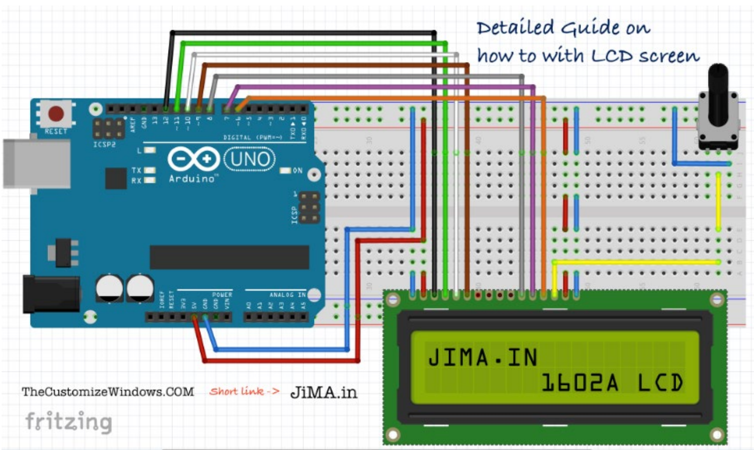

Figure 26: *A picture of Arduino connected to LCD*

Connect the LCD to the Arduino following the typical 16x2 LCD wiring

1. RS to digital pin 12
2. E to digital pin 11
3. D4 to digital pin 5
4. D5 to digital pin 4
5. D6 to digital pin 3
6. D7 to digital pin 2
7. VSS to ground
8. VDD to 5V
9. V0 to the middle pin of the potentiometer
10. Potentiometer ends to 5V and ground
11. A (anode) to 5V through a 220Ω resistor
12. K (cathode) to ground

Code

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
  lcd.begin(16, 2);
  lcd.print("Hello, World!");
}

void loop() {
  lcd.setCursor(0, 1);
  lcd.print(millis() / 1000);
}
```

Figure 27: *A picture of Displaying Text on LCD code*

Example 3: Relay Control with an IR Sensor

Components

1. Arduino Uno
2. Relay module
3. IR Sensor module
4. Breadboard and jumper wires

Circuit Diagram

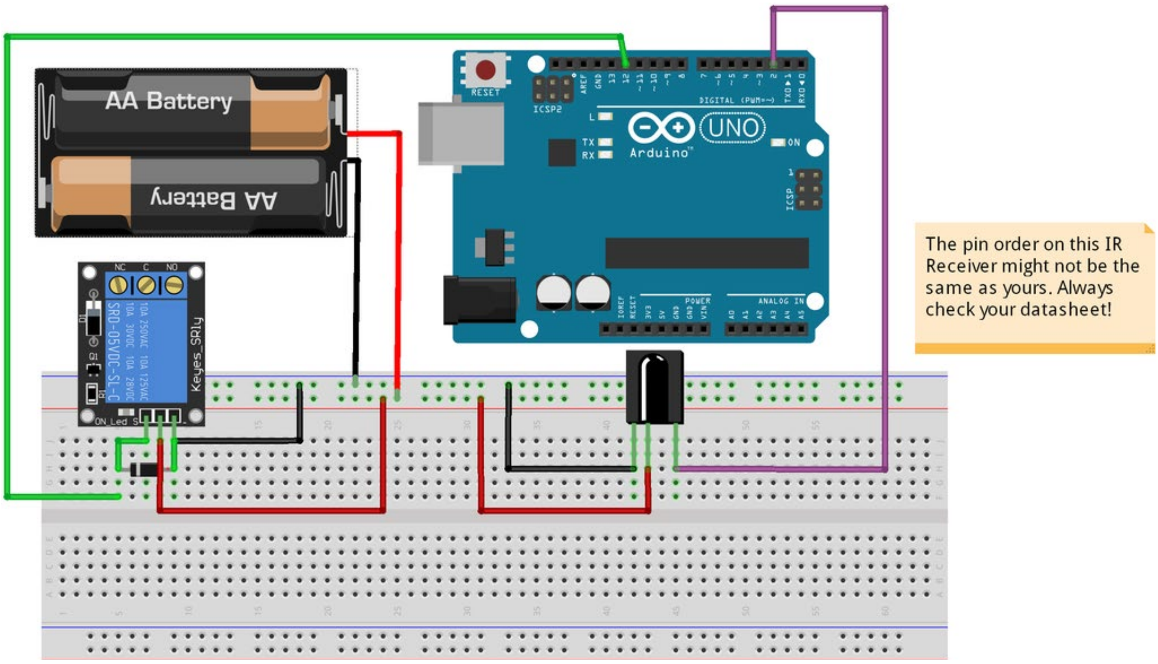

Figure 28: *A picture of Arduino connected to Relay and IR Sensor*

1. Connect the IR sensor output to digital pin 7 of the Arduino.
2. Connect the relay control pin to digital pin 8 of the Arduino.
3. Connect the relay module according to its specifications, typically:
   a. VCC to 5V
   b. GND to ground
   c. IN to digital pin 8

Code

```
const int irSensorPin = 7;
const int relayPin = 8;
int sensorState = 0;

void setup() {
  pinMode(irSensorPin, INPUT);
  pinMode(relayPin, OUTPUT);
}

void loop() {
  sensorState = digitalRead(irSensorPin);
  if (sensorState == HIGH) {
    digitalWrite(relayPin, HIGH);
  } else {
    digitalWrite(relayPin, LOW);
  }
}
```

Figure 29: *A picture of Relay Control with an IR Sensor Code*

Example 4: Seven-Segment Display Counter

Components

1. Arduino Uno
2. 7-Segment Display
3. Resistors (330Ω)
4. Breadboard and jumper wires

Circuit Diagram

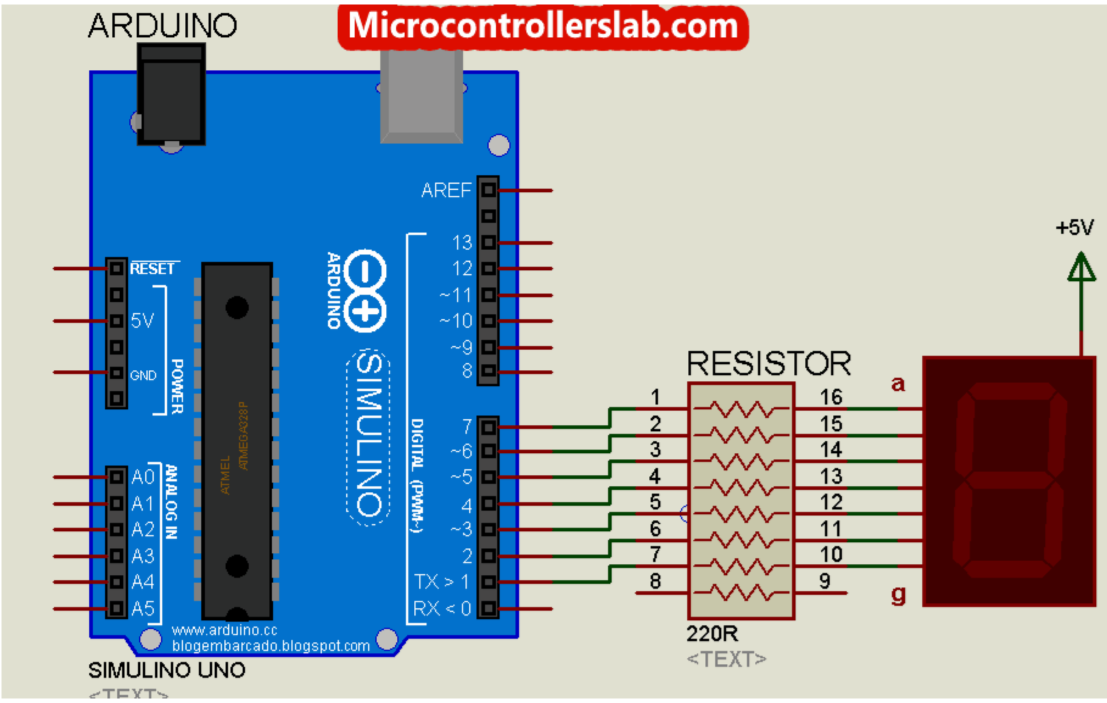

Figure 30: *A picture of Arduino connected to 7-Segment Display*

1. Connect segments of the seven-segment display to digital pins 2 to 8 on the Arduino, with 330Ω resistors in series.
2. Common cathode to ground or common anode to 5V, depending on the type of display.

Code

```
const int segmentPins[7] = {2, 3, 4, 5, 6, 7, 8};

const byte digits[10][7] = {
  {1, 1, 1, 1, 1, 1, 0}, // 0
  {0, 1, 1, 0, 0, 0, 0}, // 1
  {1, 1, 0, 1, 1, 0, 1}, // 2
  {1, 1, 1, 1, 0, 0, 1}, // 3
  {0, 1, 1, 0, 0, 1, 1}, // 4
  {1, 0, 1, 1, 0, 1, 1}, // 5
  {1, 0, 1, 1, 1, 1, 1}, // 6
  {1, 1, 1, 0, 0, 0, 0}, // 7
  {1, 1, 1, 1, 1, 1, 1}, // 8
  {1, 1, 1, 1, 0, 1, 1}  // 9
};

void setup() {
  for (int i = 0; i < 7; i++) {
    pinMode(segmentPins[i], OUTPUT);
  }
}

void loop() {
  for (int i = 0; i < 10; i++) {
    displayDigit(i);
    delay(1000);  // Wait for 1 second
  }
}

void displayDigit(int digit) {
  for (int i = 0; i < 7; i++) {
    digitalWrite(segmentPins[i], digits[digit][i]);
  }
}
```

Figure 31: *A picture of Seven-Segment Display Counter Code*

Example 5: Temperature Monitoring with an LM35 Sensor

Components

1. Arduino Uno
2. LM35 Temperature Sensor
3. Breadboard and jumper wires

Circuit Diagram

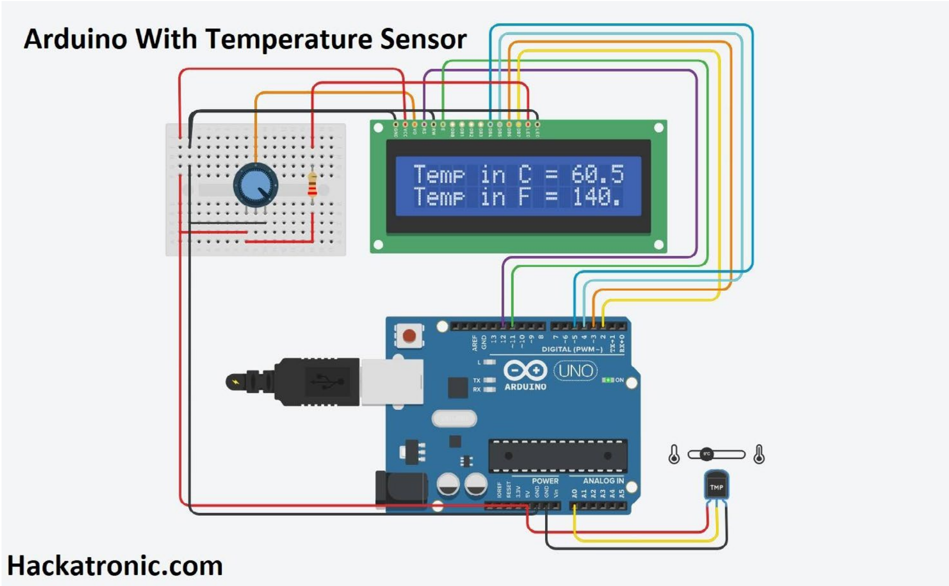

Figure 32: *A picture of Arduino connected to Temperature Monitoring with an LM35 Sensor*

1. Connect the VCC pin of the LM35 to 5V on the Arduino.
2. Connect the GND pin to the ground.
3. Connect the output pin to the analog pin A0.

Code

```
const int tempSensorPin = A0;

void setup() {
  Serial.begin(9600);
}

void loop() {
  int sensorValue = analogRead(tempSensorPin);
  float voltage = sensorValue * (5.0 / 1023.0);
  float temperatureC = voltage * 100;

  Serial.print("Temperature: ");
  Serial.print(temperatureC);
  Serial.println(" C");

  delay(1000);
}
```

Figure 33: *A picture of Temperature Monitoring with an LM35 Sensor Code*

Testing and Debugging

1. **Upload the Code:** Load the code onto your Arduino using the Arduino IDE.
2. **Open the Serial Monitor:** For projects involving serial output, use the Serial Monitor in the Arduino IDE to view real-time data.
3. **Check Connections:** Ensure all connections are secure and components are properly wired.
4. **Debugging**: Use Serial.print() statements to debug and monitor values of variables and sensor readings.

Learning Task

1. Work with learners to explain how to use the SPI protocol to connect an Arduino to an external device (like an SD card module).
2. Guide learners to write a program to create a digital thermometer using a DHT11 sensor and an LCD.
3. Discuss with learners and help them appreciate how to interface a multi-segment LED display with an Arduino to show different patterns. Provide a sample code.
4. Work with learners to explain how to implement a basic security system using an IR sensor, a relay, and an Arduino.
5. Guide learners to describe the process of using an Arduino to log sensor data to an SD card.
6. Help learners write a program to control an RGB LED using three potentiometers to adjust the red, green, and blue values.

Pedagogical Exemplars

Project-based Experiential Learning

1. Through simple projects, the facilitator guides learners to assemble circuits involving hardware such as switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays as well as other digital sensors on solderless breadboards to be interfaced with the Arduino microcontroller.
2. The facilitator uses these mini projects to demonstrate the relevant sections of code for interfacing these respective hardware and leaves the learners to manipulate the hardware and code to observe the changes which occur. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
3. These projects should be carefully selected to have relevance to the environment and interest of the learners.
4. Examples of such projects could be but are not limited to the following; the display of current date and time on LCDs, intelligent traffic light displays, stopwatches, countdown timers, intelligent street lights, and the display and scrolling of names on multi-segment displays.

Self-Directed Learning

1. Learners are given access to online resources to explore further hardware interfacing projects for implementation and experimentation.
2. Learners should be motivated to individually build and test at least three (3) of such projects on their own and in groups and present to peers. With support given to individuals or groups working at a slower pace.

Collaborative Learning

1. Learners work in groups to design, implement, test and document simple embedded solutions involving interfacing with hardware like switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays, as well as other digital sensors. Remember to consider socio-emotional learning by encouraging respectful and open communication among learners. Promote gender equality and social inclusion by ensuring that all learners, regardless of gender or social background, are given equal opportunities to participate in the discussion. Lastly, incorporate national core values in your teaching by relating the discussion to real-life scenarios or issues relevant to Ghana.
2. Each group should assign a specific role(s) to members towards the solution of the challenge. Assign specific roles to learners to ensure that all learners fully participate in the challenge. Let learners decide on the mode of presentation such as written reports, oral presentation or video presentations and receive feedback.
3. Roles may, for example, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop team and collaborative skills in them.

Key Assessment

Level 1 Recall

1. What is a pull-up resistor, and why is it used with switches?
2. Write a simple Arduino code to read the state of a push button and turn on an LED when the button is pressed.
3. Describe the process of using the analogRead() function to read values from an analog sensor.

Level 2 Skills of conceptual understanding

1. How do you debounce a switch in an Arduino program? Write a sample code.
2. Explain how to use PWM to control the brightness of an LED with an Arduino.
3. Write a program to control a relay based on the input from a digital temperature sensor.
4. How do you multiplex multiple seven-segment displays with an Arduino? Provide a sample code.

Level 3 Strategic reasoning

1. How do you connect an LED to an Arduino pin and write a simple program to turn it on and off?

2. How do you connect a relay module to an Arduino and control it with a digital pin?
3. Write a program to display a custom character on an LCD connected to an Arduino.

Level 4 Extended critical thinking and reasoning

1. How do you interface an ultrasonic sensor with an Arduino to measure distance? Provide a sample code
2. Write a program to control the speed of a DC motor using a potentiometer and PWM on an Arduino.
3. How do you use a shift register (like the 74HC595) to expand the number of output pins on an Arduino?
4. Design a mini project into a functional system such as Home Automation System, Smart Irrigation System, Weather Station

Hint

- The recommended mode of assessment for week 23 is **Project work presentation.** Use level 4 question 4 as sample question for the individual project work.
- Remind learners to include copies of their responses to this individual project work in their portfolios and submit them for scoring.

WEEK 24: LEARNERS DESIGN A MINI PROJECT TO A FUNCTIONAL SYSTEM

Learning Indicator: *Design a mini project into a functional system*

FOCAL AREA 1: TO DESIGN AND CONSTRUCT A FUNCTIONAL SYSTEM

The facilitator puts the learners into mixed-ability groups to design and construct any one of the following projects selecting components, circuit design, CAD tools for simulation, 3D modelling for enclosures, and Arduino for control.

1. Home Automation System

Components: Relays, sensors (temperature, motion, light), LCD display, push buttons, Arduino.

CAD Tools: Proteus, Fritzing, or Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to control appliances with relays.
- **b.** Integrate sensors for temperature and motion detection.
- **c.** Create an enclosure using 3D modelling tools.

2. Smart Irrigation System

Components: Soil moisture sensor, water pump, relays, temperature and humidity sensor, Arduino.

CAD Tools: Proteus, LTspice for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to control the water pump based on soil moisture levels.
- **b.** Use sensors to monitor environmental conditions.
- **c.** Design a waterproof enclosure for the electronics.

3. Weather Station

Components: Temperature and humidity sensor, barometer, rain gauge, SD card module, LCD display, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Create circuits to read weather data from sensors and display it.
- **b.** Use an SD card module for data logging.
- **c.** Design a weather-resistant enclosure.

4. Smart Parking System

Components: Ultrasonic sensors, LEDs, LCD display, WiFi module, Arduino.

CAD Tools: Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits for detecting car presence and displaying parking status.
- **b.** Integrate a WiFi module for remote monitoring.
- **c.** Create a durable enclosure for outdoor use.

5. Automated Greenhouse

Components: Temperature and humidity sensor, soil moisture sensor, relays, fans, heaters, water pump, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to control fans, heaters, and water pumps.
- **b.** Monitor environmental conditions with sensors.
- **c.** Design an enclosure for controlling the greenhouse environment.

6. Health Monitoring System

Components: Heart rate sensor, temperature sensor, pulse oximeter, LCD display, Arduino.

CAD Tools: Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to read and display vital signs.
- **b.** Integrate sensors for accurate health monitoring.
- **c.** Design a wearable or portable enclosure.

7. Intruder Alert System

Components: PIR motion sensor, buzzer, GSM module, LEDs, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits for motion detection and alarm activation.
- **b.** Use a GSM module to send alerts.
- **c.** Create an inconspicuous enclosure for indoor use.

8. Smart Door Lock

Components: Keypad, RFID reader, fingerprint sensor, servo motor, LCD display, Arduino.
CAD Tools: Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits for access control using keypad, RFID, or fingerprint.

b. Control a servo motor for locking and unlocking.

c. Design a secure and tamper-proof enclosure.

9. Energy Monitoring System

Components: Current sensors, voltage sensors, SD card module, LCD display, Arduino. **CAD Tools:** LTspice for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to monitor and log energy consumption.

b. Use sensors to measure current and voltage.

c. Design an enclosure for home use.

10. Automated Pet Feeder

Components: Servo motor, RTC module, LCD display, push buttons, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to control a servo motor for dispensing food.

b. Use an RTC module for scheduling feed times.

c. Create a pet-friendly enclosure.

11. Smart Waste Management System

Components: Ultrasonic sensors, GSM module, LCD display, LEDs, Arduino.

CAD Tools: Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to monitor waste levels with ultrasonic sensors.

b. Use a GSM module to send notifications.

c. Design an outdoor enclosure.

12. Environmental Monitoring System

Components: Air quality sensor, temperature and humidity sensor, LCD display, WiFi module, Arduino.

CAD Tools: LTspice for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to monitor air quality and environmental parameters.

b. Integrate a WiFi module for data upload.

c. Create a weather-resistant enclosure.

13. Home Security System

Components: Magnetic door sensors, PIR motion sensors, buzzer, GSM module, LEDs, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits for detecting unauthorised entry and triggering alarms.

b. Use a GSM module for sending alerts.

c. Design a discreet enclosure.

14. Personal Fitness Tracker

Components: Accelerometer, heart rate sensor, OLED display, Bluetooth module, Arduino. **CAD Tools:** Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to track fitness activities and display data.

b. Use Bluetooth for smartphone connectivity.

c. Create a wearable enclosure.

15. Automated Aquarium

Components: Temperature sensor, pH sensor, servo motor, relays, LCD display, Arduino. **CAD Tools:** Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits to control and monitor aquarium conditions.

b. Automate feeding and water quality maintenance.

c. Design a waterproof enclosure.

16. Voice-Controlled Home Automation

Components: Microphone module, relays, Bluetooth or WiFi module, speaker, Arduino. **CAD Tools:** Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

a. Design circuits for voice command recognition and appliance control.

b. Integrate wireless communication modules.

c. Create an easy-to-use enclosure.

17. Smart Garden

Components: Soil moisture sensor, temperature and humidity sensor, LDR, water pump, LCD display, Arduino.

CAD Tools: Tinkercad for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to monitor and control garden conditions.
- **b.** Automate watering based on soil moisture.
- **c.** Design an outdoor enclosure.

18. Automated Curtain System

Components: LDR, RTC module, servo motor, push buttons, Arduino.

CAD Tools: Proteus for circuit design; Fusion 360 for 3D modelling.

Procedure

- **a.** Design circuits to control curtains based on light levels and time.
- **b.** Use an RTC module for scheduling.
- **c.** Create a durable enclosure.

General Steps for Each Project

1. Circuit Design

- **a.** Use CAD tools like Proteus, LTspice, or Tinkercad to design and simulate the circuits.
- **b.** Ensure all components are properly connected and functioning as intended.

2. Programming

- **a.** Write the Arduino code to control the system.
- **b.** Test the code with the simulated circuit before uploading it to the actual Arduino board.

3. 3D Modelling

- **a.** Use tools like Fusion 360 or Tinkercad to design the enclosures for the electronic components.
- **b.** Ensure the design is practical, user-friendly, and provides adequate protection for the components.

4. Assembly

- **a.** Assemble the components on a breadboard or PCB based on the circuit design.
- **b.** Place the assembled circuit inside the 3D-printed enclosure.

5. Testing

- **a.** Test the complete system to ensure all functionalities are working as intended.
- **b.** Make any necessary adjustments to the circuit or code based on the test results.

6. **Deployment**
   a. Once tested and verified, deploy the system in its intended environment.
   b. Monitor the system for any issues and perform maintenance as needed.

Learning Task

1. Direct learners to watch YouTube videos on the various projects.
2. Guide learners to design and construct the projects selected.
3. Work with learners to create the circuit diagrams of the projects.
4. Demonstrate to learners how to connect the circuits and simulate them.

Pedagogical Exemplars

Project-based experiential Learning

1. Through simple projects, the facilitator guides learners to assemble circuits involving hardware such as switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays as well as other digital sensors on solderless breadboards to be interfaced with the Arduino microcontroller. Anticipate that some learners may struggle with certain concepts and plan for additional support or resources to help these learners.
2. The facilitator uses these mini projects to demonstrate the relevant sections of code for interfacing these respective hardware and leaves the learners to manipulate the hardware and code to observe the changes which occur.
3. These projects should be carefully selected to have relevance to the environment and interest of the learners. Monitor learner progress and adjust your approach as needed. For example, if a learner is struggling, you could provide additional support or modify the activity.
4. Examples of such projects could be but are not limited to the following; the display of current date and time on LCDs, intelligent traffic light displays, stopwatches, countdown timers, intelligent street lights, and the display and scrolling of names on multi-segment displays.

Self-Directed Learning

1. Learners are given access to online resources to explore further hardware interfacing projects for implementation and experimentation.
2. Learners should be motivated to individually build and test at least three (3) of such projects on their own and in groups and present to peers. With support given to individuals or groups working at a slower pace.

Collaborative Learning

1. Learners work in groups to design, implement, test and document simple embedded solutions involving interfacing with hardware like switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays, as well as other digital sensors. Use your

knowledge of your learners and your creativity to adapt the activity as needed. For example, you could incorporate elements of gamification, or use technology tools to enhance learning

2. Each group should assign a specific role(s) to members towards the solution of the challenge.
3. Roles may, for example, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop team and collaborative skills in them.
4. The teacher can work with certain learners on an extension activity to stretch those who have grasped the content whilst the remainder of the class continues to work independently

Key Assessment

Level 2 Skills of conceptual understanding

1. What is the expected lifespan of the motor and other moving parts in the system?
2. What is the range of the motor in terms of curtain weight and size?
3. What maintenance is required to ensure the longevity of the system?

Level 3 Strategic reasoning

1. How does the automated curtain system detect when to open or close the curtains?
2. How does the system ensure safety, particularly with regard to children and pets?
3. How does the system handle power outages? Is there a backup power option?

Level 4 Extended critical thinking and reasoning

1. How is the system compatible with smart home platforms (e.g., Google Home, Amazon Alexa, Apple HomeKit)?
2. How is the system designed to minimise waste or environmental impact during installation and operation?

Hint

The recommended mode of assessment for week 24 is **end of semester examination.** Refer to Appendix G for table of specifications on how to develop assessment items for end of semester examinations.

SECTION 9 REVIEW

1. Would learners be able to design a complete automation system that includes a light-activated switch, motor control, and temperature-controlled fan?
2. Can learners propose a method to improve the sensitivity of a light-activated switch using an LDR?
3. Would learners be able to create a circuit diagram for a motor control system that uses both relay contacts and transistor switching?

4. Would learners be able to explain how to use the SPI protocol to connect an Arduino to an external device (like an SD card module)?
5. Can learners write a program to create a digital thermometer using a DHT11 sensor and an LCD?
6. Would learners be able to explain how to implement a basic security system using an IR sensor, a relay, and an Arduino?
7. Would learners be able to describe the process of using an Arduino to log sensor data to an SD card?
8. Can learners write a program to control an RGB LED using three potentiometers to adjust the red, green, and blue values?

Additional Reading

Malik, S., Hussain, W., Sheikh, A. A., (2015) Comparison of RISC and CISC Architectures, International Journal of Scientific and Engineering Research

Teaching/Learning Resources:

1. Analogue electronic components
2. Bread board
3. Arduino Embedded Systems Kits
4. Video documentaries any of the projects
5. Arduino-visual equipment and laptops with MS Office installed
6. 3D Modelling Software, example Autodesk Fusion 360, Tinkercad and SketchUp 3D Printer, Online Tutorials on 3D printers and modelling software.

The marking scheme and rubrics for scoring the Demonstration task

a. Identify an array of electronic components needed for practical work

	3 marks	2 marks	1 mark
Completeness of components	Identifies 3 components of the circuit under consideration (i.e., resistors, transistors, Arduino, diodes)	Identifies 2 components of the circuit under consideration (i.e., resistors, transistors, Arduino, diodes)	Identifies 1 component of the circuit under consideration (i.e., resistors, transistors, Arduino, diodes)
Justification of selection	Selecting 3 components with logical reasoning for choices.	Selecting 2 components with logical reasoning for choices.	Selecting 1 component with logical reasoning for choice.
Understanding of Function	Showing understanding of 3 component's role.	Showing understanding of 2 component's role.	Showing understanding of 1 component role.

Total – 9 marks

b. Build the circuits using circuit diagrams

	3 marks	2 marks	1 mark
Circuit assembly accuracy	Show 3 skills of circuit assembly (i.e., Component placement, Connections and wiring, Voltage, and current ratings)	Show 2 skills of circuit assembly (i.e., Component placement, Connections and wiring, Voltage, and current ratings)	Show 3 skills of circuit assembly (i.e., Component placement, Connections and wiring, Voltage, and current ratings)
Following circuit diagram	Show 3 skills in Adherence to diagram, Functional verification, connecting path.	Show 2 skills in Adherence to diagram, Functional verification, connection path.	Show 1 skill in Adherence to diagram, Functional verification, connection path.
Functionality	Show 3 skills in software and programming, efficiency and performance, reliability, and error handling	Show 2 skills in software and programming, efficiency and performance, reliability, and error handling	Show 1 skill in software and programming, efficiency and performance, reliability, and error handling

Total – 9 marks

The marking scheme and rubrics for scoring the Simulation task

	4 marks	3 marks	2 marks	1 mark
Declare variables and constants	Showing four steps of declaring variables and constants (i.e., Keyword, Initialization, Scope, and Visibility, Modifiers)	Showing three steps of declaring variables and constants (i.e., Keyword, Initialization, Scope, and Visibility, Modifiers)	Showing two steps of declaring variables and constants (i.e., Keyword, Initialization, Scope, and Visibility, Modifiers)	Showing one step of declaring variables and constants (i.e., Keyword, Initialization, Scope, and Visibility, Modifiers)
Perform control actions and loops	Showing four steps to perform control actions and loops (i.e., Control Structures, Loops for Repeated Execution, Iteration Control, Nested Loops and Control Structures)	Showing three steps to perform control actions and loops (i.e., Control Structures, Loops for Repeated Execution, Iteration Control, Nested Loops and Control Structures)	Showing two steps to perform control actions and loops (i.e., Control Structures, Loops for Repeated Execution, Iteration Control, Nested Loops and Control Structures)	Showing one step to perform control actions and loops (i.e., Control Structures, Loops for Repeated Execution, Iteration Control, Nested Loops and Control Structures)

Test and debug programmes	Showing four steps of Test and debug programmes (i.e., Testing Strategies, Test Cases, Debugging Techniques, Validation and Verification)	Showing three steps of Test and debug programmes (i.e., Testing Strategies, Test Cases, Debugging Techniques, Validation and Verification)	Showing two steps of Test and debug programmes (i.e., Testing Strategies, Test Cases, Debugging Techniques, Validation and Verification)	Showing one step of Test and debug programmes (i.e., Testing Strategies, Test Cases, Debugging Techniques, Validation and Verification)

Total Mark = 12 marks

The marking scheme and rubrics for scoring the Individual project work task

Criteria	4 marks	3 marks	2 marks	1 mark
Design and Conceptualization	The design shows creativity and organisation of any four of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.	The design shows creativity and organisation of any three of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.	The design shows creativity and organisation of any two of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.	The design shows creativity and organisation of any one of these: layout that draws attention to key points. Visuals are eye-catching, relevant, and enhance understanding of the content. Circuit diagrams and purpose of design meet expectation.
Component Selection and Integration	Selects and integrates four components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.	Selects and integrates three components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.	Selects and integrates two components (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.	Selects and integrates one component (e.g., microcontrollers, sensors, relays, and resistors) with excellent reasoning and functionality.

System Functionality	Demonstrates four intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security	Demonstrates three intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security	Demonstrates two intended features and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security	Demonstrates one intended feature and is reliable. (e.g., Home Automation System: Control and Monitoring, Sensors Integration, Automation, Safety and Security
Programming and Code Efficiency	With four constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)	With three constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)	With two constituents of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)	With one constituent of programming and code efficiency. (e.g., Execution Context, Algorithm Efficiency, Code Readability, Resource Management, Scalability, Code Optimization)
Report and Documentation	Shows four items such as functions of components used, circuit diagrams, explanations, and pictures	Shows three items such as functions of components used, circuit diagrams, explanations, and pictures	Shows two items such as functions of components used, circuit diagrams, explanations, and pictures	Shows one item such as functions of components used, circuit diagrams, explanations, and pictures
Presentation and Demonstration	Shows four items such as final design, installation process, demonstration, functionality	Shows three items such as final design, installation process, demonstration, functionality	Shows two items such as final design, installation process, demonstration, functionality	Shows one item such as final design, installation process, demonstration, functionality

Total = 24 marks

APPENDIX G: SECOND SEMESTER EXAMINATION

Structure of End of semester Examination

1 Examination will cover focal areas covered in each table of specification (weeks 13-24 for semester 2)

- **a.** Paper 1: 30 MCQs.
- **b.** Paper 2: PART A and PART B
  - i) Part A: 1 compulsory question
  - ii) Part B: 4 questions from which learners will answer only 3 questions.

2 **Duration**: 2 hours

3 **Materials Needed**: Printer, A4 sheets, A large exam room, answer booklets, stationery, timers; for e-Assessment, consider a stable internet, computer, or tablet as well, etc.

4 **Marking Scheme/Rubrics**

- i) MCQs: 1 mark for each option. Total marks: 50 marks
- ii) Essay type question: 20 marks for Part A and 30 marks for Part B (15 marks per question)

TABLE OF SPECIFICATION FOR END OF SECOND SEMESTER EXAMS

The specifications for the number of questions for each week are indicated in the table below

Content /week		*DoK (Number of questions)*				
		Level 1	*Level 2*	*Level 3*	*Level 4*	*Total*
1. Operate and maintain simple photovoltaic and solar thermal energy systems	*Objectives*	–	1	1	–	3
	Essay	–	–	–	–	
	Case study	1	–	–	–	
2. Design and install simple photovoltaic and solar thermal systems	*Objectives*	–	1	1	–	3
	Essay	–	1	–	–	
	Case study	–	–	–	–	
3. Energy management plan and basic energy audit plan	*Objectives*	1	–	–	1	3
	Essay	–	1	–	–	
	Case study	–	–	–	–	
4. Energy-saving methods for electrical and thermal systems	*Objectives*	1	–	–	1	3
	Essay	–	1	–	–	
	Case study	–	–	–	–	

5. *Solutions and suitable solutions(s) based on a set of constraints.*	*Objectives*	1	–	–	–	3
	Essay	–	1	–	–	
	Case study	–	–	–	1	
6. *Prototypes based on given solution requirements*	*Objectives*	1	1	1	–	3
	Essay	–	–	–	–	
	Case study	–	–	–	–	
7. *The use of CAD tools for the design of models*	*Objectives*	1	1	1	–	4
	Essay	–	1	–	–	
	Case study	–	–	–	–	
8. *Implement CAD models using 3D printing systems*	*Objectives*	1	1	1	–	3
	Essay	–	–	–	–	
	Case study	–	–	–	–	
9. *Basic electronic components for simple automation tasks*	*Objectives*	1	1	1	–	4
	Essay	–	1	–	–	
	Case study	–	–	–	–	
10. *The use of IDE of Arduino to write simple programmes*	*Objectives*	1	1	–	–	3
	Essay	–	1	–	–	
	Case study	–	–	–	–	
11. *Design simple Arduino-based embedded systems which interface with basic hardware like switches, LEDs, LCDs, Relays, IR Sensors, Seven and Multi-Segment Displays, as well as other digital sensors*	*Objectives*	1	1	1	–	3
	Essay	–	–	–	–	
	Case study	–	–	–	–	
Total		*10/35x 100 =28.5%*	*15/35 x100= 42.9%*	*7/35 x 100 = 20%*	*3/35 x100 =8.5%*	*35/35 x 100=100%*

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No	Name of image	Reference (link)
Figure 1	*An image of a workplace*	https://www.hseblog.com/different-types-hazards/
Figure 2	*An image of a office*	https://youngworkers.org/injuries/hazards/hazards-activity-page
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