



MINISTRY OF EDUCATION

Engineering for Senior High Schools

TEACHER MANUAL



YEAR THREE



NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION



REPUBLIC OF GHANA

Engineering for Senior High Schools

Teacher Manual

Year Three



**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 the third and final set of curriculum materials to support the implementation of the new Senior High School curriculum.

This Year Three Teacher Manual for Engineering covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively support learners in their final year of Senior High School. All the necessary information for the Student Assessment Portal has been included in the Year Three Teacher Manual to simplify the development of weekly learning plans, meaning that teachers have a single reference document.

The Year Three Teacher Manual has two main objectives:

- To support learners to consolidate and deepen their understanding of the content, pedagogy, and assessment across all three years of the new Senior High School curriculum in preparation for the West Africa Senior Secondary Certificate Examination (WASSCE).
- To equip teachers with the tools and resources needed to deliver revision-focused, assessment-led lessons that build on the knowledge learners have acquired from Year One to Year Three.

In this third year, teachers will be supporting learners to prepare for the WASSCE. Each section of the Teacher Manual is therefore structured around the highest Depth of Knowledge (DoK) levels, allowing learners to build progressively on knowledge acquired from Year One to Year Three. For each week, learning tasks and pedagogy are built around the assessment, ensuring that classroom activities directly prepare learners for the demands of the examination. Two sets of sample examination papers are also provided; one administered by Week 12 as a first semester practice examination, and one by Week 20 as a mock examination, to gauge learners' competencies and identify areas requiring remediation.

To further support teachers in delivering Year Three, NaCCA, working with the Ghana Education Service, has developed a subject specific App for each subject.

The Year Three PLC sessions have been revised in response to findings from the 2025 annual evaluation survey. The survey confirmed that teachers have made strong progress in lesson planning, use of varied instructional methods, ICT integration and modes of assessment. To address the identified gap in explaining concepts clearly using examples familiar to learners, each PLC session now includes a dedicated Content Exploration segment. This ten-minute segment brings the subject group together to work through one challenging problem or concept from the week's Teacher Manual content, not to plan how to teach it, but to ensure that every teacher in the group fully understands it.

The PLC sessions in Year Three also place particular emphasis on connecting the week's content to equivalent topics taught in Years One and Two. Teachers are encouraged to note the recap weeks signposted throughout the Teacher Manual and to use the App to explore how content across all three years links together.

As in previous years, teachers are expected to integrate National Values, Gender Equality and Social Inclusion (GESI), Social and Emotional Learning (SEL), and 21st-century skills into

their learning activities, assessment tasks, and rubrics and mark schemes. The subject-specific App will support teachers in doing this throughout the year.

Ghana Education Service acknowledges the dedication of the teachers who have implemented the new curriculum across Years One and Two and recognises that Year Three represents both the culmination of that effort and a critical moment for learners. The Year Three Teacher Manual and its accompanying resources have been developed to ensure that every learner, regardless of background, ability, or school context, is fully prepared to demonstrate what they know and can do in the WASSCE and to progress confidently to further studies, the world of work, and adult life.

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SECTION 1: ENGINEERING PRACTICE IN SOCIETY

STRAND: ENGINEERING PRACTICE

Sub-Strand: Engineering in Society

WEEK 1

Learning Outcomes: *Demonstrate an understanding of the role of engineering in the attainment of the Sustainable Development Goals (SDGs).*

Content Standard: Engineering in Society

WEEK 2

Learning Outcomes: *Propose solutions to engineering-related SDGs*

Content Standard: Engineering in Society

INTRODUCTION AND SECTION SUMMARY

In this section learners will be exposed to the Sustainable Development Goals related to Engineering. The Sustainable Development Goals (SDGs) are 17 global goals adopted by all UN Member States in 2015 to address poverty, inequality, climate change, environmental degradation, peace, and justice by 2030. The Sustainable Development Goals play a major role in shaping a better society by providing a clear roadmap for countries, communities, and individuals to work towards achieving a better society. Engineers play a crucial role in solving global challenges by designing and building technologies, systems, and infrastructure that support the achievement of the Sustainable Development Goals. To achieve the Sustainable Development Goals, engineers, scientists, designers, and entrepreneurs must create new ideas, technologies, and systems that solve real-world problems in sustainable ways. Innovative solutions combine creativity, innovation, technology, and a deep understanding of social and environmental needs.

The weeks and the indicators covered by the section are:

- Week 1:
 1. Definition of the Sustainable Development Goals.
 2. Explanation of the role of the SDGs in societal development
- Week 2:
 3. Description of engineering solutions for attaining specific SDGs
 4. Design and development of innovative solutions towards the attainment of SDGs

Recap weeks

Year 1	Week 2: Outline the contributions of each engineering discipline in solving societal problems. Week 5: Outline the common skill set required by the respective engineering disciplines.
Year 2	Week 1: Systematic investigation and its relevance in engineering professional practice Week 2: Processes for systematic investigation.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teachers play a crucial role in educating learners about the Sustainable Development Goals (SDGs) by encouraging and guiding them to develop practical solutions to real-world issues; integrating sustainable development concepts into engineering solutions, and promoting real-world applications of engineering solutions, such as green technology in waste management and energy solutions. Teachers should use learner-centred and interactive pedagogies to promote deeper understanding of the SDGs. These include managing Talk-for-Learning, fostering collaborative learning, and Problem-Based Learning (PBL). In Talk-for-Learning, encourage learners to express their thoughts, challenge assumptions, and create meaning collectively. In Collaborative learning, guide learners to develop multidisciplinary thinking, empathy and teamwork. Finally, in PBL, expose learners to multi-level problem solving of real-world issues connected to SDG objectives. Teachers also facilitate inquiry by tasking learners to research local and global issues related to the SDGs and encourage active participation of learners in class discussion, promoting learner-driven inquiry and problem-solving.

ASSESSMENT SUMMARY

Teachers should use assessment strategies that encourage critical thinking, creativity, teamwork, and practical application to effectively teach the Sustainable Development Goals (SDGs). These assessments serve both as evaluation tools as well as teaching tools; helping learners understand the complexities of sustainability issues and contribute to the development of solutions. Engineering-based activities should link global objectives with local realities, promoting inquiry, creativity, and real-world problem-solving. Presentations, case studies, group research work, and homework assignments can help learners apply theory, develop analytical abilities, and foster teamwork. These methods help learners understand the complexities of sustainability issues and contribute to their development.

For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain the role of the SDGs in societal development	Level 3	Presentation (Individual work)
Describe engineering solutions for attaining specific SDGs	Level 3	Group research for 2 weeks
Design and develop innovative solutions towards the attainment of SDGs	Level 4	Case study (Group work)

WEEK 1

Learning Indicators

1. *Define the Sustainable Development Goals*
2. *Explain the role of the SDGs in societal development*

FOCAL AREA 1: DEFINE THE SUSTAINABLE DEVELOPMENT GOALS

Definition

The Sustainable Development Goals (SDGs) are a collection of 17 interlinked global goals designed to be a blueprint for achieving a better and more sustainable future for all. Adopted by all United Nations Member States in 2015, they aim to address urgent global challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice, with a target of achieving them by 2030.

The 17 Sustainable Development Goals are:

1. No Poverty – End poverty in all its forms everywhere.
2. Zero Hunger – End hunger, achieve food security, and promote sustainable agriculture.
3. Good Health and Well-being – Ensure healthy lives and promote well-being for all at all ages.
4. Quality Education – Ensure inclusive and equitable quality education and promote lifelong learning opportunities.
5. Gender Equality – Achieve gender equality and empower all women and girls.
6. Clean Water and Sanitation – Ensure availability and sustainable management of water and sanitation for all.
7. Affordable and Clean Energy – Ensure access to affordable, reliable, sustainable, and modern energy for all.
8. Decent Work and Economic Growth – Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work.
9. Industry, Innovation, and Infrastructure – Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation.
10. Reduced Inequalities – Reduce inequality within and among countries.
11. Sustainable Cities and Communities – Make cities and human settlements inclusive, safe, resilient, and sustainable.
12. Responsible Consumption and Production – Ensure sustainable consumption and production patterns.
13. Climate Action – Take urgent action to combat climate change and its impacts.
14. Life Below Water – Conserve and sustainably use the oceans, seas, and marine resources.

15. Life on Land – Protect, restore, and promote sustainable use of terrestrial ecosystems, forests, and biodiversity.
16. Peace, Justice, and Strong Institutions – Promote peaceful and inclusive societies, provide access to justice for all, and build effective, accountable institutions.
17. Partnerships for the Goals – Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Learning Tasks

1. Discuss with learners the membership and activities of the UN.
2. Help learners identify the rationale for setting the SDGs and some of the SDGs relevant to their communities.
3. Discuss with learners the rationale for setting the SDGs and help them appreciate how the SDGs benefit society.
4. Have learners working in groups make presentations on the extent of the attainment of the SDGs in Ghana.
5. Show videos to learners on the progress various countries have made in achieving the SDGs.

Pedagogical Exemplars

Managing Talk for Learning: Put learners in small groups and have moderated discussion on the extent of the attainment of the SDGs in Ghana. Ask learners to present their findings.

Experiential Learning: Learners watch videos on the progress made in attaining the SDGs by other countries and present their finding on how the SDGs benefits humanity.

Key Assessment Level 3: Presentation

1. Explain how two specific SDGs could present challenges when both are applied to an urban development project. Suggest one engineering strategy that could help manage these challenges, and justify your choice. [20 marks]
2. Explain how the concept of Sustainable Development underpins the structure and purpose of the Sustainable Development Goals (SDGs). Provide examples to support your explanation. [8marks]
3. Evaluate the significance of having a global framework like the SDGs in addressing interconnected challenges such as poverty, climate change, and inequality. [10marks]

FOCAL AREA 2: EXPLAIN THE ROLE OF THE SDGS IN SOCIETAL DEVELOPMENT

The Role of the SDGs in Societal Development

The Sustainable Development Goals (SDGs) play a major role in shaping a better society by providing a clear roadmap for countries, communities, and individuals. Examples of such roles include:

1. Ending Poverty and Inequality

The SDGs guide efforts to lift people out of poverty and reduce inequalities within and between societies, creating fairer opportunities for all.

2. Promoting Education and Health

The SDGs stress the importance of quality education and good health, which are key foundations for a productive and successful society.

3. Protecting the Environment

The SDGs encourage societies to use natural resources responsibly, protect ecosystems, and fight climate change to ensure a healthy planet for future generations.

4. Building Strong Institutions and Communities

They promote good governance, peace, justice, and the building of resilient cities and communities that can adapt to change and support human well-being.

5. Encouraging Economic Growth

By focusing on decent work, innovation, and sustainable industries, the SDGs support societies in building strong economies that do not harm people or the planet.

6. Fostering Global Partnerships

They emphasise collaboration between countries, organisations, and individuals, recognising that working together is necessary to solve global challenges.

Learning Tasks

1. Moderate discussions reviewing the role of the SDGs in societal development.
2. Have learners work in groups to select one SDG and discuss the role it plays in shaping a better society.

Pedagogical Exemplars

Initiating Talk for Learning: Through questions and answers or debate, learners brainstorm the role of the SDGs in societal development. In small mixed-ability/gender groups, learners select one SDG, discuss how it can be attained, and share findings with the class

Key Assessment Level 3: Presentation

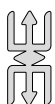
1. Explain how SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth) are interconnected in promoting societal development. [10 marks]
2. Describe two ways in which the SDGs address social inequalities that previous development frameworks might have overlooked. [10 marks]
3. Explain how the principle of “leaving no one behind” in the SDGs influences approaches to societal development. [20 marks]
4. Identify two SDGs that are particularly relevant to Ghana’s development challenges and explain how they address specific national priorities [10 marks].

PLC Session 1

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

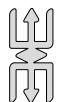
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **presentation**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the presentation (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 2

Learning Indicators

1. *Describe engineering solutions for attaining specific SDGs*
2. *Designing and developing innovative solutions towards the attainment of SDGs*

FOCAL AREA 3: DESCRIBE ENGINEERING SOLUTIONS FOR ATTAINING SPECIFIC SDGS

Refer back to Year 1 Section 1 week 1 (Outline the contributions of each engineering discipline in solving societal problems)

Engineering Solutions for Attaining Specific SDGs

Engineers play a crucial role in solving global challenges by designing and building technologies, systems, and infrastructure that support the achievement of the Sustainable Development Goals (SDGs).

Here are examples of engineering solutions linked to specific SDGs:

1. **SDG 6 – Clean Water and Sanitation**
 - a. Designing affordable water filtration systems for rural areas.
 - b. Building efficient wastewater treatment plants to recycle water.
2. **SDG 7 – Affordable and Clean Energy**
 - a. Developing solar panels, wind turbines, and microgrids for renewable, off-grid energy solutions.
 - b. Creating energy-efficient appliances and smart grids.
3. **SDG 9 – Industry, Innovation, and Infrastructure**
 - a. Designing sustainable transportation networks like electric railways.
 - b. Building resilient bridges and buildings that can withstand natural disasters.
4. **SDG 11 – Sustainable Cities and Communities**
 - a. Engineering green buildings with low energy consumption.
 - b. Designing smart waste management systems to reduce landfill use.
5. **SDG 13 – Climate Action**
 - a. Innovating carbon capture technologies to reduce industrial emissions.
 - b. Developing early warning systems for natural disasters like floods , rainstorms and bushfires.
6. **SDG 3 – Good Health and Well-being**
 - a. Creating medical devices like low-cost ventilators and portable diagnostic tools.

- b. Designing safe sanitation facilities to prevent the spread of diseases.

7. SDG 2 – Zero Hunger

- a. Building automated irrigation systems to help farmers grow more food sustainably.
- b. Designing storage solutions that prevent food spoilage.

Learning Tasks

1. Discuss with learners and help them appreciate some engineering solutions for the attainment of specific SDGs.
2. Have learners work in groups to brainstorm on the engineering solutions to the other SDGs not mentioned above.

Pedagogical Exemplars

Collaborative Learning: In their small groups, learners discuss selected SDGs and how engineering can be used to provide solutions. Groups share findings with the whole class for comments. Summarise learners' thoughts using concept maps for each SDG and proposed solutions. Refer back to Year 1 week 2 Outline the common skill set required by the respective engineering disciplines.

Key Assessment Level 4: Individual Class Exercise

1. Adaklu, a rural community in Ghana, faces challenges with clean water access, agricultural productivity, and energy reliability.
 - a. Analyse how these challenges are interconnected within the SDG framework. [5marks]
 - b. Develop an integrated engineering solution that addresses at least two of these challenges simultaneously. [7marks]
 - c. Evaluate potential unintended consequences of your proposed solution. [8marks]
2. Compare and contrast centralised versus decentralised engineering approaches to achieving SDG 7 (Affordable and Clean Energy) in Ghana. Under what specific conditions would you recommend each approach? Justify your reasoning with evidence.
3. The implementation of engineering solutions for SDG 11 (Sustainable Cities) often conflicts with short-term economic priorities. a) Analyse this conflict in a specific urban context. b) Develop a strategy that addresses these competing priorities. c) Explain how your approach maintains the integrity of sustainability goals while addressing economic concerns. (18 marks)

FOCAL AREA 4: DESIGNING AND DEVELOPING INNOVATIVE SOLUTIONS TOWARDS THE ATTAINMENT OF SDGS

To achieve the Sustainable Development Goals (SDGs), engineers, scientists, designers, and entrepreneurs must create new ideas, technologies, and systems that solve real-world problems

in sustainable ways. Innovative solutions combine creativity, technology, and a deep understanding of social and environmental needs. Refer back to Year 2; week 1 systematic investigation and its relevance in engineering professional practice.

Key Approaches

a) Human-Centred Design

Solutions must be designed with the needs of people (especially vulnerable groups) in mind.

Example: Low-cost water filters for remote communities (supporting SDG 6: Clean Water).

b) Use of Emerging Technologies

Applying new tools like AI (Artificial Intelligence), IoT (Internet of Things), renewable energy systems, biotechnology, and advanced materials.

Example: Smart farming systems that use sensors to optimise crop yields (supporting SDG 2: Zero Hunger).

c) Sustainability Focus

Solutions must reduce resource consumption, minimise waste, and protect the environment.

Example: Biodegradable packaging materials to replace plastics (supporting SDG 12: Responsible Consumption).

d) Affordability and Scalability

Innovations must be low-cost and easily expandable to different regions or populations.

Example: Modular, solar-powered classrooms that can be installed quickly in underserved areas (supporting SDG 4: Quality Education).

e) Collaboration and Partnerships

Successful solutions often involve partnerships between governments, industries, communities, and researchers.

Example: Public-private partnerships to build clean energy plants (supporting SDG 7: Affordable and Clean Energy).

Examples of Innovative Solutions

Solution	Related SDG	Brief Description
Solar-powered water pumps	SDG 6	Provide clean water in drought-affected areas.
Vertical farming	SDG 2	Grow food using less land and water in urban areas.
E-health platforms	SDG 3	Deliver healthcare remotely to rural populations.
Electric public transport	SDG 11	Reduce pollution and improve urban mobility.
Carbon capture technology	SDG 13	Trap CO ₂ emissions from factories to fight climate change.

Learning Tasks

1. Discuss with learners and help them appreciate some real-world engineering solutions to SDG problems.
2. Have learners work in groups to brainstorm an innovative engineering solution to the attainment of at least one of the SDGs.

Pedagogical Exemplars

Problem-based Learning: Learners in groups select and execute group projects by conceiving and developing innovative engineering solutions to address at least one SDG. The groups present their projects to the class for comments

Key Assessment Level 4: Group Research

1.
 - a. Design an integrated engineering solution for a coastal community in Ghana facing three concurrent challenges: rising sea levels (SDG 13), declining fish stocks (SDG 14), and high youth unemployment (SDG 8). Your solution must address all three challenges simultaneously (8 marks)
 - b. Evaluate trade-offs between immediate needs and long-term sustainability (6 marks)
 - c. Analyse how your solution might create unintended consequences and how these would be mitigated (6 marks)
 - d. Defend the ethical dimensions of your proposed approach, considering equitable access and distribution of benefits (6 marks)
2. A rapidly urbanising region must develop new infrastructure while meeting net-zero carbon goals. Create a comprehensive engineering master plan that:
 - a. Integrates at least four (4) SDGs in a mutually reinforcing manner (6marks)
 - b. Reconciles conflicting priorities between development and environmental protection (6marks)
 - c. Incorporates both technological and social innovations (6marks)
 - d. Establishes metrics to evaluate success across multiple timeframes (5, 15, and 30 years) (6marks)
 - e. Creates mechanisms for adaptation as conditions change (6marks) (30 marks total)

Hint



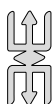
Assign Group Project to learners and give them reasonable time to complete it. Use the SS App to generate the project as well as the rubric. Learners' projects should be marked immediately and scores entered into the SAP.

PLC Session 2

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand.
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 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
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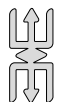
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP).
 - a. The key assessment for the week is **group research**. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the research (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
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 - c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 1 Review

1. Would learners be able to define Sustainable Development Goals?
2. Can learners explain the role of the SDGs in societal development?
3. Would learners be able to describe engineering solutions for attaining specific SDGs?
4. Are learners able to design and develop innovative solutions towards the attainment of SDGs?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 1

FOCAL AREA 1

Question 1

Criteria	Marks	Description
1. Identification and Explanation of Two Relevant SDGs	4	2 marks for naming two appropriate and potentially conflicting SDGs (1 mark each). 2 marks for explaining each goal clearly in the context of urban development (1 mark for each goal).
2. Description of potential conflict between the SDGs	4	2 marks per SDG for outlining how it might clash with the other in a realistic urban setting. 2 marks Must show understanding of competing priorities (e.g., economic growth vs. environmental protection).
3. Suggested engineering strategy	4	2 marks for identifying a plausible and relevant engineering strategy. 2 marks for aligning the strategy to the nature of the SDG conflict.
4. Justification of strategy	6	1–3 marks for explaining how the strategy addresses the conflict. 1–3 marks for reasoning how it maximises positive outcomes (e.g., sustainable trade-offs, long-term benefits, stakeholder balance).
5. Clarity, Structure, and Use of Technical Language	2	1 mark for logical structure and clarity. 1 mark for accurate and appropriate use of subject-specific vocabulary (e.g., sustainability, infrastructure, emissions, resilience).

Question 2

Criterion	Marks	Description
Definition of sustainable development	2	1–2 marks for clear definition (e.g., development that meets present needs without compromising future generations).
Explanation of how SD is reflected in the SDGs	2	1–2 marks for showing understanding that SDGs balance social, economic, and environmental sustainability.
Use of examples (e.g., SDG 1, SDG 13, SDG 4)	2	1–2 marks for two relevant examples explained briefly.
Coherence and depth of explanation	2	1–2 marks for logical structure, depth of thought, connection between concept and examples.

Question 3

Criterion	Marks	Description
Definition of sustainable development	2	1–2 marks for clear definition (e.g., development that meets present needs without compromising future generations).
Explanation of how SD is reflected in the SDGs	2	1–2 marks for showing understanding that SDGs balance social, economic, and environmental sustainability.
Use of examples (e.g., SDG 1, SDG 13, SDG 4)	2	1–2 marks for two relevant examples explained briefly.
Coherence and depth of explanation	2	1–2 marks for logical structure, depth of thought, connection between concept and examples.

FOCAL AREA 2

Question 1

Criteria	Marks	Description
1. Clear Explanation of SDG 4 (Quality Education)	2	1 mark for accurate description of SDG 4's aims (e.g., inclusive, equitable education; lifelong learning). 1 mark for referencing to components like literacy, skills training, access to education.
2. Clear Explanation of SDG 8 (Decent Work and Economic Growth)	2	1 mark for clear explanation of SDG 8 (e.g., full and productive employment, safe work environments, and sustainable economic growth). 1 mark for Including mention of innovation, entrepreneurship, and youth employment.
3. Explanation of the Inter-connection Between SDG 4 and SDG 8	3	1 mark for demonstrating how quality education contributes to decent work (e.g., skills development, employability). 1 mark for showing how economic growth supports education systems (e.g., investment in schools/training). 1 mark for referencing cyclical or reinforcing effects.
4. Analysis of Societal Impact from Their Synergy	2	1 mark for discussing how the combined effect promotes societal development (e.g., poverty reduction, reduced inequality, increased productivity). 1 mark for referencing examples like improved social mobility, gender equality, or sustainable economies.
5. Structure, Clarity, and Use of Key Terminology	1	1 mark for well-organised response with technical language (e.g., human capital, labour market, inclusive development). Logical flow and coherent argumentation.

Question 2

Criteria	Marks	Description
1. Identification and Description of First Way	3	1 mark for clearly describes one specific mechanism or approach in the SDGs that addresses social inequality (e.g., focus on marginalised groups, gender equality, disability inclusion, etc.). 1 mark for explaining how this approach goes beyond earlier frameworks like the Millennium Development Goals (MDGs). 1 mark for relevant example.
2. Identification and Description of Second Way	3	As above, a second distinct and well-explained way the SDGs address inequality. 1 mark for not overlapping with the first point. 2 marks for highlighting how it was overlooked or inadequately addressed in past development agendas.
3. Reference to Previous Frameworks (e.g., MDGs)	2	1–2 marks for showing understanding of previous development frameworks' limitations. May mention the MDGs' narrower scope, lack of emphasis on inequality, or absence of data disaggregation. Provides a comparison to demonstrate SDG improvement.
4. Clarity, Organisation, and Use of Appropriate Terminology	2	Logical structure with clear paragraphing. 1–2 marks for using development-related terms (e.g., inclusivity, equity, intersectionality, vulnerable populations). Fluent and coherent expression.

Question 3

Criteria	Marks	Description
1. Explanation of the Principle “Leaving No One Behind”	5	Clear definition and understanding of the principle (1 mark) Emphasises inclusivity, equity, and prioritisation of the most marginalised (2 marks). Acknowledges it as a core, cross-cutting principle of the SDGs (2 marks).
2. Influence on Societal Development Approaches	7	Explains how the principle changes or strengthens development efforts (3marks). Promotes data disaggregation, targeted interventions, and inclusive policies (2marks). May include examples (e.g., gender-sensitive programs, rural access to education and health, disability inclusion) (2marks).

3. Contrast with Previous Development Approaches	4	Shows how earlier frameworks (e.g., MDGs) did not fully integrate equity or often focused on averages (2 marks). Highlights the shift toward reaching the most disadvantaged first (2 marks).
4. Clarity, Organisation, and Use of Development Terminology	4	Clear, well-structured response. Uses appropriate terms (e.g., vulnerable populations, marginalisation, social equity, inclusive development) (2 marks). Logical flow of ideas (2 marks).

Question 4

Criteria	Marks	Description
1. Identification of Two Relevant SDGs	2	1 mark per SDG The SDGs must be clearly named and relevant to Ghana's context (e.g., SDG 1 – No Poverty; SDG 4 – Quality Education; SDG 6 – Clean Water and Sanitation; SDG 8 – Decent Work and Economic Growth).
2. Explanation of National Development Challenges	2	1 mark per SDG Clearly connects each SDG to a specific development challenge in Ghana (e.g., unemployment, access to quality education, sanitation deficits, inequality, and youth development).
3. Explanation of How the SDGs Address These Challenges	4	2 marks per SDG. Provides a clear explanation of how the SDG targets or strategies support Ghana's national development priorities. May include references to government policies, development plans (e.g., Ghana's Coordinated Programme of Economic and Social Development Policies), or real examples (e.g., Free SHS policy, job creation programmes, water initiatives).
4. Clarity, Structure, and Use of Development Terminology	2	Logical and well-structured answer. Uses appropriate language (e.g., sustainable development, economic inclusion, human capital, infrastructure, poverty alleviation). Ideas are clearly and coherently expressed.

WEEK 2**FOCAL AREA 1****Question 1**

- a. interconnection of challenges within the SDG framework [5marks]

Sub-Criteria	Marks	Description
Identification of Relevant SDGs	1	Identifies appropriate SDGs (e.g., SDG 6 – Clean Water and Sanitation, SDG 7 – Affordable and Clean Energy, SDG 2 – Zero Hunger, SDG 13 – Climate Action).
Explanation of Inter-connections	2	1–2 marks for explaining how clean water, agriculture, and energy are linked (e.g., irrigation depends on water and energy; clean water access affects health and productivity).
Use of Contextual Understanding (Adaklu/ Ghana)	2	1–2 marks for applying analysis to rural Ghana, showing local relevance (e.g., boreholes needing solar power, rain-fed agriculture challenges).

- b. integrated Engineering solution [7marks]

Sub-Criteria	Marks	Description
Feasibility of the Solution	2	1–2 marks for any two technically realistic, locally appropriate engineering solution (e.g., solar-powered boreholes for water and irrigation).
Integration Across Challenges	2	1–2 marks for solution that address at least two challenges in a coordinated way (e.g., water and energy; energy and agriculture).
Innovation and Sustainability	2	1–2 marks for demonstrating creative thinking and long-term viability (e.g., low maintenance, renewable sources, community involvement).
Use of Engineering Concepts	1	Shows technical understanding (e.g., off-grid energy systems, water harvesting, and drip irrigation).

- c. evaluation of unintended consequences [8marks]

Sub-Criteria	Marks	Description
Identification of Possible Unintended Effects	3	1–3 for any three realistic considerations of risks (e.g., overuse of groundwater, system maintenance issues, and local ownership problems).
Analysis of Consequences	3	1–3 for explaining how these unintended outcomes could affect sustainability or community dynamics.
Mitigation Strategies	2	1–2 for suggesting ways to reduce risks (e.g., training programs, water-use regulations, phased implementation).

Question 2

a. Comparison and Contrast of Centralised vs Decentralised Approaches [6marks]

Sub-Criteria	Marks	Description
Definition of Centralised and Decentralised Approaches	2	1–2 marks for clear and accurate explanation of each approach: — Centralised: large-scale generation, national grid systems. — Decentralised: off-grid, mini-grid, local renewable solutions. Ghana-specific energy context mentioned.
Comparison (Advantages/Disadvantages)	2	1–2 for comparing in terms of cost, scalability, reliability, implementation speed, accessibility, environmental impact, etc. Must provide balanced view.
Use of Examples (Ghana context)	2	1–2 for including Ghanaian specific examples such as Akosombo Dam (centralised) vs solar mini-grids in Northern Ghana (decentralised).

a. Conditions for Recommending Each Approach [6 marks]

Sub-Criteria	Marks	Description
Identification of Specific Conditions	2	1–2 marks for outlining when each approach is suitable (e.g., rural vs urban, geographic isolation, energy demand scale, infrastructure availability).
Justification and Alignment with SDG 7	2	1–2 marks for explaining any two recommendations contribute to affordability, accessibility, reliability, and sustainability. Considers equity and inclusiveness.
Supporting Evidence	2	1–2 marks for citing data, policies, or case studies (e.g., Renewable Energy Act, Ghana Energy Commission initiatives, and global best practices).

c. Clarity, Coherence, and Use of Technical Terminology [8marks]

Sub-Criteria	Marks	Description
Structure and Logical Flow	4	1–2 for clear, organised comparison and argument. 1–2 for each part of the question is addressed coherently.
Technical Accuracy and Terminology	4	1–4 for correct use of energy-related terms (e.g., grid parity, load management, energy access, generation capacity, intermittency, demand-side management).

Question 3**a. Analysis of the Tension [6 marks]**

Sub-Criteria	Marks	Description
Identification of a Relevant Urban Context	2	Names and briefly describes a real urban setting (e.g., Accra, Kumasi, Lagos, Nairobi). -Sets the context for the analysis.
Explanation of SDG 11 Goals	1	Describes SDG 11's focus: sustainable transport, affordable housing, inclusive planning, green infrastructure, etc.
Analysis of Conflict with Short-Term Economic Priorities	3	1-2 marks for exploring how sustainability goals (e.g., reducing emissions, long-term infrastructure planning) may clash with short-term goals like rapid development, industrial growth, or limited budgets. 1 mark for using examples such as resistance to green building costs, land-use conflicts, or delays in ROI.

b. Development of a Balanced Strategy [6 marks]

Sub-Criteria	Marks	Description
Realistic Engineering or Planning Strategy Proposed	2	1-2 marks for feasible and innovative solution (e.g., phased green infrastructure, smart city technologies, PPP funding models).
Integration of Sustainability and Economic Concerns	2	1-2 marks for strategy that demonstrates how sustainability measures are balanced with affordability, job creation, or short-term economic viability.
Relevance to the Chosen Urban Context	1	Strategy is tailored to the urban conditions described in Part A.
Use of Technical and Planning Knowledge	1	Shows understanding of relevant engineering/planning principles (e.g., life-cycle costing, urban mobility systems, energy efficiency).

c. Explanation of Sustainability, Integrity and Economic Balance [6 marks]

Sub-Criteria	Marks	Description
Clarity in Linking Strategy to SDG 11 Objectives	2	1-2 marks for clearly explains how the strategy continues to meet long-term urban sustainability goals.
Addressing Economic Concerns Without Compromising Goals	2	1-2 marks for showing understanding of trade-offs and how to mitigate them (e.g., incremental investment, incentives, stakeholder engagement).
Overall Coherence and Justification	2	1-2 marks for logical and persuasive argument that connects back to earlier parts.

FOCAL AREA 2

Question 1

a. Integrated Engineering Solution [8 marks]

Sub-Criteria	Marks	Description
Identification of Relevant SDGs and Local Context	2	1 mark for demonstrating understanding of SDGs 13, 14, and 8. 1 mark for accurately contextualises the issues in a Ghanaian coastal setting.
Integration of All Three Challenges	2	1–2 marks for proposing a solution that simultaneously addresses climate resilience, marine sustainability, and employment (e.g., eco-friendly aquaculture, coastal defences integrated with blue economy jobs, or renewable energy-based fish processing).
Technical Feasibility and Innovation	2	1–2 marks for using realistic and practical engineering or technological components tailored to local capacity and resources.
Use of Stakeholder Involvement and Local Knowledge	2	1–2 marks for demonstrating awareness of the need for community participation and knowledge co-production.

b. Evaluation of Trade-offs [6 marks]

Sub-Criteria	Marks	Description
Identification of Trade-offs	2	1–2 marks for discussing short-term benefits vs long-term sustainability (e.g., rapid job creation vs ecosystem degradation or expensive infrastructure vs gradual adaptation).
Depth of Evaluation	2	1–2 marks for explaining how decisions balance urgent needs (e.g., jobs) with resilience and regeneration (e.g., marine conservation or climate adaptation).
Reference to Sustainability Principles	2	1–2 marks for using relevant frameworks (e.g., systems thinking, circular economy, resilience building).

c. Unintended Consequences and Mitigation [6marks]

Sub-Criteria	Marks	Description
Identification of Risks or Unintended Effects	2	1–2 marks for examples may include overdependence on a new industry, exclusion of certain groups, ecological disturbance.
Mitigation Measures	2	1–2 marks for providing feasible, proactive steps (e.g., capacity building, environmental monitoring, and inclusive consultation).

Realism and Awareness	2	1–2 marks for reflecting deep understanding of complexity and limitations of intervention.
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d. Ethical Justification [6marks]

Sub-Criteria	Marks	Description
Consideration of Equity and Access	2	1–2 marks for addressing who benefits (e.g., youth, fishers, women) and ensures inclusive access.
Ethical Justification of Choices	2	1–2 marks for justifying why the approach is fair, participatory, and sensitive to cultural or social norms.
Clarity and Persuasiveness	2	1–2 marks for presenting a well-argued ethical defence that aligns with sustainability and social justice values.

Question 2

a. Integration of Four SDGs [6 marks]

Sub-Criteria	Marks	Description
Selection of Relevant SDGs	2	1–2 marks for correctly identifies at least four SDGs (e.g., SDG 9 – Industry, Innovation and Infrastructure; SDG 11 – Sustainable Cities; SDG 13 – Climate Action; SDG 7 – Clean Energy; SDG 6 – Water and Sanitation).
Mutual Reinforcement	2	1–2 marks for demonstrating how selected SDGs work together to create synergies (e.g., renewable energy supporting sustainable cities and climate action).
Relevance to Urbanisation Context	2	1–2 marks for clearly aligns goals with infrastructure needs in a rapidly growing urban region.

b. Reconciling Development and Environmental Protection [6 marks]

Sub-Criteria	Marks	Description
Identification of Conflicting Priorities	2	Examples include land use, emissions, resource consumption, and displacement vs conservation.
Strategy for Reconciliation	2	1–2 marks for presenting a clear plan to balance development and environmental impact (e.g., green zoning, low-carbon materials, mixed-use urban planning).
Use of Sustainable Design Principles	2	1–2 marks for demonstrating understanding of concepts like passive design, green infrastructure, and lifecycle assessment.

c. Incorporation of Technological and Social Innovations [6 marks]

Sub-Criteria	Marks	Description
Technological Innovations	2	1–2 marks for examples: smart grids, green buildings, mobility tech, water recycling, digital twins.
Social Innovations	2	1–2 marks for examples: inclusive housing policies, participatory planning, and community energy cooperatives.
Integration and Practicality	2	1–2 marks for demonstrating realistic application and coherence between social and technological elements.

d. Evaluation Metrics Across Timeframes (6 marks)

Sub-Criteria	Marks	Description
5-Year Metrics	2	1–2 marks for short-term outputs and early-stage outcomes (e.g., % renewable energy installations, public transport expansion).
15-Year Metrics	2	1–2 marks for medium-term indicators (e.g., emissions reduction %, infrastructure resilience, SDG progress alignment).
30-Year Metrics	2	1–2 marks for long-term goals (e.g., net-zero targets, sustainable land use, biodiversity health).
Use of SMART Indicators		All metrics should be Specific, Measurable, Achievable, Relevant, and Time-bound.

e. Adaptation Mechanisms [6 marks]

Sub-Criteria	Marks	Description
Identification of Potential Changing Conditions	2	1–2 marks for conditions such as, climate variability, demographic shifts, economic disruptions, tech evolution.
Flexibility and Feedback Loops	2	1–2 marks for describing systems for adaptive planning, community feedback, continuous monitoring.
Resilience and Risk Management	2	1–2 marks for incorporating proactive risk mitigation and climate resilience strategies.

SECTION 2: HEALTH AND SAFETY

STRAND: ENGINEERING PRACTICE

Sub-Strand: Health and Safety in Engineering Practice

WEEK 3

Learning Outcomes: *Implement good housekeeping measures*

Content Standard: Demonstrate understanding of workplace safety and welfare.

WEEK 4

Learning Outcome: *Administering appropriate first aid for various workplace accidents*

Content Standard: Demonstrate understanding of workplace safety and welfare.

INTRODUCTION AND SECTION SUMMARY

In this section, learners will be exposed to the implementation of good housekeeping measures. Maintaining a clean, orderly, and secure environment at work, home, or in other settings is known as good housekeeping. Untidy, messy, filthy, or disorganised spaces are examples of poor housekeeping, which can have detrimental effects on individuals, companies, and the environment. Learners will understand that whether in a bustling production line, a quiet office or a rough construction site, good housekeeping enhances appearance, safety and efficiency. The section will also help learners to identify essential materials for treating small wounds, avoiding infection, which are included in a typical first aid kit. Learners will also acquire skill to handle a crisis until expert assistance arrives. In order to ensure a prompt and efficient reaction to common incidents, learners will understand the need to keep a first aid box which usually contains bandages, gauze, antiseptic wipes, tweezers, pain medicines, gloves, cold packs, and a first aid manual.

The weeks and the indicators covered by the section are:

- Week 3:
 1. Explain the need for good housekeeping
 2. Explain the consequences of poor housekeeping
- Week 4:
 1. Outline housekeeping rules at construction sites, manufacturing or production areas and offices
 2. Administer first aid to victims of common workplace accidents

Recap

Year 1	Week 3: Identify accidents that occur in engineering practice. Week 4: Explain the health and safety protocols associated with basic workshop tools/ machinery.
Year 2	Week 3: Describe risk assessment and outline its relevance. Week 4: Explain the procedure for risk assessment.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Employing learner-centred approach in this section, interactive pedagogical strategies that encourage critical thinking, active participation, and skill development could help teachers effectively teach the value of good housekeeping and first aid protocols in the workplace. These interactive pedagogical strategies consist of experiential learning, talk-for-learning, and group learning. In small groups, learners investigate the consequence of poor housekeeping on safety at the workplace and demonstrate how such consequences can be avoided. By posing open-ended questions and promoting conversation about actual events, teachers foster discussion. Learning by doing and reflecting on first-hand experience can be achieved by setting up hands-on simulations where learners practice organising a safe workspace or perform first aid techniques like treating cuts or burns using role-play scenarios. Using these strategies, teachers foster not only knowledge acquisition but also the practical skills and safety mindset that learners need to contribute to healthy and secure work environments.

ASSESSMENT SUMMARY

To effectively assess learners' understanding of the importance of good housekeeping and the correct administration of first aid for common workplace accidents, teachers should utilise a blend of active, applied, and collaborative assessment strategies. Assessment modes such as individual exercise, group research and case study can be used for this section. Group work encourages collaboration, communication, and peer learning. Research develops critical thinking, information gathering, and synthesis skills. Case study promotes analysis of real or hypothetical workplace incidents. Practical activity assesses hands-on ability to apply first aid and housekeeping principles. These methods allow learners to not only grasp theoretical knowledge but also develop practical skills essential for real-world occupational health and safety. These modes can allow learners to critically answer the level 3 and 4 questions related to the indicators. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain the need for good housekeeping	Level 2	Class work–Multiple choice
Explain the consequences of poor housekeeping	Level 2	Case study
Outline housekeeping rules at construction sites, manufacturing/production areas and offices	Level 2	Individual assignment
Administer first aid to victims of common workplace accidents	Level 4	Practical activity

WEEK 3

Learning Indicators

1. *Explain the need for good housekeeping*
2. *Explain the consequences of poor housekeeping*

FOCAL AREA 1: EXPLAIN THE NEED FOR GOOD HOUSEKEEPING

The Need for Good Housekeeping

Good housekeeping means keeping a workplace, home, or environment **clean, organised, and safe**. It is **essential** for several important reasons:

1. Promotes Safety

- a. A clean and organised space reduces the risk of accidents such as trips, slips, and falls.
- b. It helps prevent fires by reducing clutter and properly storing flammable materials.

2. Improves Efficiency

- a. When tools, equipment, and materials are neatly stored and labelled, it saves time and effort in finding them.
- b. Workflows become faster and more organised.

3. Enhances Health

- a. Good housekeeping reduces dust, mould, and harmful contaminants that can cause allergies or illnesses.
- b. It creates a healthier environment for everyone.

4. Boosts Morale and Professionalism

- a. A clean, orderly space improves the mood of workers and shows pride and respect for the workplace.
- b. It gives a positive impression to visitors, customers, and clients.

5. Protects Equipment and Materials

- a. Proper storage and care prevent damage to tools, machines, and supplies, reducing repair and replacement costs.

6. Supports Compliance

- a. Good housekeeping helps organisations meet health, safety, and environmental regulations and avoid legal penalties.

Learning Tasks

1. Work with learners to discuss how they keep their dormitories and homes in order and the benefits they derive from such good housekeeping.

2. Have learners work in groups to brainstorm on tools and equipment needed for good housekeeping.
3. In moderated discussions, guide learners to share experiences related to the essence of keeping the engineering environment clean, organised, and safe, summarise views using webbing.

Pedagogical Exemplars

Initiating Talk for Learning: Assign groups to develop a workplace safety plan that emphasises good housekeeping practices and outlines emergency response protocols. They focus on the ability to work in a team, role delegation, quality of the safety plan, and understanding of preventive measures.

Have learners conduct research on the causes and consequences of poor housekeeping (e.g., slips, trips, and falls), and on standard first-aid procedures for cuts, burns, or fainting.

Key Assessment Level 2: Classwork

1. Explain three reasons why good housekeeping is important in the workplace. *(6 marks)*
2. How does good housekeeping contribute to fire safety? *(3 marks)*
3. Explain two good practices for maintaining good housekeeping at work. *(4 marks)*

FOCAL AREA 2: CONSEQUENCES OF POOR HOUSEKEEPING

Refer back to Year 2 Section 2 (week 3 Risk Assessment and its relevance)

Poor housekeeping -meaning untidy, cluttered, dirty, or disorganised spaces can lead to serious negative outcomes for people, workplaces, and the environment. Some key consequences include:

a) Increased Accidents and Injuries

- i. Cluttered walkways, spilt liquids, and misplaced tools cause trips, slips, falls, and collisions.
- ii. Poorly stored materials can fall and injure people.

b) Fire Hazards

Accumulated waste, flammable materials, and blocked fire exits increase the risk of fires and make emergency evacuation more difficult.

c) Health Risks

- i. Dust, mould, pests, and chemical spills can cause respiratory issues, allergies, infections, and other health problems.
- ii. Poor sanitation can spread diseases.

d) Low Productivity and Efficiency

- i) Time is wasted searching for misplaced tools, documents, or materials.
- ii) Workers become frustrated and work more slowly in a disorganised environment.

e) Damage to Equipment and Property

- i) Dust, dirt, and spills can damage machines, tools, and electronic equipment.
- ii) Poor maintenance shortens the lifespan of valuable assets.

f) Negative Image and Reputation

- i) Visitors, customers, or inspectors may view an untidy place as unsafe and unprofessional.
- ii) This can hurt business credibility and future opportunities.

g) Legal and Financial Consequences

- i) Poor housekeeping can lead to violations of safety laws and standards.
- ii) Organisations may face fines, lawsuits, or shutdowns after inspections or accidents.

Poor housekeeping creates unsafe, unhealthy, inefficient, and costly environments and can even lead to serious injuries, major financial losses, and damage to reputation.

Learning Tasks

1. In moderated discussions, guide learners to share experiences related to the consequences of poor housekeeping within their school communities.
2. Discuss with learners and help them appreciate some good behaviours that prevent the consequences of poor housekeeping. Refer back to Year 1 Section 2 (Week 3 Identify the causes of accidents).

Pedagogical Exemplars

Collaborative Learning: In small groups, learners discuss the adverse effects of poor housekeeping and share their views with the whole class. Add to what groups say to refine their ideas. Present groups with case studies involving accidents caused by poor housekeeping or poor first aid response. Learners identify the hazards, analyse outcomes, and recommend improvements. The focus is to develop problem-solving ability, understanding of cause-and-effect relationships, and application of safety principles

Key Assessment Level 2: Classwork

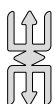
1. Explain three possible accidents that can occur due to poor housekeeping in a workshop. (6 marks)
2. Describe two ways poor housekeeping can negatively affect workplace productivity. (4 marks)
3. Describe three situations where poor housekeeping in the workplace could result in legal action against a company. (3 marks)
4. Explain two long-term effects of poor housekeeping on a business. (4 marks)
5. Describe two consequences of poor housekeeping in an industrial setting. (4 marks)

PLC Session 3

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have about the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

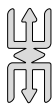
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **classwork**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the classwork (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How should this be thought?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not developed separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 4

Learning Indicators

1. *Outline housekeeping rules at construction sites, manufacturing/production areas and offices*
2. *Administering First Aid to Victims of Common Workplace Accidents*

FOCAL AREA 3: **OUTLINE HOUSEKEEPING RULES AT CONSTRUCTION SITES, MANUFACTURING/ PRODUCTION AREAS AND OFFICES**

Housekeeping Rules at Construction Sites, Manufacturing or Production Areas, and Offices

a. Construction Sites

- i. Keep pathways and work areas clear of debris, tools, and materials.
- ii. Remove waste materials daily (wood scraps, nails, packaging).
- iii. Store tools and equipment properly.
- iv. Cover or secure openings and trenches to prevent falls.
- v. Organise materials safely to prevent tipping or collapse.
- vi. Keep flammable materials stored away from ignition sources.
- vii. Install proper signage to warn of hazards and restricted areas.
- viii. Ensure proper lighting in all work areas, especially stairways and exits.

b. Manufacturing or Production Areas

- i. Clear floors of spills, oil, and debris immediately to avoid slips.
- ii. Arrange tools and materials in designated storage racks or bins.
- iii. Label and store hazardous chemicals properly according to regulations.
- iv. Dispose of scrap materials and packaging waste regularly.
- v. Keep emergency exits, fire extinguishers, and aisles free of obstruction.
- vi. Use proper ventilation to avoid build-up of fumes and dust.
- vii. Maintain and clean machines according to a regular schedule.
- viii. Inspect and maintain safety equipment such as eyewash stations and alarms.

c. Offices

- i. Keep desks, floors, and common areas tidy and organised.
- ii. Manage cables and cords to prevent tripping hazards.
- iii. Dispose of paper waste properly; recycle whenever possible.
- iv. Keep fire exits, corridors, and emergency equipment clear.
- v. Store files and supplies neatly in cabinets or shelves.

- vi. Clean spills immediately to prevent slips or damage.
- vii. Regularly sanitise high-touch surfaces (keyboards, door handles).
- viii. Ensure proper lighting and ventilation for a healthy workspace.

Good housekeeping improves safety, efficiency, and appearance in all work environments — whether it is a rough construction site, a busy production line, or a quiet office.

Learning Tasks

1. Facilitate discussions reviewing the importance of good housekeeping. Refer back to Year 2 Section 2 (week 3 Risk Assessment and its relevance)
2. Have learners work in groups to brainstorm some housekeeping rules that might exist at construction sites, manufacturing areas, and offices, and the relevance of each rule.

Pedagogical Exemplars

Initiating Talk for Learning: In a question-and-answer session, learners discuss housekeeping rules at construction sites, manufacturing/production areas, and offices and the relevance of each rule.

Experiential Learning

The focus is on construction sites which are dynamic environments where safety hazards like clutter, misplaced tools, and obstructed pathways can lead to accidents. Experiential learning here should incorporate real-world simulations and practical problem-solving. Create controlled scenarios on actual or simulated construction sites. For example, set up a course with both proper and improper housekeeping examples. Learners can walk through the area, identify hazards, and participate in clean-up drills. This hands-on approach makes the risks and benefits immediately observable.

Key Assessment Level 2: Homework

1. State and explain three housekeeping rules that should be followed at a construction site. (6 marks)
2. Describe two housekeeping rules specific to a manufacturing/production area. (4 marks)
3. Explain why office housekeeping rules are different from those in a production area. Provide two examples of office housekeeping rules. (5 marks)
4. Describe two general housekeeping rules that apply to all workplaces (construction, manufacturing, and offices). (4 marks)

FOCAL AREA 4: ADMINISTERING FIRST AID TO VICTIMS OF COMMON WORKPLACE ACCIDENTS

A standard first aid kit contains essential supplies for treating minor injuries, preventing infection, and managing emergencies until professional help arrives. It typically includes

bandages, gauze, antiseptic wipes, tweezers, pain relievers, gloves, cold packs, and a first aid manual, ensuring a quick and effective response to common accidents.

Table 1: Common items found in a standard first aid kit, along with their uses.

	Item	Use
1.	Adhesive bandages (plasters)	Cover small cuts, blisters, or abrasions to prevent infection.
2.	Sterile gauze pads	Absorb blood and exudate from larger wounds; used under bandages.
3.	Adhesive tape	Secure gauze pads or dressings in place.
4.	Antiseptic wipes	Clean wounds or hands to kill germs before dressing a wound.
5.	Antibiotic ointment	Prevent infection in minor cuts and scrapes.
6.	Hydrogen peroxide	Disinfect wounds (use with caution, can damage tissue).
7.	Tweezers	Remove splinters, debris, or stingers from the skin.
8.	Scissors	Cut gauze, tape, or clothing around a wound.
9.	Instant cold pack	Reduce swelling, pain, or bruising from sprains or insect bites.
10.	Elastic bandage (ACE bandage)	Support sprains and strains; reduce swelling.
11.	Thermometer	Measure body temperature to detect fever.
12.	Disposable gloves	Protect the wearer and patient from infection during treatment.
13.	CPR face shield/mask	Provide safe mouth-to-mouth resuscitation.
14.	Burn cream or gel	Soothe minor burns and prevent infection.
15.	Eye wash or saline solution	Rinse out foreign objects or chemicals from the eyes.
16.	Safety pins	Secure bandages or create slings.
17.	Triangular bandage	Create slings or support injured limbs.
18.	Pain relievers (e.g. paracetamol, ibuprofen)	Relieve pain, inflammation, or fever.
19.	Alcohol pads	Disinfect skin or instruments.
20.	First aid manual	Provide instructions on basic emergency care.

First aid is the immediate care given to an injured or ill person before professional medical help arrives.

Here is how to handle common workplace accidents:

a. Cuts and Bleeding

- i. Wear gloves if available to protect yourself.
- ii. Apply direct pressure to the wound with a clean cloth or bandage.

- iii. Elevate the injured area, if possible, to reduce bleeding.
- iv. Clean the wound with water (if minor) and apply an antiseptic.
- v. Cover with a sterile bandage.
- vi. Seek medical help for deep or large wounds.

b. Burns (Thermal, Chemical, or Electrical)

- i. Remove the person from the source of the burn safely.
- ii. Cool the burn with cool (not cold) running water for at least 10 minutes.
- iii. Do not apply ice, creams, or butter.
- iv. Cover the burn loosely with a clean, non-stick cloth or dressing.
- v. Seek urgent medical attention for serious burns (especially chemical or electrical).

c. Fractures (Broken Bones)

- i. Do not move the person unless necessary for safety.
- ii. Support the injured area using a splint or padding.
- iii. Keep the person still and calm.
- iv. Apply ice packs wrapped in a cloth to reduce swelling.
- v. Call emergency services immediately.

d. Sprains and Strains

Use the RICE method:

- i. Rest the injured area.
- ii. Ice it for 15–20 minutes every hour.
- iii. Compress with an elastic bandage.
- iv. Elevate above heart level if possible.
- v. Seek medical advice if severe.

e. Eye Injuries (Chemical Splashes or Debris)

- i. Rinse the eye immediately with clean water for at least 15 minutes.
- ii. Do not rub the eye.
- iii. Cover the eye with a clean cloth.
- iv. Seek emergency medical help.

f. Choking

- i. Ask if they can cough or speak. If not:
- ii. Use current choking-response guidance:
 - Stand behind the person.
 - Place your fist just above their navel.
 - Grasp your fist with your other hand and give quick upward thrusts.

- iii. Repeat until the object is expelled or the person becomes unconscious (then perform CPR if trained).

g. Electric Shock

- i. Switch off the power source immediately if safe to do so.
- ii. Do not touch the person while they are in contact with electricity.
- iii. Check for breathing and pulse once safe.
- iv. Start CPR if necessary and if trained.
- v. Call emergency services immediately.

Important Reminders

1. Stay calm at all times.
2. Protect yourself first before helping others.
3. Call professional medical services for serious injuries.
4. Always report accidents to supervisors according to workplace procedures.



Figure 1: Items found in a First Aid kit

Learning Tasks

1. Discuss with learners what first aid is and how to administer first aid to victims of common workplace accidents. Also, discuss the importance of first aid and the basic tools and materials used.
2. Guide learners to role-play workplace accidents and some colleagues to administer first aid whilst others observe and comment.

Pedagogical Exemplars

Experiential Learning: Learners watch videos on tools and materials for first aid and how they are used. Learners discuss how to administer first aid to victims of common workplace accidents. Learner role-play workplace accidents for colleagues to practice administering first aid. Other learners observe and comment. Allow learners to demonstrate procedures such as cleaning up a hazardous spill, organising a cluttered workspace, or administering basic first aid (e.g., bandaging, CPR simulation). The focus is to develop accuracy of skills, confidence, safety awareness, adherence to correct procedure, and teamwork in learners.

Key Assessment Level 3: Case Study

1. Scenario-Based Response

A worker in a manufacturing plant suffers a deep laceration on their forearm from a metal shard. Blood is flowing steadily. Describe the step-by-step first-aid response you would provide, including safety considerations. (10 marks)

2. Evaluation

A construction worker falls from scaffolding and complains of severe back pain. Discuss the first aid priorities and potential risks if moved incorrectly. (5 marks)

3. Problem-Solving

An office worker collapses and is unresponsive. You suspect cardiac arrest. Outline the first aid steps, including how to use an AED (Automated External Defibrillator). (7 marks)

4. Critical Analysis

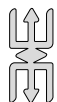
A colleague is burned by a chemical splash in a laboratory. Compare the first aid steps for a chemical burn versus a thermal burn, justifying the differences. (8 marks)

PLC Session 4

45 minutes

Planning & Reviewing the Learning Plan

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2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
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 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app

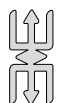
- The key assessment for the week is **case study**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

- use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
- all teachers in the group work through a similar problem individually for 3–4 minutes
- the group then works through the problem together step by step
- highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).

- Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
- After the enactment, ask for structured feedback from the group
 - was the concept explained in a way that a learner with no prior knowledge could follow?
 - were the examples grounded in contexts familiar to Ghanaian learners?
 - did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 2 Review

1. Would learners be able to explain the need for good housekeeping?
2. Can learners explain the consequences of poor housekeeping?
3. Can learners outline housekeeping rules at construction sites, manufacturing/production areas and offices?
4. Would learners be able to administer first aid to victims of common workplace accidents?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 3

FOCAL AREA 1

Question 1

2 marks per reason (1 for identifying the reason, 1 for a clear explanation).

Total: 6 marks

Answer

- b. Prevents Accidents and Injuries – A clean and organised workplace reduces hazards like slips, trips, and falls caused by clutter or spills.
- c. Improves Efficiency and Productivity – Properly arranged tools and materials save time, allowing workers to perform tasks faster.
- d. Enhances Safety Compliance – Good housekeeping ensures compliance with safety regulations, reducing the risk of fines or legal issues.

Question 2

1mark per valid point (must be clearly explained).

Total: 3 marks

Answer

Good housekeeping reduces fire risks by:

- a. Preventing accumulation of flammable materials (e.g., paper, chemicals).
- b. Ensuring clear emergency exits for safe evacuation.
- c. Reducing ignition sources (e.g., clutter near electrical equipment).

Question 3

Marking Scheme

2 marks per correct practice (must be relevant and practical).

Total: 4 marks

Answer

- a. Regular cleaning schedules (daily or weekly).
- b. Proper waste disposal (separating hazardous and non-hazardous waste).
- c. Organised storage (labelling and designated spaces for tools/materials).
- d. Spill control measures (immediate clean-up of leaks).

FOCAL AREA 2**Question 1****Answer**

- a. Slips, Trips, and Falls – Oil spills, loose cables, or scattered tools can cause workers to slip or trip.
- b. Fires and Explosions – Accumulation of flammable materials (e.g., paper, chemicals) near heat sources increases fire risks.
- c. Falling Objects – Poorly stacked materials or unsecured shelves can lead to objects falling and injuring workers.

Marking Scheme

2 marks per accident (1 for naming the accident, 1 for explaining how poor housekeeping causes it).

Total: 6 marks

Question 2**Answer**

- a. Time Wasted Searching for Tools and Materials – Disorganisation forces workers to spend extra time locating items.
- b. Increased Downtime Due to Accidents – Poor housekeeping leads to more injuries, causing work delays.

Marking Scheme

2 marks per effect (1 for stating the effect, 1 for a clear description).

Total: 4 marks

Question 3**Answer**

Fines from Safety Inspectors – If a workplace fails safety audits due to clutter or hazards.

Workers' Compensation Claims – Employees injured due to poor housekeeping may sue the company.

When Factories violate Inspection Regulatory Standard – Non-compliance with workplace safety laws can result in penalties.

Marking Scheme

1 mark per valid point (must be clearly explained).

Total: 3 marks

Question 4**Answer**

1. Higher Insurance Costs – Due to increased accident claims.
2. Lower Employee Morale – Workers feel unsafe and demotivated in a messy environment.
3. Damage to Company Reputation – Clients may perceive the business as unprofessional.
4. Increased Equipment Wear and Tear – Dust and poor maintenance reduce machinery lifespan.

Marking Scheme

- 2 marks per correct effect (must be relevant and logical).
- Total: 4 marks

Question 5

Answer:

- a. Increased Risk of Accidents – Cluttered walkways and improperly stored materials can lead to trips, fires, or equipment malfunctions.
- b. Reduced Morale and Productivity – A disorganised workplace can lower employee motivation, leading to slower work and more errors.

Marking Scheme:

2 marks per consequence (1 for stating the consequence, 1 for describing it).

Total: 4 marks

WEEK 4**FOCAL AREA 3****Question 1****Answer**

- a. Clear Walkways and Work Areas – Remove debris, tools, and materials from pathways to prevent trips and falls.

- b. Proper Waste Disposal – Separate and dispose of construction waste (e.g., wood, metal, hazardous materials) in designated containers.
- c. Secure Materials and Tools – Store materials properly (e.g., stacking bricks safely) and return tools to their storage areas after use.

Marking Scheme

2 marks per rule (1 for stating the rule, 1 for a clear explanation).

Total: 6 marks

Question 2

Answer

- a. Regular Machine Maintenance & Cleanliness – Keep machines free of oil, dust, and debris to prevent malfunctions and fire hazards.
- b. Spill Control Measures – Immediately clean up spills (e.g., oil, chemicals) and use absorbent materials to prevent slips and contamination.

Marking Scheme

2 marks per rule (1 for stating the rule, 1 for describing its importance).

Total: 4 marks

Question 3

Answer

Reason for Difference

Offices have fewer physical hazards but require organisation for efficiency, whereas production areas deal with machinery, chemicals, and safety risks.

Examples of Office Housekeeping Rules

- a. Cable Management – Secure loose wires under desks to prevent tripping.
- b. Paperless Practices – Reduce clutter by storing documents digitally and shredding unnecessary papers.

Marking Scheme

1 mark for explaining the difference

2 marks per office rule (1 for stating the rule, 1 for justification).

Total: 5 marks

Question 4

Answer

- a. Daily Cleaning Schedules – Ensure workspaces are cleaned regularly.
- b. Proper Storage – Keep items in labelled, designated areas.
- c. Keeping Emergency Exits Clear – Never block fire exits or evacuation routes.
- d. Personal Responsibility – Each worker must clean their workstation.

Marking Scheme

2 marks per correct rule (must be universally applicable).

Total: 4 marks

FOCAL AREA 4

Question 1

Answer

- a. Ensure Scene Safety – Check for ongoing hazards (e.g., machinery still running) before approaching.
- b. Protect Yourself – Put on gloves to avoid bloodborne pathogen exposure.
- c. Apply Direct Pressure – Use a clean cloth or sterile gauze to press firmly on the wound.
- d. Elevate the Limb – Raise the arm above heart level to reduce blood flow.
- e. Secure Dressing – If bleeding persists, add more layers without removing the initial dressing.
- f. Call for Emergency Help – If bleeding is uncontrolled after 10 minutes, seek medical assistance.
- g. Monitor for Shock – Keep the victim warm and lying down if symptoms (e.g., pale skin, dizziness) appear.

Marking Scheme

1 mark per correct step (7 steps).

2 marks for safety considerations (PPE and hazard awareness).

1 mark for logical sequence.

Total: 10 marks.

Question 2

Answer

Priorities

1. Immobilise the Spine – Tell the victim not to move. Support head/neck manually.
2. Seek urgent medical attention – Await trained responders with a spinal board.
3. Monitor Breathing – Ensure the airway is open if the victim is conscious.

Risks of Incorrect Movement

Paralysis – Spinal cord damage from misalignment.

Internal Injuries – Displaced fractures may puncture organs.

Marking Scheme

3 marks for priorities (1 per point).

2 marks for risks (1 per risk).

Total: 5 marks.

Question 3

Answer

1. Check Responsiveness – Tap and shout, “Are you okay?”
2. Call Emergency Services – Activate EMS/code blue if available.
3. Begin CPR – 30 chest compressions (5 cm/2 inches deep) followed by 2 rescue breaths.
4. Retrieve AED – Turn it on and follow voice prompts.
5. Apply Pads – Place one pad on the upper right chest, the other on the lower left side.
6. Analyse Rhythm – Ensure no one touches the victim during analysis.
7. Deliver Shock **if Advised** – Resume CPR immediately after shock.

Marking Scheme

1 mark per step (7 steps).

Bonus 1 mark for correct pad placement.

Total: 7 marks.

Question 4

Answer

Chemical Burn

1. Immediate Irrigation – Flush with water for 15–20 minutes to dilute/remove the chemical.
2. Remove Contaminated Clothing – Carefully cut away affected clothing without spreading the chemical.
3. Avoid neutralising agents – Never apply neutralising agents (e.g., acids/bases) unless instructed.

Thermal Burn

1. Cool with Running Water – Apply cool (not icy) water for 10 minutes to reduce heat.
2. Cover with Sterile Dressing – Use non-stick gauze to prevent infection.
3. Do Not Pop Blisters – Avoid breaking blisters to reduce infection risk.

Justification

Chemical burns require prolonged flushing due to residual contamination, while thermal burns focus on stopping heat damage. Neutralisers can worsen chemical reactions.

Marking Scheme:

3 marks for chemical burn steps.

3 marks for thermal burn steps.

2 marks for justification.

Total: 8 marks.

SECTION 3: PROFESSIONAL ETHICS

STRAND: ENGINEERING PRACTICE

Sub-Strand: Ethics and Professional Practice.

WEEK 5

Learning Outcome: *Demonstrate an understanding of professional codes of ethics.*

Content Standard: Ethics and Professional Practice.

WEEK 6

Learning Outcome: *Demonstrate an understanding of professional codes of ethics.*

Content Standard: Ethics and Professional Practice.

INTRODUCTION AND SECTION SUMMARY

Ethics and professional conduct are fundamental to engineering practice. Engineering institutions, such as the Ghana Institution of Engineering (GhIE), establish ethical guidelines to ensure engineers uphold integrity, safety, and accountability in their work. These principles protect public welfare, guide professional behaviour, and maintain trust in engineering solutions that shape society. Learning about ethics fosters responsible decision-making, critical thinking, and a commitment to professionalism. It also prepares learners for future challenges in engineering careers. In this section, ethical guidelines and professional practice covering integrity Public Safety, Competence, Accountability and Sustainability will be explored. Learners will be able to adhere to ethical standards set by engineering institutions, maintain confidentiality and respect intellectual property rights, as well as avoid conflicts of interest and act in the best interest of society.

The weeks and the indicators covered by the section are:

- Week 5: 1. Describe the nature, relevance, and mandate of professional bodies.
2. Explain the importance and nature of professional code of ethics.
- Week 6: 3. Determine whether or not a conduct violates a code of ethics.

Recap

Year 1	Week 5: Explain ethical and unethical behaviours Week 6: Demonstrate ethical behaviour in case study scenarios
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Year 2	Week 6: Explain professionalism in Engineering practice Week 7: Characteristics of an ethical and professional workplace Week 8: Attributes of an engineer Week 9: Unprofessional behaviour
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SUMMARY OF PEDAGOGICAL EXEMPLARS

Consider using interactive pedagogical strategies that encourage critical thinking, active participation, and skill development. This could help teachers effectively teach the value of ethics and professional conduct in engineering. Learners can visit the websites of various professional bodies and learn individually or in groups, the various codes of conduct and professional practices governing the respective professional bodies. Learners can then engage in lively class discussions on their views on these codes and their impact on society. By posing open-ended questions and promoting conversation about actual cases of professional misconduct, teachers can foster discussion and understanding of the impacts of these instances of misconduct and the requisite remedial actions taken by professional bodies.

ASSESSMENT SUMMARY

To effectively assess learners' understanding of the importance of ethics and professional practice, teachers should utilise a blend of active, applied, and collaborative assessment strategies. Assessment modes such as individual exercise, group research and case study can be used for this section. Group work encourages collaboration, communication, and peer learning. Research develops critical thinking, information gathering, and synthesis skills. Case studies promote analysis of real or hypothetical cases of misconduct. These methods allow learners to not only grasp theoretical knowledge but also develop practical skills essential for real-world occupational situations. These modes can allow learners to critically answer the level 2 and 3 questions related to the indicators. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
<i>Describe the nature, relevance, and mandate of professional bodies.</i>	Level 3	Individual assignment
<i>Explain the importance and nature of professional codes of ethics.</i>	Level 2	Individual assignment
<i>Determine whether or not a conduct violates a code of ethics.</i>	Level 3	Case study

WEEK 5

Learning Indicators

1. *Describe the nature, relevance, and mandate of professional bodies*
2. *Explain the importance and nature of professional code of ethics*

FOCAL AREA 1: DESCRIBE THE NATURE, RELEVANCE, AND MANDATE OF PROFESSIONAL BODIES

Nature of Professional Bodies

Professional bodies are formal organisations that represent individuals who work in specific professions, such as engineering, law, medicine, accounting, or education. These organisations are usually non-profit, member-driven, and are often governed by elected councils or boards. Their nature is to act as custodians of professional standards, knowledge, and ethics, supporting the continuous development and recognition of their members.

These are some **professional bodies in Ghana**:

- a. **Ghana Institution of Engineering (GhIE)** – for engineers.
- b. **Ghana Bar Association (GBA)** – for lawyers.
- c. **Ghana Medical Association (GMA)** – for medical doctors.
- d. **Pharmaceutical Society of Ghana (PSGH)** – for pharmacists.
- e. **Ghana Institute of Architects (GIA)** – for architects.
- f. **Ghana Institute of Surveyors (GhIS)** – for surveyors.
- g. **Ghana Chartered Institute of Bankers (CIB Ghana)** – for banking professionals.
- h. **Ghana Institute of Journalism (GIJ)** (also functions partly as a professional training body for journalists).
- i. **Institute of Chartered Accountants, Ghana (ICAG)** – for accountants.
- j. **Chartered Institute of Marketing, Ghana (CIMG)** – for marketing professionals.
- k. **Ghana Psychological Association (GPA)** – for psychologists.
- l. **Ghana Nurses and Midwives Association (GNMA)** – for nurses and midwives.
- m. **Chartered Institute of Human Resource Management, Ghana (CIHRM)** – for HR professionals.

Relevance of Professional Bodies: (Refer back to Year 1, Section 3, Week 5, Focal Area 2: Capable of explaining the relevance of ethics in engineering practice)

Professional bodies are highly relevant because they:

- a. **Set and maintain standards** of practice, ensuring quality and integrity within the profession.
- b. **Certify and accredit** individuals through professional qualifications and registration.

- c. **Support professional development** by offering training, workshops, seminars, and continuous learning opportunities.
- d. **Advocate** for the profession in public, governmental, and industry spheres.
- e. **Protect the public interest** by ensuring that professionals adhere to ethical codes and are competent in their fields.
- f. **Foster networking and collaboration** among members, promoting innovation and knowledge sharing.

Mandate of Professional Bodies: (Refer back to Year 2, Section 3, Week 6, Focal Area 1: Professionalism in engineering)

Typically, professional bodies have the following mandates:

- a. **Regulate the profession** by setting entry requirements, maintaining professional registers, and enforcing codes of conduct.
- b. **Promote professional excellence** through certification programmes, awards, and continuing education requirements.
- c. **Safeguard the public** by handling complaints, disciplinary procedures, and taking action against misconduct.
- d. **Develop the profession** by contributing to policy discussions, setting future trends, and shaping educational curricula.
- e. **Support members** by providing career services, legal advice, technical resources, and professional recognition.

Learning Tasks

1. Learners think, pair, and share their views on the professional bodies they know of in Ghana.
2. Organise/summarise their thoughts using concept maps/webbing. In pairs, let them research a particular professional body and the body's relevance and mandate.

Pedagogical Exemplars

Initiating Talk for Learning: The facilitator leads a discussion to list professional bodies in Ghana. In small groups, learners select and discuss a particular professional body and their relevance and mandate. Groups share findings with the whole class.

Key Assessment Level 3: Individual Assignment

1. Analyse how the key characteristics of professional bodies influence their role in promoting ethical standards and professional development in Ghana. Use examples to support your answer. [8 marks]
2. Analyse how professional bodies contribute to national development in Ghana. (7 marks)
3. Compare the mandates of the Nursing and Midwifery Council (NMC) and the Ghana Institution of Engineers (GhIE). (6 marks)

4. “Some people say that professional bodies make work harder by adding too many rules and delays.” Do you agree or disagree with this view? Give reasons for your answer and use examples from Ghana to support your points (15 marks)

FOCAL AREA 2: EXPLAIN THE IMPORTANCE AND NATURE OF PROFESSIONAL CODE OF ETHICS

- a) **Importance of a Professional Code of Ethics:** (Refer back to Year 1, Section 3, Week 5, Focal Area 2: the reasons ethics are relevant to engineering engineering practice)

A code of ethics is important because it:

- i. **Builds public trust** by showing that professionals are committed to acting responsibly and with integrity.
- ii. **Promotes professionalism** by setting high standards of behaviour and performance.
- iii. **Protects clients and the public** from malpractice, misconduct, and unethical behaviour.
- iv. **Provides a framework for decision-making** when facing complex or unclear situations.
- v. **Enhances the reputation of the profession** by ensuring consistent, ethical practices across the field.
- vi. **Supports fairness and accountability** by making it clear how misconduct will be dealt with.
- vii. **Promotes self-regulation** and reduces the need for external control by governments or other authorities.

- b) **Nature of a Professional Code of Ethics**

A professional code of ethics is a set of formal guidelines and principles that govern the behaviour, actions, and decision-making of members within a profession. It outlines what is considered acceptable and unacceptable conduct. These codes are usually developed by professional bodies and are binding on all members. The nature of a code of ethics is:

- i. **Prescriptive** – it tells professionals how they should act.
- ii. **Protective** – it safeguards the interests of the public and clients.
- iii. **Guiding** – it helps professionals handle ethical dilemmas.
- iv. **Binding** – members are expected to comply, and violations can lead to disciplinary action.

Learning Tasks

1. Have learners work in groups to brainstorm the nature and importance of their school's code of conduct.

2. Facilitate discussions that review the importance of professional codes of ethics.
3. Through a question-and-answer session, facilitate learners to explain the differences between codes of ethics and codes of conduct.

Pedagogical Exemplars

Collaborative Learning: In groups, learners are tasked to visit the websites of some engineering professional bodies in Ghana and report on relevant codes of conduct.

In a facilitator-moderated discussion, learners discuss the appropriateness or otherwise of the codes of ethics presented by the groups.

Key Assessment Level 2: Individual Assignment

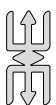
1. What is a professional code of ethics, and why is it important in workplaces?
2. Describe **three** features of a professional code of ethics.
3. How are professional codes of ethics enforced? Give two methods.
4. How is a professional code of ethics different from personal ethics?
5. Explain two ways a professional code of ethics benefits society.

PLC Session 5

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app

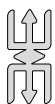
- a. The key assessment for the week is ***individual assignment***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assignment (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

- a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
- b. all teachers in the group work through a similar problem individually for 3–4 minutes
- c. the group then works through the problem together step by step
- d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).

- a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
- b. After the enactment, ask for structured feedback from the group
 - i. Was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. Were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. Did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC session conducted (NTS 1f, 1g).

9. Remember to

- a.** transfer your chats into your learning planner template.
- b.** read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
- c.** integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 6

Learning Indicator: *Determine whether or not a conduct violates a code of ethics*

FOCAL AREA 3: DETERMINE WHETHER OR NOT A CONDUCT VIOLATES A CODE OF ETHICS

To determine whether conduct violates a code of ethics, you should:

a) Identify the Relevant Ethical Principles

Identify the relevant provisions of the professional code (e.g., honesty, competence, public safety) apply to the situation.

b) Describe the Conduct Clearly

What exactly happened? Who was involved? What actions were taken?

c) Compare the Conduct to the Ethical Standards

Does the behaviour match the required ethical behaviour stated in the code?

Did the person act with integrity, competence, respect, confidentiality?

d) Assess the Impact

Did the conduct harm anyone (the public, the client, the environment, the profession)?

Did it create a conflict of interest, show dishonesty, or put public safety at risk?

e) Make a judgement

If the conduct clearly goes against the principles (e.g., lying about qualifications, ignoring safety risks, leaking confidential information), then it **violates the code of ethics**.

If the conduct supports and aligns with the principles, it **does not violate the code**.

f) Check for Disciplinary Guidelines

Some professional bodies (such as GhIE) also describe specific consequences for different types of ethical violations.

Examples of conduct that violates the professional code of ethics:

1. Legal Profession (General Legal Council of Ghana)

Scenario

A lawyer represents both the plaintiff and defendant in a divorce case without full disclosure to either party.

Violation?

Yes

Code Breached: GLC Rule 9(1) – Conflict of interest prohibition.

Analysis

Lawyers cannot serve opposing parties in the same matter (undivided loyalty required).

Must disclose potential conflicts and obtain informed consent (not done here).

Consequence: Disciplinary action by GLC, including suspension.

2. Medical Profession (Medical and Dental Council Ghana)

Scenario

A doctor prescribes expensive, branded drugs to patients because he receives kickbacks from the pharmaceutical company.

Violation?

Yes

Code Breached: *MDCG Ethics Rule 4.3* – Prohibition of undue financial influence.

Key Issues

Puts personal gain above patient welfare.

Violates principles of beneficence and non-maleficence.

Penalty: License revocation and criminal prosecution under the *Health Professions Regulatory Bodies Act 2013*.

3. Teaching Profession (National Teaching Council Ghana)

Scenario

A teacher alters WASSCE exam scripts for students who paid her.

Violation?

Yes

Code Breached: *NTC Code 2.1* – Integrity in assessment.

Ethical Principles Violated

Fairness (advantages for paying students).

Professional honesty (academic fraud).

Consequence

Deregistration by NTC.

Possible imprisonment under the *Education Act 2008 (Act 778)*.

4. Accounting Profession (Institute of Chartered Accountants Ghana)

Scenario

An auditor omits findings of fraud in a client's financial report to maintain the contract.

Violation?

Yes

Code Breached: *ICAG Fundamental Principle – Objectivity*.

Relevant Rules

Section 240.5: Must report material misstatements.

Section 290: Independence compromised by fear of losing client.

Outcome

ICAG disciplinary sanctions.

Liability under *Companies Act 2019 (Act 992)*.

5. Engineering Profession (Ghana Institution of Engineering)

Scenario

An engineer approves substandard building materials for a project to cut costs, knowing it compromises safety.

Violation?

Yes

Code Breached: *GhIE Bye-Law 13* – Duty to prioritise public safety.

Key Failures

Negligence in professional duty.

Endangers lives (violates *Engineering Council Act 2011*).

Action

Striking off the GhIE register.

Criminal negligence charges.

6. Banking Profession (Chartered Institute of Bankers Ghana)

Scenario

A bank manager shares a client's financial records with a friend for gossip.

Violation?

Yes

Code Breached: *CIBG Code 6* – Confidentiality obligation.

Legal Ramifications

Breach of the *Data Protection Act 2012 (Act 843)*.

Civil lawsuit for damages.

Professional Sanction

CIBG membership revocation.

Blacklisting by Bank of Ghana.

Learning Tasks

1. Guide learners in moderated discussion of various cases or scenarios of conduct to assess whether they violate any professional code of ethics.
2. Work with learners to describe the conduct of some professionals for class review using their professional codes of conduct.

Pedagogical Exemplars

Initiating Talk for Learning: In a moderated discussion, the facilitator presents various cases or scenarios of conduct for learners to assess whether they violate any professional ethical code. Learners also present various forms of conduct for review by the class.

Key Assessment: Mid-Semester Examination

1. Medical Ethics (Ghana Health Service Code of Conduct)

Scenario

Dr. Mensah, a physician at a public hospital in Accra, accepts a “gift” of ₵,000 from a patient’s family to prioritise their surgery over others on the waiting list. The **Ghana Health Service Code of Conduct** prohibits soliciting or accepting bribes and requires fair treatment of all patients.

Question

Does Dr. Mensah’s conduct violate the **Ghana Health Service Code of Conduct**? Justify your answer with reference to ethical principles.

2. Legal Ethics (Ghana Legal Profession Code of Conduct)

Scenario

Lawyer Ama Ansah represents a client in a land dispute. She discovers that her client submitted forged documents as evidence but decides not to disclose this to the court, fearing it will harm her case.

Question

Does Lawyer Ansah’s silence violate the **Ghana Legal Profession (Professional Conduct and Etiquette) Rules**? Analyse using ethical principles.

3. Corporate Ethics (Ghana Securities and Exchange Commission (SEC) Code of Corporate Governance)

Scenario

The CEO of a Ghanaian mining company approves a project that will displace a rural community without adequate compensation or consultation, despite the company’s **Sustainability Policy** pledging to respect human rights and engage stakeholders.

Question

Does the CEO’s decision violate the **Ghana SEC Code of Corporate Governance** and ethical best practices? Discuss.

4. Public Sector Ethics (Ghana Civil Service Code of Conduct)

Scenario

A senior official at the Ministry of Education awards a textbook procurement contract to his brother’s company without competitive bidding. The Civil Service Code of Conduct prohibits nepotism and requires transparency in procurement.

Question

Does the official's action violate Ghana's public sector ethics? Argue with reference to relevant anti-corruption laws.

Hint



Conduct the Mid-semester **Examination**. It should cover contents taught from Week 1 to 5. Refer to the **Table of Specification and Structure of the Paper** to guide you. Learners' papers should be marked immediately and scores entered into the SAP.

Structure

Section A: 25 Multiple-choice questions

Section B: 2 Essay Questions

Table of specification for item construction for section A and B

Week	Focal area	Types of questions	DoK Levels				Total
			1	2	3	4	
1	Define the Sustainable development goals Explain the role of the SDGs in societal development	MCQs	2	2	-		4
		ESSAY	-	-	-		-
2	Describe engineering solutions for attaining specific SDGs Designing and developing innovative solutions towards the attainment of SDGs	MCQs	2	2	2		6
		ESSAY	-	-	1		1
3	Explain the need for good housekeeping Explain the consequences of poor housekeeping	MCQs	-	2	1		3
		ESSAY	-	-	-		
4	Outline housekeeping rules at construction sites, manufacturing/production areas and offices Administering First Aid to Victims of Common Workplace Accidents	MCQs	3	2	1		6
		ESSAY					
5	Describe the nature, relevance, and mandate of professional bodies Explain the importance and nature of professional code of ethics	MCQs	1	3	2		6
		ESSAY			1		1
		Total	8	11	8		27

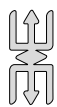
PLC Session 6

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.

2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand.
 - b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

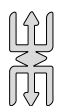
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP).
 - a. The key assessment for the week is **mid-semester examination**. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the mid-semester examination (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through the problem individually for 3–4 minutes
 - c. the group then works through it together the problem, step by step
 - d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not 'How do I teach this?' but how do i teach it so that learners understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 3 Review

2. Are learners able to list professional bodies in Ghana?
3. Are learners able to present sample cases of the violation of code of ethics of the Ghana Institution of Engineering?
4. When presented with a case of professional misconducts, are learners able to identify the ethical principle violated?
5. Are learners able to judge the impact of professional misconducts on the society?
6. Do learners have copies of the GhIE code of ethics manual in their folios?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 5

FOCAL AREA 1

Question 1

Answer

Identification of relevant characteristics (e.g., regulation, licensing, training, ethical oversight) — at least 2 clearly explained 2 marks
 Explanation of how characteristics promote ethical standards (e.g., codes of conduct, disciplinary processes, accountability) 2 marks
 Explanation of how characteristics support professional development (e.g., continuing education, skills upgrading, certification) 2 marks
 Use of relevant Ghanaian examples (e.g., GhIE, GMA, GNMA, and GBA) with clear linkage to the above points.

Question 2

Answer

- Quality Assurance – Ensure professionals meet standards (e.g., *NTC* certifies qualified teachers).
- Public Protection – Prevent malpractice (e.g., *Pharmacy Council* regulates drug dispensing).
- Economic Growth – Foster trust in sectors (e.g., *Ghana Bar Association* boosts legal investment confidence).
- Continuous Learning – Mandate CPD (e.g., *GhIS* requires surveyors to update skills).

Marking Scheme

1.5 marks per point (1 for relevance, 0.5 for example).

1 mark for clarity/logic.

Total: 7 marks.

Question 3

Answer

	Nursing and Midwifery Council	GhIE
a.	Regulates nursing education/training	Accredits engineering programs
b.	Enforces healthcare ethics	Sets safety standards for infrastructure
c.	Licenses nurses/midwives	Certifies chartered engineers
d.	Focuses on patient care	Focuses on public safety in construction

Marking Scheme

1 mark per valid comparison (max 4).

2 marks for clear differentiation of focus areas.

Total: 6 marks.

Question 4

Criteria	(3marks)	(2 marks)	(1 marks)
Understanding of the Topic	Shows all three qualities (such as understanding of professional bodies, explains the issue of rules and delays)	Shows any two qualities	Shows one quality.
Clarity of Position	Clearly states and consistently supports a well-considered position (agree, disagree, or balanced).	States a position and supports it.	Position is inconsistently supported.
Arguments and Reasoning	Provides strong, logical arguments with clear reasoning and balance (both sides if applicable).	Provides good arguments with some logic and relevance.	Provides basic logical arguments.
Use of Ghanaian Examples	Uses three well-explained, relevant examples from Ghana.	Uses two well-explained, relevant examples from Ghana.	Uses one well-explained, relevant examples from Ghana.
Structure and Organisation	Essay is well-organised with a clear introduction, body, and conclusion. Ideas flow logically.	Essay has clear structure but some issues with transitions or flow.	Organisation is attempted but ideas are not well connected.

FOCAL AREA 2

Question 1 (5 Marks)

Answer

A **professional code of ethics** is a set of guidelines that outline acceptable behaviour for members of a profession (1 mark). It is important because:

- Ensures accountability** – Employees follow standards, reducing misconduct (1 mark).
- Builds public trust** – Clients rely on ethical professionals (1 mark).

Example: Doctors follow the **Hippocratic Oath** to prioritise patient care (1 mark). The explanation is clear (1 mark).

Question 2 (6 Marks)

Answer

- Rule-Based** – Provides clear dos and don'ts (e.g., “Do not accept bribes”) (2 marks).
- Enforceable** – Violations lead to penalties (e.g., license suspension) (2 marks).
- Profession-Specific** – Tailored to fields (e.g., legal vs. medical ethics) (2 marks).

Question 3(4 Marks)

Answer

Enforcement methods include:

- a. **Fines/Suspensions** – Penalties for minor violations (1 mark).
- b. **Licence Revocation** – For serious breaches (1 mark).

Enforcement ensures compliance and maintains public trust (2 marks).

Question 4 (5 marks)

Answer

- a. **Formal vs. Informal** – Professional codes are written rules; personal ethics are unwritten beliefs (1 mark).
- b. **Mandatory** – Violating a code can cost a job; personal ethics have no penalties (1 mark).
- c. **Field-Specific** – Lawyers follow different rules from engineers (1 mark).

Example: A banker must follow financial laws, but personal honesty is a choice (1 mark). Well-explained (1 mark).

Question 5 (4 marks)

Answer

- a. **Public Safety** – Ensures doctors/nurses prioritise patient care (2 marks).
- b. **Fair Services** – Prevents lawyers/accountants from exploiting clients (2 marks).

WEEK 6

Question 1 (Total: 10 Marks)

Criteria	Marks
Identifies relevant ethical principles (e.g., Integrity, Non-Discrimination, Anti-Corruption)	2
References specific sections of the Ghana Health Service Code (e.g., Sec. 4.1: “No staff shall solicit or accept bribes”)	2
Explains how the conduct breaches ethical standards	3
Considers possible justifications (if any) and rebuts them	2
Clear, well-structured conclusion	1

Sample Answer

Yes, Dr. Mensah’s conduct violates the **Ghana Health Service Code of Conduct**:

Integrity & Anti-Corruption (Sec. 4.1): Accepting money for preferential treatment is a bribe, which is explicitly prohibited.

Non-Discrimination (Sec. 3.2): All patients must be treated fairly; prioritising one due to payment undermines equity.

Public Trust: Such acts erode confidence in Ghana’s healthcare system.

No justification (e.g., “its common practice”) overrides these ethical breaches.

Question 2 (Total: 10 Marks)

Criteria	Marks
Identifies key ethical duties (e.g., Honesty, Duty to the Court)	2
Cites relevant rules (e.g., Rule 9: “A lawyer shall not mislead the court”)	2
Evaluates the conflict between client loyalty and professional ethics	3
Suggests alternative actions (e.g., withdrawing from the case)	2
Clear, logical conclusion	1

Sample Answer

Yes, Lawyer Ansah violates **Rule 9** of the Ghana Legal Profession Rules:

Duty to the Court: Lawyers must not assist in fraud (Rule 9(3)). Concealing forgery misleads the court.

Integrity (Rule 1): Her silence breaches professional honesty, even if it helps her client.

Remedy: She should either withdraw or disclose the forgery to the court, as the justice system’s integrity outweighs client interests in this case.

Questions 3 (Total: 10 Marks)

Criteria	Marks
Identifies relevant SEC principles (e.g., Stakeholder Engagement, Sustainability)	2
References international standards (e.g., UN Guiding Principles on Business and Human Rights)	1
Analyses harm to the community vs. business interests	3
Discusses consequences (e.g., reputational risk, legal liability)	2
Clear, justified verdict	2

Sample Answer

Yes, the CEO’s actions violate

- **Ghana SEC Code (Art. 13):** Companies must engage affected communities and address their concerns.
- **Sustainability Commitment:** Displacement without consultation breaches the company’s own policy.
- **UN Guiding Principles:** Forced displacement without redress violates human rights standards.

This could lead to lawsuits, protests, and loss of investor confidence. Ethical practice requires fair compensation and dialogue.

Question 4 (Total: 10 marks)

Criteria	Marks
Names relevant laws (e.g., Public Procurement Act 2003 (Act 663))	2
Cites Civil Service Code (e.g., Sec. 5.4: “No conflict of interest”)	2

Explains why nepotism undermines public trust	3
Links to broader anti-corruption efforts (e.g., Ghana's NACAP)	1
Convincing conclusion	2

Sample Answer

Yes, this violates

- **Civil Service Code (Sec. 5.4):** Awarding contracts to family members is nepotism and a conflict of interest.
- **Public Procurement Act (Act 663):** Contracts above threshold must use competitive bidding (Section 35).
- **National Anti-Corruption Action Plan (NACAP):** Such acts perpetuate corruption, harming Ghana's development. The official should face disciplinary action.

SECTION 4: ENERGY SYSTEMS

STRAND: ENERGY SYSTEMS

Sub-Strand: Circuits and Machines

WEEK 7

Learning Outcomes: *Explain the types and uses of various electrical machines*

Content Standard: Demonstrate understanding of the application of electrical machines

WEEK 8

Learning Outcomes: *Demonstrate how to operate various electrical machines*

Content Standard: Demonstrate understanding of the application of electrical machines

INTRODUCTION AND SECTION SUMMARY

Section 4 is on Energy Systems which is a continuation of Year 1 and Year 2 concepts in circuits and machines. This section exposes learners to the types, uses and operation of electrical machines. Devices that transform electrical energy into mechanical energy or the other way around are known as electrical machines. Learners will be exposed to the essential roles that transformers, motors, generators and specialised electrical machinery play in a variety of electrical systems and applications. Connecting electrical machinery to a power source, managing their operation, and removing them when required are all processes in the operating process. To avoid mishaps and protect operators' health, safety precautions are essential when using a variety of electrical devices.

The weeks and the indicators covered by the section are:

- Week 7
 1. Identify various electrical machines
 2. Explain the uses of transformers, DC and AC motors, DC and AC generators, and special electrical machines (i.e., Stepper motors, servo motors)
- Week 8
 1. Operate (connect control, and disconnect) electrical machines.
 2. Explain the safety measures associated with the use of the various electrical machines

Recap

Year 1	<i>Week 8: Identify the basic elements of DC electric and electronic circuit and sketch their circuit symbols</i> <i>Week 9: Classify circuit elements into passive and active elements.</i>
Year 2	<i>Week 10: Identify the basic components of analogue electronic circuits</i> <i>Week 11: Use CAD tools for the design and analysis of simple analogue electronic circuits</i>

SUMMARY OF PEDAGOGICAL EXEMPLARS

This section suggests that teachers adopt a blended pedagogical approach such as experiential learning, talk-for-learning, demonstration, Collaborative and Problem-Based Learning. Experiential learning is a powerful strategy for teaching technical and practical concepts in electrical engineering. By actively engaging learners in hands-on experiences, real-world applications, and reflective practice, it enhances their ability to identify, use, operate, and handle electrical machines safely and effectively. Teachers can group learners to investigate real-world applications of machines (e.g., how motors are used in electric vehicles or pumps). Assign learners problem-solving tasks such as selecting the right machine for a specific job. Teachers can adopt Demonstration and Modelling where you have to show learners how each machine works before learners try. Use real machines, charts, and simulation software to illustrate internal mechanisms and control methods.

ASSESSMENT SUMMARY

Assessment for this section includes practical task, project work, case study, presentation, written tests, peer or self-assessment. These strategies offer a balanced and effective way to evaluate both theoretical knowledge and practical competence, which are essential in the teaching of electrical machines and safety. Practical task focuses on skills in machine operation and safety which is performance-based. Project work focuses real-world application and integration, this is a project-based assessment. Case study focuses on analytical thinking and safety analysis for critical thinking. Presentation helps learners in communication and conceptual understanding for oral or visual explanation. Peer or self-assessment help learners develop reflective learning skills. These assessment tools will help teachers to set test items in DoK level 2-4.

Provide a summary of the assessment used *against the indicator. For instance:*

Indicators	DOK Level	Assessment Strategy and/or Mode
Identify various electrical machines	Level 2	Group oral presentation
Explain the uses of transformers, DC & AC motors, DC & AC generators and special electrical machines (i.e. stepper motors, servo motors, etc.)	Level 3	Written test (multiple choice)
Operate (connect, control, and disconnect) electrical machine	Level 2	Group project work
Explain the safety measures associated with the use of the various electrical machines	Level 2	Case study.

WEEK 7

Learning Indicators

1. Identify various electrical machines
2. Explain the uses of transformers, DC and AC motors, DC and AC generators, and special electrical machines (i.e., stepper motors, servo motors, etc.)

FOCAL AREA 1: IDENTIFY VARIOUS ELECTRICAL MACHINES

Refer back to Year 1 Week 8 (Identify the basic elements of DC electrical and electronic circuits and sketch their circuit symbols) and Year 2 Week 10 (Identify the basic components of analogue electronic circuits)

Electrical machines are devices that convert electrical energy into mechanical energy or vice versa, or transform electrical energy from one form to another. They are broadly classified based on their function:

1. Electric Motors

Convert electrical energy into mechanical energy.

Types include

- a. **AC Motors** (e.g., induction motors, synchronous motors)

An AC motor converts electrical energy supplied as alternating current into mechanical energy.

Types

Induction Motors (most common)

- i. Single-phase (household appliances)
- ii. Three-phase (industrial machinery)

Practical Example

- Ceiling fan: Powered by a single-phase induction motor.
- Industrial air compressor: Uses a three-phase AC motor for high-power operation.

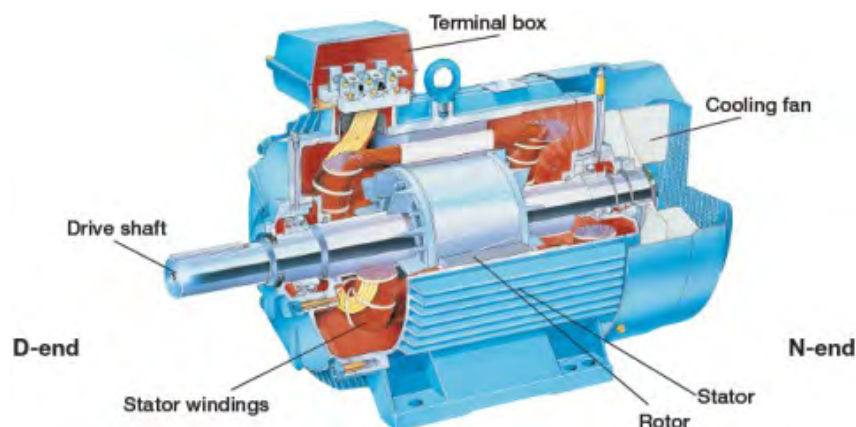


Figure 2: An AC motor

b. DC Motors (e.g., series, shunt, compound motors)

A DC motor converts direct current electrical energy into mechanical energy.

Types

- i. Shunt DC Motor – Constant speed
- ii. Series DC Motor – High starting torque
- iii. Compound DC Motor – A combination of both

Practical Example

- Electric wheelchair: Uses a DC motor for precise speed control and movement.
- Conveyor belts: Where variable speed is required.

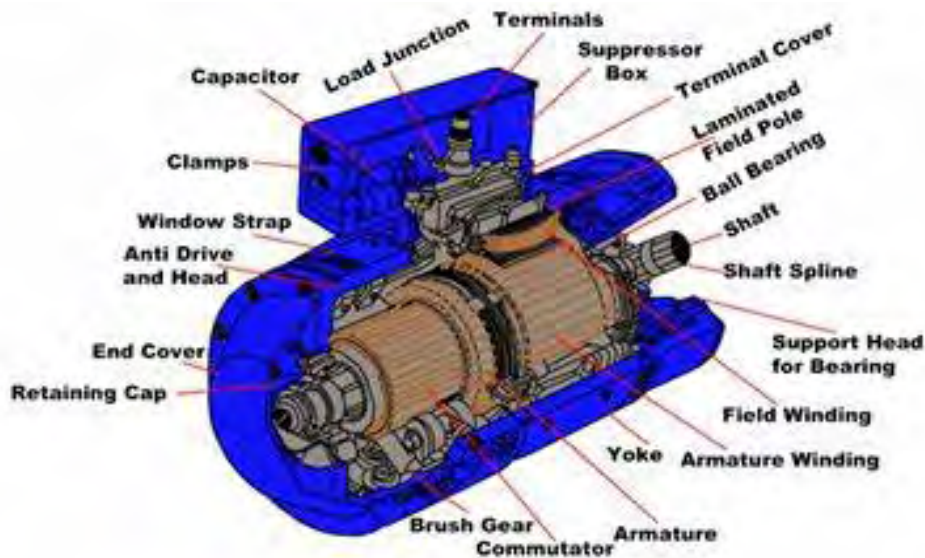


Figure 3: *DC motor*

2. Electric Generators

Convert mechanical energy into electrical energy.

Types include:

a. DC Generator

A DC generator converts mechanical energy into direct electrical energy.

Types

- i. Shunt-wound: Constant voltage
- ii. Series-wound: Variable voltage
- iii. Compound-wound: Combination of both

Practical Example

- Wind-up torches or bikes with hub generators to charge batteries.
- Older railway coaches for onboard DC supply.

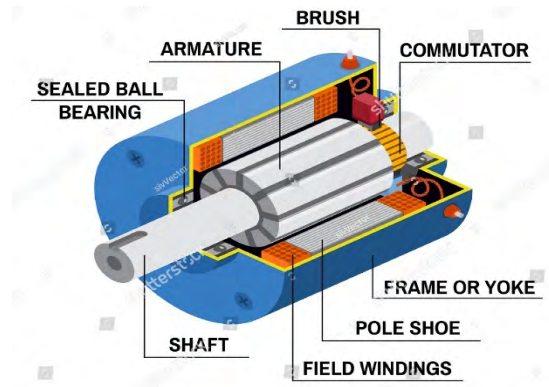


Figure 4: A DC generator

b. AC Generators (Alternators):

An AC generator converts mechanical energy into alternating current electricity.

Types

- i. Single-phase alternator: For small-scale needs
- ii. Three-phase alternator: For industrial and utility generation

Practical Example

- Diesel generators at hospitals provide AC power during outages.
- Wind turbines: Mechanical rotation is converted into AC using alternators.

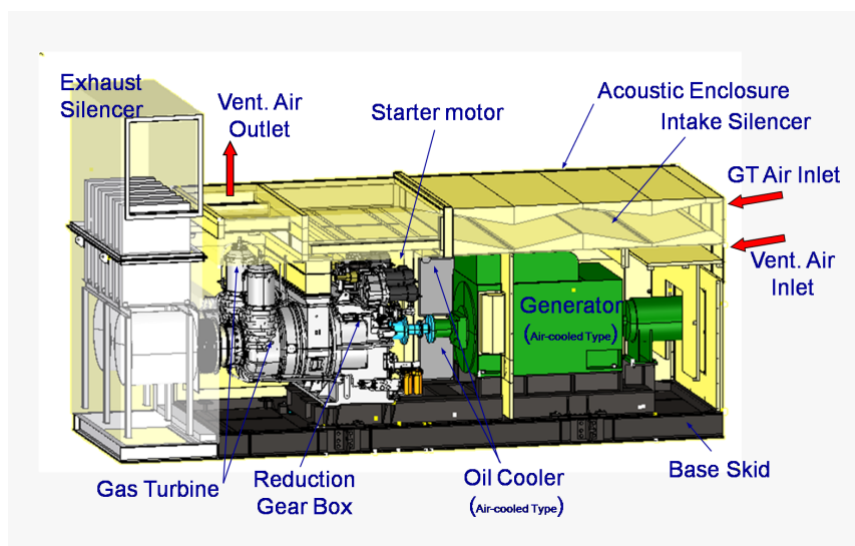


Figure 5: An AC generator

3. Special Electrical Machines

a. Stepper Motors

Electromechanical devices that divide a full rotation into a number of equal steps.

Example: A 3D printer uses stepper motors to move the print head in precise steps along X, Y, and Z axes.

b. Servo Motors:

Motors with built-in feedback to control position, speed, and acceleration.

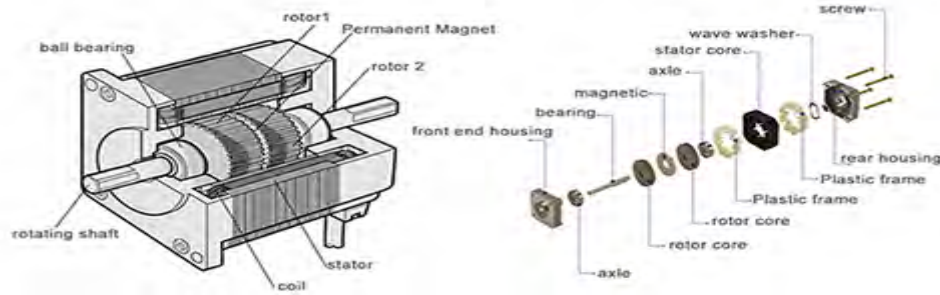


Figure 6: *The parts of a Stepper motor*

Learning Tasks

1. Recap with learners on energy systems in year 1 and 2
2. Task learners with working in groups to investigate real-world applications of machines (e.g., how motors are used in electric vehicles or pumps).
3. Have learners observe real machines, charts, and simulation software to illustrate internal mechanisms and control methods.
4. Ask guiding questions that prompt learners to explain what they observe.

Pedagogical Exemplars

Experiential Learning: Learners familiarise themselves with various electrical generators, motors, and transformers

Talk-for-Learning: Initiate classroom discussions around the function and uses of each type of machine. In a moderated discussion, learners discuss the physical features of the machines they have familiarised themselves with.

Ask guiding questions that prompt learners to explain what they observe.

Key Assessment Level 2: Group Oral Presentation

1. Describe an electrical machine and give three examples. (5 marks)
2. List two AC machines and two DC machines. State one application for each. (8 marks)
3. Differentiate between rotating and static electrical machines with two examples of each.
4. Name two special-purpose electrical machines and describe where they are used.
5. Classify three categories of electrical machines based on how they convert energy, and provide one example of each.

FOCAL AREA 2: EXPLAIN THE USES OF TRANSFORMERS, DC & AC MOTORS, DC AND AC GENERATORS, AND SPECIAL ELECTRICAL MACHINES (I.E., STEPPER MOTORS, SERVO MOTORS, ETC.)

Refer back to Year 2 Week 11 (Use CAD tools for the design and analysis of simple analogue electronic

Circuits)

1. Transformers

Transfer electrical energy through electromagnetic induction (without changing frequency).

Types of Transformers

- a. Step-up transformer: Increases voltage (used in power transmission).
- b. Step-down transformer: Decreases voltage (used in appliances, power distribution).
- c. Isolation transformer: For safety; no change in voltage but isolates circuits.

Practical Example

- a. Mobile phone charger: Converts 230V AC to 5V DC using an SMPS design, which involves rectification, high-frequency switching through a ferrite transformer, and voltage regulation.
- b. Electrical substations: Use step-up transformers to raise voltage from 11 kV to 132 kV for transmission.

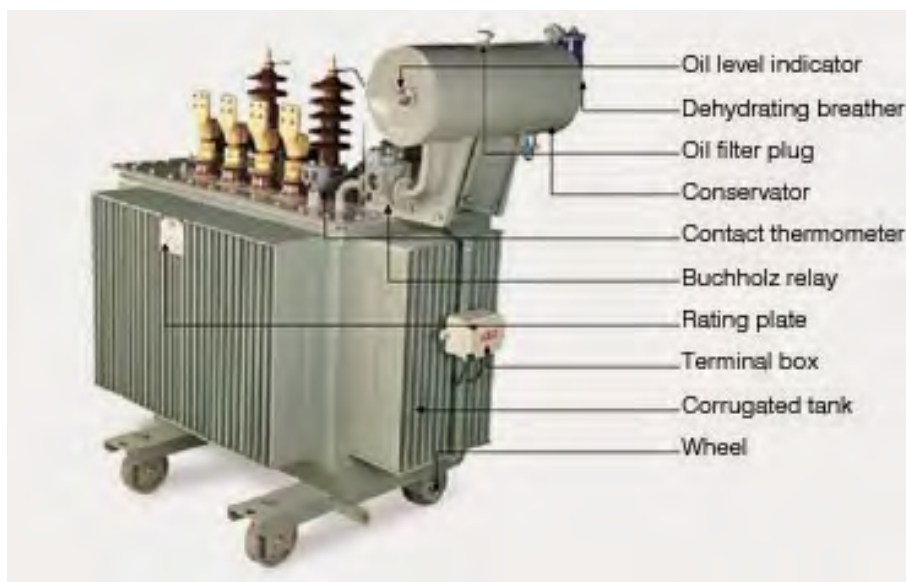


Figure 7: *power transformer*

- a. Uses of transformers
 - i. Voltage step-up/step-down – Used in power transmission lines to increase (stepup) or decrease (stepdown) voltages efficiently.
 - ii. Power supply units – Provide correct voltages to electronic devices (like chargers, TVs).

- iii. Isolation – Provides safety by electrically isolating two parts of a circuit (e.g., in medical equipment).
- b. Uses of DC Motors**
 - i. Electric vehicles – Drive motors for cars, scooters, and trains.
 - ii. Cranes and lifts – Where high starting torque is needed.
 - iii. Small appliances – Toys, fans, and tools like drills.
 - iv. Industrial machines: Lathes, conveyors, and hoists where speed control is needed
 - v. Robotics and automation: Where precise speed and torque control is required.
- c. Uses of AC Motors**
 - i. Industrial machines – Pumps, compressors, conveyor belts in factories.
 - ii. Home appliances – Washing machines, refrigerators, air conditioners.
 - iii. HVAC systems – Heating, ventilation, and air conditioning systems.
 - iv. Large machinery: Used in cranes, mills, and other heavy-duty applications.
- d. Uses of DC Generators**
 - i. Battery charging – Charging batteries where a DC supply is needed.
 - ii. Welding equipment – Provides power for DC welding machines.
 - iii. Laboratory applications – Supply stable DC power for experiments.
 - iv. Electroplating and electrolysis: Where constant DC voltage is needed.
 - v. Excitation systems: In large AC generators (to provide DC field current).
- e. Uses of AC Generators (Alternators)**
 - i. Power stations – Produce electricity for homes, offices, industries.
 - ii. Backup generators – Emergency power supply for hospitals, airports.
 - iii. Renewable energy systems – Wind turbines use AC generators.
 - iv. Vehicles: Supply power for electrical systems in cars and aircraft.
- f. Uses of special electrical machines**
 - i. Stepper Motors: Precision control in printers, CNC machines, and 3D printers
 - ii. Printers – Move print heads with precision.
 - iii. Robotics – Precise control of movements.
 - iv. CNC Machines – Accurate tool positioning.
 - v. Servo Motors:
 - vi. Robotics – For precise control of joint movements.
 - vii. Camera auto focus – Adjusting lens position quickly and accurately.
 - viii. Antenna positioning systems – Moving antennas to exact angles.

Learning Tasks

1. Have learners to explain how transformers step voltage up or down and where they're used (e.g., power grids, devices).
2. Put learners in groups to discuss projects on design machine-based systems (e.g., a power supply using a transformer and generator).

Pedagogical Exemplars

Experiential Learning: Learners watch videos about the applications of the various machines. Learners share their observations on the uses of the various electrical machines.

Key Assessment Level 3: Group oral Presentation

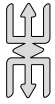
1. Explain the role of transformers in electrical power distribution, comparing step-up and step-down transformers. Provide THREE (3) real-world examples of their applications.
2. Compare the applications of AC induction motors and DC shunt motors, justifying why each is suited to specific uses. Include one (1) industrial example of each.
3. Analyse the use of AC synchronous generators in wind turbines versus DC generators in small-scale solar systems. Highlight efficiency and practicality factors.
4. Evaluate the advantages of stepper motors over servo motors in 3D printers, and vice versa in CNC machines. Discuss precision, cost, and complexity.
5. How are servo motors transforming robotics, and what limitations do they face compared with traditional AC motors?

PLC Session 7

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app

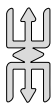
- The key assessment for the week is **group oral presentation**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the presentation (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

- use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
- all teachers in the group work through a similar problem individually for 3–4 minutes
- the group then works through the problem together step by step
- highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).

- Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
- After the enactment, ask for structured feedback from the group
 - was the concept explained in a way that a learner with no prior knowledge could follow?
 - were the examples grounded in contexts familiar to Ghanaian learners?
 - did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 8

Learning Indicators

1. *Operate (Connect, control, and disconnect) electrical machines*
2. *Explain the safety measures associated with the use of the various electrical machines*

FOCAL AREA 3: OPERATE (CONNECT, CONTROL, AND DISCONNECT) ELECTRICAL MACHINES

Refer back to Year 2 Week 11 (Use CAD tools for the design and analysis of simple analogue electronic circuits)

Circuits)

1. Connect Electrical Machines

a. Check Ratings

Make sure the voltage, current, and frequency ratings of the machine match the power supply.

b. Use the Correct Wiring

Connect the terminals properly (e.g., motor terminals to a contactor or switch, generator output to load, transformer input to supply).

c. Install Protection Devices

Use fuses, circuit breakers, overload relays, or surge protectors to prevent damage from faults.

d. Follow Safety Procedures

Ensure the system is grounded, and the supply is OFF before making connections.

2. Control Electrical Machines

a. Switches/Starters

Use ON/OFF switches, contactors, or motor starters to start and stop machines safely.

b. Speed Control (where needed)

For DC Motors: Adjust field current or armature voltage.

For AC Motors: Use Variable Frequency Drives (VFDs) to control speed.

c. Direction Control

Reverse connections (like changing polarity in DC motors or swapping two phases in AC motors) to change the direction of rotation.

d. Monitoring

Monitor indicators such as voltage, current, temperature, and speed to ensure the machine is operating properly.

3. Disconnect Electrical Machines

a. Power down first

Always switch off the supply before disconnecting any machine.

b. Use isolation devices

Use an isolator switch, circuit breaker, or contactor to safely disconnect.

c. Check for residual energy

Make sure capacitors or inductors have discharged before touching terminals.

d. Secure the machine

Lockout/Tagout (LOTO) procedures may be needed in industrial settings to ensure the machine remains off during maintenance.

Example for a Motor

- **Connect:** Wire the motor to the correct supply with a contactor and overload protection.
- **Control:** Use a push-button (start/stop) to run and stop the motor. Monitor the running current.
- **Disconnect:** Switch off the supply, open the circuit breaker, and safely disconnect wires if needed.

Learning Tasks

1. Have learners self-assess their skills and understanding after demonstrations.
2. Assign learners to research and present the uses and applications of a selected electrical machine.

Pedagogical Exemplars

Experiential Learning: Learners are assisted to switch on the electrical machines, vary their speed, power output, torque, etc., as applicable, and finally turn them off. Furthermore, learners watch videos on how to operate the various machines.

Key Assessment Level 2: Test

1. Explain the step-by-step procedure to safely connect a single-phase induction motor to the power supply.
2. Describe two control methods used to start and stop a three-phase induction motor.
3. What precautions should be taken before disconnecting a motor from the supply? Give at least three.
4. Draw a simple labelled diagram showing the connection of a single-phase motor using a DOL starter.
5. State one possible effect of connecting a three-phase motor incorrectly and one safety device used to prevent this.

FOCAL AREA 4: EXPLAIN THE SAFETY MEASURES ASSOCIATED WITH THE USE OF THE VARIOUS ELECTRICAL MACHINES

Electrical machines, including transformers, motors (AC and DC), generators, stepper motors, and servo motors, are widely used in domestic, commercial, and industrial applications. However, their operation involves electricity, mechanical motion, heat, and electromagnetic effects, which can pose safety risks to operators and equipment if not handled correctly. Understanding and applying safety measures helps prevent electric shock, fire hazards, mechanical injury, equipment damage and operational downtime.

1. General Safety Measures for All Electrical Machines

These apply to most types of electrical machines, regardless of their specific function:

- a. **Personal protective equipment (PPE)**
 - i. Wear **insulated gloves** and **electrically rated boots**.
 - ii. Use **safety goggles** when near rotating parts or electrical arcs.
 - iii. Wear **hearing protection** if machines are noisy.
- b. **Lockout or Tagout (LOTO) procedures**
 - i. Disconnect the machine from the power source before servicing.
 - ii. Attach a visible **lock and tag** indicating maintenance is in progress.
 - iii. Only authorised personnel should remove the lockout tag.
- c. **Circuit protection devices**
 - i. Use **fuses, circuit breakers, and overload relays** to prevent overcurrent.
 - ii. Ensure the system is designed with **earth leakage protection [Residual Current Device (RCD) or Earth Leakage Circuit Breaker (ELCB)]**.
- d. **Proper earthing**
 - i. Ensure all machines are **properly earthed** to prevent electric shock from leakage current.
- e. **Safe work environment**
 - i. Keep the area **dry and well-lit**.
 - ii. Ensure **adequate ventilation** to prevent overheating.
 - iii. Remove **clutter** and avoid trailing cables or sharp tools near machines.

2. Specific Safety Measures by Machine Type

- a. **Transformers**
 - i. **Avoid overloading:** Match the load to the transformer's rated capacity.
 - ii. **Check for oil leaks** (in oil-cooled types): Leaks can cause fires or explosions.
 - iii. **Regular insulation testing:** Prevents flashover and short circuits.
 - iv. **Install in dry, ventilated areas:** Moisture can degrade insulation and cause failures.

b. AC and DC motors

- i. **Install overload protection:** This prevents overheating and motor burnout.
- ii. **Use correct starters:** e.g., DOL, Star-Delta, or VFDs to safely start/stop the motor.
- iii. **Guard moving parts:** Install covers to prevent contact with rotating shafts or fans.
- iv. **Avoid Excessive Vibration:** Could indicate imbalance or misalignment.

c. Generators (AC and DC)

- i. **Isolate before Maintenance:** Generators must be turned off and isolated before any inspection.
- ii. **Install AVR (Automatic Voltage Regulator):** Maintains a stable voltage output.
- iii. **Monitor Fuel Storage and Handling** (for engine-driven types): Avoid fire or explosion risks.
- iv. **Use Circuit Breakers:** Prevents back-feeding power into the grid or connected loads.

d. Stepper motors

- i. **Use current-limiting drivers:** Prevents overheating.
- ii. **Secure Mechanical Mounts:** Loose fixtures can cause position errors or damage.
- iii. **Follow Manufacturer Specifications:** Step sizes and voltages must match the system design.

e. Servo motors

- i. **Calibrate Feedback Devices:** Encoders or potentiometers must be correctly aligned.
- ii. **Use Mechanical Brakes if Needed:** Especially in vertical movement applications.
- iii. **Control Acceleration/Deceleration Rates:** Prevents mechanical shock or sudden motion.

3. Maintenance and inspection safety

- a. **Schedule periodic checks:** For wear, loose terminals, bearing noise, and heat.
- b. **Use Insulation Resistance Testing:** To check winding health.
- c. **Clean Machines:** Dust, oil, and moisture build-up can cause short circuits or overheating.
- d. **Log All Activities:** Document maintenance and test results for traceability.

4. Training and supervision

- a. Train personnel on basic operation and controls, emergency shutdown procedures and recognising warning signs (such as smell, noise, heat)
- b. Supervise new or untrained staff working near high-power machines.

5. Common Hazards to Avoid

Hazard	Risk	Prevention
Exposed wires	Electric shock	Insulate and secure all wiring
Overheated machines	Fire, damage	Provide ventilation and cooling
Unbalanced loads	Mechanical failure	Ensure correct load distribution
Poor earthing	Electric shock	Use proper earth connections
Ignoring warning alarms	Equipment damage or injury	Train users to respond to alerts

Learning Tasks

1. Have learners watch a video case of an accident or failure involving an electrical machine then analyse what went wrong and how safety protocols could have prevented it.
2. Have learners create models or reports that explain uses and safety considerations
3. In moderated discussions, guide learners to share experiences related to maintenance and Inspection Safety
4. Have learners use a type of machine and discuss the safety precautions that should be observed when operating the various electrical machines

Pedagogical Exemplars

Experiential Learning: Learners watch videos on safety precautions in the use of electrical machines. Through questioning, learners provide a comprehensive list of precautionary measures and their relevance

Key Assessment Level 2: Test

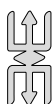
1. a. Why is it important to wear personal protective equipment (PPE) when operating electrical machines?
b. Identify two types of PPE and describe their specific functions. (5 marks)
2. State and explain two safety checks that should be performed before switching on an electrical machine. (4 marks)
3. Explain why electrical machines should not be operated with wet hands or in damp conditions. (3 marks)
4. What is the purpose of an emergency stop button on electrical machines, and when should it be used? (3 marks)
5. Explain two safety practices to follow during maintenance of electrical machines. (6 marks)

PLC Session 8

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

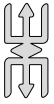
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **test**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the test (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 4 Review

1. Were learners able to identify various electrical machines?
2. Can learners explain the uses of transformers, DC and AC motors, DC and AC generators and special electrical machines?
3. Can learners safely operate electrical machines?
4. Can learners explain the safety measures associated with the use of the various electrical machines?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 7

FOCAL AREA 1

Question 1

An electrical machine is a device that converts electrical energy to mechanical energy or vice versa (2 marks). Examples

Transformer – Changes voltage levels in AC systems (1 mark).

DC Motor – Converts DC electrical energy into mechanical rotation (1 mark).

Induction Generator – Produces electricity from mechanical input (wind/hydro) (1 mark).

Question 2

AC Machines

1. Synchronous Motor – Used in clocks and industrial drives (2 marks).
2. Induction Motor – Powers household fans and pumps (2 marks).

DC Machines:

3. DC Shunt Motor – Used in lathe machines and elevators (2 marks).
4. DC Series Motor – Applied in electric trains and cranes (2 marks).

Question 3 (6 Marks)

Rotating machines have moving parts (e.g., motors, generators) (2 marks).

Examples

Alternator – Generates AC power in vehicles (1 mark).

Universal Motor – Runs on AC or DC (used in drills) (1 mark).

Static machines have no moving parts (e.g., transformers, inverters) (1 mark each).

Question 4 (4 Marks)

Stepper motor – Used in 3D printers for precise motion control (2 marks).

Servo motor – Applied in robotics and CNC machines for accuracy (2 marks).

Question 5 (6 Marks)

Generator – Converts mechanical into electrical energy (e.g., Thermal power plant alternator) (2 marks).

Motor – Converts electrical to mechanical energy (e.g., Electric vehicle motor) (2 marks).

Transducer – Converts energy forms (e.g., Piezoelectric sensor for sound electricity) (2 marks).

FOCAL AREA 2

Question 1 (9 Marks)

Transformers transfer electrical energy between circuits via electromagnetic induction, adjusting voltage levels for efficient transmission (2 marks).

Step-up transformers increase voltage (e.g., at power plants to reduce grid losses) (2 marks).

Step-down transformers decrease voltage (e.g., in homes for safe appliance use) (2 marks).

Examples

National grid: 11kV→400kV step-up for long-distance transmission (1 mark).

Phone chargers: Step-down 230V→5V (1 mark).

Industrial plants: Medium-voltage step-down for machinery (1 mark).

Question 2 (10 Marks)

AC Induction Motors

Applications: Pumps, compressors, conveyor belts (1 mark).

Justification: Rugged, low maintenance, ideal for constant-speed operations (2 marks).

DC Shunt Motors

Applications: Cranes, elevators, lathes (1 mark).

Justification: Precise speed control, high starting torque (2 marks).

Comparison: AC motors dominate industries due to cost; DC motors excel where control is critical (2 marks).

Examples

AC: HVAC systems in buildings (1 mark).

DC: Robotic arm joints (1 mark).

Question 3 (9 Marks)

AC Synchronous Generators (Wind Turbines)

Convert wind energy to grid-compatible AC (1 mark).

Use gearboxes to match grid frequency (1 mark).

High efficiency (90–95%) for large-scale power (1 mark).

DC Generators (Solar)

Pair with solar panels for direct DC output (1 mark).

Simpler, no synchronisation needed (1 mark).

Lower efficiency (80–85%) but cost-effective for small systems (1 mark).

Comparison: AC suits grid-tied wind farms; DC fits off-grid solar due to storage compatibility (3 marks).

Question 4 (10 Marks)

Stepper Motors in 3D Printers

Advantages: Low cost, open-loop control, sufficient precision for layer deposition (3 marks).

Servo Motors in CNC Machines

Advantages: Closed-loop feedback, high torque at high speeds, micron-level accuracy (3 marks).

Trade-offs: Steppers are cheaper but lose steps; servos are precise but expensive (3 marks).

Justification: 3D printers prioritise cost; CNC machines need accuracy for metal cutting (1 mark).

Question 5 (10 Marks)

Servo motors enable precision motion control in robotics (e.g., assembly line arms, surgical robots) (3 marks).

Advantages

Programmable for complex trajectories (1 mark).

Encoders provide real-time feedback (1 mark).

Compact size for modular designs (1 mark).

Limitations

High cost (1 mark).

Complex maintenance (1 mark).

Overkill for simple tasks (1 mark).

Future: AI integration will expand their role (1 mark).

WEEK 8

FOCAL AREA 3

Question 1

Answer

1. Turn off the power at the main switch.
2. Inspect the motor and ensure it is rated for the available voltage.
3. Connect the live (L) and neutral (N) wires to the appropriate terminals on the motor.
4. Attach a capacitor (if required for start/run operation).
5. Ensure a proper earth connection is made.
6. Use a switch or contactor for control.
7. After double-checking connections, turn on the power and start the motor.

Marking Scheme (Total: 6 marks)

Identifies safety (turn off power): 1 mark

Checks voltage compatibility: 1 mark

Correct connection of L and N: 1 mark

Capacitor connection (if applicable): 1 mark

Earth connection: 1 mark

Controlled power-on: 1 mark

Question 2

Answer

1. Direct-On-Line (DOL) Starter: A simple method using a contactor and overload relay to directly connect the motor to the supply.
2. Star-Delta Starter: Initially connects the motor in star configuration to reduce starting current, then switches to delta for normal operation.

Marking Scheme (Total: 4 marks):

Identifies DOL with explanation: 2 marks

Identifies Star-Delta with explanation: 2 marks

Question 3

Answer

Ensure the motor is switched off and has come to a complete stop.

Disconnect power at the circuit breaker or isolation switch.

Use proper insulated tools and wear protective equipment.

Verify no residual voltage is present using a multimeter.

Marking Scheme (Total: 3 marks)

Any correct precaution (1 mark each $\times$ 3)

Question 4

Answer

(Diagram includes motor, contactor, overload relay, push buttons, and connections to supply.)

Marking Scheme (Total: 5 marks)

Power supply shown: 1 mark

Contactor and overload relay: 1 mark

Push button controls: 1 mark

Motor connection: 1 mark

Correct labelling: 1 mark

Question 5

Answer

Effect: Motor may rotate in the wrong direction or not start at all.

Safety Device: Overload relay or phase failure relay.

Marking Scheme (Total: 2 marks)

Correct effect: 1 mark

Correct safety device: 1 mark

FOCAL AREA 4

Question 1

Answer

Importance: PPE helps protect the user from electrical hazards such as shocks, burns, and injuries. *(1 mark)*

Two examples of PPE and their functions

Insulated gloves (1 mark): Protect against electric shock. *(1 mark)*

Safety goggles (1 mark): Protect eyes from sparks, dust, or debris. *(1 mark)*

Total: 5 marks

Question 2

Answer

Check for visible damage or loose connections: Prevents starting a machine that may short circuit or cause a shock. *(2 marks)*

Ensure proper earthing: Prevents current from flowing through the body in case of a fault. *(2 marks)*

Total: 4 marks

Question 3

Answer

Water is a good conductor of electricity. *(1 mark)*

Using machines with wet hands increases the risk of electric shock. *(1 mark)*

It can result in serious injury or death. *(1 mark)*

Total: 3 marks

Question 4

Answer

The emergency stop button quickly shuts off power to prevent injury or damage. *(2 marks)*

It should be used in any emergency situation or if a fault occurs. *(1 mark)*

Total: 3 marks

Question 5

Answer

Personal Protective Equipment (PPE)

- i. Wear insulated gloves and electrically rated boots.
- ii. Use safety goggles when near rotating parts or electrical arcs.
- iii. Wear hearing protection if machines are noisy.

Lockout/Tagout (LOTO) Procedures

- i. Disconnect the machine from the power source before servicing.

- ii. Attach a visible lock and tag indicating maintenance is in progress.
- iii. Only authorised personnel should remove the lockout tag.

Etc.

Identification of Safety Practices	Accurately identifies two safety practices (2marks)	Identifies one safety practice. (1 mark)
Explanation of Practice	Explanation of two safety practices, and their importance (4 marks)	Explanation of any one safety practice and its importance (2 marks)

SECTION 5: RENEWABLE ENERGY SYSTEMS

STRAND: ENERGY SYSTEMS

Sub-Strand: Renewable Energy Systems

WEEK 9

Learning Outcomes: *Explain wind and bioenergy systems*

Content Standard: Demonstrate understanding of basic wind and bioenergy systems

WEEK 10

Learning Outcomes: *Explain the architecture of wind and bioenergy systems*

Content Standard: Demonstrate understanding of basic wind and bioenergy systems

INTRODUCTION AND SECTION SUMMARY

Section 5 covers the final aspect of Renewable Energy Systems. The focus of this section is to introduce learners to wind and bioenergy systems. The purpose of wind energy systems is to use a wind turbine to transform the kinetic energy of moving air, or wind, into electrical energy. These systems form important sources of clean, renewable electricity. Bioenergy systems transform biomass organic resources such as wood, animal dung, food waste, and plant waste into usable energy sources such as heat, power, or biofuel. Learners will understand that these devices provide a sustainable energy source and aid in waste reduction. Understanding how the essential components of wind and bioenergy system contributes to the production of renewable energy is the main goal of this study. Bioenergy systems transform biomass, or organic material, into usable energy like fuel, heat, or electricity.

The weeks and the indicators covered by the section are:

- Week 9:
 1. Identify the basic components of wind and bioenergy systems
 2. Explain the functions of the basic components of wind and bioenergy systems
- Week 10:
 3. Design and install simple wind and bioenergy systems
 4. Operate and maintain simple wind and bioenergy systems

Recap

Year 1	Week 11: Explain how electricity is generated from water, wind, solar, biomass and biogas energy sources
Year 2	Week 12: Explain the functions of the basic components of photovoltaic and solar thermal systems Week 13: Operate and maintain simple photovoltaic and solar thermal energy systems

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section, collaborative learning and experiential learning are suggested pedagogical exemplars. The goal is to encourage teamwork, discussion, and shared problem-solving, enabling learners to learn through doing, observing, and reflecting. For collaborative learning, assign learners to small teams to research wind or bioenergy systems and present their findings. Give each group a different part of the system (e.g., rotor blades, digester, and generator) to study and present their findings to the class. After group research, let students teach other groups about their component. Organise classroom debates on which energy system is better for a local community wind energy or bioenergy and explain why. In experiential learning, allow learners to construct simple models of wind turbines or biogas digesters using local or recycled materials. Visit local renewable energy sites or show videos to connect classroom learning with real-world systems. Use fans, water, or simple bio-materials to simulate how energy is generated or stored. After hands-on tasks, ask learners to write or discuss what they discovered, what challenges occurred, and how to improve. This strategy makes abstract concepts real and memorable, encourages critical thinking through trial and error and enhances practical skills and creativity.

ASSESSMENT SUMMARY

This section suggests that teachers should set test items at DOK level 3 for learners since Renewable Energy Systems were introduced in Years 1 and 2. Some key assessment modes such as debate, group or individual research, case study and presentation may be ideal for the pedagogical strategies suggested. In group research and presentations, each group investigates wind or bioenergy systems and presents their findings. Teachers may score learners' verbal articulation of understanding and depth of individual knowledge. Learners can be tasked to explain the functions of the basic components of wind and bioenergy systems. Teachers may score for identification of components of wind or bioenergy systems, explanation for each component's function and demonstration of teamwork and collaboration. Learner's portfolio can also be taken and scored in this section. A collection of learners' work over time showing; research notes, diagrams or system drawings, photos or records of model-building and reflections on what was learned.

Provide a summary of the assessment used against the indicator. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
1. Identify the basic components of wind and bioenergy systems	Level 2	Classwork (individual)
2. Explain the functions of the basic components of wind and bioenergy systems	Level 3	Presentation (group)
3. Design and install simple wind and bioenergy systems	Level 3	Portfolio
4. Operate and maintain simple wind and bio-energy systems	Level 3	Essay

WEEK 9

Learning Indicators

1. Identify the basic components of wind and bioenergy systems
2. Explain the functions of the basic components of wind and bioenergy systems

FOCAL AREA 1: IDENTIFY THE BASIC COMPONENTS OF WIND AND BIOENERGY SYSTEMS

Refer back to Year 1 Week 11 (explain how electricity is generated from water, wind, solar, biomass and biogas energy sources)

1. Wind Energy Systems

Wind energy systems are designed to convert the **kinetic energy of moving air (wind)** into **electrical energy** using a wind turbine. These systems are a key source of clean and renewable electricity.

Basic Components of a Wind Energy System

a. Rotor Blades

Design: Typically shaped like aeroplane wings to create lift.

Wind turbines usually have three blades for stability and efficiency.

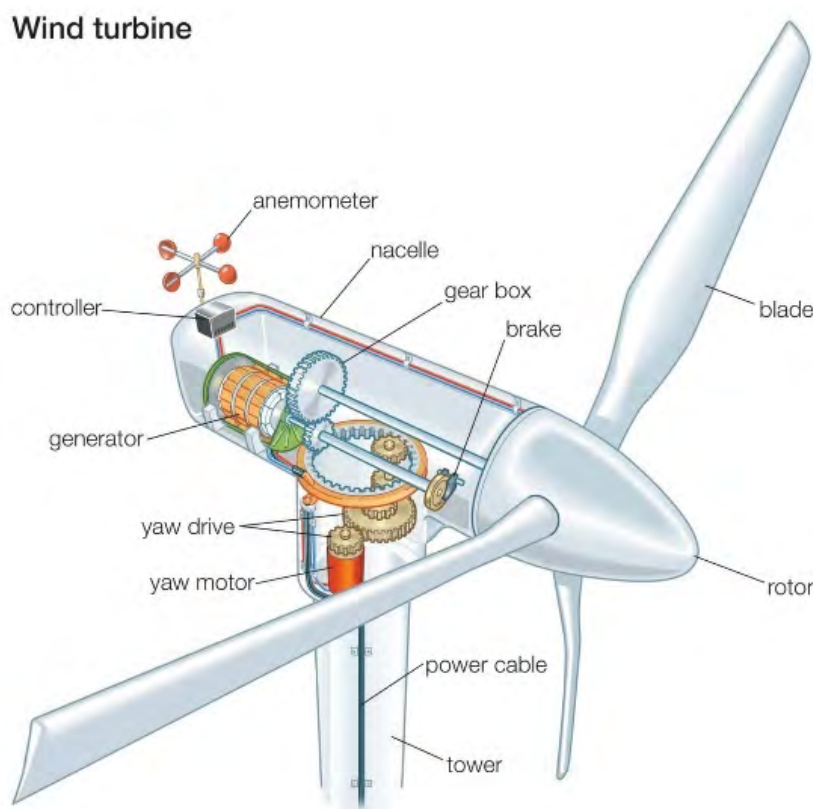


Figure 8: Rotor Blades

b. Hub

The hub rotates with the blades and forms part of the rotor.

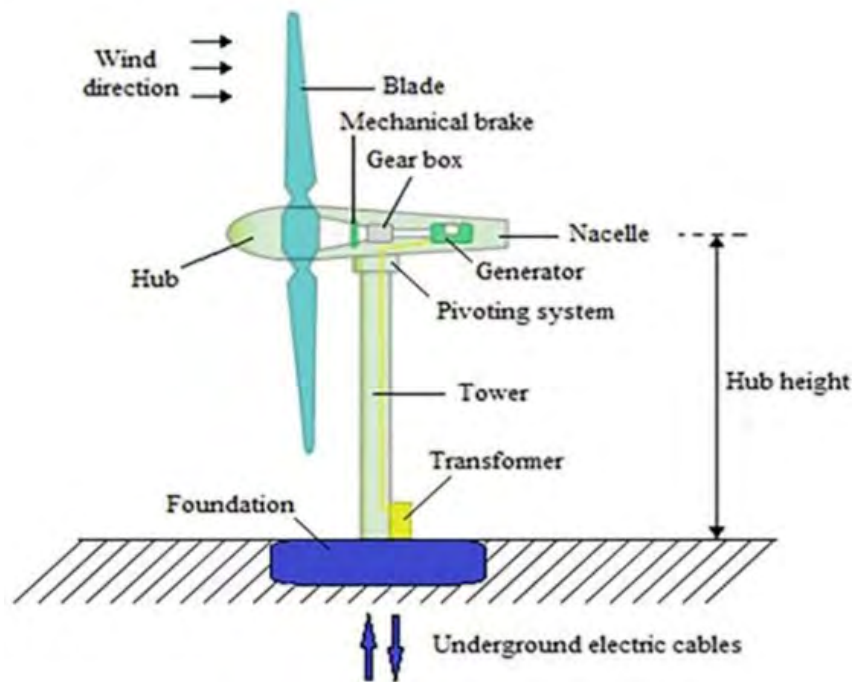


Figure 9: A Hub

c. Nacelle

The nacelle is a protective casing located at the top of the tower.

It houses key components such as:

- i. **Gearbox:** The gearbox increases the rotational speed of the rotor shaft to suit the generator.
- ii. **Generator:** Converts mechanical energy into electrical energy.
- iii. **Brake system:** Stops the rotor during excessive wind speeds to prevent damage.

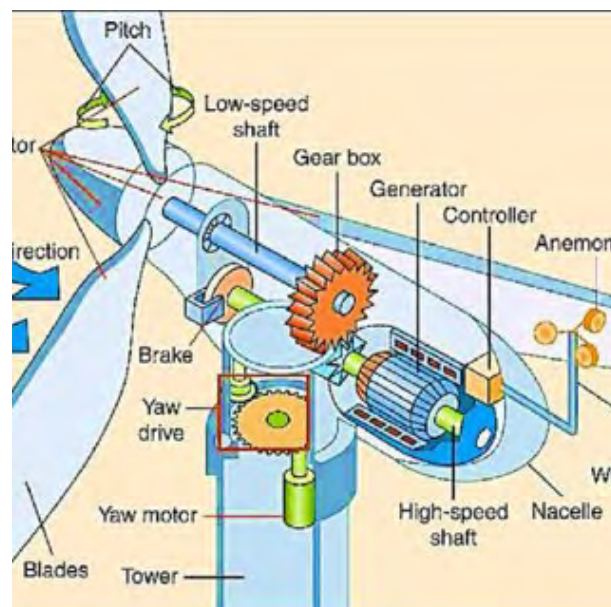


Figure 10: Nacelle

d. Tower

Greater tower height can provide access to stronger and more consistent winds.
Made from steel or concrete and anchored into the ground.

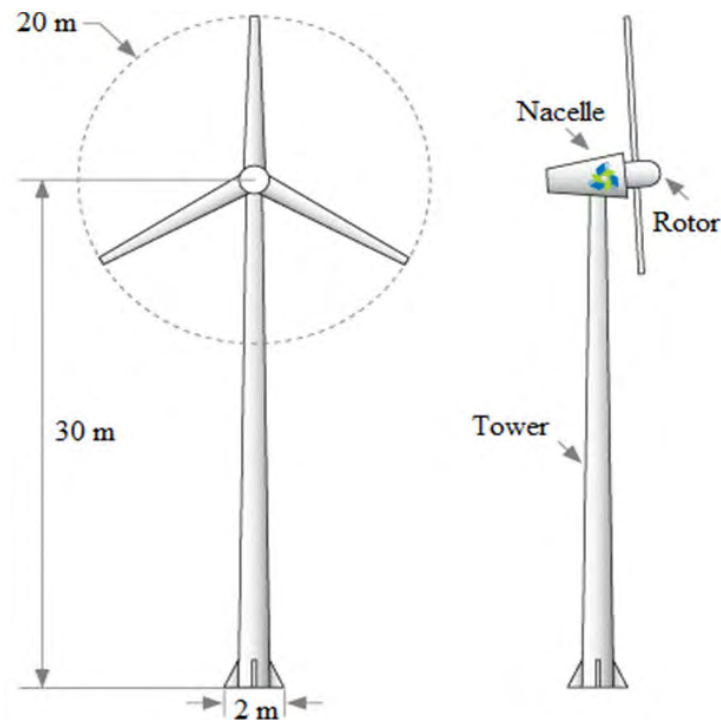


Figure 11: A tower

e. Yaw System

Aligns the nacelle with the wind direction for effective wind capture.

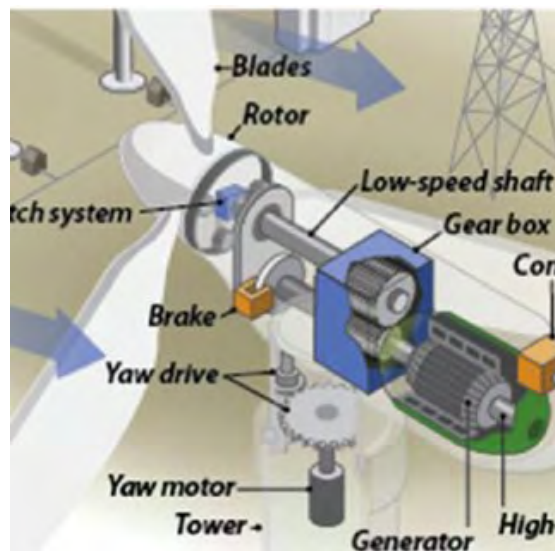


Figure 12: Yaw system

f. Anemometer and Wind Vane

- i. **Anemometer:** Measures wind speed.
- ii. **Wind vane:** Measures wind direction.

These devices provide data to the controller for operational decisions.



Figure 13: *Anemometer and Wind Vane*

g. Controller

Automatically starts the turbine when wind speeds are within a safe and efficient range.

Shuts down the system during very high winds to prevent damage.

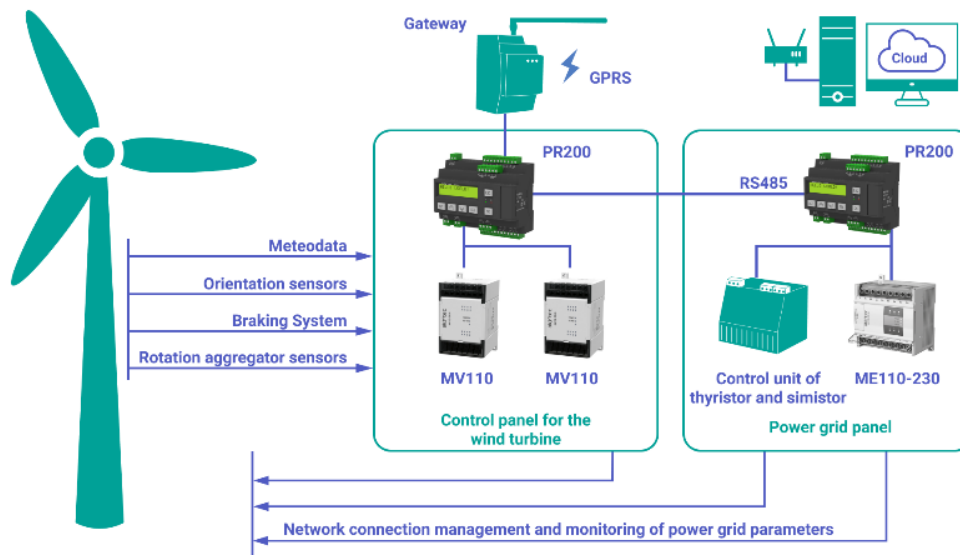


Figure 14: *Controller*

h. Electrical Cables and Grid Interface

- i. Carry the electrical output from the generator down the tower.
- ii. Connect the turbine to the local grid or storage batteries.

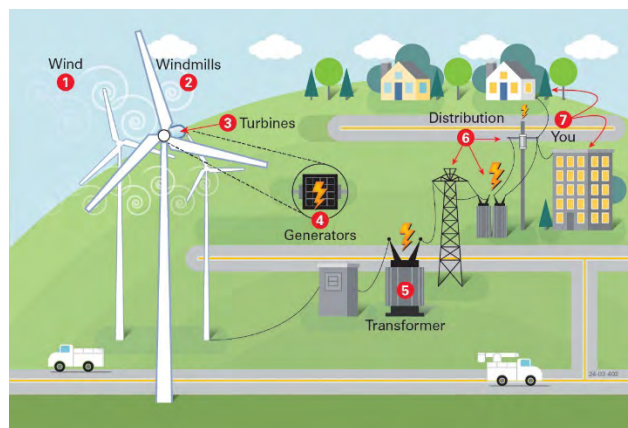


Figure 15: *Wind turbine Electrical connections to Grid interface*

2. Bioenergy Systems

Bioenergy systems convert biomass—organic materials such as plant waste, food waste, animal manure, and wood—into useful forms of energy like electricity, heat, or biofuel. These systems help reduce waste and offer a renewable source of energy.

Basic Components of a Bioenergy System

1. Biomass Feedstock

Raw organic material used to generate energy.

Types

- i. Solid: wood, agricultural residues
- ii. Liquid: oils, wastewater
- iii. Gaseous: biogas (methane, CO₂)



Figure 16: *Biomass Feedstocks*

2. Storage System

Holds the feedstock before it enters the processing unit.

Ensures a steady and controlled supply of fuel.



Figure 17: *Bioenergy Storage System*

3. Feeding Mechanism

Transfers feedstock from storage to the processing or conversion unit.

Can include mechanical conveyors, hoppers, or pumps, depending on the feedstock type.



Figure 18: *Feeding Mechanism of a Bioenergy system*

4. Conversion Technology

The process used to transform biomass into energy.

Main types

- i. Combustion: Burns biomass to produce heat or steam.
- ii. Anaerobic Digestion: Breaks down organic matter in oxygen-free conditions to produce biogas.
- iii. Gasification: Converts biomass into a combustible gas by heating with limited oxygen.
- iv. Pyrolysis: Heats biomass in the absence of oxygen to produce bio-oil and syngas.

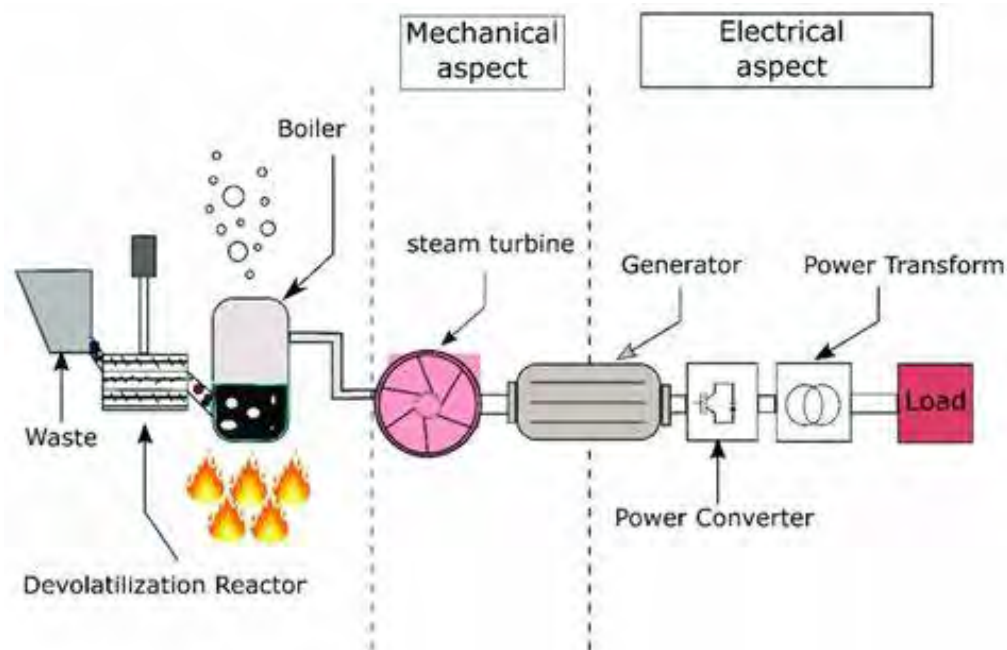


Figure 19: *Conversion Technology*

5. Reactor / Digester / Combustion Chamber

Where the energy conversion takes place.

Examples:

- i. Digesters for biogas production
- ii. Boilers for steam generation from combustion

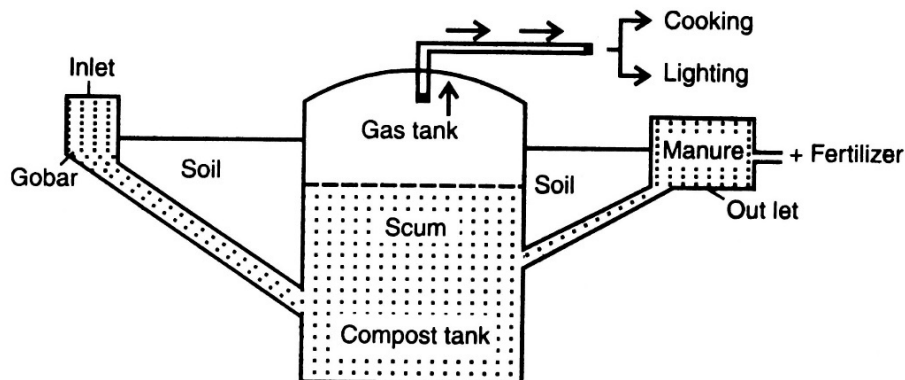


Figure 20: *Biogas Combustion Chamber*

6. Turbine and Generator (if used for electricity)

- i. The steam or gas produced from biomass is used to spin a turbine.
- ii. The turbine drives a generator to produce electricity.

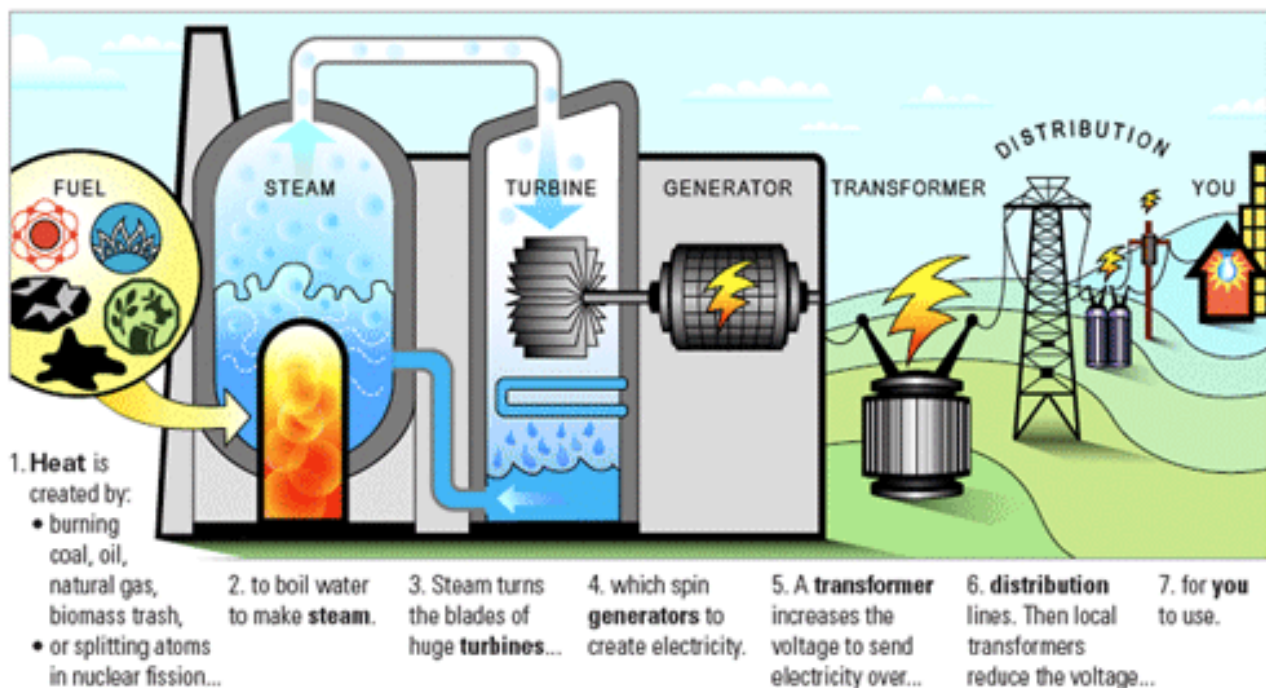


Figure 21: *Biogas Steam Generation Station*

7. Emission Control Systems

- i. Filters, scrubbers, or catalytic converters to reduce harmful emissions.
- ii. Ensures compliance with environmental standards.

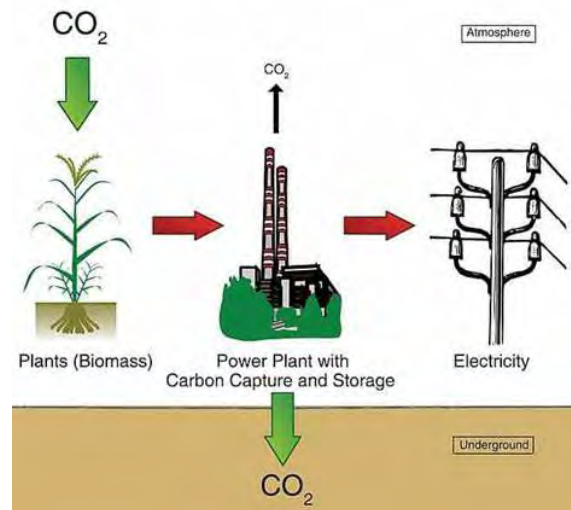


Figure 22: Carbon Capture and Storage Control System

8. Energy Output System

Distributes the final energy product:

- i. Heat may go to heating systems.
- ii. Electricity can be used locally or sent to the grid.
- iii. Biogas can be stored or converted to electricity.



Figure 23: Biogas Energy Output System

Learning Tasks

1. Guide learners to identify basic components of wind energy systems.
2. Learners should work in groups to outline the components of bioenergy systems.

Pedagogical Exemplars

Experiential Learning: Learners inspect basic components of wind and bioenergy systems and discuss their features. Further, learners watch videos on the installation of the two systems and share their observations.

Key Assessment Level 1: Class Work

1. List any four basic components of a wind energy system. (4 marks)
2. Match the components to their correct energy system. Write 'W' for Wind and 'B' for Bioenergy. (6 marks)

Component	Energy System (W or B)
Yaw System	
Biomass Feedstock	
Feeding Mechanism	
Generator	
Conversion Unit	
Tower	

3. Identify three components that are common in most bioenergy systems. (3 marks)
4. Which of the following is NOT a component of a wind energy system? (1 mark)
 - A. Rotor Blades
 - B. Anemometer
 - C. Digester
 - D. Hub
5. State two key components found in both wind and bioenergy systems. (2 marks)

FOCAL AREA 2: EXPLAIN THE FUNCTIONS OF THE BASIC COMPONENTS OF WIND AND BIOENERGY SYSTEMS

Refer back to Year 2, Week 12 (Explain the functions of the basic components of photovoltaic and solar thermal systems)

This topic focuses on understanding how each **key component** in **wind** and **bioenergy** systems contributes to the generation of renewable energy.

Functions of Basic Components of a Wind Energy System

A wind energy system converts the kinetic energy of wind into mechanical and then electrical energy using turbines.

1. Rotor Blades

Function

- i. Capture the kinetic energy from the wind and rotate.
- ii. The aerodynamic shape creates lift, allowing the blades to spin.
- iii. The rotation is transferred to the main shaft.

2. Hub

Function

- i. Connects the rotor blades together and to the main shaft.
- ii. Transfers the rotational motion from the blades to the shaft.
- iii. Helps balance and distribute mechanical load.

3. Nacelle

Function

- i. Houses critical components such as the gearbox, generator, braking system, and controller.
- ii. Protects these components from environmental damage (e.g., rain and dust).
- iii. Acts as the central point for energy conversion.

4. Gearbox (inside the nacelle)

Function

- i. Increases the rotation speed from the rotor (low-speed shaft) to the high-speed shaft connected to the generator.
- ii. Ensures that the generator operates at its required speed.

5. Generator (inside the nacelle)

Function

Converts mechanical energy from the rotating shaft into electrical energy using electromagnetic induction.

6. Tower

Function

- i. Elevates the rotor and nacelle to a height where wind speeds are stronger and more consistent.
- ii. Provides structural support and stability to the entire wind turbine.

7. Yaw Mechanism

Function

- i. Rotates the nacelle so the blades face the wind direction.
- ii. Maximises energy capture by ensuring the rotor is always aligned with the wind.

8. Anemometer and Wind Vane

Anemometer function: Measures wind speed.

Wind vane function: Determines wind direction.

These inputs help the controller decide whether to activate or shut down the turbine.

9. Controller

Function

- i. Monitors turbine performance and environmental conditions.
- ii. Starts the turbine at cut-in wind speeds and shuts it down at high speeds to prevent damage.

10. Electrical Cables and Grid Connection

Function

- i. Transmit the generated electricity from the turbine down the tower to the ground.
- ii. Connects to inverters, batteries, or the power grid for usage or storage.

Functions of Basic Components of a Bioenergy System

Bioenergy systems convert organic material (biomass) into useful energy such as electricity, heat, or fuel.

1. Biomass Feedstock

Function

- i. Acts as the raw material (e.g., food waste, crop residue, manure) for energy production.
- ii. Provides the chemical energy that will be converted to usable energy forms.

2. Storage System

Function

- i. Stores feedstock safely and securely before it is processed.
- ii. Allows a continuous and regulated supply of biomass to the conversion unit.

3. Feeding Mechanism

Function

- i. Transfers biomass from the storage unit to the conversion unit (e.g., digester, combustion chamber).
- ii. Can be mechanical (conveyors, augers) or hydraulic (pumps).

4. Conversion Unit (varies by technology)

a) Anaerobic Digester

Function

- i. Breaks down organic waste in the absence of oxygen using bacteria.
- ii. Produces biogas (mainly methane) and digestate (organic fertiliser).

b) Combustion Chamber

Function

- i. Burns dry biomass to produce heat or steam.
- ii. Heat may be used directly or to power a steam turbine for electricity generation.

c) Gasifier

Function

- i. Converts solid biomass into producer gas (syngas) by heating in a low-oxygen environment.
- ii. Syngas can be used to power engines or turbines.

d) Pyrolysis Unit

Function

- i. Decomposes biomass at high temperatures without oxygen.
- ii. Produces bio-oil, syngas, and biochar.

5. Generator or Turbine

Function

The generator converts mechanical energy into electrical energy while the turbine converts thermal or gas energy into mechanical energy.

6. Emission Control System

Function

- i. Reduces or captures harmful gases and particulates released during biomass combustion or gasification.
- ii. Helps meet environmental standards.

7. Energy Output Systems

Function

- i. Directs the produced energy (heat, electricity, and biogas) to where it is used or stored.
- ii. Electricity may be sent to the grid or stored in batteries.
- iii. Heat may be used for buildings or industrial processes.
- iv. Biogas may be used as fuel for cooking or power generation.

Learning Tasks

1. Discuss with learners the functions of the basic components of wind energy systems.
2. Help learners to explain the functions of the basic components of bioenergy systems.

Pedagogical Exemplars

Experiential Learning: Learners watch videos on the functions of the basic components of wind and

Bioenergy systems, as well as the installation of the two systems, and share observations.

Key Assessment Level 3: Group Presentation

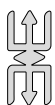
1. Compare the function of the rotor blades in a wind energy system with the function of biomass feedstock in a bioenergy system. (6 marks)
2. Analyse the roles of the nacelle in wind systems and the digester in bioenergy systems in the energy conversion process. (6 marks)
3. Justify why the yaw system and anemometer are essential for the effective operation of wind turbines. (6 marks)
4. Explain how the energy output systems of both wind and bioenergy systems handle and deliver the final energy product. (5 marks)
5. Evaluate why emission control systems are more critical in bioenergy systems than in wind energy systems. (5 marks)

PLC Session 9

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app

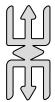
- a. The key assessment for the week is **group presentation**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the presentation (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

- a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
- b. all teachers in the group work through a similar problem individually for 3–4 minutes
- c. the group then works through the problem together step by step
- d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).

- a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
- b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).

9. Remember to

- a.** transfer your chats into your learning planner template.
- b.** read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
- c.** integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 10

Learning Indicators

1. *Design and install simple wind and bioenergy systems*
2. *Operate and maintain simple wind and bioenergy systems*

FOCAL AREA 3: DESIGN AND INSTALL SIMPLE WIND AND BIOENERGY SYSTEMS

Wind and bioenergy systems are two important types of renewable energy technologies. They are used to generate electricity or useful heat without relying on fossil fuels. Designing and installing simple systems involves understanding their components, layout, working principles, and basic engineering practices for setup and operation.

1. Simple Wind Energy Systems

A wind energy system converts the kinetic energy of wind into mechanical and then electrical energy using a wind turbine. Small wind systems can power homes, farms, or schools.

a. Basic Design Considerations

- i. Site Selection: Open area with strong, consistent wind (ideally greater than 4 m/s)
- ii. Turbine Size: Depends on energy need (e.g., 400W for small appliances)
- iii. Tower Height: Higher towers reach steadier wind (usually 10–20m for small systems)
- iv. Load Requirements: Match the system size with the electricity demand

b. Key Components

- i. Rotor Blades – Capture wind energy
- ii. Hub and Nacelle – House the shaft, gearbox, and generator
- iii. Gearbox – Increases rotor speed to suitable levels
- iv. Generator – Converts mechanical to electrical energy
- v. Tower – Elevates the turbine for better wind exposure
- vi. Yaw System – Keeps blades facing the wind
- vii. Controller – Starts or stops the turbine based on wind conditions
- viii. Cabling and Inverter – Transmit and convert electricity for use

c. Installation Steps

- i. Select site and check wind resource
- ii. Assemble and erect the tower securely
- iii. Mount rotor and nacelle components
- iv. Install wiring from turbine to controller and load/inverter

- v. Connect to battery or grid system
- vi. Test system performance and safety cut-offs
- d. Safety and Maintenance**
 - i. Use grounding and lightning protection
 - ii. Secure blades and tower during storms
 - iii. Regularly check bolts, cabling, and bearings
 - iv. Lubricate moving parts as recommended

2. Simple Bioenergy Systems

Bioenergy systems use organic materials (biomass) such as food waste, wood, or animal dung to produce biogas, electricity, or heat. These systems are ideal for rural, agricultural, or school environments with biomass availability.

- a. Basic Design Considerations**
 - i. Type of Biomass Available: Solid, liquid, or gaseous
 - ii. Energy Need: Heating, cooking, electricity
 - iii. Conversion Method: Anaerobic digestion, combustion, or gasification
 - iv. Output Method: Stove, generator, or grid feed
- b. Key Components**
 - i. Feedstock Storage – Holds biomass input
 - ii. Feeding Mechanism – Transfers material into the reactor
 - iii. Conversion Unit:
 - Digester – For biogas via anaerobic digestion
 - Combustion Chamber – For burning biomass to heat water or air
 - iv. Gas or Heat Collection System
 - v. Turbine and Generator (optional) – For producing electricity
 - vi. Emission Control Systems – Reduce smoke and harmful gases
 - vii. Energy Distribution System – Piping, cabling, or heat exchangers
- c. Installation Steps**
 - i. Select location near feedstock supply
 - ii. Construct or install the digester or combustion unit
 - iii. Install feeding and storage systems
 - iv. Connect gas lines or heat ducts if the system is generating electricity, then connect the generator and wiring
 - v. Start the system and test output levels
- d. Safety and Maintenance**
 - i. Prevent leakage of biogas (especially methane)

- ii. Ensure proper ventilation and temperature control
- iii. Clean digesters or combustion units periodically
- iv. Use filters or scrubbers for smoke reduction
- v. Monitor gas pressure and composition

Learning Tasks

1. Discuss with learners the processes involved in designing a wind energy system.
2. Learners should participate in installing a simple bioenergy system.

Pedagogical Exemplars

Experiential Learning: Learners watch videos on the operation and maintenance of wind and bioenergy systems or research and share their findings with the class.

Key Assessment Level 3: Portfolio

1. You are tasked with designing a simple wind energy system for a remote school. Describe three key factors you would consider in your design. (6 marks)
2. List and describe the installation steps involved in setting up a small wind turbine system for electricity generation. (8 marks)
3. A farm owner wants to install a simple bioenergy system using cow manure. Identify the key components required and describe their roles briefly. (6 marks)
4. Compare one major advantage and one limitation of installing a wind energy system versus a bioenergy system in a rural community. (4 marks)
5. Propose two safety measures that must be observed when installing a wind or bioenergy system. Justify your choices. (6 marks)

FOCAL AREA 4: OPERATE AND MAINTAIN SIMPLE WIND AND BIOENERGY SYSTEMS

Refer back to Year 2 Week 13 (*Operate and maintain simple photovoltaic and solar thermal energy systems*)

Operating and maintaining simple wind and bioenergy systems is essential to ensure continuous, safe, and efficient energy generation. These systems rely on natural sources—wind and biomass—to produce electricity or heat. Proper operation involves monitoring system performance, while maintenance includes cleaning, inspection, and repair.

Wind Energy Systems

1. Operating a Simple Wind Energy System

- a. Pre-Start Safety Checks
 - i. Inspect the rotor blades for cracks or damage.

- ii. Confirm that the tower and foundation are secure.
- iii. Check electrical cables and connections.
- iv. Ensure the brake system is functional.
- b. System Start-up**
 - i. Monitor the wind speed using the anemometer (system usually starts at 3–4 m/s).
 - ii. When conditions are suitable, the controller automatically starts the system.
 - iii. The yaw system aligns the turbine to face the wind direction.
- c. Ongoing Operation**
 - i. The rotor blades spin, turning the generator via a gearbox.
 - ii. Generated electricity is either stored in batteries or sent to the power grid.
 - iii. The controller continuously monitors performance and ensures safe operation.
- d. Shutdown Procedure**
 - i. The system shuts down automatically in dangerously high winds.
 - ii. Manual shutdown may be done for maintenance using the brake or stop switch.

2. Maintaining a Simple Wind Energy System

- a. Daily or Weekly Checks**
 - i. Inspect for visible damage to blades, tower, and cables.
 - ii. Listen for unusual sounds from the generator or gearbox.
 - iii. Check battery charge levels (in off-grid systems).
- b. Monthly Maintenance**
 - i. Tighten bolts and inspect support structures.
 - ii. Clean dirt or debris from the rotor blades and sensors.
 - iii. Test the braking system and electrical safety disconnects.
- c. Annual Maintenance**
 - i. Lubricate moving parts like bearings and yaw mechanism.
 - ii. Inspect and clean generator and controller components.
 - iii. Perform a full system test (brakes, grounding, output monitoring).
- d. Record Keeping**
 - i. Maintain logs of wind speed, energy output, and service dates.
 - ii. Track any component replacements or system errors.

Bioenergy Systems

1. Operating a Simple Bioenergy System

- a. Pre-Start Inspection**
 - i. Ensure feedstock (e.g., food waste, manure) is available and not contaminated.
 - ii. Inspect the digester, valves, pipes, and gas storage tank.
 - iii. Confirm proper seals and that there are no leaks.
- b. System Start-up**
 - i. Add the prepared biomass feedstock into the digester or combustion chamber.
 - ii. For anaerobic systems, maintain optimal temperature (e.g., 35–55°C).
 - iii. Begin gas production or heat generation as feedstock breaks down.
- c. Daily Operation**
 - i. Feed the system regularly to maintain steady production.
 - ii. Remove digestate or ash (depending on system type).
 - iii. Monitor gas pressure, flame quality (if biogas is burned), and output.
- d. Shutdown Procedure**
 - i. Stop feedstock input.
 - ii. Safely vent or store remaining gas.
 - iii. Clean the system if required.

2. Maintaining a Simple Bioenergy System

- a. Routine Maintenance Tasks**
 - i. Clean input hoppers, pipes, and digesters weekly.
 - ii. Check gas pipelines and storage for leaks (soap bubble test or sensors).
 - iii. Inspect burners and replace clogged nozzles.
- b. Monthly or Seasonal Tasks**
 - i. Dislodge the digester or clean combustion chamber.
 - ii. Lubricate moving parts like pumps or mixers.
 - iii. Test pressure gauges and control valves.
- c. Health and Safety Checks**
 - i. Ensure good ventilation around the digester or combustion unit.
 - ii. Use flame arrestors and gas leak detectors.
 - iii. Wear gloves, masks, and safety gear when handling organic waste.
- d. Record Keeping**

- i. Log feedstock input, energy output, and system faults.
- ii. Maintain a maintenance and inspection record.
- iii. Record environmental data like temperature and gas production rate.

Learning Tasks

1. Guide learners to operate simple wind energy systems.
2. Help learners to describe the steps involved in installing a wind energy and a bioenergy system and summarise the process using a flowchart for each system.

Pedagogical Exemplars

Experiential Learning: Learners watch videos on the operation and maintenance of wind and bioenergy systems or research and share their findings with the class. **Or** learners visit a facility with installed wind and bioenergy systems to interact with engineers/technicians about the installations.

Problem-based and Collaborative Learning: Learners are given group assignments to design wind and bioenergy systems for a facility. Learners present the project to the class for comments.

Key Assessment Level 3: Essay

1. Describe the steps involved in the daily operation of a simple wind energy system, highlighting how safety and efficiency are ensured. (6 marks)
2. Explain three key maintenance activities that should be performed monthly on a simple bioenergy system and state their importance. (6 marks)
3. Compare the shutdown procedures for wind energy systems and bioenergy systems. Identify one key difference and one similarity. (4 marks)
4. Outline two reasons why record keeping is essential in the maintenance of wind and bioenergy systems. (4 marks)
5. List four daily or weekly inspection tasks for a wind energy system. (4 marks)

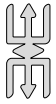
PLC Session 10

45 minutes

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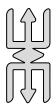
4. Plan the week's key assessment with your app

- a. The key assessment for the week is *essay*. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the essay (NTS 3k-3q).

10 minutes

Content Exploration

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5 minutes	Reflection
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 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 5 Review

1. Can learners identify the basic components of wind energy systems?
2. Were learners able to identify the basic components of bioenergy systems?
3. Would learners be able to explain the functions of the basic components of wind and bioenergy systems?
4. Were learners able to design and install simple wind and bioenergy systems?
5. Could learners operate and maintain simple wind and bioenergy systems?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 9

FOCAL AREA 1

Question 1

Rotor Blades

Hub

Nacelle

Tower

Marking Scheme

1 mark for each correct component ($4 \times 1 = 4$ marks)

Question 2

Answer

Component	Energy System (W or B)
Yaw System	W
Biomass Feedstock	B
Feeding Mechanism	B
Generator	W
Conversion Unit	B
Tower	W

Marking Scheme:

1 mark per correct match ($6 \times 1 = 6$ marks)**Question 3**

Answer

Biomass Feedstock

Storage System

Conversion Unit

Marking Scheme

1 mark for each correct component ($3 \times 1 = 3$ marks)**Question 4**

Answer

C. Digester

Marking Scheme:

1 mark for correct option**Question 5**

Answer

Generator

Electrical Cables

Marking Scheme:

1 mark per correct shared component ($2 \times 1 = 2$ marks)**FOCAL AREA 2****Question 1**

Answer

Rotor Blades (Wind Energy System):

Capture kinetic energy from the wind and convert it into rotational mechanical energy.

Biomass Feedstock (Bioenergy System):

Acts as the raw material that provides chemical energy for conversion into heat, electricity, or fuel.

Comparison:

Both components are the *primary energy input* in their systems — rotor blades capture *natural motion* (wind), while biomass feedstock contains *stored organic energy*.

Marking Scheme

1-2 marks for correct explanation of rotor blades

1-2 marks for correct explanation of biomass feedstock

1-2 marks for clear comparison between their roles as input energy sources

Question 2

Answer

Nacelle (Wind System)

Houses key conversion components such as the gearbox and generator, which convert the mechanical rotation into electrical energy.

Digester (Bioenergy System)

Converts organic matter into biogas through anaerobic digestion, enabling chemical-to-gas energy conversion.

Analysis

Both serve as central units for *energy transformation*: nacelle for *mechanical to electrical*, digester for *chemical to gaseous* energy conversion.

Marking Scheme

1-2 marks for nacelle's conversion role

1-2 marks for digester's conversion role

1-2 marks for comparing their function as energy conversion units

Question 3

Answer

Yaw System

Rotates the turbine to face the wind direction for optimal efficiency.

Anemometer

Measures wind speed, providing data to adjust or stop the turbine during unsafe conditions.

Justification

Both components help maintain safe and efficient operation by ensuring the turbine operates only under favourable wind conditions and always aligns correctly with the wind.

Marking Scheme

2 marks for yaw system function

2 marks for the anemometer function

2 marks for strong justification of operational importance

Question 4

Answer

Wind System

Electrical cables carry electricity from the generator down the tower to be fed into the grid or batteries.

Bioenergy System

Distributes usable energy in the form of heat, electricity, or gas through pipes, wires, or storage tanks.

Conclusion

Both systems include an output component that ensures the produced energy is transmitted, stored, or used efficiently.

Marking Scheme

1-2 marks for wind system output process

1-2 marks for bioenergy system output process

1 mark for overall explanation or comparison

Question 5

Answer

Bioenergy Systems

Involve combustion or chemical breakdown processes that can release pollutants like CO₂, NO_x and particulate matter.

Wind Energy Systems

Are clean processes with no combustion, hence no emissions.

Evaluation

Emission control systems are critical in bioenergy to meet environmental standards and minimise air pollution, unlike in wind systems where they are largely unnecessary.

Marking Scheme

1-2 marks for identifying emission concerns in bioenergy

1 mark for contrasting with wind energy

1-2 marks for justification and evaluation of importance

WEEK 10**FOCAL AREA 3****Question 1**

Answer:

Wind Resource Availability – The site should have consistent wind speeds above 4 m/s. (2 marks)

Energy Requirement – Estimate the school's energy needs to size the turbine correctly. (2 marks)

Tower Height and Location – Choose a suitable elevated location with no obstructions for better wind access.

(2 marks)

Question 2

Answer

Site Assessment – Check wind speed and open space. (1 mark)

Foundation Preparation – Prepare a secure base for the tower. (1 mark)

Tower Installation – Erect the tower to required height. (1 mark)

Mounting Turbine Components – Install rotor blades, hub, and nacelle. (2 marks)

Electrical Wiring – Connect generator to controller, inverter, and battery or grid. (2 marks)

System Testing – Start and test turbine under actual wind conditions. (1 mark)

Question 3

Answer

Feedstock Storage – Stores cow manure before use. (1 mark)

Feeding Mechanism – Transfers manure to the digester. (1 mark)

Anaerobic Digester – Breaks down manure to produce biogas. (1 mark)

Gas Storage Tank – Collects and stores produced biogas. (1 mark)

Burner or Engine Generator – Uses biogas for cooking or power generation. (1 mark)

Slurry Outlet – Removes digested material used as fertiliser. (1 mark)

Question 4

Answer

Advantage: Wind energy systems have zero emissions during operation and are ideal for windy locations. (2 marks)

Limitation: Wind systems depend on wind availability, while bioenergy systems can operate continuously if biomass is available. (2 marks)

Question 5

Answer

Use of Proper Grounding and Lightning Protection – Prevents electrical hazards in wind systems. (3 marks: 1 for identification, 2 for justification)

Gas Leak Detection for Biogas Units – Methane is flammable; leak detection ensures safety. (3 marks: 1 for identification, 2 for justification)

FOCAL AREA 4**Question 1**

Answer

Inspect rotor blades, tower, and electrical connections before start-up. (1 mark)

Monitor wind speed using the anemometer; system starts at safe wind speeds. (1 mark)

The controller initiates automatic start-up if wind speed is within the optimal range. (1 mark)

The yaw system adjusts the rotor to face the wind for maximum efficiency. (1 mark)

Generated electricity is directed to batteries or grid. (1 mark)

The brake system or controller shuts down the system during high winds to prevent damage. (1 mark)

Marking Scheme

1 mark for each correctly explained step (Max 6 marks)

Question 2

Answer

Desludging the digester – Prevents blockage and ensures optimal gas production. (2 marks)

Cleaning gas pipelines and checking for leaks – Maintains safe operation and avoids gas loss. (2 marks)

Lubricating moving parts such as mixers or pumps – Prevents mechanical wear and extends component life. (2 marks)

Marking Scheme

1 mark for correctly identifying the activity

1 mark for clearly explaining its importance

Total: 3 activities × 2 marks = 6 marks

Question 3

Answer

Similarity: Both systems require the cessation of input or operation to ensure safety and allow for maintenance. (2 marks)

Difference: Wind systems typically have automatic shutdowns during high wind speeds, while bioenergy systems require manual stopping of feedstock input and safe handling of residual gas or waste. (2 marks)

Marking Scheme

2 marks for correct similarity

2 marks for correct and clearly stated difference

Question 4

Answer

Tracking performance – Logs help monitor energy output trends and detect system issues early. (2 marks)

Scheduling maintenance – Records of inspections and repairs help plan future maintenance efficiently. (2 marks)

Marking Scheme

2 marks per valid reason (1 for idea, 1 for explanation)

Question 5

Answer

Inspect rotor blades for cracks or damage. (1 mark)

Check tower stability and grounding wires. (1 mark)

Listen for abnormal sounds from gearbox or generator. (1 mark)

Monitor battery charge levels (in standalone systems). (1 mark)

Marking Scheme

1 mark per relevant and correctly stated task

SECTION 6: ENERGY EFFICIENCY AND CONSERVATION

STRAND: ENERGY SYSTEMS

Sub-Strand: Energy Efficiency and Conservation

WEEK 11

Learning Outcomes: *Demonstrate understanding of devices for energy conservation*

Content Standard: Develop the skills to design and construct devices for Energy Conservation

WEEK 12

Learning Outcomes: *Design simple solutions for energy conservation in the use of lighting and consumer appliances*

Content Standard: Develop the skills to design and construct devices for Energy Conservation

INTRODUCTION AND SECTION SUMMARY

This section will enable learners to develop the skills to design and construct devices for energy conservation. Using energy-efficient devices and practices to reduce energy usage is known as energy conservation. Energy-saving devices help preserve natural resources, cut down on waste, and lower energy costs. Learners will understand the need to maximise energy use without compromising performance, these gadgets are commonly utilised in homes, workplaces, schools, and industries. Technologies or instruments known as energy conservation devices are made to lower energy usage and boost effectiveness in many contexts. Learners are aware of rising energy prices, erratic power supplies in some regions, and the requirement for sustainable energy management are all issues Ghana is facing. Therefore, learners will be exposed to designing devices that minimise energy waste that can help lessen the strain on the national grid, lower electricity bills, and promote environmental sustainability in households, schools, public institutions, and rural communities. For consumer appliances and lighting, an Energy Management System (EMS) is a collection of devices, software, and techniques used to track, manage, and maximise energy use. Learners will develop the skills to cut down on energy waste, enhance device performance, and support sustainable energy practices, it combines sensors, controls, actuators, and software.

The weeks and the indicators covered by the section are:

- Week 11: 1. Describe devices used for energy conservation.
2. Explain the application areas for the various devices used for energy conservation
- Week 12: 3. Explain the methodology for designing devices for energy conservation
4. Design and construct energy management systems solutions for lighting and consumer appliances

Recap

Year 1	Week 12: Use various instruments to accurately measure electrical and non-electrical quantities
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SUMMARY OF PEDAGOGICAL EXEMPLARS

This section aims to help learners not just understand energy conservation, but also apply their knowledge by designing and constructing practical energy management systems solutions for lighting and consumer appliances as well as application areas for the various devices used for energy conservation. This pedagogy will help learners to share ideas and listen to others, clarify and build on each other's thinking also use language to develop reasoning and creativity. Teachers are to encourage learners to keep talking during construction, explaining their choices then ask each other questions and finally reflect on what works and what needs fixing. Teachers are to guide discussions with thoughtful questioning, give wait time, and value all contributions. The goal is to move from talk to action building real solutions that conserve energy. Experiential learning is a learner-centred approach where learners gain knowledge and skills through direct experience, followed by reflection, analysis, and application. It involves learning by doing. Teachers are to present a scenario that is connected to their local issues or use a video. Organise learners into small groups to design a device for a specific purpose, plan the materials and steps they will use. Allow learners to test their devices then guide them to observe performance and note what worked and what did not work.

ASSESSMENT SUMMARY

Developing the skills to design and construct devices for energy conservation should be taught by teachers using assessment techniques that promote creativity, critical thinking, teamwork, and real-world application. These assessment approaches help learners comprehend the methodology for designing devices for energy conservation. Inquiry, creativity, and practical problem-solving should be encouraged by engineering-based activities that connect global goals with local realities. Learners can apply theory, hone their analytical skills, and promote teamwork with the aid of presentations, case studies, group research projects, homework and assignments. These approaches support learners' growth and aid in their understanding of the devices for energy conservation. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
1) Describe devices used for energy conservation.	Level 3	Assignment
2) Explain the application areas for the various devices used for energy conservation	Level 2	Group Research

3) <i>Explain the methodology for designing devices for energy conservation</i>	<i>Level 2</i>	<i>Case Study</i>
4) <i>Design and construct energy management systems solutions for lighting and consumer appliances</i>	<i>Level 4</i>	<i>Project</i>

WEEK 11

Learning Indicators

1. Describe devices used for energy conservation
2. Explain the application areas for the various devices used for energy conservation

FOCAL AREA 1: DESCRIBE DEVICES USED FOR ENERGY CONSERVATION

Energy conservation means reducing energy consumption by using energy-efficient technologies and practices. Devices designed for energy conservation help minimise waste, reduce energy bills, and protect natural resources. These devices are widely used in homes, schools, offices, and industries to optimise energy usage without sacrificing performance.

1. Categories of Energy Conservation Devices

a. Lighting Systems

i. LED (light-emitting diode) bulbs

Function: Use less electricity and have a longer lifespan than incandescent or fluorescent bulbs.

Energy Savings: Consume up to 80% less energy than traditional bulbs.

Practical Example: A school replaces all fluorescent bulbs in classrooms with LED bulbs, reducing electricity costs significantly over a school term.



Figure 24: LED bulb

ii. Motion and Occupancy Sensors

Function: Automatically turn lights on when someone enters a room and off when the room is empty.

Energy Savings: Prevents lights from staying on unnecessarily.

Practical Example: Installed in restrooms and corridors of an office to turn off lights after 5 minutes of no movement.



Figure 25: Motion and Occupancy sensors

iii. Daylight Sensors

Function: Adjust artificial lighting based on the amount of natural light in a space.

Practical Example: In a modern library, lights near windows dim automatically on bright sunny days.



Figure 26: daylight sensor

b. Heating, Ventilation, and Air Conditioning (HVAC)

i. Programmable Thermostats

Function: Allow users to set temperature schedules based on usage patterns.

Energy Savings: Reduces heating or cooling when spaces are unoccupied.

Practical Example: A home thermostat is programmed to lower the temperature at night and increase it in the morning.



Figure 27: Programmable Thermostat

ii. Smart Thermostats

Function: Learn user behaviour and make automatic energy-saving adjustments.

Practical Example: A smart thermostat in an office building reduces air conditioning use during at weekends when the office is closed.



Figure 28: *Smart Thermostat*

iii. Ceiling Fans with Timers

Function: Help circulate air efficiently and shut off automatically after set periods.

Practical Example: Used in school classrooms to complement natural ventilation during mild weather.



Figure 29: *Ceiling Fan with Timer*

c. Appliance and Device Controls

i. Smart Plugs and Power Strips

Function: Allow remote control and automatic scheduling of connected devices.

Energy Savings: Reduce phantom loads (energy consumed by devices on standby).

Practical Example: A smart plug shuts off a classroom projector after 6 p.m. if not already turned off manually.



Figure 30: *a Smart Plug in a socket*

ii. Advanced Power Strips

Function: Cut power to peripheral devices when the main device is turned off.

Practical Example: In a computer lab, monitors and printers power down when the computer is shut off.

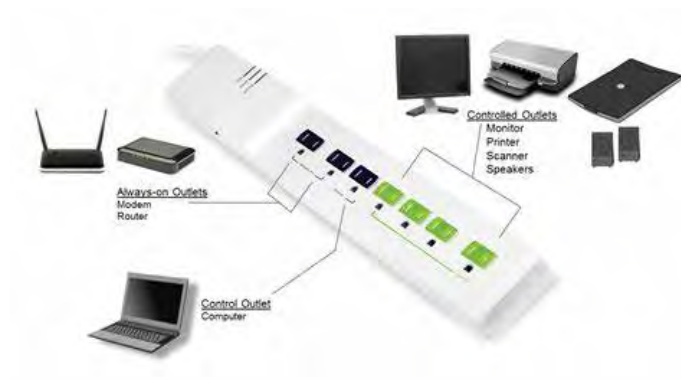


Figure 31: *Advanced Power Strips*

iii. **Energy-Efficient Appliances (e.g., ENERGY STAR)**

Function: Use improved designs and technologies to perform the same functions while consuming less energy.

Practical Example: ENERGY STAR-rated refrigerators in a school kitchen use 40% less electricity than older models.



Figure 32: *Energy-Efficient Appliances*

d. **Renewable Energy and Passive Systems**

i. **Solar Water Heaters**

Function: Use solar energy to heat water.

Practical Example: A boarding school uses solar heaters to provide hot water in dormitories.



Figure 33: *Solar Water Heaters*

ii. **Solar Outdoor Lighting**

Function: Use solar panels to charge batteries and light outdoor areas at night.

Practical Example: Installed along school pathways or playgrounds for safety lighting at night without grid electricity.



Figure 34: *Solar Outdoor Lighting*

iii. Building Insulation and Double-Glazed Windows

Function: Reduce heat loss or gain, thereby minimising heating and cooling needs.

Practical Example: An office building installs insulation in ceilings and walls to maintain indoor temperatures naturally.



Figure 35: *Double-Glazed Windows*

e. Industrial and Facility Energy Optimisation

i. Variable Frequency Drives (VFDs)

Function: Adjust the speed of electric motors based on load demand.

Practical Example: A workshop fan slows down when fewer machines are running, reducing energy use.



Figure 36: *Variable Frequency Drives*

ii. Power Factor Correction Devices

Function: Improve the efficiency of power delivery by correcting lagging power factor, especially in industrial settings.

Practical Example: A technical college installs capacitors in its machine lab to reduce energy losses and lower electricity bills.



Figure 37: Power Factor Correction Device

iii. Energy Management Systems (EMS)

Function: Monitor and control energy usage in large buildings or campuses.

Practical Example: A university campus uses EMS to monitor lighting, HVAC, and lab equipment energy use in real-time.

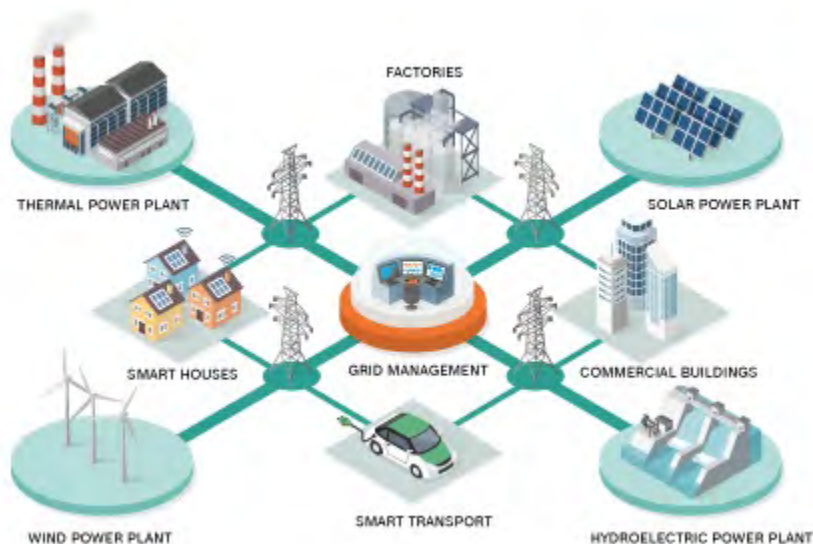


Figure 38: Energy Management System

Learning Tasks

1. Ask learners to categorise energy conservation devices.
2. Guide learners to describe devices used for energy conservation.

Pedagogical Exemplars

Initiate Talk for Learning: In a question-and-answer session, learners brainstorm and share views on the importance of energy conservation and further share their experiences on energy conservation efforts.

Experiential Learning: Learners watch videos or pictures of devices used to aid energy conservation (e.g., photocells, timer switches, dimmers, occupancy sensors, motion sensors, etc.)

Learners familiarise themselves with various energy conservation devices and share their observations.

Key Assessment Level 3: Assignment

1. A computer lab in a technical college runs multiple devices (computers, monitors, printers) for about 8 hours a day. The energy bill is significantly high. Recommend two energy conservation devices that could be installed to reduce energy consumption. Describe how each device contributes to energy savings.
2. Describe how the use of a smart thermostat and daylight sensor in a school building contributes to energy conservation. Include the specific energy systems each device affects and the nature of savings achieved.
3. Compare and contrast the roles of LED lighting and solar water heaters in promoting energy conservation in a school setting. Include at least one benefit and limitation of each.

FOCAL AREA 2: EXPLAIN THE APPLICATION AREAS FOR THE VARIOUS DEVICES USED FOR ENERGY CONSERVATION

Energy conservation devices are technologies or tools designed to reduce energy consumption and improve efficiency across different settings. Their use spans from residential households to large-scale industrial environments. Below is a breakdown of key devices used for energy conservation and their specific application areas, including how and where they are effectively applied.

1. LED Lighting

LEDs (Light Emitting Diodes) are highly energy-efficient light sources that use a fraction of the electricity consumed by traditional incandescent or fluorescent bulbs.

Application Areas

Homes and Apartments: Used for indoor and outdoor lighting.

Schools and Universities: Classroom and corridor lighting.

Street Lighting: Urban and rural roads.

Commercial Buildings: Retail shops, office lighting.

Benefits

Lower power consumption, long service life, and reduced maintenance costs.

2. Smart Thermostats

Smart thermostats automatically regulate heating and cooling by learning user habits and adjusting temperatures accordingly.

Application Areas

Residential Buildings: Smart control of HVAC systems.

Offices: Energy management in central air conditioning.

Hotels: Optimising energy use in unoccupied rooms.

Benefits

Reduces heating/cooling when not in use, provides remote access and control, improves user comfort, and lowers bills.

3. Occupancy and Motion Sensors

These sensors detect movement or presence and automatically switch electrical loads (mainly lights) on or off.

Application Areas

Classrooms, Libraries, and Lecture Halls: Automatic lighting control.

Public toilets: Lights and exhaust fans.

Warehouses and Corridors: Motion-based lighting activation.

Benefits

Reduces lighting waste in unoccupied areas, enhances security, and convenience.

4. Advanced Power Strips (APS)

APS detects when devices are in standby mode and automatically cuts off power, preventing phantom loads.

Application Areas

Computer Labs: Managing printers, monitors, and (personal computers).

Home Entertainment Centres: Managing TVs, sound systems, and game consoles.

Offices: At workstations and meeting rooms.

Benefits

Reduces standby energy waste and enhances power control.

5. Energy-Efficient Appliances (e.g., Energy Star-rated)

Appliances are designed to meet high-efficiency standards, consuming less power while maintaining performance.

Application Areas

Kitchens in homes and restaurants: Refrigerators, microwaves.

Laundries: Washing machines and dryers.

Office break rooms: Coffee makers, water dispensers.

Benefits

Lowers electricity bills and reduce environmental impact.

6. Solar Water Heaters

Systems that use solar collectors to heat water, reducing dependence on electricity or gas water heaters.

Application Areas

Residential Homes: Daily hot water usage.

Hotels and Hostels: High-volume hot water needs.

Hospitals: Continuous hot water demand for sterilisation and washing.

Benefits

Reduces fossil fuel use and has low operating costs after installation.

7. Variable Frequency Drives (VFDs)

VFDs control the speed of electric motors based on the required load, thus minimising energy waste.

Application Areas

Industrial Pumps and Fans: Adjust flow and speed as needed.

HVAC Systems in Commercial Buildings: Dynamic control of air circulation.

Water Treatment Facilities: Variable motor speed based on demand.

Benefits

Optimised motor performance, reduced wear and tear, and energy savings.

8. Energy Management Systems (EMS)

Computer-based systems that monitor, control, and optimise energy usage within a building or industrial facility.

Application Areas

Industrial Plants: Load shedding and peak demand monitoring.

Universities and Campuses: Centralised control of lighting and HVAC.

Large Commercial Buildings: Real-time usage analysis and adjustments.

Benefits

Data-driven energy decisions and detection of inefficiencies.

9. Daylight Sensors (Photocells)

Devices that measure ambient light and adjust artificial lighting accordingly.

Application Areas

Offices and Classrooms: Light dimming when daylight is sufficient.

Shopping Malls and Atriums: Natural-light integration.

Parking Areas: Turn lights on at dusk and off at dawn.

Benefits

Reduces lighting costs and enhances user comfort by mimicking natural light patterns.

10. Insulation Materials and Double-Glazed Windows

Thermal insulation reduces the need for heating/cooling by keeping internal temperatures stable.

Application Areas

Houses and Apartments: Walls, ceilings, and floors.

Commercial Offices: Glazed windows and insulation panels.

Schools: Reducing energy demand for heating in winter and cooling in summer.

Benefits

Enhances energy efficiency of buildings and improves indoor comfort levels.

Learning Task

Help learners to explain the application areas for various devices for energy conservation.

Pedagogical Exemplars

Initiating Talk for Learning: Facilitator-led discussion, explain the application areas for various devices for energy conservation.

Experiential Learning: Learners watch videos on the application of various devices for energy conservation and share their observations with the class.

Key Assessment Level 2: Group Assignment

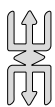
1. Explain one reason why smart thermostats are useful in residential homes. (5 marks)
2. Describe one application of solar water heaters in public buildings. (5 marks)
3. What are advanced power strips used for in office environments? (5 marks)

PLC Session 11

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

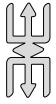
4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **group assignment**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assignment (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

- a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
- b. all teachers in the group work through a similar problem individually for 3–4 minutes
- c. the group then works through the problem together step by step
- d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e–3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a–1b, 1e–lg, 2c, 2e, 2f, 3c–3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 12

Learning Indicators

1. *Explain the methodology for designing devices for energy conservation*
2. *Design and construct energy management systems solutions for lighting and consumer appliances*

FOCAL AREA 3: EXPLAIN THE METHODOLOGY FOR DESIGNING DEVICES FOR ENERGY CONSERVATION

Ghana faces rising energy costs, unstable power supply in some areas, and the need for sustainable energy management. These challenges make energy conservation a national priority. Whether in homes, schools, public institutions, or rural communities, designing devices that reduce energy waste can help ease the pressure on the national grid, reduce electricity bills, and support environmental sustainability.

The process of designing such devices involves a clear methodology—a step-by-step approach that help ensure solutions are effective, affordable, and tailored.

Methodology for Designing Energy Conservation Devices

1. Identify the Problem or Energy Wastage Area

Start by identifying where and how energy is being wasted. This involves:

Observing usage patterns

- a. Conducting basic energy audits
- b. Engaging with users (e.g., households, teachers, students, school management)

Example

In a junior high school in Kumasi, it was observed that classroom lights and ceiling fans remain on even when students are outside during break times.

2. Define the Design Requirements and Constraints

Define the goal of the energy-saving device and the constraints that must be considered, such as:

- a. Cost of components
- b. Availability of materials locally
- c. Technical skills of users
- d. Environmental conditions (e.g., dusty or humid environments)

Example

Design a device to automatically switch off lights and fans in classrooms after 10 minutes of inactivity.

3. Research and Select Suitable Components

Based on the objective, research the type of sensors, control units, and output devices needed. Select components that are:

- a. Affordable
- b. Available in the local market
- c. Easy to use or replace

Suggested Components:

- a. PIR sensor to detect human presence
- b. Arduino Uno or 555 timer as the controller
- c. Relay module to control fans or lights
- d. Rechargeable battery or mains supply

4. Design, Simulate, and Plan

- a. Draw a circuit diagram using CAD tools (e.g., Proteus, Fritzing)
- b. Simulate to test the design virtually
- c. Write any microcontroller code where required

Example

Learners use Proteus to simulate the PIR sensor triggering a relay to power down lights and fans. The code is written in Arduino IDE and uploaded in the school computer lab.

5. Build the Prototype and Test in the Field

- b. Assemble components on a breadboard or Vero board
- c. Test in real conditions (e.g., in a classroom or office)
- d. Observe performance and take user feedback

Example

The prototype is installed in a SHS classroom. Teachers report it helps learners remember to turn off lights, and headteachers note a small drop in the electricity bill.

6. Evaluate, Refine, and Document

- b. Review the device's performance
- c. Troubleshoot and improve the system
- d. Document the design process, results, and user feedback

Example

After one week, it was discovered that the PIR sensor did not detect seated learners clearly. The team adds an ultrasonic sensor for better detection and documents the adjustment in a learners innovation logbook.

Learning Task

Guide learners to explain the methodology for designing devices for energy conservation

Pedagogical Exemplars

Initiating Talk for Learning: Use a flowchart to explain the methodology for designing devices for energy conservation. Through questions, learners explain the methodology using the flowchart.

Key Assessment Level 2: Homework

1. Outline the key steps involved in the methodology for designing a device aimed at conserving energy. (20 marks)
2. Discuss the role of an energy audit and baseline analysis in the design of an energy-conserving device.
3. Explain how component selection (e.g., sensors, actuators, and controllers) impacts the effectiveness of an energy conservation device. (10 marks)
4. Explain the step-by-step methodology involved in designing a basic device to conserve energy in a home, school, or workplace environment.

FOCAL AREA 4: DESIGN AND CONSTRUCT ENERGY MANAGEMENT SYSTEMS SOLUTIONS FOR LIGHTING AND CONSUMER APPLIANCES

An Energy Management System (EMS) for lighting and consumer appliances is a set of tools, hardware, and strategies used to monitor, control, and optimise energy consumption. It integrates sensors, controllers, actuators, and software to reduce energy waste, improve device performance, and promote sustainable energy practices.

1. Objectives of an EMS

- a. Reduce energy bills by minimising waste
- b. Extend the life of lighting and appliances
- c. Improve convenience through automation
- d. Enable smart control (manual, timed, sensor-based, or remote)
- e. Gather data for informed decision-making

2. Core Components of an EMS for Lighting and Appliances

Component	Function
Sensors	Detect ambient light, motion, temperature, current flow
Microcontroller	Processes input signals and executes control logic (e.g., Arduino, ESP32)

Relays/Switch Modules	Switch the connected appliances or lighting circuits on or off
Power Meters	Measure energy usage of connected devices
User Interface	Allows user control and display (e.g., push buttons, LCDs, mobile apps)
Connectivity Modules	Provide remote monitoring/control via Wi-Fi, Bluetooth, Zigbee
Power Supply Unit	Supplies low voltage (5V/12V) to EMS components safely

3. Methodology for Designing EMS Solutions

Step 1: Conduct a Basic Energy Audit

Identify the energy-intensive appliances (lights, fans, TVs, air conditioners).

Measure baseline energy consumption using a plug-in energy meter.

Determine usage patterns and user behaviour

Step 2: Define the Problem and Objectives

Problem: Lights are often left on unnecessarily in classrooms.

Objective: Reduce lighting energy consumption by 30% using occupancy-based automation.

Step 3: Select Appropriate Components

Lighting EMS

PIR motion sensor – to detect presence

LDR (Light Dependent Resistor) – to measure ambient light

Relay module – to control light circuit

Arduino Uno – to process data and control relays

LED light bulbs – as load

Appliance EMS

Current sensor (e.g., ACS712) – to monitor appliance energy draw

Real-time clock module (DS3231) – for scheduled control

Smart plug or Wi-Fi relay – for remote control

LCD Display or IoT dashboard – for user feedback

Step 4: Design the System Architecture

Example 1: Smart Lighting System

Motion detected + low ambient light = lights ON

No motion for 10 minutes = lights OFF

Example 2: Smart Appliance Scheduler

The television switches off automatically after 11 PM

Iron turns OFF after 15 minutes of inactivity

Step 5: Develop the Control Algorithm

```
if (motionDetected && lightLevel < threshold) {turnLightOn();} else if (!motionDetected
&& timeSinceLastMotion > 10 minutes) {turnLightOff();}
```

Step 6: Build the Prototype

Assemble components on a breadboard or PCB

Use Arduino IDE to program microcontroller

Test each sensor and relay separately, then as a complete system

Step 7: Testing and Calibration

Simulate real-life conditions (e.g., people entering/leaving)

Adjust sensor thresholds and delays for responsiveness

Step 8: Install and Monitor

Install sensors and relays in actual environments (e.g., classrooms, offices)

Use data logging to track system performance

Collect user feedback for fine-tuning

4. Practical Example Projects**Example 1: Smart Classroom Lighting Controller**

Inputs: PIR sensor (motion), LDR (light level)

Output: Relay switching LED light

Microcontroller: Arduino Uno

Logic: Lights turn ON only if classroom is occupied and it's dark

Outcome: ~35% reduction in lighting energy usage

Example 2: Smart Appliance Usage Monitor

Appliance: Electric iron or microwave

Input: Current sensor (ACS712)

Output: LCD shows usage time and wattage

Microcontroller: ESP32 with Wi-Fi to send data to an IoT dashboard

Outcome: Tracks energy use and alerts users if devices are left on too long

Example 3: Remote-Controlled Smart Power Strip

Controlled Devices: TV, fan, heater

Control: Smartphone app (via Blynk or Home Assistant)

Hardware: ESP8266 Wi-Fi module, 4-channel relay

User Functionality: Manual ON or OFF, scheduling, and monitoring from anywhere

Outcome: Enables better load management and user awareness

5. Considerations during Design

Safety: Use opto-isolated relays, fuses, proper casing

Scalability: Modular design allows future expansion

User-friendliness: Simple interface (buttons, displays, or app)

Cost-effectiveness: Use affordable and easily available components

Power backup: Consider using a rechargeable battery or UPS for controller

6. Evaluation Metrics

Metric	How to Measure
Reduction in energy usage	Compare pre- and post-installation consumption (kWh)
System reliability	Monitor uptime and error rates
User satisfaction	Conduct user surveys and gather feedback
Cost savings	Calculate based on reduced electricity bills

7. Conclusion

Designing and constructing energy management systems for lighting and consumer appliances allows learners and professionals to implement practical solutions for energy conservation. These systems not only save costs but also foster a culture of environmental responsibility. With the use of simple microcontrollers, sensors, and basic coding, EMS projects are accessible and scalable for real-world impact.

Practical Context Example

Project Title: Smart Energy Management System for a Rural Classroom

Problem

In a basic school in the Upper East Region, classroom lights and ceiling fans are left on even when the room is empty or when there is enough daylight. The school has a solar system and limited battery storage, so energy conservation is crucial.

Project Goal

Design and construct a low-cost system to automatically turn off lights and fans when:

- natural daylight is sufficient
- the classroom is empty for more than 5 minutes

Materials

- Arduino Uno
- LDR (Light Dependent Resistor) to detect light level
- PIR sensor to detect motion
- Relay module to switch fan/light
- 12V LED bulbs or energy-saving bulbs
- Solar panel + battery setup (already in school)

- g. Cables, resistors, and housing unit

Step-by-Step Design and Construction

1. Identify Energy Waste
 - a. Determine when and how energy is being wasted (e.g., lights left on).
2. Specify Requirements
 - a. Motion-activated control
 - b. Light-sensitive automation
 - c. Should run on existing solar power
3. Circuit Design and Simulation
 - a. Use Proteus or Tinkercad to simulate the Arduino circuit
 - b. Write Arduino code to:
 - i. Read LDR and PIR input
 - ii. Activate relay to turn on light/fan only when needed
4. Build and Test
 - a. Assemble on a breadboard or Vero board
 - b. Install in the classroom
 - c. Test behaviour over a few days
5. Evaluate and Refine
 - a. Collect feedback from teachers
 - b. Adjust light threshold or delay timing in code

Arduino Logic (Simplified Pseudocode)

If (LDR detects low light AND PIR detects motion) {Turn the light on}

Else if (No motion for 5 minutes) {Turn the light and fan off}

Learning Tasks

1. Guide learners to design energy management system solutions for lighting and appliances
2. Help learners to construct energy management system solutions for consumer appliances

Pedagogical Exemplars

Problem-based and Collaborative Learning: Learners are organised into groups, and each group is assigned a lighting or consumer appliance to design and construct an energy conservation device for. Share their projects later with the class for comments.

Key Assessment: Practice Paper 1

You have been asked to develop an energy management system for a small room that automatically controls lighting and at least one consumer appliance to reduce energy waste. (25 marks)

Your task is to

1. Design a basic energy management system circuit using available components (e.g., Arduino, relays, sensors, LEDs).
2. Construct and test your working prototype.
3. Explain how the system works to manage energy usage.
4. Justify how your design reduces energy consumption and benefits users.

Hint



Conduct **Practice Paper 1**. It should cover contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section to guide you. Learners' papers should be marked immediately and scores entered into the SAP.

PRACTICE PAPER 1.

Structure

- 1 Examination will cover focal areas covered in each table of specification.
 - a. Paper 1: 40 MCQs.
 - b. Paper 2: PART A and PART B
 - i) Part A: 1 compulsory question
 - ii) Part B: 5 questions from which learners will answer only 4 questions.
 - c. Paper 3: 1 Practical question.
- 2 **Duration:** 2 hours
- 3 **Materials Needed:** Printer, A4 sheets, A large exam room, answer booklets, stationary, 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: 40 marks
 - ii) Essay type question: 20 marks for Part A and 40 marks for Part B (10 marks per question)
 - iii) Practical question: 100 marks

TABLE OF SPECIFICATION FOR THE PAPER 1

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

			DoK (Number of questions)				
			L1	L2	L3	L4	
1.1	Engineering in Society	Classify the various engineering occupational disciplines	1				1
		Outline the common skill set required by the respective engineering disciplines.		1			1
		Explain the role of the SDGs in societal development.		1			1
		Describing engineering solutions for attaining specific SDGs			1		1
1.2	Health and Safety in Engineering Practice	Identify accidents that occur in engineering practice.	1				1
		Identify the causes of accidents in engineering practice and explain their effects.		1			1
		Describe risk assessment and outline its relevance.			1		1
		Explain the need for good house-keeping.		1			1
1.3	Ethics and Professional Practice	Explain ethical and unethical behaviour in the field of engineering	1				1
		Explain professionalism in engineering practice		1			1
		Describe the consequences of unprofessional behaviour.			1		1
		Describe the nature, relevance, and mandate of professional bodies.	1				1
2.1	Circuit and machines	Sketch the circuit symbols of DC and AC circuit elements.	1				1
		Use Ohm's and Kirchhoff's laws to find current and voltage in DC circuits.			1		1
		Explain the functions of the basic components of analogue electronic circuits			1		1
		Identify various electrical machines.	1				1

2.2	Renewable energy systems	Explain how renewable energy sources benefit humanity and contribute towards the attainment of the SDGs.		1			1
		Explain the functions of the basic components of photovoltaic and solar thermal systems.		1			1
		Explain the functions of the basic components of wind and bioenergy systems.			1		1
		Operate and maintain simple wind and bioenergy systems				1	1
2.3	Energy efficiency and conservation	Identify instruments used for measuring electrical and non-electrical quantities in renewable energy systems		1			1
		Extract data from nameplates of equipment		1			1
		Develop energy management plans.		1			1
		Describe devices used for energy conservation.	1				1
3.1	Engineering Design	Identify the various elements within the engineering design process	1				1
		Develop relevant research questions for a given problem.			1		1
		Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution.		1			1
		Test and validate a prototype	1				1
3.2	Rapid Prototyping	Describe the fundamental principles behind 3D printing, casting, PCB production and laser cutters and the specific use case applications.		1			1
		Apply CAD tools to create models		1			1
		Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit.			1		1

		Convert a given electronic circuit into a PCB and produce a functioning PCB board using CAD and CAM tools.		1			1
4.1	Automation Technologies	Identify basic automation components and materials and their respective functions or roles in the automation industry.			1		1
		Interpret and connect system components according to technical drawings and vice versa.		1			1
		Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc.			1		1
		Design and implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements.			1		1
4.2	Embedded Systems	Identify examples of embedded systems in the community.	1				1
		Describe the CISC, RISC and ARISC architectures	1				1
		Declare variables and constants, perform control actions and loops, write functions in C, test and debug programmes within the Arduino IDE.		1			1
		Learners should be able to design embedded systems to interface with sensors and actuators given design objectives	1				1
	TOTAL		$\frac{12}{40} \times 100$	$\frac{16}{40} \times 100$	$\frac{12}{40} \times 100$		100%
			30	40	30		

TABLE OF SPECIFICATION FOR THE PAPER 2 (ESSAY MOCK 1)

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

			DoK (Number of questions)				
	Sub-strand	Learning Indicator	L1	L2	L3	L4	Total
1.	a. Engineering in Society	Explain the unique knowledge requirement of the disciplines – careers	1				1
		Explain systematic investigation and its relevance in engineering professional practice		1			1
	b. Health and Safety in Engineering Practice	Explain the health and safety protocols associated with basic workshop tools/machinery		1			1
		Explain the types of risk assessment	1				1
	c. Ethics and Professional Practice	Outline the desired attributes of an engineer and explain how those attributes could be developed.			1		1
2.	Circuit and machines	Explain the functions of the basic components of analogue electronic circuits	1				1
		Explain the safety measures associated with the use of the various electrical machines.		1			1
3.	Renewable energy systems	Explain how electricity is generated from water, wind, solar, biomass, and biogas energy sources.		1			1
		Operate and maintain simple photovoltaic and solar thermal energy systems.			1		1
4.	Energy efficiency and conservation	Identify appropriate energy-saving tips for thermal equipment.	1				1
		Explain the methodology for designing devices for energy conservation.		1			1

5.	<i>Engineering Design and Prototyping</i>	Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution			1		1
		Set up, configure and utilise a 3D printer to produce CAD prototype models			1		1
6.	<i>Automation Technologies and Embedded Systems</i>	Discuss the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations for specific scenarios			1		1
		Describe the memory architectures of RAM and ROM.		1			1
	TOTAL		$\frac{4}{15} \times 100$	$\frac{6}{15} \times 100$	$\frac{5}{15} \times 100$		100%
			26.66	40.00	33.33		

TABLE OF SPECIFICATION FOR THE PAPER 3 (PRACTICAL MOCK 1)

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

			DoK (Number of questions)				
	Sub-strand	Learning Indicator	L1	L2	L3	L4	Total
1.	Circuit and machines	Identify and determine values of basic elements of DC and AC electric circuits (resistors, inductors, capacitors, diodes, transistors, transformers, dc and ac sources) using instruments, colour codes and datasheets					
		Sketch the circuit symbols of DC and AC circuit elements.					
		Use a software tool to simulate simple circuits to derive current, voltage, and power in DC and AC circuits.					
		Identify basic components of analogue electronic circuits (resistors, inductors, capacitors, diodes, transistors, transformers and op-amps)					
		Use CAD tools for the design and analysis of simple analogue electronic circuits.					

2.	<i>Engineering Design and Prototyping</i>	Develop relevant research questions for a given problem.					
		Formulate research objectives for a given problem					
		Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution.					
		Design a working prototype based on design requirements					
		Test and validate a prototype					
		Analyse failures associated with prototypes and provide appropriate remedies					
		Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit.					
3.	<i>Automation Technologies and Embedded Systems</i>	Identify basic automation components and materials and their respective functions or roles in the automation industry.					
		Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc.					
		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					
		Learners should be able to design embedded systems to interface with sensors and actuators given design objectives					
	Total		1				1

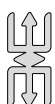
PLC Session 12

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand.

- b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

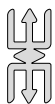
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP).
 - a. The key assessment for the week is **practice paper 1**. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the practice paper (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through the problem individually for 3–4 minutes
 - c. the group then works through it together the problem, step by step
 - d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes	Enactment
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6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes	Reflection
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7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 6 Review

1. Can learners describe devices used for energy conservation?
2. Would learners be able to explain the application areas for the various devices used for energy conservation?
3. Can learners explain the methodology for designing devices for energy conservation?
4. Were learners able to design and construct energy management systems solutions for lighting and consumer appliances?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 11

FOCAL AREA 1

Question 1

Answer

Advanced power strips: These disconnect peripheral devices (such as monitors and printers) when the main device (computer) is turned off, reducing standby power consumption.

Smart plugs: These can be scheduled to turn off all devices after operating hours, preventing energy waste at night and during weekends.

Marking Scheme (6 marks)

Identification of 2 appropriate devices (e.g., advanced power strips, smart plugs) – 2 marks
(1 mark each)

Explanation of how each device works and contributes to energy saving – 4 marks (2 marks each)

Question 2

Answer

A smart thermostat controls heating and cooling by adjusting settings based on occupancy and weather, reducing unnecessary HVAC use.

A daylight sensor reduces the need for artificial lighting by dimming lights when sufficient natural light is present.

This results in lower electricity use and reduced energy bills.

Marking Scheme (5 marks)

Identifying the two devices and their target systems (HVAC and lighting) – 2 marks

Explanation of their function – 2 marks

Description of the type of savings (e.g., reduced operating hours, automatic adjustment) – 1 mark

Question 3

Answer

LED lighting is used to reduce lighting energy consumption, while solar water heaters reduce the need for electricity or gas for heating water.

Benefit of LED: Very efficient and long-lasting.

Limitation: Initial cost may be higher than traditional bulbs.

Benefit of solar heater: Uses renewable energy.

Limitation: Performance depends on sunlight availability

Marking Scheme (6 marks)

Comparison of functions (lighting vs. water heating) – 2 marks

One benefit and one limitation of LED lighting – 2 marks

One benefit and one limitation of solar water heaters – 2 marks

FOCAL AREA 2

Question 1

Answer

Smart thermostats are useful in residential homes because they automatically regulate heating and cooling based on occupancy and user preferences, helping to reduce energy consumption and lower utility bills. They can be controlled remotely via smartphones and learn usage patterns to optimise comfort and efficiency.

Marking Scheme

Identifies smart thermostat as a device for HVAC control (1 mark)

Explains automatic or programmable temperature regulation (2 marks)

Gives a practical example such as reduced heating when nobody is home (2 marks)

Question 2

Answer

Solar water heaters are commonly used in public buildings such as hospitals, schools, and government offices to provide a reliable and cost-effective source of hot water. For example, in hospitals, solar water heaters supply hot water for patient bathing, laundry, and sterilisation of equipment, reducing dependence on electricity or fossil fuels and helping to lower energy costs while promoting environmental sustainability.

Marking Scheme

Identifies solar water heater (1 mark)

Describes use for supplying hot water (1 mark)

Specifies a public building (e.g., hospital or hotel) (1 mark)

Explains how it reduces electricity or gas use (1 mark)

Gives a practical benefit (e.g., cost savings or eco-friendly) (1 mark)

Question 3

Answer

Advanced power strips are used in office environments to automatically cut power to devices that are not in use, such as monitors, printers, and chargers. This helps to eliminate phantom (standby) power consumption, reduce electricity waste, and improve energy efficiency, leading to lower utility bills and a more sustainable workplace.

Marking Scheme

Identifies advanced power strip (1 mark)

Describes function of cutting power to idle devices (2 marks)

Provides an office-based example such as computers or printers (2 marks)

WEEK 12**FOCAL 3****Question 1**

Answer

1. Problem Identification and Needs Analysis
2. Research and Data Collection
3. Concept Development
4. Design Specification
5. Prototyping and Circuit Design
6. Testing and Evaluation
7. Refinement and Optimisation
8. Documentation and Deployment
9. Monitoring and Maintenance

Marking Scheme

Criteria	Marks	Description
Identification of steps	6	Lists at least five sequential steps (e.g., problem definition, audit, concept design).
Explanation of each step	8	Provides clear, accurate descriptions of what happens in each step.
Logical sequencing	4	Steps are presented in a coherent, correct order.
Use of an example	2	Brief illustrative example (e.g., lighting, HVAC) showing application of the steps.

Question 2

Answer

An **energy audit** is a systematic examination of how energy is consumed in a facility, system, or process. It plays a critical role in the early stages of designing an energy-conserving device by:

- a. Identifying major energy-consuming equipment and systems.
- b. Revealing inefficiencies, such as unnecessary standby power, poor insulation, or outdated lighting.
- c. Highlighting user behaviour patterns that contribute to energy waste (e.g. lights left on in unoccupied rooms).
- d. Providing data for targeted solutions, ensuring the device addresses real-world issues rather than assumed problems.

A baseline analysis involves collecting and analysing data on energy consumption over a period of time to determine the normal usage level before any intervention.

Its role includes:

- a. Quantifying current energy usage and establishing reference values.
- b. Setting measurable energy saving goals (e.g. reducing energy use by 15%).
- c. Providing a benchmark to evaluate the effectiveness of the device once implemented.
- d. Supporting cost-benefit analysis by comparing expected savings with the cost of the device.

Marking Scheme

Criteria	Marks	Description
Definition of an energy audit	4	2–4 marks for clear definition of what an energy audit is.
Purpose of baseline analysis	4	2–4 marks for explaining why establishing current energy use is critical.
Methods and tools	6	3–6 marks for describing at least two tools/techniques (e.g., data loggers, power meters, surveys).
Link to device design	4	2–4 marks for showing how audit results inform selection of strategies/components.
Clarity and organisation	2	1–2 marks for writing is well-structured and focused on the question.

Question 3

Marking Scheme

Criteria	Marks	Description
Identification of component types	3	1–3 marks for naming at least three key components (e.g., temperature sensor, microcontroller, relay, VFD).
Justification of sensor choice	3	1–3 marks for explaining criteria (accuracy, range, cost) for selecting appropriate sensors.
Discussion of control elements	3	1–3 marks for describing the role of controllers/actuators and their impact on energy savings (e.g., precision, responsiveness).
Practical example	1	Gives a concise, relevant example (e.g., thermostat-based lighting control) illustrating how component choice affects performance.

Question 4

Marking Scheme (20 Marks Total)

Assessment Criteria	Marks	Details
1. Problem Identification and Objective Setting	4	2–4 marks for clearly describes the energy conservation need and defines a specific design goal.
2. Research and Data Collection	2	1–2 mark for explaining gathering information (e.g., existing solutions, user needs, and energy data).
3. Component Selection	2	1–2 marks for identifying appropriate components (e.g., sensors, microcontrollers) and justifies their use.

4. Design and Planning	4	2–4 marks for describing planning the structure or schematic of the device with functionality in mind.
5. Prototype Development and Testing	3	1–3 marks for mentioning prototyping, simulation, or physical testing and refining of the device.
6. Clarity, Relevance, and Logical Flow	3	1–3 marks for writing is well-organised, clearly written, and maintains focus on energy conservation.

FOCAL AREA 4

Answer (Sample Response)

1. Design (Sketch and Explanation)

- a. Microcontroller (Arduino Uno) controls system logic.
- b. PIR sensor detects occupancy.
- c. LDR sensor measures ambient light.
- d. Relay controls a light bulb and small appliance (e.g., fan).
- e. Logic:
 - i. If room is occupied and light level is low → turn on light.
 - ii. If temperature is high (optional) → turn on fan.
 - iii. Devices turn off when no one is present.

2. Construction & Testing

- a. Prototype connected on a breadboard.
- b. Code uploaded to Arduino via IDE.
- c. Sensors tested using Serial Monitor.
- d. Verified correct switching of devices based on sensor readings.
- e. Observed system for stability over time.

3. Explanation of Functionality

- a. The system senses when someone is in the room.
- b. It only turns lights on when needed, avoiding waste.
- c. The appliance (e.g., fan or charger) runs only when required.
- d. System uses low-power sensors and components.

4. Justification of Energy Savings

- a. Saves energy by operating devices only when necessary.
- b. Reduces standby energy use.
- c. Promotes user awareness of smart energy use.
- d. Aligns with SDG Goal 7: Affordable and Clean Energy.

Marking Scheme (25 Marks Total)

Criteria	Description	Marks
Design Quality	3–6 marks for clear sketch with labelled components and correct logic flow	6
Prototype Construction	3–6 marks for functioning circuit built with correct sensor and component connections	6
System Explanation	2–5 marks for logical description of how sensors and devices interact to save energy	5
Testing & Troubleshooting	2–4 marks for description of how the system was tested and what adjustments were made	4
Justification of Energy Efficiency	2–4 marks for clear explanation of how system reduces energy consumption and benefits users	4

Criteria	Description	Marks
System Design: Circuit Diagram & Component Selection	• Clear, labelled circuit diagram using appropriate components (3 marks) - o 1 mark: Neatness and clarity - o 1 mark: Correct connections between components - o 1 mark: Use of appropriate components for task (e.g., Arduino, relay, sensor) • Rationale for component selection (3 marks) - o 1 mark: Sensor (e.g., motion, light, temperature) - o 1 mark: Actuator/appliance control (e.g., relay for lamp/fan) - o 1 mark: Controller (e.g., Arduino or similar logic control)	6
Construction and Testing of Prototype	• Correct physical assembly of components (2 marks) • Functionality: Does the system perform the task? (3 marks) - o 1 mark: Lights control automatically - o 1 mark: Appliance control (e.g., fan, heater) - o 1 mark: System reacts to input (e.g., sensor triggers control) • Testing and adjustments demonstrated / documented (1 mark)	6
Explanation of System Operation	• Step-by-step explanation of how the system works (3 marks) - o Inputs (sensor detection) - o Processing (microcontroller logic) - o Output (device actuation) • Clarity and logic of explanation (2 marks) • Use of technical language appropriate to level (1 mark)	6

Justification of Energy Savings and User Benefits	• Energy-saving features clearly identified (3 marks) - o 1 mark: Use of automation to reduce idle device use - o 1 mark: On-demand appliance control - o 1 mark: Efficient sensor deployment • User-focused benefits explained (2 marks) - o E.g., convenience, reduced electricity bills, safety (1 mark for each benefit – max 2 marks) • Sustainability and impact considerations (2 marks) - o E.g., reduced carbon footprint, long-term energy conservation impact (1 mark for each impact consideration – max 2 marks)	7
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SECTION 7: ENGINEERING DESIGN

STRAND: SYSTEMS DESIGN AND PROTOTYPING

Sub-Strand: Engineering Design

WEEK 13

Learning Outcomes: *Evaluate a prototype and test it using all possible variable constraints*

Content Standards: Demonstrate the ability to test and evaluate prototypes

WEEK 14

Learning Outcomes: *Use feedback and observations made from testing and evaluation to improve a solution or prototype*

Content Standards: Apply iteration to improve engineering designs

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to iteration in improving engineering designs. An essential part of the engineering design process is testing and validating a prototype. It entails determining whether a prototype satisfies the design specifications and performs dependably in practical settings. In this process, the prototype is compared to the design specifications, stakeholders' input is gathered, the design is iteratively improved based on testing outcomes, and compliance with industry standards is confirmed. Learners will understand that before going into production, a prototype can be refined for effectiveness, dependability, and general usability through extensive testing and validation. Additionally, before the product is completed for mass production or deployment, this procedure guarantees that any issues or flaws are found and fixed. Although prototypes sometimes fail in their early stages, they are a crucial element of the engineering and design process. Instead of being indicators of bad design, these errors provide opportunities to learn and improve the solution. Learners will examine these problems, pinpoint the underlying reasons, address them, and improve the prototype's dependability, performance, and safety.

The weeks and indicators covered in this section are:

- Week 13: 1. Test and validate a prototype
- Week 14: 2. Analyse failures associated with prototypes and provide appropriate remedies

Recap

Year 1	Week 14: Document solution requirements for a given problem. Week 15: Develop relevant research questions for a given problem.
Year 2	Week 17: Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution Week 18: Design a working prototype based on design requirements

SUMMARY OF PEDAGOGICAL EXEMPLARS

This section involves a lot of practical work, therefore it is suggested that teachers use pedagogical exemplars such as inquiry-based learning, problem-based learning and collaborative learning. In inquiry-based learning, learners should investigate and discover the “why” behind prototype failures. Allow learners to conduct tests or re-run models, collect measurements or performance data, and compare outcomes with their original design goals. The goal of using problem-based learning is to guide learners to solve real-world design problems using critical thinking. Allow learners to redesign part of the prototype, try new materials or construction techniques, iterate, retest, and evaluate the effectiveness of the remedy. Collaborative learning helps learners to work and think together. Put learners in groups to discuss and analyse test results. Teachers are to delegate tasks (e.g., someone fixes the frame, another improves airflow). Then allow learners to present and defend proposed improvements to the class

ASSESSMENT SUMMARY

This section suggests that teachers should set assessment items at level 3 and 4 for learners since engineering design was introduced in Year 1 and 2. Some key assessment modes, such as research and project work, may be ideal for the pedagogical strategies suggested. In group research and presentations, learners may carry out research on real-life examples of prototype failures (e.g., faulty biogas units, wind turbines with low efficiency, solar dryers that lose heat), causes of those failures (e.g., design flaws, material weaknesses, environmental factors) and how the problems were solved (remedies or redesigns). Teachers may award marks for the introduction: prototype purpose and background, failure analysis (what went wrong and why), remedial actions taken or proposed and lessons learned. In project work, learners (individually or in groups) are to build or use a given prototype, test it under realistic conditions, observe and document any failures or malfunctions, analyse what caused the failure then propose and apply improvements. Teachers may award marks for identification and explanation and the feasibility and effectiveness of the remedy, quality of improved prototype, teamwork and participation and clarity of presentation. For example:

Indicators	DOK Level	Assessment Strategy and/or Mode
Test and validate a prototype	Level 4	Individual assignment
Analyse failures associated with prototypes and provide appropriate remedies	Level 4	Project

WEEK 13

Learning Indicators: *Test and validate a prototype*

FOCAL AREA 1: TEST AND VALIDATE A PROTOTYPE

Refer back to year 1 Week 14 (Document solution requirements for a given problem) and Week 15 (Develop relevant research questions for a given problem)

Testing and validating a prototype is a critical step in the engineering design process. It involves checking whether a prototype meets the specified design requirements and functions reliably in real-world conditions. This process involves comparing the prototype against design requirements, gathering feedback from stakeholders, refining the design iteratively based on testing results, and verifying compliance with industry standards. Through thorough testing and validation, a prototype can be optimised for efficiency, reliability, and overall usability before moving into production. This process also ensures that any problems or shortcomings are identified and addressed before the product is finalised for mass production or deployment.

1. Purpose of Testing and Validation

The purpose of testing and validation is to ensure that a prototype or product meets the required specifications, performs reliably, and aligns with user expectations before full-scale production or deployment. Testing focuses on evaluating functionality, performance, durability, and usability under real-world conditions, identifying weaknesses, and refining the design. Validation, on the other hand, confirms that the prototype fulfils predefined standards, regulatory requirements, and stakeholder needs. Together, these processes help minimise risks, improve efficiency, enhance reliability, and ensure that the final product is both practical and optimised for its intended use.

- a. **Confirm Functionality:** The primary aim is to ensure that the prototype performs the tasks it was designed for. This involves verifying that all components work together as intended and that the prototype can achieve its objectives.
- b. **Measure Performance:** It is important to assess how efficiently and effectively the prototype operates under various conditions. This includes evaluating its speed, accuracy, energy consumption, and overall effectiveness in performing its functions.
- c. **Ensure Safety and Reliability:** Testing helps identify any potential hazards or failure points that could pose risks to users or compromise the prototype's performance in real-world scenarios. Ensuring safety and reliability is key to user acceptance and regulatory compliance.
- d. **Gather User Feedback:** By observing how users interact with the prototype, designers can gain insights into usability and user satisfaction. This feedback is invaluable for making adjustments that improve the user experience and functionality.
- e. **Support Design Improvements:** Testing provides critical data and insights that highlight areas where the prototype can be refined and optimised. This iterative process of improvement ensures that the final product is not only functional but also efficient and user-friendly.

- f. **Validate Real-World Applicability:** Field testing can reveal how the prototype interacts with its intended environment, such as coping with weather conditions or user behaviour. This step ensures that the prototype is practical and meets users' needs in actual use cases.

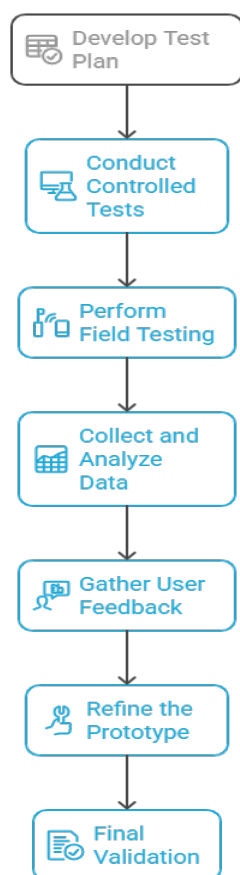


Figure 39: A flow chart of validation

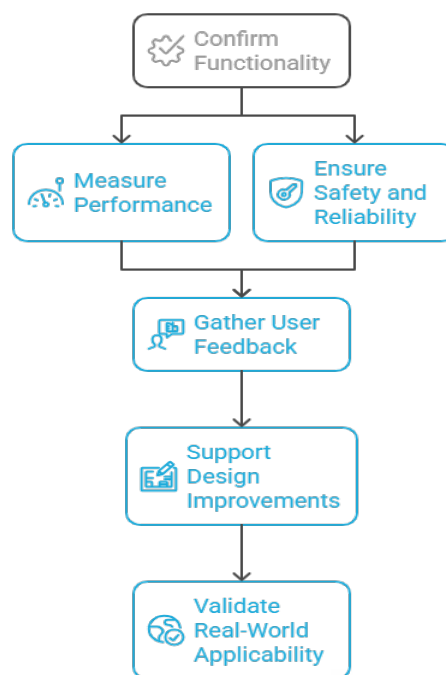


Figure 40: A flow chart of functionality

2. Key Steps in Testing and Validation

Testing and validation are essential processes in ensuring the reliability, functionality, and compliance of a prototype or system before full-scale implementation. This section outlines the key steps involved in systematically evaluating a product to identify potential weaknesses, optimise performance, and confirm adherence to predefined standards. By following a structured approach, developers can refine their designs, mitigate risks, and enhance overall usability, resulting in a robust and effective final product.

Step 1: Develop a Test Plan

The first step is to create a comprehensive test plan that outlines what needs to be evaluated, such as energy efficiency, responsiveness, and user interface. This involves determining the appropriate test methods, which can include simulation, laboratory testing, and field trials. Establishing clear success criteria, like achieving 90% accuracy or a 30% energy savings target, is essential to gauge the prototype's performance against its design goals.

Step 2: Conduct Controlled Tests

Once the test plan is established, the next phase is to conduct controlled tests in a laboratory environment. This involves using various tools such as multimeters, data loggers, and software simulations to measure performance metrics such as speed, accuracy, and energy consumption.

Controlled testing allows for the identification of immediate issues in a predictable setting, providing a baseline for further testing.

Step 3: Perform Field Testing

Field testing involves deploying the prototype in its intended real-world environment, such as a home or garden. This step is critical for observing how the prototype interacts with actual conditions, including user behaviour, weather variations, and voltage fluctuations. Field testing provides insights into the practical applicability and robustness of the prototype, ensuring it can withstand real-world challenges.

Step 4: Collect and Analyse Data

During both controlled and field testing, it is important to monitor and log performance indicators over time. This data is then compared to baseline measurements to identify inconsistencies, inefficiencies, or potential failure points. Analysing this information helps in understanding how well the prototype aligns with its design specifications and highlights areas needing improvement.

Step 5: Gather User Feedback

User feedback is gathered to gain insights into how end-users interact with the prototype. This involves asking users about their experiences, such as ease of use, interface clarity, and overall satisfaction. Feedback is useful for identifying areas of confusion, discomfort, or misuse that may not be apparent through technical testing alone.

Step 6: Refine the Prototype

Based on the data and feedback collected, the prototype is refined to address any identified issues. This iterative process includes making necessary improvements to enhance functionality and user experience. The updated prototype is then retested to confirm that these enhancements have been successful and that the prototype meets the intended design objectives.

Step 7: Final Validation

Once all refinements have been implemented, the prototype undergoes a final validation process. Engineers verify that it meets all design, performance, and user requirements. A detailed report is prepared, summarising test results, modifications made, and the overall success of the prototype in fulfilling its intended purpose.

Real-World Example of a Valid Prototype

Project Title: *Smart Solar-Powered Irrigation System for Small Gardens*

Objective

To conserve water and energy by automatically irrigating a garden only when soil moisture is low, using solar energy as the power source.

1. Prototype Description

The prototype included:

- a. **Soil moisture sensors** to detect dry soil.
- b. **Arduino Uno** microcontroller to process sensor data.
- c. **Relay module** to control a water pump.

- d. **Solar panel and battery** for off-grid power supply.
- e. **LCD display** to show soil moisture levels and system status.

2. Testing and Validation Process

a. Laboratory Testing

- i. Each component was tested individually:
 - Moisture sensors were calibrated using dry, damp, and wet soil.
 - The pump was tested for flow rate and responsiveness.
 - The solar panel was tested for charging efficiency.
- ii. The full system was assembled on a breadboard and tested using simulated input values.

b. Field Testing in a Real Garden

- i. The prototype was installed in a small vegetable garden.
- ii. Performance was monitored over a 7-day period under different weather conditions.
- iii. Key parameters logged:
 - Frequency and duration of pump activation.
 - Battery voltage levels throughout the day.
 - Soil moisture levels before and after watering.
 - Solar charging performance during cloudy and sunny days.

c. Results

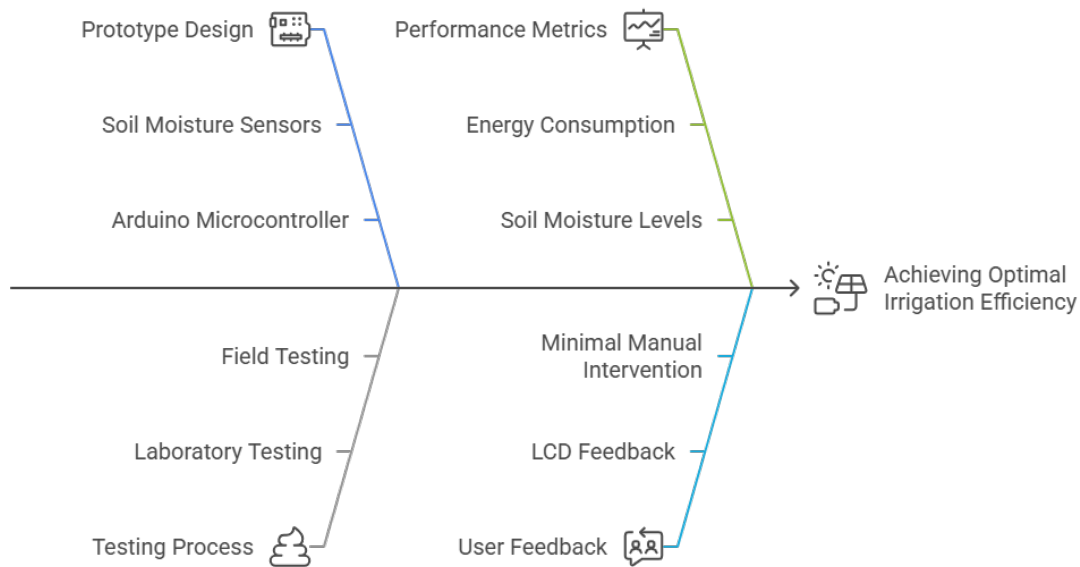
- i. The system successfully maintained ideal soil moisture without overwatering.
- ii. Energy consumption was fully supported by the solar panel.
- iii. The battery maintained an average charge of 85%.
- iv. Users appreciated the LCD feedback and minimal manual intervention.

d. Improvements Made

- i. The pump activation threshold was adjusted to prevent watering during light rain.
- ii. Waterproof casing was added to protect the Arduino.
- iii. An additional solar panel was added for greater reliability in cloudy conditions.

Conclusion

Testing and validating a prototype is essential to ensure it meets design objectives and operates reliably in the real world. The *Smart Solar-Powered Irrigation System* is an example of a valid prototype that demonstrated measurable water and energy savings during field tests. It also received positive user feedback, confirming its value and practicality for small-scale farming or home gardening.



Learning Tasks

1. Guide learners to test and validate a prototype
2. Allow learners to validate a prototype

Pedagogical Exemplars

Inquiry-based Learning: Encourage learners to ask questions, gather information, and come up with their own solutions to problems. This can be a useful approach for prototype testing, as it allows learners to develop critical thinking skills and approach testing with a sense of curiosity and creativity.

Project-based Learning: Involve learners in the design and testing of a prototype. Learners apply their knowledge and skills in a hands-on, experiential way.

Problem-based Learning: Learners are presented with a real-world problem and encouraged to work together to find a solution. This can be a useful approach for prototype testing, as it allows learners to develop problem-solving skills and think critically about the testing process.

Collaborative Learning: Involves learners working together in small groups to complete tasks and projects. This can be an effective way to learn about prototype testing, as it allows learners to learn from one another and share ideas and approaches to testing.

Key Assessment Level 4: Individual Assignment

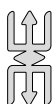
1. You are part of a team developing a solar-powered irrigation system for small gardens. Describe the procedures you would follow to test and validate the prototype before recommending it for public use. (20 marks)
2. Explain how environmental and user testing helped improve a real-world prototype you have studied or worked on. What changes were made based on the test results? (20 marks)
3. A team has designed a low-cost water level monitor for community boreholes. Discuss how this prototype can be tested and validated in real-world conditions and how test failures might lead to improvements. (20 marks)

PLC Session 13

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

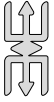
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **individual assignment**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assignment (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems or ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 14

Learning Indicators: *Analyse failures associated with prototypes and provide appropriate remedies*

FOCAL AREA 2: ANALYSE FAILURES ASSOCIATED WITH PROTOTYPES AND PROVIDE APPROPRIATE REMEDIES

Refer back to year 2 Week 17 (Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution) and Week 18 (Design a working prototype based on design requirements)

Prototyping is an essential part of the engineering and design process, but prototypes often fail in their early stages. These failures are not signs of poor design—instead, they are valuable opportunities to learn, improve, and refine the solution. Analysing these failures critically allows designers to identify the root causes, correct them, and enhance the prototype's performance, safety, and reliability.

1. Types of Failures in Prototypes

a. Functional Failures

A functional failure occurs when the prototype does not perform its intended task correctly.

Example: A sensor fails to detect changes, or a motor does not activate.

b. Performance Failures

The prototype performs the task, but not efficiently or consistently.

Example: Inaccurate readings, slow response times, or energy inefficiency.

c. Structural Failures

Physical parts of the prototype break, wear out, or degrade.

Example: Enclosures that are not weatherproofed, loose wiring, water damage.

d. Electrical Failures

Power delivery issues, component burnout, short circuits.

Example: The battery does not hold a charge or component damage due to voltage spikes.

e. User Interface Failures

Difficulty understanding or interacting with the prototype.

Example: Confusing labels, unclear feedback, or poor layout.

2. Real-World Example: Smart Solar-Powered Irrigation System

Prototype Objective Recap:

To automate plant irrigation using a solar-powered system triggered by soil moisture levels, with feedback displayed on an LCD.

3. Failures Encountered and Their Analysis

Type of Failure	Description of Failure	Root Cause	Remedy or Improvement
Performance Failure	Watering system activated even during rain or wet conditions	Soil moisture threshold too low, no weather compensation	Adjusted the sensor threshold; added rain detection through sensor/logic adjustment
Electrical Failure	System stopped functioning on overcast days due to battery draining	Solar panel size was too small for consistent energy supply	Added an extra solar panel and used a higher capacity rechargeable battery
Structural Failure	Arduino and sensor connections became unstable due to moisture exposure	No proper weather-proof enclosure	Installed a sealed, weather-proof casing and used silicone to seal wiring points
User Interface Failure	Users couldn't interpret the LCD readings clearly	LCD messages were unclear and not user-friendly	Updated LCD code with clearer, concise status messages (e.g., "Watering in Progress")
Functional Failure	Pump occasionally failed to activate even when soil was dry	Relay module connection was loose; power spike issue	Secured wiring with soldering and used a diode for back EMF protection for the pump

4. Remedies and Best Practices

- a. Improve Design Robustness
 - i. Use quality components suitable for outdoor or harsh environments.
 - ii. Ensure solid electrical connections through soldering and heat-shrink tubing.
- b. Integrate Feedback Mechanisms
 - i. Use indicators (e.g., LED or display) to show real-time system status.
 - ii. Add error-handling code to manage failures like sensor disconnection.
- c. Conduct Simulated Stress Testing

Test prototypes in different weather conditions, power scenarios, and use cases.
- d. Make Designs Modular

Design in a way that parts can be replaced or upgraded individually if they fail.
- e. Document Test Results and Revisions

Keep detailed logs of what failed, why it failed, and what was done to fix it.

5. Conclusion

Failures in prototypes are not setbacks, they are stepping stones to innovation. Analysing failures systematically helps refine and optimise a design, resulting in a more robust, reliable,

and user-friendly product. In the Smart Solar-Powered Irrigation System, early failures led to vital design changes that significantly improved performance, durability, and user experience.

Learning Tasks

Guide learners to analyse failures associated with prototypes and provide appropriate remedies.

Pedagogical Exemplars

Hands-on experimentation: Have learners test prototypes under different conditions and analyse the results to identify any failures. Encourage learners to come up with potential solutions to these failures and test them through further experimentation.

Design Thinking: Use design thinking principles to guide learners through the process of failure testing and correction. This involves encouraging learners to empathise with users, define problems, ideate solutions, prototype, and test their prototypes.

Collaborative Learning: Learners work in teams to test and evaluate prototypes. This can involve dividing learners into small groups and having each group work on a different prototype or having learners work together to test and evaluate a single prototype.

Project-based Learning: Use a project-based learning approach to teach failure testing and correction of prototypes. This involves having learners work on a real-world design challenge, such as creating a new product or improving an existing one and using failure testing and correction as part of the design process.

Inquiry-based Learning: This involves posing questions or problems for learners to explore, encouraging them to come up with their own hypotheses and test them through experimentation, and helping them to analyse and interpret their results.

Critical thinking and problem-solving: Learners will need to think critically and creatively in order to design and create prototypes using laser cutting. They will also need to troubleshoot problems and find solutions as they work.

Collaboration and Communication: Collaborative learning approaches, such as group projects, can help learners develop teamwork and communication skills. They will need to work effectively with others in order to complete their project and share their ideas and knowledge.

Creativity and Innovation: Laser cutting allows learners to be creative and innovative as they design and create prototypes. They can explore different materials, shapes, and patterns and use their imagination to come up with new ideas.

Digital Literacy: Using CAD software and laser cutting equipment requires learners to have a certain level of digital literacy. They will need to be able to navigate and use these tools effectively in order to complete their projects.

Leadership and responsibility: Learners can learn leadership skills as they work on projects and take on various roles within their group. They will also need to be responsible and manage their time and resources effectively in order to complete their project on schedule.

Global Citizenship: By exploring the applications and capabilities of laser cutting, learners can learn about the global impact of this technology and the ways in which it can be used to address real-world challenges.

Key Assessment Level 4: Group Project

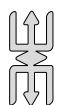
1. During testing, a prototype solar-powered irrigation system failed to deliver water consistently due to poor sensor feedback. Analyse the possible causes of failure and suggest appropriate remedies to improve the system. (20 marks)
2. A team developed a water level monitoring device for boreholes, but the community reported inaccurate readings after a few days of use. Identify potential causes of the failure and recommend suitable remedies. (20 marks)
3. A prototype smart lighting system designed to turn on when someone enters a room failed to detect movement in dim light. Analyse this failure and propose ways to resolve it. (20 marks)
4. After deploying a prototype low-cost air quality monitor, the readings were consistently off compared with commercial equipment. Analyse the failure and suggest remedies. (20 marks)

PLC Session 14

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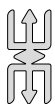
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Section 7 Review

1. Can the learner test a prototype?
2. Were learners able to validate a prototype?
3. Would learners be able to analyse failures associated with prototypes and provide appropriate remedies?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 13

FOCAL AREA 1

Question 1

Answer

To test and validate the solar-powered irrigation system prototype, the following procedures should be followed:

- a. Define Performance Metrics

We start by outlining what we expect the prototype to achieve—e.g., detect soil dryness accurately, activate the pump appropriately, charge the battery using solar energy, and display system status.
- b. Simulated Testing

Before field deployment, we test the system under controlled conditions. This includes:

 - i. Testing the soil moisture sensor with wet and dry soil samples.
 - ii. Simulating solar panel charging under artificial light.
 - iii. Running the pump via relay control using test inputs from the microcontroller.
- c. Field Testing

We deploy the prototype in a real garden over several days:

 - i. Monitor sensor accuracy under varying weather conditions.
 - ii. Log pump activation times and duration.
 - iii. Track the battery voltage and power consumption using data logging.
- d. User Interaction and Feedback

A small group of users is asked to interact with the system. They report issues with the interface, unclear messages on the display, or installation difficulties.

e. Failure Observation

During field use, we note that the pump sometimes fails to activate after cloudy days. Investigations show that the battery was not sufficiently charged. We solve this by using a larger solar panel and increasing the battery capacity.

f. Validation

After modifications, we repeat the tests and consistent performance. The system waters only when needed, charges properly, and users can read the LCD messages clearly

Marking Scheme (Total: 20 marks)

Criteria	Marks	Details
1. Clear Identification of Testing Objectives	3	Candidate identifies the key performance metrics (e.g. water delivery, solar efficiency, soil moisture accuracy, battery performance). • 3 = Clear and complete identification • 2 = Partial but relevant identification • 1 = Vague or minimal reference
2. Description of Simulated or Lab Testing	3	Describes testing of sensors, pump control, solar charging in controlled conditions. • 3 = Accurate and complete description of procedures • 2 = Basic steps given, with limited detail • 1 = Very brief or unclear description
3. Field Testing Explanation	4	Explains real-world deployment in gardens, testing system reliability over time, collecting data on environmental influence (e.g. cloudy days, soil variation). • 4 = Thorough explanation with real-world focus • 3 = Reasonable explanation, some context missing • 2 = Basic mention without deeper analysis • 1 = Incomplete or unclear response
4. User Feedback and Involvement	3	Describes user trials and feedback on ease of use, interface clarity, usability improvements. • 3 = Clearly integrates the role of user feedback • 2 = Mentions users but lacks depth • 1 = Brief or implied only
5. Analysis of Test Failures and Adjustments	4	Identifies issues found during testing and describes specific modifications (e.g. adding larger panel, waterproofing, adjusting code). • 4 = Detailed with specific examples • 3 = Some examples provided • 2 = Limited or unclear issues/solutions • 1 = Weak or general analysis

6. Final Validation and Conclusion	3	Explains how the revised prototype was validated and proven ready for public use. • 3 = Clear and justified conclusion • 2 = General conclusion only • 1 = Weak or unclear summary
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Question 2

Answer

Environmental and user testing are essential steps in refining a prototype. The project involved a smart automatic room lighting and appliance control system based on motion sensors.

Environmental Testing Results

The system was first tested in different lighting conditions. It worked well in the daytime but failed to detect motion in the dark due to poor PIR sensor positioning. The sensor was repositioned and fitted with an LED indicator for debugging. We also noted the system was turning lights on with every slight movement, even from pets. So, we updated the Arduino code to include a delay and sensitivity threshold.

User Testing Feedback

Users noted that the system sometimes kept lights on unnecessarily or turned them off too quickly. Based on this feedback

- a. We adjusted how long lights stay on after the last motion is detected.
- b. We added a manual override button for user control.

Outcome

These changes made the system smarter, more energy efficient, and more user-friendly. Testing under real conditions and obtaining user input were key to turning a basic prototype into a valid, working system.

Marking Scheme (Total: 20 marks)

Criteria	Marks	Details
1. Description of the Real-World Prototype	3	Clearly identifies the prototype and its intended purpose (e.g., smart lighting system, solar irrigation system). • 3 = Clear, concise, and relevant description • 2 = Mostly clear but lacking detail • 1 = Vague or incomplete description
2. Explanation of Environmental Testing	4	Describes specific environmental conditions the prototype was tested under (e.g., temperature, light, dust, rain) and the outcomes observed. • 4 = Clear, relevant examples with outcomes • 3 = Moderate detail provided • 2 = Minimal or unclear explanation • 1 = Incomplete or superficial mention

3. Explanation of User Testing and Feedback	4	Outlines how users interacted with the prototype, what feedback was collected, and how it was used. • 4 = Detailed explanation with specific user feedback • 3 = Reasonable explanation with general feedback • 2 = Limited reference to users • 1 = Weak or vague user focus
4. Identification and Analysis of Problems Detected	4	Clearly identifies key problems revealed during testing (e.g., sensor misreading, unreliable performance, poor UX design). • 4 = Multiple valid issues, clearly analysed • 3 = At least one main issue discussed well • 2 = Limited or underdeveloped problem discussion • 1 = Vague or unclear issues
5. Description of Modifications/Improvements Made	4	Describes specific changes made in response to testing (e.g., repositioned sensors, updated code, improved display or casing). • 4 = Clear, well-justified, and technically sound improvements • 3 = Mostly clear improvements • 2 = Some ideas but limited depth • 1 = Weak or insufficient changes explained
6. Conclusion and Impact of Testing	1	Summarises how testing led to a more effective prototype. • 1 = Clear and reflective • 0 = Missing or unclear conclusion

Question 3

Answer

To test and validate the water level monitor for boreholes, the team would follow these real-world steps:

a. Initial Testing in Controlled Conditions

In the lab, they simulate different water levels using a tank and float sensors or ultrasonic sensors. They verify that the sensor readings match actual levels and trigger the buzzer or LED indicators.

b. Field Testing in a Borehole Environment

The system is installed at a real community borehole. Daily water use, recharge rates, and power availability are monitored. It is exposed to weather, dust, and user handling.

c. Test Failures and Observations

- i. The sensor starts giving inaccurate readings due to sediment build-up. The team adds a protective casing with mesh to prevent direct contact with particles.
- ii. Power fluctuations affect the microcontroller. They install a capacitor-based smoothing circuit and change the power supply to a solar + battery combo.

- iii. Users complain they cannot understand the alert system. The team replaces vague beeps with a simple LCD and colour-coded LED status lights.

d. Validation

After adjustments, the system works reliably for two weeks, even during heavy use and rain. The data is logged and used by community managers to plan water usage more effectively.

Conclusion

Failures during real-world testing often highlight weaknesses in design that lab tests cannot reveal. Using feedback and data, the prototype becomes more durable, and usable and better suited for wider deployment.

Marking Scheme (Total: 20 Marks)

Criteria	Marks	Details
1. Clear Understanding of Prototype Function and Context	3	Identifies the purpose of the water level monitor (e.g. to monitor water availability in boreholes for community use). • 3 = Accurate and detailed explanation of function and context • 2 = General but relevant understanding • 1 = Vague or limited understanding
2. Testing in Real-World Conditions	4	Describes how the prototype would be tested in actual boreholes, under various conditions (e.g. dry/rainy seasons, different depths, exposure to dust and moisture). • 4 = Detailed explanation with realistic scenarios • 3 = Adequate explanation with minor omissions • 2 = Superficial or limited detail • 1 = Weak or unclear explanation
3. Types of Tests and Data Collection Methods	3	Outlines tests for accuracy, reliability, sensor performance, power consumption, durability, and how data would be gathered (e.g. logs, alerts, sensor readings). • 3 = Clear and appropriate methods described • 2 = Some valid testing described • 1 = Minimal or generic reference
4. Involvement of Community or End-Users	2	Describes how users (e.g. borehole caretakers or residents) are involved in testing and providing feedback. • 2 = Specific examples of user involvement • 1 = Brief or unclear mention • 0 = No mention of users
5. Identification of Failures/Challenges During Testing	4	Identifies possible issues during testing (e.g. false readings, power failure, poor installation, sensor drift) and explains their impact. • 4 = Several relevant issues well explained • 3 = At least one key issue discussed in detail • 2 = Limited or general issues • 1 = Very weak or unclear issues

6. Improvements Based on Testing Results	4	Clearly links problems identified to specific corrective actions (e.g. waterproofing components, adding real-time display, recalibrating sensors, improving housing design). • 4 = Specific, relevant, and technically sound improvements • 3 = Mostly appropriate with minor gaps • 2 = Some basic improvements mentioned • 1 = Weak or unrelated improvements
7. Conclusion on Effectiveness of Testing and Validation	2	Summarises the value of the testing process in improving the prototype and preparing it for community use. • 2 = Clear and reflective conclusion • 1 = Basic summary • 0 = No or poor conclusion

WEEK 14

FOCAL AREA 2

Question 1

Answer

The inconsistent water delivery in the solar-powered irrigation system could be due to several factors:

- Faulty or Misplaced Soil Moisture Sensors:** If the sensors are not correctly inserted into the soil or are of low quality, they may give inaccurate readings, leading to under- or over-watering.
- Inadequate Power Supply:** On cloudy days, insufficient solar energy may prevent the pump from activating, disrupting the system's schedule.
- Loose Wiring or Poor Soldering:** Electrical instability may cause intermittent failures.

Remedies

- Upgrade Sensors:** Use higher-quality soil moisture sensors with calibration capabilities.
- Battery Backup:** Integrate a battery storage system to maintain operation during low sunlight.
- Improve Assembly:** Ensure wiring is secure and soldered properly to prevent connection failures.

These changes would enhance the system's reliability and ensure consistent irrigation performance.

Marking Scheme (Total: 20 Marks)

Criteria	Marks	Details
1. Identification of Core Problem	2	Clearly identifies that inconsistent water delivery may be caused by poor sensor feedback. • 2 = Clear and accurate • 1 = Partial or vague • 0 = Not identified
2. Analysis of Sensor-Related Failures	4	Explains potential sensor-related issues such as: • Faulty or low-quality sensors • Incorrect sensor placement • Lack of calibration • Environmental impact (e.g., waterlogging, corrosion) • 4 = Multiple issues well explained • 2–3 = Some relevant issues • 1 = Minimal or unclear analysis
3. Analysis of Supporting System Failures	4	Discusses other contributing issues: • Inconsistent power supply (e.g., cloudy weather affecting solar input) • Wiring or connectivity problems • Microcontroller or software logic errors • 4 = Clear analysis with at least two non-sensor-related failures • 2–3 = One or two issues moderately explained • 1 = Weak or unclear reasoning
4. Suggested Remedies for Sensor Failures	4	Recommends specific solutions: • Use higher-quality or industrial-grade moisture sensors • Recalibrate or reposition sensors • Protect sensors from environmental damage (e.g., waterproofing) • 4 = All remedies relevant and clearly linked to failure • 2–3 = Some reasonable suggestions • 1 = Superficial remedies
5. Suggested Remedies for System Integration or Power Issues	4	Proposes system-wide improvements: • Add battery backup or power regulator • Improve circuit design and testing • Revise software logic to account for sensor delays or errors • 4 = All suggestions well-reasoned • 2–3 = Some partial solutions • 1 = General or vague ideas
6. Clarity, Structure, and Technical Accuracy	2	Logical flow, correct terminology, and clear communication. • 2 = Clear, well-structured, and technically correct • 1 = Understandable but with minor issues • 0 = Poorly written or confusing

Question 2

Answer

Possible causes of inaccurate readings include:

- a. **Sensor Drift or Water Damage:** The water level sensor may degrade over time or get damaged due to poor waterproofing.
- b. **Electromagnetic Interference (EMI):** Nearby electrical systems or phones could affect the sensor's accuracy.
- c. **Power Supply Fluctuations:** Inconsistent voltage from the solar panel may affect the microcontroller's performance.

Remedies

- a. **Use Waterproof, Industrial-Grade Sensors:** These are designed for long-term immersion and higher accuracy.
- b. **Shield the Circuit:** Employ EMI shielding and grounding techniques in the design.
- c. **Voltage Regulation:** Include a voltage regulator or a stable power management module.

These remedies would increase data accuracy and improve the credibility of the monitoring system among users.

Marking Scheme (Total: 20 Marks)

Criteria	Marks	Details
1. Identification of Core Problem	2	Identifies that inconsistent water delivery is caused by inaccurate sensor readings. • 2 = Clear and accurate • 1 = Partial or vague • 0 = Not identified
2. Analysis of Sensor-Related Failures	4	Explains potential sensor-related issues such as: • Faulty or low-quality sensors • Incorrect sensor placement • Lack of calibration • Environmental impact (e.g., waterlogging, corrosion) • 4 = Multiple issues well explained • 2–3 = Some relevant issues • 1 = Minimal or unclear analysis
3. Analysis of Supporting System Failures	4	Discusses other contributing issues: • Inconsistent power supply (e.g., cloudy weather affecting solar input) • Wiring or connectivity problems • Microcontroller or software logic errors • 4 = Clear analysis with at least two non-sensor-related failures • 2–3 = One or two issues moderately explained • 1 = Weak or unclear reasoning

4. Suggested Remedies for Sensor Failures	4	Recommends specific solutions: • Use higher-quality or industrial-grade moisture sensors • Recalibrate or reposition sensors • Protect sensors from environmental damage (e.g., waterproofing) • 4 = All remedies relevant and clearly linked to failure • 2–3 = Some reasonable suggestions • 1 = Superficial remedies
5. Suggested Remedies for System Integration or Power Issues	4	Proposes system-wide improvements: • Add battery backup or power regulator • Improve circuit design and testing • Revise software logic to account for sensor delays or errors • 4 = All suggestions well-reasoned • 2–3 = Some partial solutions • 1 = General or vague ideas
6. Clarity, Structure, and Technical Accuracy	2	Logical flow, correct terminology, and clear communication. • 2 = Clear, well-structured, and technically correct • 1 = Understandable but with minor issues • 0 = Poorly written or confusing

Question 3

Answer

The likely cause of failure is related to the type of motion detection sensor used:

- a. **Infrared Sensor Limitations:** PIR (Passive Infrared) sensors struggle to detect motion when temperature differences between the human body and the environment are small, especially in dim or warm conditions.
- b. **Poor Sensor Placement:** If the sensor is not angled correctly, it may not detect movement reliably.

Remedies

- a. **Use Dual-Technology Sensors:** Combine PIR with ultrasonic or microwave sensors for better detection in various lighting and temperature conditions.
- b. **Reposition Sensors:** Install sensors at locations that maximise coverage, such as above doorways or room corners.

With these improvements, the system would function more reliably regardless of light levels.

Marking Scheme (Total: 20 Marks)

Assessment Criteria	Marks	Details
1. Identification of the Core Failure	2	– Accurately identifies that the lighting system fails to detect motion in dim lighting conditions. • 2 = Clear and precise statement of the problem • 1 = Partial or vague identification • 0 = Not addressed

2. Analysis of Sensor Technology Limitations	4	– Explains how Passive Infrared (PIR) sensors struggle in low contrast environments (low temperature difference or low light). • 4 = Thorough explanation with technical accuracy • 2–3 = Partial but generally correct • 1 = Weak or superficial explanation
3. Consideration of Sensor Placement or Environmental Factors	4	– Discusses factors like poor positioning, blockage, or low motion sensitivity. • 4 = Insightful and well-developed analysis • 2–3 = Some relevant points but lacking depth • 1 = Minimal consideration
4. Proposed Remedies – Sensor Upgrade or Technology Alternatives	4	– Suggests realistic improvements such as: • Using dual-technology (PIR + microwave or ultrasonic sensors) • Installing active infrared sensors or cameras • 4 = Multiple relevant and feasible solutions • 2–3 = At least one good solution • 1 = Vague or impractical suggestions
5. Proposed Remedies – Installation and Calibration	4	– Recommends actions such as: • Repositioning sensors • Adjusting detection range • Improving sensitivity or recalibrating software • 4 = Multiple thoughtful remedies • 2–3 = Some useful actions suggested • 1 = Limited response
6. Communication and Technical Clarity	2	– Use of correct technical terms, structured explanation, and logical flow. • 2 = Clear and technically sound • 1 = Understandable with minor flaws • 0 = Disorganised or unclear

Question 4

Answer

Possible causes include

- Inaccurate Calibration:** The sensor may not have been calibrated against known standards.
- Poor Component Quality:** Low-cost components often lack the precision of industrial-grade alternatives.
- Environmental Contamination:** Dust or moisture may have entered the sensor housing.

Remedies

- Calibrate with Reference Devices:** Regularly calibrate using trusted commercial air quality monitors.
- Upgrade to Mid-Tier Sensors:** Choose sensors that offer better accuracy without being prohibitively expensive.

- c. Protective Enclosure: Use dust- and water-resistant housing with appropriate ventilation.

These changes would significantly enhance the reliability and usefulness of the device for community air monitoring.

Marking Scheme (Total: 20 Marks)

Assessment Criteria	Marks	Details
1. Identification of the Core Issue	2	Accurately states the problem: inaccurate readings compared to benchmark commercial monitors. • 2 = Clearly and accurately stated • 1 = Partially identified • 0 = Not addressed
2. Analysis of Possible Technical Failures	4	Discusses potential causes such as: • Use of low-cost or uncalibrated sensors • Lack of data filtering or averaging • Sensor drift over time • Poor enclosure design affecting airflow • 4 = Clear, comprehensive, and technically sound analysis • 2–3 = Partial but relevant analysis • 1 = Minimal or vague explanation
3. Environmental or Deployment Factors	4	Considers factors like: • Humidity, temperature, or dust affecting sensors • Improper positioning or exposure to direct sunlight • Variation in airflow around the sensor • 4 = Detailed and realistic explanation of environmental impacts • 2–3 = Some relevant factors mentioned • 1 = Weak or irrelevant points
4. Suggested Remedies – Sensor Improvements	4	Proposes technical improvements such as: • Switching to higher-accuracy sensors • Implementing sensor calibration against known standards • 4 = Practical, clearly explained solutions • 2–3 = At least one sound idea • 1 = General or superficial suggestions
5. Suggested Remedies – Software and Data Handling	4	Recommends improvements such as: • Adding averaging or smoothing filters • Implementing error correction algorithms • Periodic recalibration or drift compensation • 4 = Technically valid and feasible remedies • 2–3 = Partially developed • 1 = Weak or vague remedy
6. Clarity, Organisation, and Technical Language	2	Structure, fluency, and correct use of technical terms. • 2 = Clear, logical, and technically accurate • 1 = Understandable with some errors • 0 = Confusing or poorly written

SECTION 8: ENGINEERING DESIGN AND PROTOTYPING

STRAND: SYSTEMS DESIGN AND PROTOTYPING

Sub-Strand: Rapid Prototyping

WEEK 15

Learning Outcomes: *Translate the content of a schematic diagram into a breadboard circuit implementation.*

Content Standards: Demonstrate an ability to interpret electronic schematic diagrams and convert them to solderless breadboard circuits.

WEEK 16

Learning Outcomes: *Convert electronic schematic diagrams into PCB format and produce a corresponding functioning PCB board.*

Content Standards: Demonstrate an ability to convert electronic schematic diagrams into Printed Circuit Board (PCB) formats.

INTRODUCTION AND SECTION SUMMARY

The focus of this section is to guide learners to be able to translate the content of a schematic diagram into a breadboard circuit implementation. Making the leap from a theoretical schematic to a functional physical circuit is a crucial ability in electronics. This procedure entails interpreting a schematic diagram, designing and assembling the circuit on a solderless breadboard, and conducting systematic tests to verify its functionality. Learners will understand that before committing to permanent designs, bread boarding is perfect for prototyping, testing, and debugging. Electronic components are mechanically supported and electrically connected by printed circuit boards (PCBs), which are thin boards composed of insulating material with conductive paths carved or printed onto them.

The weeks and the indicators covered by the section are:

- Week 15: 1. Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit.
- Week 16: 2. Convert a given electronic circuit into a PCB and produce a functioning PCB board using CAD and CAM tools

Year 1	Week 20: Describe the fundamental principles behind 3D printing, casting, PCB production and laser cutters and the specific use case applications.
Year 2	Week 20: Set up, configure and utilise a 3D printer to produce CAD prototype models

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section, the pedagogical exemplars are Self-Directed Learning, Creativity and Innovation, Technical Literacy, Computational Thinking and Digital Literacy. These pedagogies will help learners to read and understand schematic diagrams, and use that knowledge to physically construct circuits on a breadboard using appropriate electronic components. Self-Directed learning encourages learners to take responsibility for their own learning. Teachers are to act as guides, offering support, not answers, use checklists to monitor learning progress and provide milestones and deadlines to structure independence. Creativity and innovation foster creativity by allowing learners to design or modify their own versions of a simple schematic, reimagine everyday solutions and present their circuit as part of a real-world application. Teachers are to encourage divergent thinking, allow open-ended challenges rather than only step-by-step instructions and celebrate original thinking, even when prototypes do not fully work. Technical literacy helps learners become proficient with tools, symbols, and physical components. Teachers are to provide labelled circuit kits and component cards, give visual aids (schematics and breadboard diagrams) then run small-group skill stations. Computational thinking guides learners to think logically about circuit function, flow, and debugging. Teachers are to model how to approach problems systematically, ask guiding questions and use simulations before physical builds. Digital literacy supports learners in using digital tools to extend their understanding and design. Teachers may provide tutorials or online videos as resources, assign digital logs or portfolios finally encourage responsible and ethical use of information.

ASSESSMENT SUMMARY

The suggested key assessments for this section are research and project. The goal of using research is to assess learners' understanding of schematic symbols and functions, component roles in the circuit and breadboard use and limitations. Teachers can score for a short written or digital report, annotated schematic with labelled components, explanation of pin configurations and connections then material list and function of each part. The goal for using a project is to assess the learner's ability to interpret the schematic, translate it into a working circuit on a breadboard, use components and tools correctly and troubleshoot and explain their implementation. Teachers can score for accurate component placement on breadboard, functionality of the circuit, problem-solving or troubleshooting during testing, oral or written explanation of implementation and use of tools, neatness, and safety. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit.	Level 4	Project (individual or group)
Convert a given electronic circuit into a PCB and produce a functioning PCB board using CAD and CAM tools	Level 3	Research (individual or group)

WEEK 15

Learning Indicator: Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit

FOCAL AREA 1: CONVERT A GIVEN SCHEMATIC DIAGRAM INTO A BREADBOARD CIRCUIT IMPLEMENTATION AND PROCEED TO ASSEMBLE COMPONENTS ON THE SOLDERLESS BREADBOARD AND TEST THE CIRCUIT

Refer back to Year 1 Week 20 (Describe the fundamental principles behind 3D printing, casting, PCB production and laser cutters and the specific use cases applications)

In electronics, translating a schematic into a working physical circuit is a critical skill. This process involves interpreting a schematic diagram, planning and assembling the circuit on a solderless breadboard, and conducting thorough testing to confirm correct operation. Breadboarding is ideal for prototyping, experimentation, and troubleshooting before committing to permanent designs.

1. Understanding the Schematic Diagram

A schematic diagram is a symbolic representation of an electronic circuit. It includes symbols for components such as:

- a. Resistors
- b. Capacitors
- c. LEDs
- d. Transistors
- e. Power sources
- f. ICs (Integrated Circuits)
- g. Wires and connections

Each symbol is labelled with a reference designator (e.g., R1, D1) and a value (e.g., $1\text{k}\Omega$).

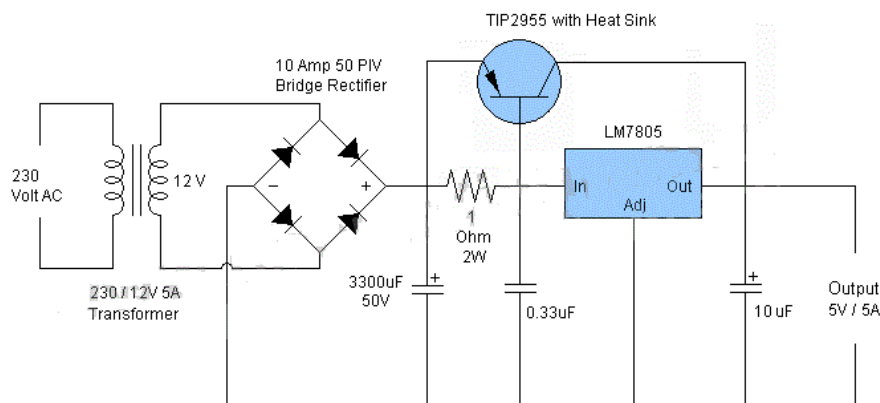


Figure 41: Schematic Diagram of a Power Supply Circuit

2. Key Skills

- a. Identify components and their values.
- b. Understand connections (nodes) and signal flow.
- c. Identify power supply and grounding requirements.

3. Plan the Breadboard Layout

A solderless breadboard contains rows and columns of interconnected sockets:

- a. Power rails are often split and may not be connected across their full length. Learners should be instructed to check the specific breadboard.
- b. Vertical columns in the middle section are connected in groups of five (excluding the divider gap in the centre).

4. Planning Tips

- a. Start with power supply connections.
- b. Place major components, such as ICs, first.
- c. Avoid crossing wires where possible.
- d. Use colour-coded jumper wires (e.g., red for +V, black for GND).

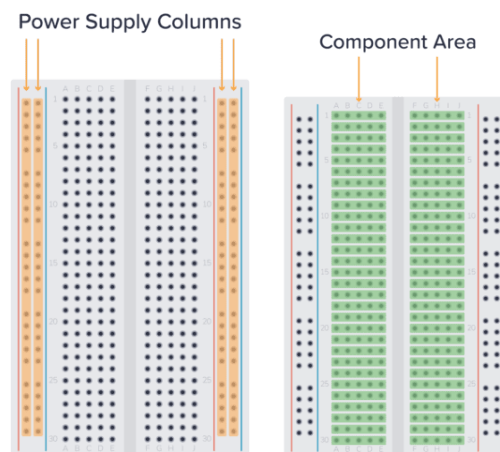


Figure 42: *Solderless Breadboard Interconnections*

5. Convert the Schematic to a Breadboard Circuit

Follow these steps to convert the schematic

Step 1: Place the IC or central component

Align it across the centre gap of the breadboard so each pin has a separate row.

Step 2: Add passive components

Insert resistors, capacitors, etc., in the correct locations as per the schematic.

Step 3: Connect using jumper wires

- i. Use wires to replicate schematic connections.
- ii. Pay close attention to pin numbers on ICs and transistor orientations.

Step 4: Power the breadboard

- i. Connect power rails to the appropriate voltage source (e.g., 5V or 9V).
- ii. Use a regulated supply if needed.

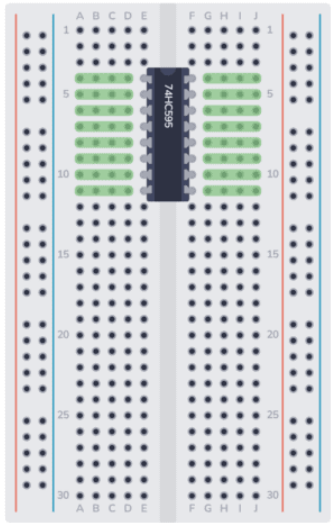


Figure 43: *Connecting an IC on a Breadboard*

6. Test the Circuit

- a. Before applying full power, conduct a visual inspection
 - i. Check for loose connections.
 - ii. Confirm component values and orientation (especially for LEDs, diodes, and ICs).
- b. Power-On Testing
 - i. Apply power gradually using a bench power supply with current limiting.
 - ii. Monitor for signs of overheating or short circuits.
 - iii. Measure voltages at key points using a multimeter.
- c. Functional Testing
 - i. Observe expected output (e.g., LED blinking, sensor response, output voltage).
 - ii. Use an oscilloscope or logic analyser for digital signals, if needed.

Practical Example: LED Blinker Circuit Using 555 Timer Components list:

Component	Value/Type	Quantity	Notes
555 Timer IC	NE555	1	Timer IC core
Resistor R1	1 k Ω	1	Controls charge rate
Resistor R2	100 k Ω	1	Sets timing
Resistor R3	470 Ω	1	Limits current to LED1
Resistor R4	470 Ω	1	Limits current to LED2
Capacitor C1	1 μ F	1	Timing capacitor

Capacitor C2	10 nF	1	Bypass capacitor
LED1, LED2	Red (or any colour)	2	Visual indicators
Switch S1	Pushbutton (NO)	1	Optional trigger
Power Supply	9V battery	1	Circuit power source
Breadboard & Wires	–	–	For assembly

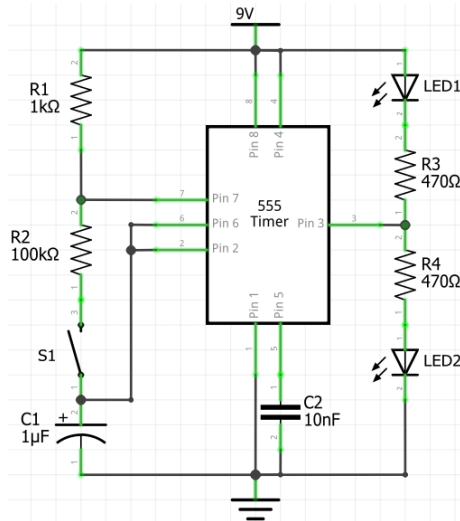


Figure 44: A circuit diagram of LED Blinker Circuit Using 555 Timer

BREADBOARD ASSEMBLY GUIDE

Step-by-step Wiring

1. Power Rails
 - a. Connect the +9V terminal of the battery to breadboard's positive rail.
 - b. Connect GND to breadboard's negative rail.
2. Place the 555 Timer
 - a. Insert the 555 timer across the middle trench of the breadboard (pins on both sides).
3. Connect Pins on the 555 Timer
 - a. Pin 1 (GND) → GND rail
 - b. Pin 8 (Vcc) → +9V rail
 - c. Pin 4 (Reset) → +9V rail
 - d. Pin 5 (Control Voltage) → Connect capacitor C2 (10nF) between pin 5 and GND
 - e. Pin 2 (Trigger) and Pin 6 (Threshold) → Tie them together and to the junction of R2 and C1
 - f. Pin 3 (Output) → Connect Pin 3 (output) to R3 and R4 (which go to LEDs)
4. Add Resistors and Capacitor for Timing
 - a. R1 (1kΩ) → Between pin 7 and Vcc
 - b. R2 (100kΩ) → Between pins 6 and 7

c. C1 (1 μ F) $\rightarrow$ Between pin 6 and GND

5. Add LEDs

a. R3 (470 Ω) $\rightarrow$ From pin 3 to the anode of LED1

b. R4 (470 Ω) $\rightarrow$ From pin 3 to the anode of LED2

c. Connect the cathodes of both LEDs $\rightarrow$ GND

6. (Optional) Add Pushbutton S1

a. Between the junction of R2 and C1 and GND – used to restart the cycle if manually triggered.

Final Testing Procedure

Steps for Functional Testing

a. Power ON the circuit by connecting a 9V battery or regulated adapter.

b. Observe the LEDs

i. LEDs should blink alternately at a fixed rate.

ii. The timing of the blinking is controlled by R1, R2, and C1.

c. Test the pushbutton (S1)

i. Pressing it may reset the cycle depending on how it is wired. If you added S1 to control triggering, check LED 1 and LED 2 response.

d. Use a multimeter

i. Measure the voltage at pin 3. It should alternate between $\sim 0V$ and $\sim 9V$.

e. Troubleshooting

If no blinking occurs:

i. Check the orientation of the 555 timer.

ii. Make sure the LEDs are not reversed.

iii. Verify capacitor polarity (C1).

iv. Confirm the resistor and capacitor values.

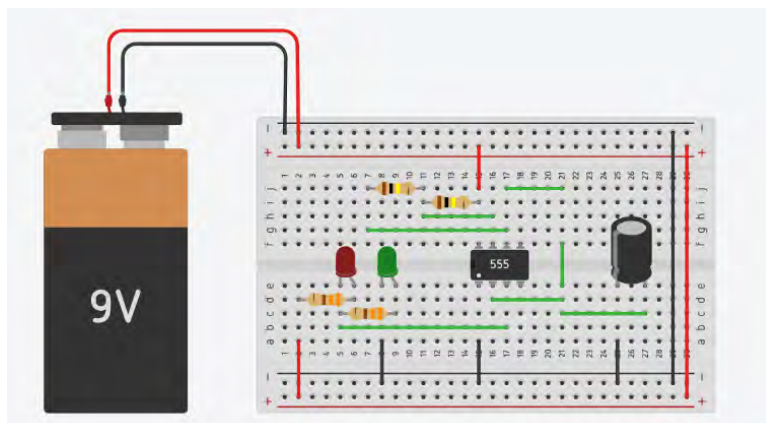


Figure 45: LED Blinker Circuit Using 555 Timer

Conclusion

Successfully translating a schematic into a breadboard requires understanding component symbols, correct placement, clean wiring, and methodical testing. This hands-on process builds foundational skills in prototyping, circuit debugging, and electronic design validation.

Learning Tasks

1. Guide learners to convert a given schematic diagram into a breadboard circuit implementation
2. Allow learners to assemble components on the solderless breadboard
3. Help learners test the circuit.

Pedagogical Exemplars

Experiential Learning: Guide learners to assemble electronic components on the breadboard by interpreting given schematic diagrams. Learners also test assembled circuits by using digital multimeters to test for continuity, measure voltage across components and make observations on circuit performance.

Project-based Learning: Learners work on a project that involves interpreting and assembling components from a given schematic diagram on a solderless breadboard. The learners should test the assembled circuit follow test instructions and report the results.

Self-Directed Learning: Explore online resources: There are many online resources available that can help learners learn more about solderless breadboard circuit construction and assembly. Learners should be tasked to find for more schematics from these sources implement them and report on the outcomes.

Key Assessment Level 4: Group Project

1. Rain Detection Alarm

Task: Build a circuit using a rain sensor, buzzer, and transistor switch to sound an alarm when it rains.

Test: Use water to simulate rain and verify buzzer operation. (40 marks)

2. Sound-Activated LED (Clap Switch)

Task: Assemble a circuit using a microphone, transistor, and 555 timer to switch ON an LED when a sound is detected.

Test: Clap near the microphone and observe the LED behaviour. (40 marks)

3. Burglar Alarm System Using IR Sensor

Objective: Construct a basic security system using an IR sensor, buzzer, and transistor switch.

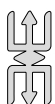
Test: Interrupt the IR beam and observe buzzer activation. (40 marks)

PLC Session 15

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

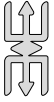
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is a **group project**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the project (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 16

Learning Indicator: *Convert a given electronic circuit into a PCB and produce a functioning PCB board using CAD and CAM tools*

FOCAL AREA 2: CONVERT A GIVEN ELECTRONIC CIRCUIT INTO A PCB AND PRODUCE A FUNCTIONING PCB BOARD USING CAD AND CAM TOOLS

Refer back to Year 2 Week 20 (Set up, configure and utilise a 3D printer to produce CAD prototype models)

A Printed Circuit Board (PCB) is a thin board made of insulating material, with conductive pathways etched or printed onto it, used to mechanically support and electrically connect electronic components.

Overview of the PCB Design and Production Process

The process of converting a schematic into a working PCB can be broken down into five main stages

Step 1: Draw the Electronic Schematic

- a. Use a CAD (Computer-Aided Design) tool such as KiCad, EasyEDA, Proteus, Fritzing, or Eagle.
- b. Place and connect all components in a logical diagram.
- c. This stage ensures the logical correctness of the circuit.

Step 2: Assign Component Footprints

- a. Each symbol used in the schematic must have a footprint (physical layout).
- b. Example: A resistor in the schematic must be matched with the correct footprint that represents its size and pin layout.

Step 3: Design the PCB Layout

- a. Arrange the footprints on a virtual board.
- b. Route the copper traces to make electrical connections between components.
- c. Add vias (holes), pads, labels, and mounting holes.
- d. Follow Design Rules (e.g., spacing, minimum trace width).
- e. Run a DRC (Design Rule Check) to catch layout errors.

Step 4: Generate CAM Files

- a. Use the CAD software's CAM (Computer-Aided Manufacturing) module to export files like:
 - i. Gerber files for copper layers, silkscreen, and solder mask.
 - ii. Drill files for vias and holes.

- b. These files are the standard format used by PCB manufacturers.

Step 5: Fabricate and Assemble the PCB

- a. Send the Gerber and drill files to a PCB fabrication service (e.g., JLCPCB, PCBWay) or use an in-school milling machine.
- b. Once the PCB is made, solder all components in place.
- c. Test the assembled PCB with tools such as a multimeter or oscilloscope to verify functionality.

Example: Temperature-Controlled Fan System

Circuit Goal: A system that turns on a fan when the temperature exceeds a set threshold.

Components

1. **BT1** – 9V Battery
2. **RV1** – Variable Resistor (10k Potentiometer)
3. **R1** – 4.7k Ω Resistor
4. **R2** – 330 Ω Resistor
5. **TH1** – NTC Thermistor (temperature-sensitive resistor)
6. **IC1** – LM741 Operational Amplifier (Op-Amp)
7. **Q1** – BC547 NPN Transistor
8. **D1** – 1N4007 Diode (for flyback protection)
9. **M1** – DC Fan
10. **PCB, jumper wires, connectors**

Temperature Controlled DC Fan Circuit

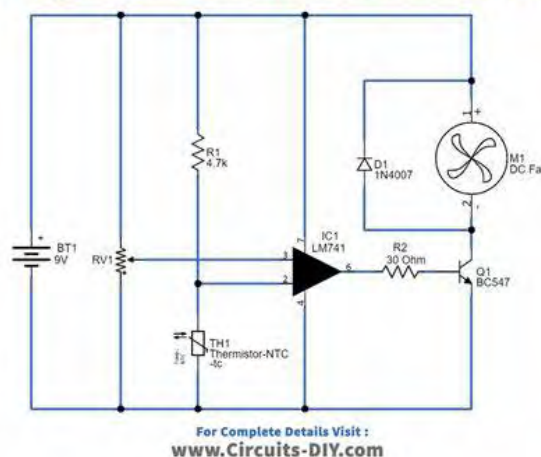


Figure 46: Circuit diagram of the DC Fan Circuit

1. Process Summary (Working Principle)

- a. Sensing Temperature

The thermistor (TH1) changes its resistance with temperature. As temperature increases, its resistance decreases (since it's an NTC type).

b. Voltage Divider

The thermistor and potentiometer form a voltage divider, providing an input voltage to the non-inverting terminal of the LM741 op-amp.

c. Comparison (Op-Amp)

The op-amp compares the voltage from the voltage divider with a reference voltage. When the temperature rises above a certain threshold, the output of the op-amp goes high.

d. Transistor Activation

The high output from the op-amp turns on the NPN transistor (BC547), which allows current to flow through the fan, thus powering it on.

e. Flyback Diode Protection

The 1N4007 diode protects the transistor from voltage spikes generated by the inductive load (DC fan).

2. Common CAD Tools for PCB Design

- a. Proteus Design Suite – Suitable for simulation and PCB design (easy for beginners).
- b. KiCad – Open-source, powerful for schematic capture and PCB layout.
- c. Eagle (by Autodesk) – Popular tool with schematic + PCB layout and 3D view.
- d. Altium Designer – Industry-standard PCB design software with rich features.
- e. EasyEDA – Cloud-based tool; integrates with LCSC for component sourcing.
- f. Fritzing – Suitable for beginners for prototyping and education.

3. Benefits of Using CAD/CAM Tools in PCB Design

- a. Accuracy and Precision: Ensures correct component placement and routing.
- b. Design Simulation: Helps verify circuit function before physical implementation.
- c. Faster Prototyping: Rapid generation of schematics and PCB layouts.
- d. 3D Visualisation: View the final product in 3D to catch design flaws.
- e. Manufacturing Integration: Directly export Gerber files for fabrication.
- f. Documentation: Automatic generation of BOM (Bill of Materials) and assembly diagrams.
- g. Error Detection: DRC (Design Rule Check) reduces risk of design errors.

4. Safety and Best Practices

a. Electrical Safety

- i. Double-check polarity for all components, especially the diode and transistor.
- ii. Use a current-limited power supply during testing.
- iii. Ensure proper insulation of wires to prevent short circuits.

b. Component Handling

- i. Handle ICs with care to avoid ESD damage.
- ii. Use appropriate heat dissipation such as heatsinks or ventilation, for transistor or fan where necessary.
- c. PCB Design Best Practices
 - i. Use thicker traces for power lines.
 - ii. Keep ground and power planes separated.
 - iii. Use bypass capacitors near ICs to reduce noise.
 - iv. Label all components clearly on the silkscreen layer.
 - v. Run a DRC and ERC (Electrical Rule Check) before exporting files.
- d. Environmental Best Practices
 - i. Recycle non-functional PCBs properly.
 - ii. Avoid lead-based solder where possible (use RoHS-compliant alternatives).
 - iii. Wear eye protection during soldering.

Learning Tasks

1. Guide learners to convert a given electronic circuit into a PCB
2. Help learners produce a functioning PCB using CAD and CAM tools

Pedagogical Exemplars

Initiating Talk for Learning: The facilitator shows learners how a PCB prototype machine works and explains the different PCB production techniques. The facilitator walks the class through the basic principles of designing a PCB layout from a given schematic layout using CAD software such as KiCad EDA. This should be limited to single-sided PCB layouts.

Experiential Learning: The facilitator guides learners to create single-layer PCB layouts using a CAD tool like KiCad EDA. Learners also produce PCBs from the single layout designs using CAM with a PCB prototyping machine. Learners are also exposed to testing procedures for single-layer PCBs.

Self-Directed Learning: Explore online resources: There are many online resources available that can help Learners learn more about PCB layout design and production. Learners should be tasked to find more schematics from these sources implement them and report on the outcomes.

Project-based Learning: Learners work on a project that involves the design of a single-layer PCB layout, production, assembly of components and testing of the complete product.

Problem-solving and Critical Thinking: Embedded systems projects often require learners to analyse complex systems, design solutions, and troubleshoot problems. Through this process, they will develop their problem-solving and critical thinking skills.

Collaboration and Teamwork: Embedded systems projects often involve working with a team of peers. By collaborating with others, learners will develop their teamwork and communication skills.

Creativity and Innovation: Through embedded systems projects, learners will be able to express their creativity and develop their innovation skills. They can come up with new ideas and designs and test them out to see if they work.

Technical Literacy: By studying embedded systems, learners will develop their technical literacy and gain knowledge in specific technical areas such as programming, microcontroller architectures, and electronics.

Computational Thinking: Understanding the concepts of embedded systems, learners will learn to think in computational terms, and will have a better understanding of how algorithms, data structures and programming languages work.

Digital Literacy: learners will be exposed to different digital technologies such as sensors and actuators, microcontroller development boards, and programming software. They will learn how to work with digital tools, as well as how to analyse, evaluate and communicate information using digital technologies.

Key Assessment Level 3: Individual Research

1. Given the schematic of a simple power supply circuit (e.g., 9V using 7809 regulator), use a CAD tool of your choice to create the PCB layout. Produce the PCB using a milling machine or CAM software, then solder and test the board for correct voltage output. (28 marks)

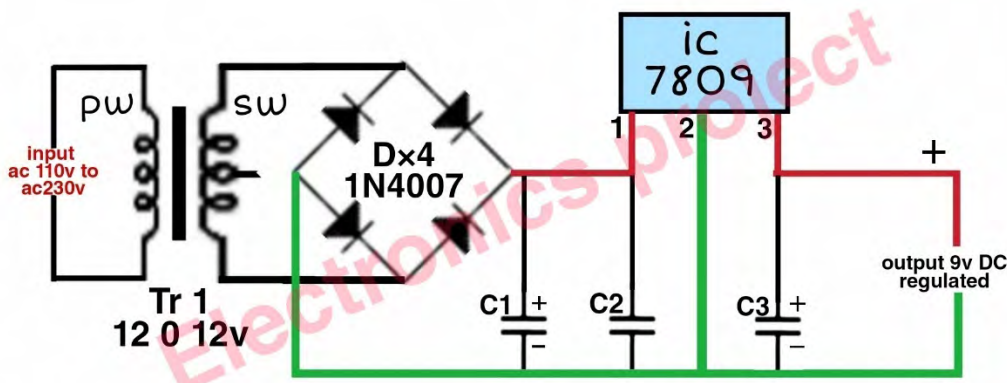


Figure 47: Schematic diagram of a simple power supply circuit of 9V

2. Using a schematic of a temperature-controlled fan circuit (using a thermistor and relay), create a PCB layout and fabricate the board. Test the system's response to temperature changes by applying heat and observing fan activation. (38 marks)
3. Design and fabricate a PCB for a basic IR sensor module using an IR LED and photodiode. Ensure correct spacing and component orientation. Test the sensor response by blocking and unblocking the IR beam. (40 marks)

PLC Session 16

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to

- a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
- a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).
4. Plan the week's key assessment with your app
- a. The key assessment for the week is **individual research**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the research (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
- a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).

Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes	Enactment
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6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
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5 minutes	Reflection
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7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 8 Review

1. Were learners able to convert a given schematic diagram into a breadboard circuit implementation?
2. Can learners proceed to assemble components on the solderless breadboard?
3. Can learners test the circuit?
4. Would learners be able to convert a given electronic circuit into a PCB?
5. Would learners be able to produce a functioning PCB board using CAD and CAM tools?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 15

FOCAL AREA 1

Question 1

Assessment Criteria	Description	Marks
1. Circuit Design and Schematic Accuracy	Schematic includes IR LED, photodiode, resistor(s), transistor/comparator (if used), power supply	4
2. Correct Component Footprints Assigned	Appropriate footprints selected in CAD for IR LED, photodiode, and other components	4
3. Component Placement and Orientation on PCB	IR LED and photodiode correctly oriented and spaced for optimal detection	5
4. PCB Layout Quality	Compact, logical, and clean trace routing; clear input/output connections	5
5. Design Rule Check (DRC) Compliance	No DRC violations; clearances, trace widths, and pad sizes meet standards	3
6. Gerber File Generation	All necessary Gerber layers (copper, silkscreen, drill, etc.) correctly generated	2
7. PCB Fabrication (Milling/CAM Tool Use)	Board accurately fabricated with clean traces and correctly drilled holes	4
8. Component Soldering and Assembly	Components properly placed and neatly soldered with no cold joints or shorts	4
9. Functional Testing (Blocking/Unblocking IR Beam)	Sensor detects object presence reliably; output signal changes when IR beam is interrupted	6
10. Safety Practices and Neatness	Proper use of PPE, soldering precautions, and organised workspace	3

Question 2

Assessment Criteria	Description	Marks
1. Circuit Understanding and Schematic Setup	Correct schematic with mic preamp stage (using transistor), 555 timer configured as monostable	4
2. Component Identification and Selection	Appropriate components selected: mic, NPN transistor, resistors, capacitors, 555 timer, LED	3
3. Breadboard/PCB Layout Planning	Clear, logical arrangement of components on breadboard or PCB	4
4. Correct Wiring and Connections	All components connected properly according to the schematic (no loose or reversed connections)	5
5. Signal Conditioning from Microphone	Microphone stage provides adequate signal to trigger 555 timer reliably	4
6. LED Switching Functionality	LED turns ON briefly upon detecting a clap or sound	6

7. Timing Configuration (Monostable Mode)	LED remains on for appropriate duration (configured via R and C values in 555 timer circuit)	3
8. Soldering/Assembly Quality (if applicable)	Neat solder joints or a well organised breadboard layout; no shorts, all components secure	3
9. Testing and Troubleshooting	Effectively tests the system and troubleshoots if it fails initially	4
10. Safe and Professional Working Practice	Use of PPE, proper handling of tools, organised workspace	4

Question 3

Assessment Criteria	Description	Marks
1. Circuit Design and Schematic Accuracy	Correct schematic includes IR LED, photodiode or IR sensor module, transistor, and buzzer	4
2. Component Identification and Selection	Correct components chosen for sensing (IR pair), switching (NPN transistor), and alert (buzzer)	3
3. Sensor Alignment and Mounting	Proper alignment of IR LED and receiver to ensure uninterrupted beam path	4
4. Transistor Switch Configuration	Transistor correctly wired in common-emitter mode to drive buzzer when sensor is triggered	5
5. Circuit Assembly Quality (Breadboard/PCB)	Neat wiring, no loose connections or short circuits; correct component polarity is observed	4
6. Alarm System	Buzzer activates only when IR beam is interrupted	6
7. Power Supply and Circuit Stability	Stable operation with chosen voltage source; circuit does not false triggering	4
8. Testing and Troubleshooting	Tests system response effectively; corrects errors where necessary	4
9. Safety and Neatness	Proper handling of tools and components, use of PPE, and clean workspace	3
10. Documentation (if applicable)	Basic report or explanation of working principle and component roles	3

WEEK 16

FOCAL AREA 2

Question 1

Assessment Criteria	Description	Marks
1. Accurate Interpretation of the Schematic	Identifies 3 components correctly (7805, capacitors, input/output pins, etc.)	3
2. Component Footprint Selection in CAD	Correct footprints chosen for 3 components (e.g., TO-220 for 7805)	3

3. PCB Layout Design	Proper component placement, logical flow, and routing of traces	3
4. Rule Compliance (DRC/ERC checks)	No design rule violations; adequate clearances and pad sizes	2
5. Gerber File Generation	Complete set of Gerber files correctly generated (copper layers, drill, etc.)	2
6. PCB Fabrication Using CAM Tools or Milling Machine	Clean board edges, accurate drilling and etching/milling	4
7. Component Soldering and Assembly	All components correctly oriented and neatly soldered	4
8. Voltage Output Testing	5V DC output correctly measured and stable under no-load/light-load condition	4
9. Documentation and Labelling	Clear silkscreen, proper labelling of input/output terminals	2
10. Safety and Handling Practices	Wears PPE, handles tools safely, avoids shorts and heat damage during soldering	1

Question 2

Assessment Criteria	Description	Marks
1. Schematic Interpretation	Identification of thermistor, comparator/trigger IC (e.g., op-amp or transistor), relay, fan	4
2. Component Footprint Assignment in CAD Tool	4 components assigned appropriate PCB footprints (relay socket, TO-92 for thermistor, etc.)	4
3. PCB Layout Design	Components logically placed, clean routing, thermal considerations observed (e.g., relay isolation)	5
4. Design Rule Compliance (DRC/ERC)	Passes design rule checks (trace width, clearance, pad size, etc.)	3
5. Gerber File Generation	All required files (top layer, drill, silkscreen, etc.) generated correctly	2
6. Fabrication of PCB (Milling/CAM Tool)	Clean PCB with accurate dimensions, holes, and trace quality	4
7. Soldering and Assembly	All components correctly placed and neatly soldered; no solder bridges or cold joints	5
8. Functional Testing of Circuit	Fan turns ON when heat is applied and OFF when cooled; threshold point correctly set	6
9. Troubleshooting (if applicable)	Student correctly identifies and resolves minor faults (reversed thermistor, loose relay, etc.)	3
10. Safety & Handling	Wears PPE, handles soldering iron and tools safely, avoids short-circuit hazards	2

Question 3

Assessment Criteria	Description	Marks
1. Circuit Design and Schematic Accuracy	Schematic includes IR LED, photodiode, resistor(s), transistor/comparator (if used), power supply	4
2. Correct Component Footprints Assigned	Appropriate footprints selected in CAD for IR LED, photodiode, and other components	4
3. Component Placement and Orientation on PCB	IR LED and photodiode correctly oriented and spaced for optimal detection	5
4. PCB Layout Quality	Compact, logical, and clean trace routing; clear input/output connections	5
5. Design Rule Check (DRC) Compliance	No DRC violations; clearances, trace widths, and pad sizes meet standards	3
6. Gerber File Generation	All necessary Gerber layers (copper, silkscreen, drill, etc.) correctly generated	2
7. PCB Fabrication (Milling/CAM Tool Use)	Board accurately fabricated with clean traces and correctly drilled holes	4
8. Component Soldering and Assembly	Components properly placed and neatly soldered with no cold joints or shorts	4
9. Functional Testing (Blocking/Unblocking IR Beam)	Sensor detects object presence reliably; output signal changes when IR beam is interrupted	6
10. Safety Practices and Neatness	Proper use of PPE, soldering precautions, and organised workspace	3

SECTION 9: AUTOMATION AND EMBEDDED SYSTEMS

STRAND: AUTOMATION AND EMBEDDED SYSTEMS

Sub-Strand 1: Automation Technologies

Sub-Strand 2: Embedded Systems

WEEK 17

Learning Outcomes: *Explain the roles of motors, fluid power systems, sensors and actuators, switches and relays in industrial automated systems.*

Content Standards: Demonstrate ability to characterise general industrial automation control devices and implement simple automated systems.

WEEK 18

Learning Outcomes: *Design simple industrial automation systems using programmable logic controllers (PLC).*

Content Standards: Demonstrate the ability to characterise general industrial automation control devices and implement simple automated systems.

WEEK 19

Learning Outcomes: *Design embedded systems to interface with sensors such as Humidity, Proximity, IR Motion, Accelerometer, Sound, Light Distance, Pressure, thermal and actuators such as motors, buzzers.*

Content Standards: Demonstrate the ability to design embedded systems to work with sensors and actuators.

INTRODUCTION AND SECTION SUMMARY

This section exposes learners to the characteristics of general industrial automation control devices and the implementation of simple automated systems. Industrial automation systems are used to control machines and processes with minimal human intervention by using mechanical, electrical, and electronic components. Learners will understand that Programmable Logic Controllers (PLC) is a rugged, digital computer used for industrial automation to monitor inputs, make logic-based decisions, and control outputs. An embedded system is a combination

of hardware and software designed to perform a specific, dedicated function within a larger system. Skills learners need to develop in this section include reading and interpreting circuit diagrams or control diagrams, wire and test basic automation circuits, identify and use common automation devices, think logically and troubleshoot errors and apply safety procedures during implementation

The weeks and the indicators covered by the section are:

- Week 17: 1. Design and implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements.
- Week 18: 2. Learners should be able to programme PLCs and use them in combination with other components to implement simple industrial automation systems based on design criteria.
- Week 19: 3. Learners should be able to design embedded systems to interface with sensors and actuators given design objectives.

Recap

Year 1	Week 23: Discuss the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations for specific scenarios.
Year 2	Week 22: Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors Week 24: 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.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Pedagogical strategies suggested for this section are field trip, guest speaker and project-based learning. Field trips help learners see automation systems in real-life settings, expose learners to working industrial environments, help learners observe how motors, sensors, relays, and fluid power systems are applied in real-time automation. Invite a guest such as an automation engineer, or technician to share their experiences. The focus is to bring real-world relevance and technical depth to learners. Let learners ask questions and explore career pathways. Project-based learning helps learners to develop skills in problem solving and system design and construction. Learners develop skills in integrating different components into one working system, how to think critically and apply their knowledge to solve real problems and how to collaborate and communicate effectively.

ASSESSMENT SUMMARY

Teachers should use assessment strategies that encourage critical thinking, creativity, teamwork, and practical application to effectively teach design and implementation of simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements). These assessments serve both as evaluation tools and teaching tools; helping learners understand the real-life industrial environments. Some suggested strategies are case study, presentation, and research. For case studies, teachers should provide a real-world industrial scenario then ask learners to analyse the design requirements, select appropriate components and propose a working design. Teachers may

score for learners' ability to interpret and meet design requirements, technical accuracy, problem-solving and decision-making and integration of multiple system components. In presentations, teachers may score clarity and coherence, justification of engineering choices, visual presentation (e.g., use of diagrams and simulations) and learners' ability to respond to questions and defend the design. Score for research depth and relevance, critical thinking and analysis, synthesis of information from diverse sources, and application to practical design contexts. For instance:

Indicators	DOK Level	Assessment Strategy and/or Mode
Design and implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements.	Level 4	Project
Learners should be able to programme PLCs and use them in combination with other components to implement simple industrial automation systems based on design criteria.	Level 4	Practical
Learners should be able to design embedded systems to interface with sensors and actuators given design objectives	Level 4	Research

WEEK 17

Learning Indicator: *Design and implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements*

FOCAL AREA 1: DESIGN AND IMPLEMENT SIMPLE INDUSTRIAL AUTOMATED SYSTEMS USING A COMBINATION OF MOTORS, FLUID POWER SYSTEMS, SENSORS AND ACTUATORS, SWITCHES AND RELAYS BASED ON DESIGN REQUIREMENTS

Refer back Year 2, Week 22 (Design and build simple automation systems using basic electronic components such as transistors, resistors, capacitors, relays, LEDs, LDRs, motors)

Industrial automation systems are used to control machines and processes with minimal human intervention by using mechanical, electrical, and electronic components.

1. Core Components

- a. Motors (e.g., AC or DC motors, stepper motors)
- b. Fluid power systems (Hydraulic and Pneumatic actuators)
- c. Sensors and Actuators (proximity sensors, temperature sensors, solenoids)
- d. Switches and Relays (limit switches, contactors, control relays)
- e. Controllers (typically PLCs or microcontrollers such as Arduino based microcontrollers)

2. System Design Approach

- a. Define the Design Requirements
 - i. Functional Requirements (e.g., move product A from point X to Y)
 - ii. Safety Requirements (e.g., emergency stop, interlocks)
 - iii. Energy Efficiency and Control Strategy
- b. Select the Components Based on the Application
 - i. Motor Type: Speed, torque, and load requirements
 - ii. Sensors: Type of feedback needed (position, presence, temperature)
 - iii. Actuators: Linear or rotary, electric or fluid powered
 - iv. Switches or Relays: Manual or automatic control logic
 - v. Control System: PLC, relay logic, or embedded controller

3. Component Overview and Selection

- a. Motors
 - i. DC motors: Used in small conveyors or robotic arms
 - ii. AC motors: Used in industrial fans, pumps, and conveyor belts

- iii. Stepper motors: Used for precision positioning such as in CNC machines

b. Fluid Power Systems

- i. Pneumatics: Used for fast, repetitive movements such as in packaging lines)
- ii. Hydraulics: Used for high force application such as presses.

c. Sensors and Actuators

- i. Proximity Sensors: Detect the presence of objects, including inductive and capacitive types.
- ii. Temperature Sensors: Used in ovens and heaters
- iii. Limit Switches: Indicate end positions
- iv. Solenoid Valves: Control fluid flow
- v. Linear Actuators: Used for push or pull operations

d. Switches and Relays

- i. Manual Switches: Provide operator control
- ii. Contactors: Used for switching motors
- iii. Relays: Used for logic implementation, and for isolating high and low voltage circuits

4. Design and Implementation Process

a. Circuit Diagrams or System Diagrams

- i. Use software like Proteus, AutoCAD Electrical, or FluidSIM
- ii. Show connections between power supply, control unit, input devices (sensors), and output devices (motors, actuators)

b. Control Logic

- i. Relay Logic or Ladder Diagram for PLC
- ii. Implement start-stop, interlocking, sequencing

c. Build the Prototype

- i. Connect all components on a panel or breadboard
- ii. Ensure proper wiring, labelling, and safety precautions

d. Test and Troubleshoot

- i. Verify sensor inputs trigger correct outputs
- ii. Test motor direction, speed, actuator position
- iii. Implement fail-safes and interlocks

Real-World Examples

Example 1: Automated Bottle Filling System

Design Requirements

- i. Detect when a bottle is in position
- ii. Fill the bottle using a fluid pump
- iii. Stop after a certain volume
- iv. Move the filled bottle using a conveyor

Components Used

- i. IR Sensor to detect the bottle
- ii. Solenoid Valve to control fluid flow
- iii. DC Motor Conveyor controlled through a relay
- iv. Limit Switch to detect bottle exit
- v. Arduino or PLC to control sequence

Implementation

- i. IR sensor triggers filling when the bottle is detected
- ii. The valve opens for fixed time or based on flow sensor
- iii. After filling, the conveyor moves the bottle to next station

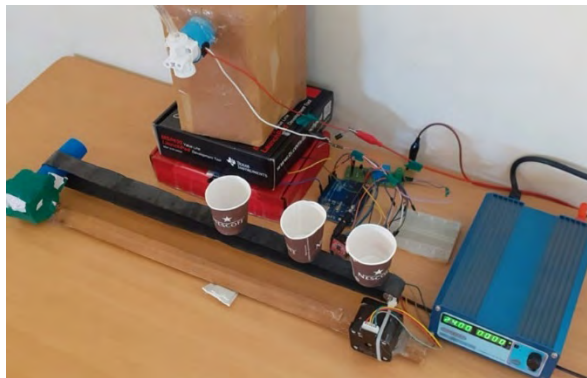


Figure 48: Automated Bottle Filling System

Example 2: Automated Sorting System

Design Requirements

- i. Sort metal and plastic items
- ii. Move items on a belt
- iii. Divert to separate bins

Components Used

- i. Inductive Sensor (metal detection)
- ii. Pneumatic Pusher or Servo Motor
- iii. DC Conveyor Motor
- iv. PLC or Arduino

Implementation

- i. The conveyor brings item to the detection point

- ii. Sensor detects if metal
- iii. Actuator pushes item into appropriate bin
- iv. System loops continuously

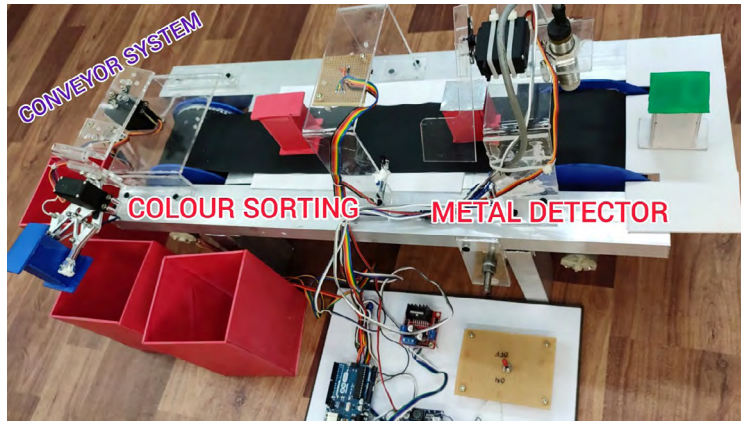


Figure 49: Automated Sorting System

Learning Tasks

1. Guide learners to design simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements.
2. Help learners to be able to implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements

Pedagogical Exemplars

Talk for Learning: The facilitator provides basic theory in the area of motor starters and control circuits, contactors and relays, switches, fluid power systems, sensors and PLCs and how they are integrated for industrial control. Learners are also introduced to the ladder programming language for PLCs.

Experiential Learning

Field Trip: Learners take a trip to a factory or site with a PLC-based industrial automation system in place and observe the roles of the various components, such as motors, sensors, contactors, relays, and fluid power systems in the respective installation, taking note of the engineering diagrams and other documentation for the site. Learners could also tour the industrial automation laboratory for a similar experience.

Project-based hands-on sessions: Learners are taken through simple concepts of industrial automation using simple PLC-based projects such as an Automated door opening system, an Automated room light controller with a bi-directional visitor counter, an Elevator controller, a Water pumping controller, etc. The learners begin with connecting components within the respective projects according to diagrams and downloading programmes onto the PLCs interfaced with the hardware for control. The facilitator explains the function of each component and code (in the case of ladder programming) in the respective project and leaves learners to further explore by manipulating components and observing system behaviour. In some projects, the facilitator may start with the simplest version of the implementation and move through the

modifications systematically with the learners to gradually introduce more complex functions or features.

Guest Speaker: Inviting automation engineers to share experiences with learners will enhance the learning experience and make it more relevant.

Self-Directed Learning: Explore online resources: There are many online resources available that can help Learners learn more about PLC programming and automation. Some good options include online tutorials, instructional videos, and forums where learners can ask questions and get feedback from experts. Learners acquire additional knowledge and experiences of PLC-based industrial control and present individual reports.

Project-based Learning: Incorporate hands-on projects that allow learners to apply their CAD skills to real-world design challenges. This can help them develop their problem-solving skills and better understand the design process.

Collaborative Learning: Learners work in groups to design, implement, test and document simple PLC-based automation systems. Each group should assign specific roles to members to address the challenge. Roles may, for example, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop teamwork and collaborative skills.

Key Assessment Level 4: Project

1. Design a simple industrial automated system for filling bottles on a production line. Your design must incorporate motors, fluid power systems, sensors, actuators, switches, and relays. Justify the choice of each component and explain how the system functions to meet the design requirements.
2. Evaluate the advantages and disadvantages of using a combination of electric motors and pneumatic actuators in a simple automated lifting and sorting system. Include how sensors and relays contribute to control and system safety.
3. Propose an innovative automated solution for a simple packaging task involving item detection, placement, and box sealing. Your system must include sensors, switches, motors, relays, and actuators. Describe how each component works in sequence to complete the task.

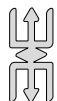
PLC Session 17

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have about week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to

- a. suggest the suitable method for teaching the week's concepts to learners with diverse backgrounds.
- b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
- c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

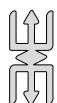
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **project**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the project (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

- b.** After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes	Reflection
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- 7.** Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
- 8.** Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
- 9.** Remember to
 - a.** transfer your chats into your learning planner template.
 - b.** read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c.** integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 18

Learning Indicator: Learners should be able to programme PLCs and use them in combination with other components to implement simple industrial automation systems based on design criteria

FOCAL AREA 2: LEARNERS SHOULD BE ABLE TO PROGRAMME PLCS AND USE THEM IN COMBINATION WITH OTHER COMPONENTS TO IMPLEMENT SIMPLE INDUSTRIAL AUTOMATION SYSTEMS BASED ON DESIGN CRITERIA

Refer back to Year 1 Week 23 (Discuss the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations for specific scenarios)

A Programmable Logic Controller (PLC) is a rugged, digital computer used for industrial automation to monitor inputs, make logic-based decisions, and control outputs.

1. Basic Components

- a. CPU (processes logic)
- b. Input module (e.g., sensors, switches)
- c. Output module (e.g., motors, relays)
- d. Power supply
- e. Programming interface (USB or Ethernet)

2. Basics of PLC Programming

- a. Programming Language: Ladder Logic (resembles relay logic diagrams)
- b. Common Instructions:
 - i. Contacts: Normally Open (NO), Normally Closed (NC)
 - ii. Coils: Output actuators
 - iii. Timers and Counters: TON, TOF, CTU
 - iv. Set or reset: Latching or unlatching
 - v. Compare: Greater than or less than
 - vi. Branching and Sequencing

3. a. Interfacing PLCs with Components

Input Components	Output Components
Push buttons	Motors (AC and DC)
Limit switches	Indicator lamps
Proximity sensors	Solenoids
IR sensors	Relays and contactors

Temperature/humidity sensors	Buzzers
------------------------------	---------

b. Design and Implementation Process

Step-by-Step Approach:

- i. Understand the Design Criteria
 - What process needs automation?
 - What are the conditions to control?
- ii. Identify Inputs or Outputs
 - Inputs (e.g., start button, sensor trigger)
 - Outputs (e.g., motor on, lamp on)
- iii. Design the Control Logic
 - Draw a process flow diagram
 - Write logic using ladder diagrams
- iv. Implement the System
 - Program the PLC
 - Connect the components
 - Test and debug
- v. Evaluate and Refine
 - Check for logic errors or sensor malfunctions
 - Optimise response time and safety

Example 1: PLC-Controlled Conveyor Belt System

Problem: Automate a conveyor system that runs when a start button is pressed and stops when an object is detected at the end of the belt.

Components

- i. PLC (Siemens LOGO! or Allen-Bradley MicroLogix)
- ii. Start and Stop push buttons
- iii. Inductive proximity sensor (at end of the belt)
- iv. Motor connected to output through a relay

Logic Summary

- i. Start button sets a latch (turns motor ON)
- ii. Proximity sensor at the end resets the latch (turns motor OFF)

Ladder Logic Overview

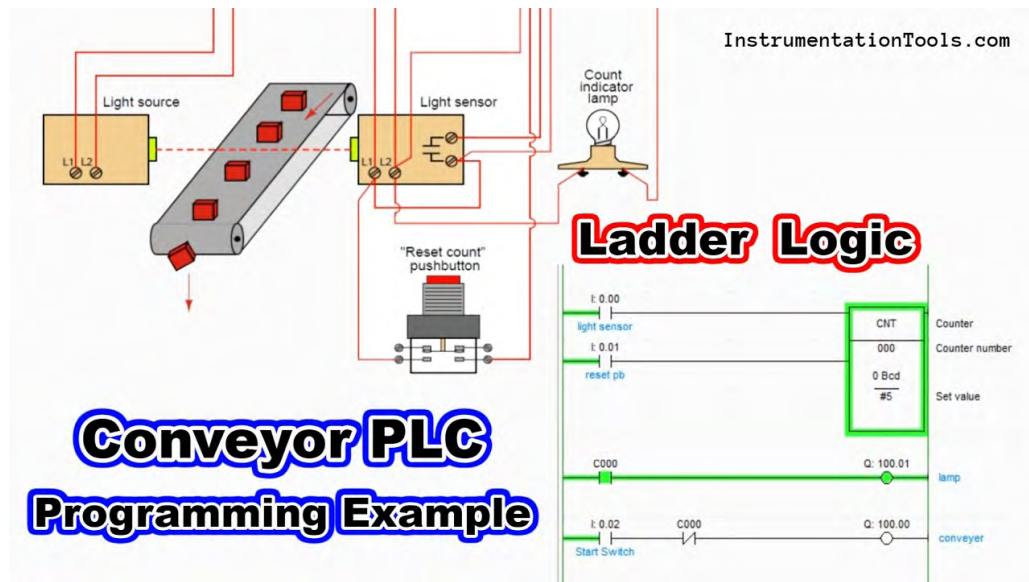


Figure 50: PLC Controlled Conveyor Belt System.

Example 2: Automated Water Tank Filling System

Problem: Automatically fill a water tank. When the water drops below the low-level sensor, the pump should start. When it reaches the high-level sensor, the pump should stop.

Components

- i. PLC with analogue/digital inputs
- ii. Two float switches (Low and High)
- iii. Water pump connected through a relay

Control Logic

- i. If Low Sensor is OFF (empty) → Turn ON pump
- ii. If High Sensor is ON (full) → Turn OFF pump

Ladder Logic Overview

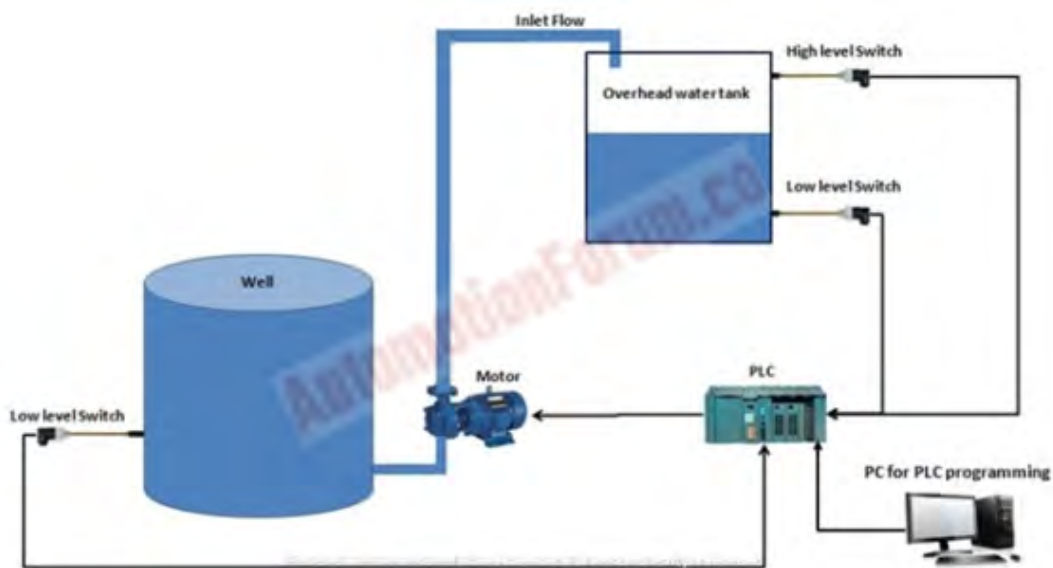


Figure 51: Automated Water Tank Filling System

Example 3: PLC-Based Traffic Light System

Problem: Automate a three-light (Red, Yellow, Green) traffic signal at a junction.

Components

- i. 3 Indicator lamps (Red, Yellow, Green)
- ii. PLC with timer functions

Control Sequence

1. Green ON (10 sec)
2. Yellow ON (3 sec)
3. Red ON (10 sec)

Ladder Logic

- i. Use timers: TON and RTO to create delays
- ii. Sequence logic using Set or Reset instructions or counters

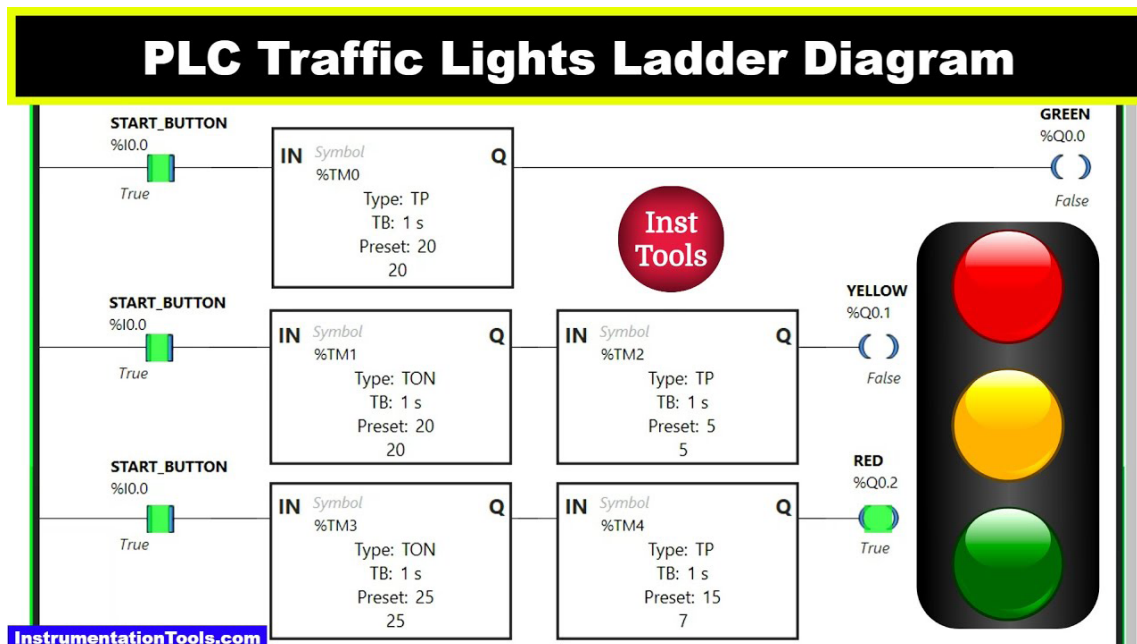


Figure 52: PLC Traffic Lights Ladder diagram

Learning Tasks

1. Guide learners to programme PLCs and use them in combination with other components.
2. Guide learners to implement simple industrial automation systems based on design criteria.

Pedagogical Exemplars

Talk for Learning: The facilitator provides basic theory in the area of motor starters and control circuits, contactors and relays, switches, fluid power systems, sensors and PLCs and

how they are integrated for industrial control. Learners are also introduced to the ladder programming language for PLCs.

Experiential Learning:

Field Trip: Learners take a trip to a factory or site with a PLC-based industrial automation system in place and observe the roles of the various components, such as motors, sensors, contactors, relays, and fluid power systems in the installation, taking note of the engineering diagrams and other documentation for the site. Learners could also tour the industrial automation laboratory for a similar experience.

Project-based hands-on sessions: Learners are taken through simple concepts of industrial automation using simple PLC-based projects such as an Automated door opening system, an Automated room light controller with a bi-directional visitor counter, an Elevator controller, a Water pumping controller, etc. The learners begin with connecting components within the respective projects according to diagrams and downloading programmes to the PLCs interfaced with the hardware for control. The facilitator explains the function of each component and the programme code (in the case of ladder programming) in the respective project and leaves learners to further explore by manipulating components and observing system behaviour. In some projects, the facilitator may start with the simplest version of the implementation and move through the modifications systematically with the learners to gradually introduce more complex functions or features.

Guest Speaker: Inviting automation engineers to share experiences with learners will enhance the learning experience and make it more relevant.

Self-Directed Learning: Explore online resources: There are many online resources available that can help Learners understand more about PLC programming and automation. Some good options include online tutorials, instructional videos, and forums where learners can ask questions and get feedback from experts. Learners acquire additional knowledge and experiences of PLC-based industrial control and present individual reports.

Project-based Experiential Learning: Incorporate hands-on projects that allow learners to apply their CAD skills to real-world design challenges. This can help them develop their problem-solving skills and better understand the design process.

Collaborative Learning: Learners work in groups to design, implement, test and document simple PLC-based automation systems. Each group should assign a specific roles to members towards the solution of the challenge. Roles may, for example, be modelled after typical design and production teams in the industry to give them the relevant exposure and develop teamwork and collaborative skills.

Key Assessment: Practice Paper 2

1. Design a simple industrial automated system for controlling a conveyor belt with an object detection feature. The system should stop the belt when an object is detected, count the number of objects, and restart after a set delay. Describe how a PLC can be programmed for this task and how it integrates with sensors, actuators, and timers. Justify your choice of components and program structure.
2. Evaluate the integration of PLCs with industrial components such as relays, limit switches, proximity sensors, and solenoids in a small-scale packaging system. How do the components interact through PLC control logic to automate the process?

3. A PLC-controlled automatic gate system occasionally fails to open or close completely. Analyse possible causes related to programming and hardware components. Propose improvements in both the PLC programme logic and hardware configuration to ensure reliable performance.
4. Propose an innovative automated solution using a PLC to manage the filling and capping process in a small beverage production line. Detail the program logic, component selection, and system operation. Justify how your solution improves productivity and consistency.

Hint



Conduct **Practice Paper 2**. It should cover contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section to guide you. Learners' papers should be marked immediately and scores entered into the SAP.

TABLE OF SPECIFICATION FOR THE PAPER 1

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

			DoK (Number of questions)				
	Sub-strand	Learning Indicators	L1	L2	L3	L4	Total
1.1	Engineering in Society	Outline the common skill set required by the respective engineering disciplines.	1				1
		Explain systematic investigation and its relevance in engineering professional practice		1			1
		Define the sustainable development goals		1			1
		Explain the processes for systematic investigation			1		1
1.2	Health and Safety in Engineering Practice	Apply the risk assessment matrix to a given risk scenario.	1				1
		Demonstrate the use of both hand and power tools according to proper health and safety protocols.		1			1
		Administer first aid to victims of common workplace accidents			1		1
		Explain the types of risk assessment		1			1

1.3	Ethics and Professional Practice	Distinguish between ethical and unethical behaviours in engineering practice.	1				1
		Explain professional behaviour		1			1
		Determine whether or not a conduct violates a code of ethics.			1		1
		Outline the desired attributes of an engineer and explain how those attributes could be developed	1				1
2.1	Circuit and machines	Classify circuit elements into passive and active elements	1				1
		Compute power in DC and single-phase AC circuits.			1		1
		Explain the uses of transformers, DC & AC motors, DC and AC generators, and special electrical machines (i.e., stepper motors, servo motors, etc.)			1		1
		Operate (connect, control, and disconnect) electrical machines.		1			1
2.2	Renewable energy systems	Identify the sources of renewable energy.	1				1
		Explain how electricity is generated from water, wind, solar, biomass, and biogas energy sources		1			1
		Operate and maintain simple photovoltaic and solar thermal energy systems.			1		1
		Design and install simple wind and bioenergy systems.			1		1
2.3	Energy efficiency and conservation	Compute and interpret energy consumption from nameplates		1			1
		Perform a walk-through energy audit of a facility and identify sources of energy wastage		1			1
		Explain the application areas for the various devices used for energy conservation.		1			1
		Identify appropriate energy-saving tips for thermal equipment.	1				1

3.1	<i>Engineering Design</i>	Document solution requirements for a given problem.			1		1
		Formulate research objectives for a given problem			1		1
		Identify the various elements within the engineering design process	1				1
		Design a working prototype based on design requirements.			1		1
3.2	<i>Rapid Prototyping</i>	Set up, configure and utilise a 3D printer to produce CAD prototype models		1			1
		Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit	1				1
		Apply CAD tools to create models		1			1
		Convert a given electronic circuit into a PCB and produce a functioning PCB board using CAD and CAM tools.		1			1
4.1	<i>Automation Technologies</i>	Learners should be able to programme PLCs and use them in combination with other components to implement simple industrial automation systems based on design criteria			1		1
		Identify basic automation components and materials and their respective functions or roles in the automation industry	1				1
		Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc.			1		1
		Interpret and connect system components according to technical drawings and vice versa		1			1

4.2	Embedded Systems	Discuss the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations for specific scenarios	1				1
		Identify examples of embedded systems in the community.	1				1
		Specify use cases for RAM/ROM		1			1
		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		1			1
	TOTAL		$\frac{12}{40} \times 100$	$\frac{16}{40} \times 100$	$\frac{12}{40} \times 100$		40
			30	40	30		

ESSAY

TABLE OF SPECIFICATION FOR THE PAPER 2

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

			DoK (Number of questions)				
	Sub-strand	Learning Indicator	L1	L2	L3	L4	Total
1.	a. Engineering in Society	Explain the unique knowledge requirement of the disciplines – careers	1				1
		Explain the role of the SDGs in societal development		1			1
	b. Health and Safety in Engineering Practice	Explain the procedure for risk assessment		1			1
		Outline housekeeping rules at construction sites, manufacturing/production areas, and offices.		1			1
	c. Ethics and Professional Practice	Determine whether or not a conduct violates a code of ethics			1		1
		Distinguish between ethical and unethical behaviours in engineering practice	1				1
2.	Circuit and machines	Identify various electrical machines.	1				1
		Explain the functions of the basic components of analogue electronic circuits		1			1

3.	Renewable energy systems	Identify the basic components of photovoltaic and solar thermal systems		1			1
		Explain the functions of the basic components of wind and bioenergy systems			1		1
4.	Energy efficiency and conservation	Identify instruments used for measuring electrical and non-electrical quantities in renewable energy systems	1				1
		Explain the application areas for the various devices used for energy conservation.		1			1
5.	<i>Engineering Design and Prototyping</i>	Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution.			1		1
		Develop relevant research questions for a given problem			1		1
6.	<i>Automation Technologies and Embedded Systems</i>	Identify basic automation components and materials and their respective functions or roles in the automation industry	1				1
		Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc.			1		1
	TOTAL		$\frac{5}{16} \times 100$	$\frac{6}{16} \times 100$	$\frac{5}{16} \times 100$		16
			31.25	37.5	31.25		

PRACTICAL**TABLE OF SPECIFICATION FOR THE PAPER 3**

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

			DoK (Number of questions)				
			L1	L2	L3	L4	
1.	Circuit and machines	Identify and determine values of basic elements of DC and AC electric circuits (resistors, inductors, capacitors, diodes, transistors, transformers, dc and ac sources) using instruments, colour codes and datasheets					
		Sketch the circuit symbols of DC and AC circuit elements.					
		Use a software tool to simulate simple circuits to derive current, voltage, and power in DC and AC circuits.					
		Identify basic components of analogue electronic circuits (resistors, inductors, capacitors, diodes, transistors, transformers and op-amps)					
		Use CAD tools for the design and analysis of simple analogue electronic circuits.					
2.	Engineering Design and Prototyping	Develop relevant research questions for a given problem.					
		Formulate research objectives for a given problem					
		Analyse critically a set of possible solutions to a given problem and justify the choice of an optimal solution.					
		Design a working prototype based on design requirements					
		Test and validate a prototype					
		Analyse failures associated with prototypes and provide appropriate remedies					
		Convert a given schematic diagram into a breadboard circuit implementation and proceed to assemble components on the solderless breadboard and test the circuit.					

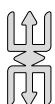
3.	<i>Automation Technologies and Embedded Systems</i>	Identify basic automation components and materials and their respective functions or roles in the automation industry.					
		Design and build simple automation systems using basic electronic components like transistors, resistors, capacitors, relays, LEDs, LDRs, motors, etc.					
		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					
		Learners should be able to design embedded systems to interface with sensors and actuators given design objectives					
	Total		1				1

PLC Session 18

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand.
 - b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

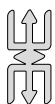
4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP).

- a. The key assessment for the week is **practice paper 2**. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the practice paper (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through the problem individually for 3–4 minutes
 - c. the group then works through it together the problem, step by step
 - d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).

**Note**

- This part is not 'How do I teach this?' but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.

- b.** read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
- c.** integrate National Values, GESI, SEL, and 21st-century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 19

Learning Indicator: 3. Learners should be able to design embedded systems to interface with sensors and actuators given design objectives

FOCAL AREA 3: LEARNERS SHOULD BE ABLE TO DESIGN EMBEDDED SYSTEMS TO INTERFACE WITH SENSORS AND ACTUATORS GIVEN DESIGN OBJECTIVES

Refer back to Year 2 Week 24 (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)

An embedded system is a combination of hardware and software designed to perform a specific, dedicated function within a larger system.

- a. Controlled by a microcontroller (e.g., Arduino, STM32, Raspberry Pi Pico)
- b. Interacts with the physical world using:
 - i. Sensors (inputs) to detect conditions
 - ii. Actuators (outputs) to perform actions

1. Design Process Overview

Step	Description
a. Define the Problem	Understand the need or task (e.g., automate lighting based on room occupancy).
b. Select Components	Choose appropriate sensors, actuators, and a microcontroller.
c. Design the Circuit	Create schematics to connect all components correctly.
d. Write the Code	Program the microcontroller to process inputs and control outputs.
e. Build and Test	Assemble the system and verify it works as intended.
f. Refine	Troubleshoot and improve performance.

2. Key Components in Embedded Design

- a. Microcontrollers (Processing Unit)

Examples: Arduino Uno, ESP32, Raspberry Pi Pico

Role: Runs software to read inputs and control outputs

b. Sensors (Inputs)

Sensors gather data from the environment.

Sensor	Measures	Signal Type
LDR	Light	Analogue
DHT11 or DHT22	Temp and Humidity	Digital
Ultrasonic Sensor	Distance	Digital
IR Sensor	Motion or obstacle	Digital
Soil Moisture	Wetness	Analog

c. Actuators (Outputs)

Devices that perform actions based on microcontroller commands.

Actuator	Function
Servo Motor	Precise angle control
DC Motor	Rotational movement
Relay	Switch AC or DC loads
LED	Light signal
Buzzer	Audio alarm

3. Interfacing Sensors and Actuators**a. Hardware Interface**

- i. Sensors → Microcontroller Input Pins
- ii. Actuators → Microcontroller Output Pins (may need transistors or relays for high current devices)
- iii. Power supply must match voltage or current requirements

b. Programming Logic

Using Arduino-style pseudocode

Code

```
int sensorValue = analogRead(A0);
if (sensorValue < threshold) {digitalWrite(LED, HIGH); // turn the actuator on} else
{digitalWrite(LED,LOW); // turn the actuator off}
```

4. Programming Considerations

- i. Use libraries such as Servo.h, DHT.h, NewPing.h when needed
- ii. Handle sensor noise with averaging or hysteresis
- iii. Use timers to delay actions (e.g., millis() instead of delay() for non-blocking code)
- iv. Modularise code into functions

5. Design Considerations

Factor	Description
Cost	Minimise unnecessary components
Energy Efficiency	Use sleep modes or low-power devices
User Interface	Add LEDs, LCDs, or buzzers for feedback
Environment	Consider waterproofing or casing for outdoor use
Scalability	Allow for easy updates or expansion

6. Assessment Ideas

Task	Criteria
Mini project	Working embedded system with clear function
Circuit diagram	Accurate wiring with correct pin usage
Code quality	Clean logic, comments, functional outcome
Troubleshooting	Ability to identify and fix issues
Design report	Description of objective, design choices, and testing results

7. Tools for Simulation and Prototyping

Tool	Use
Tinkercad Circuits	Online simulation of Arduino circuits
Fritzing	Design circuit diagrams
Proteus	Advanced simulation with real-time feedback
Arduino IDE	Programming environment

Example Projects

Example 1: Automatic Room Light System

Design Objective: Light turns ON when someone enters the room and OFF after a delay.

Components

- i. PIR Motion Sensor
- ii. Relay Module
- iii. Light Bulb or LED
- iv. Arduino Uno

Logic

- i. Sensor detects motion → Arduino activates relay → light turns ON

- ii. After no motion for a set time → light turns OFF

Automatic Room Light Controller with Bidirectional Visitor Counter

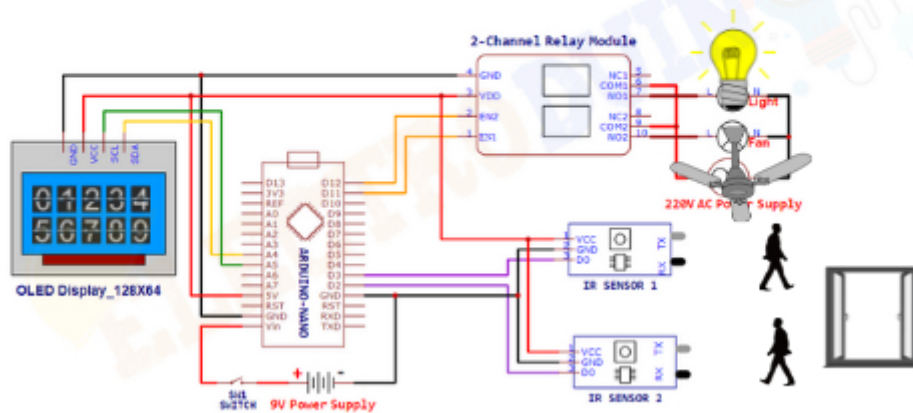


Figure 53: Automatic room light system

Example 2: Smart Plant Watering System

Design Objective: Water the plant only when the soil is dry.

Components

- i. Soil Moisture Sensor
- ii. Relay Module
- iii. Water Pump
- iv. Arduino Uno

Logic

- i. If soil moisture < threshold → activate relay → pump ON
- ii. Else → pump OFF



Figure 54: Smart Plant Watering System

Example 3: Fire or Gas Leak Alarm System

Design Objective: Trigger a buzzer and alert when fire or gas is detected.

Components

- i. Flame or MQ2 Gas Sensor
- ii. Buzzer
- iii. Arduino Uno

Logic

If sensor signal exceeds safe level → buzzer ON

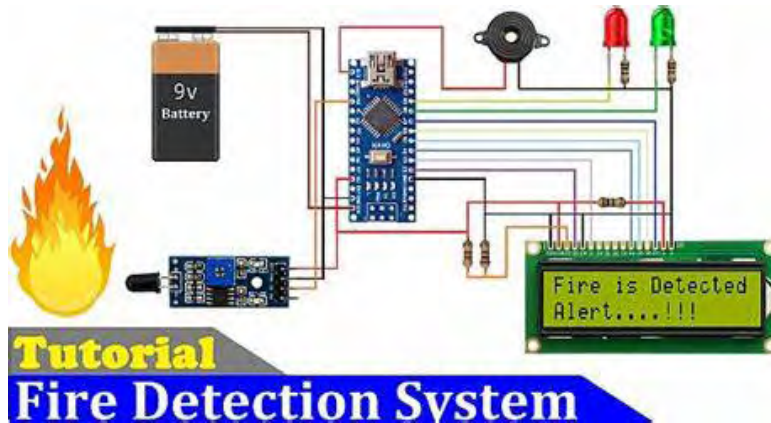


Figure 55: Fire Alarm System using Arduino

Example 4: Smart Dustbin

Design Objective: Open the lid when a person approaches.

Components

- i. Ultrasonic Sensor
- ii. Servo Motor
- iii. Arduino Uno

Logic

1. If distance < 20cm → rotate servo to open lid
2. After delay → close lid

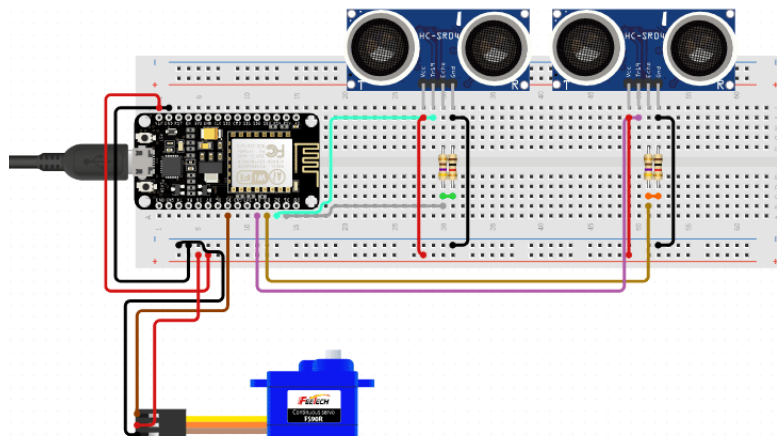


Figure 56: A smart dustbin circuit

Learning Task

Guide learners to design embedded systems to interface with sensors and actuators given design objectives

Pedagogical Exemplars

Project-based experiential Learning: Through simple projects, the facilitator guides learners to assemble circuits involving sensors such as Humidity, Proximity, IR Motion, Accelerometer, Sound, Light Distance, Pressure, thermal and actuators such as motors, buzzers on solderless breadboards to be interfaced with the Arduino microcontroller. The facilitator uses these mini projects to demonstrate the relevant sections of code for interfacing these respective hardware and allow the learners to manipulate the hardware and code to observe the changes which occur. These projects should be carefully selected to have relevance to the environment and learners' interests. Examples of such projects could include but are not limited to the following: weather station, heartbeat monitor, digital thermometer, home security system, digital tachometer, water bottling system, water flow and volume measurement, and soil moisture measurement.

Self-Directed Learning: Learners are given access to online resources to explore further hardware interfacing projects for implementation and experimentation. 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.

Collaborative Learning: Learners work in groups to design, implement, test and document simple embedded solutions involving interfacing with sensors such as Humidity, Proximity, IR Motion, Accelerometer, Sound, Light Distance, Pressure, thermal and actuators such as motors and buzzers.

Each group should assign a specific role(s) to members towards the solution of the challenge. 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.

Key Assessment Level 4: Research

1. Design an embedded system for monitoring room temperature and automatically controlling a fan. Describe the components used (microcontroller, sensor, actuator) and explain the control logic. Justify your design choices and how the system meets the objective of maintaining a desired temperature range.
2. Evaluate the process of designing an embedded system that uses motion sensors to activate lighting systems in a hallway. Discuss how the microcontroller interfaces with both the sensor and the actuator, and explain the advantages and limitations of such a system.
3. An embedded soil moisture monitoring system for a smart garden fails to activate the water pump when soil is dry. Identify potential faults in the design, programming, or interfacing. Propose a redesign that improves reliability, and explain how your changes address the issue.
4. Propose a novel embedded system that uses multiple sensors (e.g., light, sound, motion) to detect intrusions in a room and activate an alarm. Explain how your system integrates the

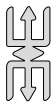
sensors with actuators, the logic used for decision-making, and how it improves security effectiveness.

PLC Session 19

45 minutes

Planning & Reviewing the Learning Plan

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject-specific app to explore the content before planning. Ask the app to
 - a. explain the week's concepts in a practical way that will make it easier for learners to understand
 - b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject-specific app to plan your lesson. Ask the app to
 - a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
 - b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
 - c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

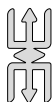
- Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.
- Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.

4. Plan the week's key assessment with your app
 - a. The key assessment for the week is **research**. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the research (NTS 3k-3q).

10 minutes

Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
 - a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
 - b. all teachers in the group work through a similar problem individually for 3–4 minutes
 - c. the group then works through the problem together step by step
 - d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- This part is not just about ‘How do I teach this?’ but how do I teach it for learners to understand?
- If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.
- Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.

30 minutes

Enactment

6. Enact a teaching activity based on your learning plan (NTS 1a-1b, 1e-1g, 2c, 2e, 2f, 3c-3j and 3o).
 - a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
 - b. After the enactment, ask for structured feedback from the group
 - i. was the concept explained in a way that a learner with no prior knowledge could follow?
 - ii. were the examples grounded in contexts familiar to Ghanaian learners?
 - iii. did any misconceptions surface and if so, how were they addressed?

5 minutes

Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
 - a. transfer your chats into your learning planner template.
 - b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
 - c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 9 Review

1. Would learners be able to design a simple industrial automated system using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements?
2. Can learners implement simple industrial automated systems using a combination of motors, fluid power systems, sensors and actuators, switches and relays based on design requirements?

3. Can learners programme PLCs and use them in combination with other components?
4. Would learners be able to implement simple industrial automation systems based on design criteria?
5. Would learners be able to design embedded systems to interface with sensors and actuators given design objectives?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 17 (20 marks total)

Question 1

Criterion	Marks	Description
Clear and logical system design	4	Diagram or description of the system layout with process flow
Appropriate selection of components	4	Motors, sensors, fluid power systems, etc., chosen correctly
Justification of component use	4	Each component's function and relevance explained
Integration of system components	4	Description of how components work together
Operational effectiveness and clarity	4	System meets filling requirements efficiently and reliably

Question 2 (20 marks total)

Criterion	Marks	Description
Description of system context	3	Clear use-case: lifting and sorting
Comparative analysis of motors vs pneumatic actuators	5	Accuracy, speed, cost, maintenance, etc.
Explanation of sensor and relay role	4	Control logic and safety mechanisms
Evaluation of system effectiveness	4	Overall system strengths and weaknesses
Conclusion with justified recommendation	4	Well-reasoned final judgment based on evaluation

Question 3 (20 marks total)

Criterion	Marks	Description
Creativity and originality	4	Innovative yet practical solution

System sequence and logic	5	Clear step-by-step operation using components
Technical accuracy in component selection	4	Correct and relevant components for each stage
Integration of components	4	Seamless coordination between control and action
Clarity and completeness	3	Well-explained and easy to follow answer

WEEK 18

Question 1 (20 marks)

Criterion	Marks	Description
System design clarity and relevance	4	Detailed layout with sensor and actuator placement
Accurate PLC program logic	5	Use of ladder logic or structured text to solve the problem
Justification of PLC instructions used	4	Use of timers, counters, inputs/outputs explained
Integration with components	4	Sensors, actuators, and timers linked to PLC correctly
Functional effectiveness and justification	3	System meets design goals efficiently

Question 2 (20 marks)

Criterion	Marks	Description
Clear description of packaging system	3	Explanation of process and involved components
Evaluation of PLC's role in the system	5	Input/output handling and sequencing logic
Interaction between PLC and components	5	Signal flow and coordination
Strengths and limitations of integration	4	Reliability, flexibility, scalability discussed
Logical conclusion with justified insights	3	Well-supported and clear analysis

Question 3 (20 marks)

Criterion	Marks	Description
Identification of potential faults	4	PLC logic, sensor misreads, actuator errors
Analysis of underlying causes	5	Reasoned explanation of why failures occur

Proposed PLC program adjustments	4	Logic refinements, use of interlocks or delays
Hardware-related improvements	4	Sensor placement, relay reliability, wiring practices
Real-world feasibility and safety	3	Practical and safe implementation suggestions

Question 4 (20 marks)

Criterion	Marks	Description
Originality and practicality of design	4	1 mark The solution is conventional or basic, with limited innovation and marginal feasibility in a real beverage line. 2 marks Some originality shown; solution is moderately practical but may lack full consideration of real-world constraints. 3 marks Design is clearly practical and demonstrates good creativity; could be implemented with standard PLC systems. 4 marks Solution is highly original, well thought out, and clearly feasible; integrates creative automation features suited to real-world operation.
Accurate PLC program structure	5	1 mark Basic outline of logic, but contains major errors or omissions (e.g., missing sequencing or control elements). 2 marks Functional logic structure present, but sequencing or condition handling is weak or incomplete. 3 marks Logic includes sequencing, conditions, and some timers; mostly accurate with minor logical issues. 4 marks Strong programme logic using appropriate sequencing, timers, and conditions; efficient but may lack full optimisation. 5 marks Fully accurate and optimised PLC programme structure; excellent use of sequencing, interlocks, conditions, and timers tailored to the filling and capping process.
Appropriateness of components	4	Correct use of sensors, actuators, switches, and relays
Operational logic and efficiency	4	System flow ensures speed and consistency
Justification and performance benefits	3	Clear value of the design explained

WEEK 19**Question 1 (20 marks)**

Criterion	Marks	Description
Clear design architecture	4	Block diagram or description showing sensor-actuator-microcontroller layout
Appropriate component selection	4	Sensor (e.g., LM35, DHT11), actuator (fan, relay), microcontroller (e.g., Arduino)
Control logic explanation	4	Code logic or algorithm for threshold-based control
Justification of design choices	4	Why each component suits the goal
Functionality and efficiency	4	System accurately controls temperature based on sensor feedback

Question 2 (20 marks)

Criterion	Marks	Description
Description of system function	4	Motion detection and light control process clearly explained
Sensor-microcontroller-actuator interface	5	How signal is read, processed, and output to actuator
Evaluation of advantages	4	Energy saving, automation, reliability
Evaluation of limitations	4	False triggers, sensor sensitivity, latency
Overall assessment and improvement ideas	3	Balanced conclusion with suggestions for enhancement

Question 3 (20 marks)

Criterion	Marks	Description
Problem identification and diagnosis	5	Sensor calibration, code logic, wiring, or power issues
Redesign proposal	5	New logic or component arrangement (e.g., better sensor, feedback loop)
Code or logic improvements	4	Conditional checks, signal filtering, delays
Hardware interfacing improvements	3	Power isolation, signal conditioning
Justification and expected improvements	3	Reasonable and clearly explained outcomes

Question 4 (20 marks)

Criterion	Marks	Description
Creativity and innovation	4	Use of multiple sensors and novel approach
System integration design	5	Interfacing microcontroller with sensors and actuators
Logic and control mechanism	4	Rules for triggering alarms, priority decisions
Security enhancement justification	4	How system improves upon basic security setups
Clarity and feasibility	3	Implementation realism and clear explanation

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List of Figures

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1	Picture of items found in a First Aid kit https://www.eslbuzz.com/wpcontent/uploads/2017/10/18341747_1845790528971286_7161416370570098869_n.jpg.webp
2	A picture of an AC motor https://www.watelectrical.com/wp-content/uploads/slipring_motor.jpg
3	Picture of DC motor https://th.bing.com/th/id/OIP.9JjSHban3fjq68S6cEfQ2QHaE4?cb=iw-c1&rs=1&pid=ImgDetMain

4	Picture of a DC generator https://image.shutterstock.com/z/stock-vector-dc-generator-cross-diagram-simplified-diagram-of-an-off-grid-system-vector-illustration-611245691.jpg
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