MINISTRY OF EDUCATION

Automotive and Metal Technology

for Senior High Schools

TEACHER MANUAL

YEAR THREE

NaCCA
NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Automotive and Metal Technology

for Senior High Schools

Teacher Manual

Year Three

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

AUTOMOTIVE AND METAL TECHNOLOGY 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 Automotive and Metal Technology 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: COMPUTER NUMERICAL CONTROL (CNC) MACHINES

The section covers the following unit (strands); Metal technology and Automotive technology.

In this section, learners will acquire knowledge and understanding of the computing coding language used in Computer Numerical Control (CNC) machines and the construction and components of fuel supply for compression ignition (C1) engines. In the Automotive technology unit, learners are expected to gain the knowledge and understanding of the main components of fuel supply for spark ignition (SI) engines and perform operations using CNC turning machines. All the above are treated from unit 1 to unit 4.

UNIT 1

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Be able to use selected manual and computerised machines.*

Content Standard: Demonstrate understanding of use and care for engineering tools and computerised machines.

INTRODUCTION AND UNIT SUMMARY

CNC machines use a programming language called G-code to control their operations. G-code gives the machine clear instructions such as where to move, how fast, when to cut, change tools, or turn the spindle and coolant on or off. CNC programming involves converting a 3D CAD (computer-aided design) model into machine-readable instructions that guide the cutting tool's actions to produce the final part. These instructions include tool selection, feed rate and precise movement paths. The unit presents the fundamental programming language for CNC machines, the types of CNC codes and the description of common C and M codes. Teaching programming language for (CNC) machines involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the CNC machines. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the basic programming Language for (CNC) machines.

This unit covers only week 1: ***Describe computing coding language used in Computer Numerical Control (CNC) machines.***

Recap weeks

Year 2	**Week 6:** Demonstrate the use of lathe and shaping machines. **Week 8:** Demonstrate the use of the milling machine and cutting fluids.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching programming for CNC machines requires various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate and apply basic understanding, interpret code, perform multi-step tasks, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding of programming language for CNC machines.

ASSESSMENT SUMMARY

To evaluate learners' understanding and practical ability to write and explain basic G-code programmes for CNC machines, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. However, by employing a DoK level 2 for assessment, teachers can effectively measure learners' understanding and application of CNC programming codes.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe the computing coding language used in Computer Numerical Control (CNC) machines	Level 2 (skills of conceptual understanding)	Discussion

WEEK 1

Learning Indicator: *Describe the computing coding language used in Computer Numerical Control (CNC) machines*

FOCAL AREA: PROGRAMMING LANGUAGE FOR (CNC) MACHINES

The main programming language used for Computer Numerical Control (CNC) machines is Geometric code (G-code). This is a simple programming language that tells the CNC machine what to do. It controls:

1. Movement (where and how fast to move)
2. Cutting actions
3. Tool changes
4. Speed of the spindle
5. Coolant on/off, etc.

CNC programming refers to converting a 3D CAD (computer-aided design) model into a set of machine-readable instructions that include which; cutting tools to use, the feed rate, and where to move the tool to create the final part. CNC programming is the process of creating instructions for cutting tools. CNC programmes list instructions to be performed in the order they are written. They read like a book, left to right and top-down. Each sentence in a CNC programme is written on a separate line, called a Block. Blocks are arranged in a specific sequence that promotes safety, predictability and readability, so it is important to adhere to a standard programme structure.

The blocks are 6 and are arranged in the following order:

1. Programme Start
2. Load Tool
3. Spindle On
4. Coolant On
5. Rapid to position above part
6. Machining operation
7. Coolant Off
8. Spindle Off
9. Move to a safe position
10. End programme

The steps listed above represent the simplest type of CNC programme, where only one tool is used and one operation is performed. Programmes that use multiple tools repeat steps two through nine for each.

Example of a Simple G-code:

G21 : Set units to millimetres

G90 : Use absolute positioning

G00 X0 Y0 : Move quickly to the starting point

G01 X50 Y0 F100 : Cut in a straight line to X=50 mm at a feed rate of 100 mm/min.

M05 : Stop the spindle

M30 : End the programme

Types of CNC codes

There are two main types of CNC codes used in programming CNC machines:. These are G-codes (Geometric Codes) and M-codes (Machine Codes). G-codes control the movement and positioning of the machine tool and M-codes control the machine's functions and actions, not movement.

Table 1 and Table 2 show the most common G and M codes that should be memorized if possible.

Table 1: *Common G-codes:*

Code	Description
G00	Rapid motion used to position the machine for non-milling moves.
G01	Line motion at a specified feed rate.
G02	Clockwise arc.
G03	Anticlockwise arc.
G04	Dwell.
G28	Return to machine home position.
G40	Cutter Diameter Compensation (CDC) off.
G41	Cutter Diameter Compensation (CDC) left.
G42	Cutter Diameter Compensation (CDC) right.
G43	Tool length offset (TLO).
G54	Fixture Offset #1.
G55	Fixture Offset #2.
G56	Fixture Offset #3.
G57	Fixture Offset #4.
G58	Fixture Offset #5.
G59	Fixture Offset #6.
G80	Cancel drill cycle.
G81	Simple drill cycle.
G82	Simple drill cycle with dwell.

G83	Peck drill cycle.
G84	Tap cycle.
G90	Absolute coordinate programming mode.
G91	Incremental coordinate programming mode.
G98	Drill cycle returns to Initial point (R).
G99	Drill cycle return to Reference plane (last Z Height)

Table 2: *Common M-codes:*

Code	Description
M00	Programme stop. Press Cycle Start button to continue.
M01	Optional stop.
M02	End of programme.
M03	Spindle on Clockwise.
M04	Spindle on Counter clockwise.
M05	Spindle stop.
M06	Change tool.
M08	Coolant on.
M09	Coolant off.
M30	End programme and press Cycle Start to run it again.

Step-by-Step Guide to Writing Basic G-code

1. Start with Basic Settings

These commands set up the unit system and positioning method.

G21: Use millimetres (G20 for inches)

G90: Use absolute positioning

2. Move to Starting Position (without cutting)

Use G00 for rapid movement (no cutting).

G00 X0 Y0 ; Move quickly to starting point (X=0, Y=0)

3. Start the Spindle

Use M03 to turn the spindle on clockwise and set spindle speed.

M03 S1000 ; Spindle on at 1000 RPM

4. Begin Cutting

Use G01 for straight line cuts and F to set feed rate.

G01 X50 Y0 F100 : Move to X=50mm with cutting at 100 mm/min

G01 X50 Y50 : Cut up to Y=50mm

G01 X0 Y50 : Cut to the left

G01 X0 Y0 : Cut back to starting point

5. Stop the Spindle and End the Programme

M05 : Stop spindle

M30 : End of programme

Full Example: Drawing a 50mm Square

G21 : Set units to millimetres

G90 : Absolute positioning

G00 X0 Y0 : Go to starting point quickly

M03 S1000 : Spindle on at 1000 RPM

G01 X50 Y0 F100 : Cut to the right

G01 X50 Y50 : Cut upwards

G01 X0 Y50 : Cut to the left

G01 X0 Y0 : Cut down to close square

M05 : Spindle off

M30 : End programme

Learning Tasks

1. Identify the programmes list instructions
2. Describe the G-code and M-code commands
3. Write a basic G-code programme

Pedagogical Exemplars

Talk for learning approaches: With video or simulation, learners are exposed to the various features of drilling and grinding machines in the manufacturing industry. Assist learners to effectively identify and describe the main features of the CNC machines.

Experiential Learning: In the school workshop or local manufacturing industry with learners or simulated activities, help learners to identify, observe and perform the operations using the drilling and grinding machines.

Group work/collaborative learning: Group learners to discuss the computing coding language used in CNC using video or simulated activities and describe the computer language. Assist learners to enter the code into the CNC machines e.g. In G-code, 5 main letters are used in this language. Each letter corresponds to a different type of action for the machine to execute. eg.M02: end of programme, M06: tool change, G02: clockwise etc.

Key Assessment Level 2: Individual Class Exercise

1. a. How does a G01 command differ from a G00 command in CNC programming? **(4marks)**

b. What is the purpose of the following commands?

i. G02 (2 marks)

ii. G03 (2 marks)

2. Given a simple G-code programme identify the commands used for movement and spindle control and explain what each command does. (12 marks)

3. A learner needs to programme a CNC machine to cut a square with 40 mm sides. The starting position is the top-left corner of the square at coordinates X10, Y10. Which sequence of G-code commands would correctly create this square with the cutting tool ending at the starting position? (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

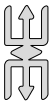
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***individual class exercise***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the exercise (NTS 3k-3q).

10 minutes	Content Exploration

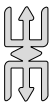
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 1 REVIEW

In this unit, learners were introduced to programming languages used in CNC (Computer Numerical Control) machines, with a focus on G-code, the most common language for controlling CNC operations. The lesson began by explaining that CNC programming allows machines like lathes, mills and grinders to perform precise tasks automatically using coded instructions. Learners learned about the two main types of CNC codes: G-codes for geometric movement and M-codes for machine functions. These codes are used together to control how the machine behaves during cutting or shaping processes. The lesson then followed a step-by-step guide to writing a basic G-code programme. They studied how to start a programme, set coordinates, define tool paths, and end the sequence correctly. Emphasis was placed on structure, safety, and accuracy in programming. By the end of the lesson, learners had a clearer understanding of how CNC machines interpret instructions and were able to write and explain simple G-code commands. This lesson successfully combined theory and practice, giving learners a strong foundation in CNC programming, which is essential for modern manufacturing and engineering careers.

UNIT 2

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Be able to analyse the principle of supercharger and turbocharger system for both spark ignition (SI) and compression ignition(C1) engines as well as air intake systems*

Content Standard: Demonstrate and apply knowledge in the working principles of fuel supply system for both spark ignition (SI) and compression ignition (C1) engines, as well air intake and exhaust systems.

INTRODUCTION AND UNIT SUMMARY

In this lesson, learners will learn about the fuel supply systems used in spark ignition (SI) and compression ignition (CI) engines. The fuel supply system is a vital part of any internal combustion engine, as it stores, filters, and delivers fuel to the engine for smooth and efficient operation. Petrol engines (SI engines) and diesel engines (CI engines) have different fuel supply methods because they work differently. We will first look at the main components found in both petrol and diesel fuel systems, such as the fuel tank, pump, filter, fuel lines, carburettor (for petrol engines), and fuel injectors. You will also understand how these components work

together to deliver the right amount of fuel at the right time. Next, we will explore the different types of fuel supply systems used in petrol engines, including gravity feed, pressure feed, and injection systems. Finally, we will study the solid injection systems used in diesel engines, such as the individual pump system, distributor system, and common rail system. This lesson will help learners understand how fuel gets from the tank to the engine in different types of vehicles. Teaching fuel supply for both SI and CI engines requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying Petrol and Diesel engine fuel systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the working principles of SI and CI engine fuel supply systems.

This unit covers only week 2:

1. ***Describe the main components of fuel supply for spark ignition (SI) engines.***
2. ***Describe the main components of fuel supply for compression ignition(CI) engines.***

Recap weeks

Year 1	**Week 2:** Identify types of engines and describe the main components of the engine. **Week 4 and 7:** Explain the constructional and operational difference between petrol and diesel engines.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the fuel supply system in spark ignition (SI) and compression ignition (CI) engines requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in analysing petrol and diesel fuel systems, teachers should incorporate a range of strategies. These may include problem-based learning, collaborative group work, scaffolded learning, experiential activities, and project-based tasks. Such approaches blend practical, visual, interactive, and theoretical methods, ensuring that different learning styles are supported. These pedagogical exemplars not only build foundational knowledge but also promote critical thinking and real-world application. Ultimately, they help learners develop a clear and practical understanding of the components, types, and working principles of fuel supply systems in both petrol and diesel engines.

ASSESSMENT SUMMARY

To assess learners' understanding of the fuel supply systems in both spark ignition (SI) and compression ignition (CI) engines, including their main components and working principles, a range of assessment levels can be used. These assessments should not only test basic knowledge but also focus on how well learners can apply what they have learned. By using Depth of Knowledge (DoK) Level 4, learners are expected to go beyond simple recall and explanation. They should be able to analyse, evaluate, and apply their knowledge in practical or problem-solving situations, such as diagnosing faults or designing basic system layouts. This level of assessment ensures that learners demonstrate a deep understanding of the fuel supply system's function and real-world applications. Teachers can use these tasks to effectively measure both theoretical knowledge and practical thinking skills.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe the main components of fuel supply for spark ignition (SI) engines.	Level 4 Extended critical thinking and reasoning	Discussion and Research
Describe the main components of fuel supply for compression ignition(C1) engines	Level 4 Extended critical thinking and reasoning	Discussion and Research

WEEK 2

Learning Indicators

1. *Describe the main components of fuel supply for spark ignition (SI) engines*
2. *Describe the main components of fuel supply for compression ignition (C1) engines*

FOCAL AREA 1: FUEL SUPPLY SYSTEM FOR SPARK IGNITION (SI) ENGINE

The fuel supply system in a Spark Ignition (SI) engine, like a gasoline engine, is responsible for delivering the correct amount of fuel and air to the combustion chamber for power generation. This system typically includes a fuel tank, fuel pump, fuel filter, carburettor or fuel injectors, and fuel lines.

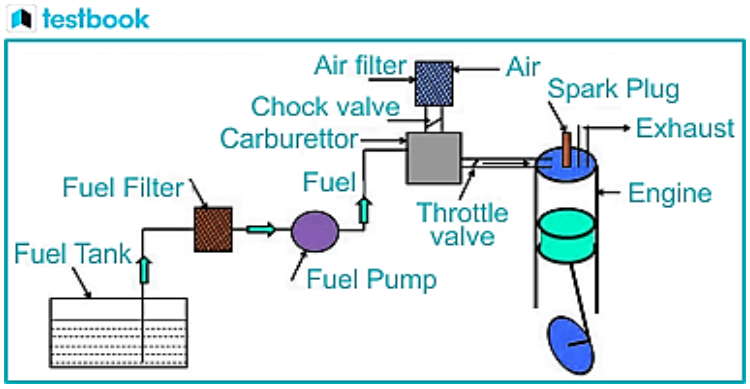


Figure 1.1: *Spark Ignition (SI) engine*

Components of Fuel Supply System in Petrol Engine

In automobiles, the basic fuel supply system with a petrol engine consists of the following components:

1. Fuel Tank: The fuel tank stores gasoline and is typically located at the rear of the vehicle, providing a reservoir for the engine's fuel needs.
2. Fuel Pump: This is responsible for pressurising the fuel and delivering it to the engine, the fuel pump ensures a consistent flow of fuel to meet engine demands.
3. Fuel Lines: These pipes transport fuel from the tank to the engine, maintaining its flow under pressure and ensuring a steady supply for combustion.
4. Air Cleaner: The air cleaner filters incoming air, removing impurities and contaminants to ensure clean air for the combustion process.
5. Fuel Filter: The fuel filter removes debris and impurities from the fuel, preventing clogs and maintaining fuel system integrity.
6. Carburettor: In older engines, the carburettor mixes fuel with incoming air to create a combustible air-fuel mixture before it enters the engine's cylinders.
7. Inlet Manifold: The inlet manifold distributes the air-fuel mixture evenly to each cylinder's intake valve, ensuring uniform combustion.

8. Supply and Return Pipelines: These pipelines are used in fuel injection systems to deliver fuel to the engine (supply) and return excess fuel to the tank (return) to regulate fuel pressure and prevent overheating.

Working of Fuel Supply System in Petrol Engine

The working of the fuel supply system can be understood by visiting the following pointers:

1. The process begins with fuel storage in the vehicle's fuel tank, typically containing gasoline or a gasoline blend**.**
2. A high-pressure fuel pump pressurises the fuel and delivers it to the engine compartment.
3. The fuel passes through a filter to remove impurities, ensuring clean fuel enters the engine.
4. A pressure regulator maintains the appropriate fuel pressure in the fuel lines.
5. A carburettor mixes fuel with air in older engines. In modern engines, a fuel injector precisely sprays fuel into the intake manifold, creating an air-fuel mixture.
6. Intake air is drawn into the engine's intake manifold through the air filter.
7. In the intake manifold, the fuel injector (or carburettor) combines the pressurised fuel with the incoming air, creating a combustible air-fuel mixture.
8. The throttle valve controls the amount of air entering the engine, affecting the air-fuel mixture's richness or leanness.
9. The intake valve opens to allow the air-fuel mixture to enter the combustion chamber during the intake stroke.
10. The piston moves upward during the compression stroke, compressing the air-fuel mixture.
11. When the piston reaches the top of the compression stroke, a spark plug produces a spark, igniting the air-fuel mixture.
12. The ignited mixture rapidly burns, generating high-pressure gases that force the piston down during the power stroke.
13. The exhaust valve opens to allow the exhaust gases to exit during the exhaust stroke.
14. The exhaust gases flow through the exhaust manifold, catalytic converter, muffler and out of the tailpipe.
15. The engine repeats this four-stroke cycle intake, compression, power and exhaust thousands of times per minute, producing mechanical power to drive the vehicle.
16. Modern engines incorporate sensors and an Engine Control Unit (ECU) to monitor and optimise the air-fuel mixture, ignition timing, and other parameters for maximum efficiency and emissions control.
17. Catalytic converters and other emissions control devices reduce harmful exhaust emissions.
18. The fuel supply system adjusts fuel delivery during idle and deceleration to conserve fuel and minimise emissions.

Types of Fuel Supply Systems in Petrol Engine

Fuel supply systems in SI engines play a crucial role in ensuring the efficient delivery of fuel to the engine cylinders. Various systems have been employed over the years to achieve this goal. The various types of fuel supply systems in SI engines are:

1. **Gravity Feed System**
   - **a.** In this system, the fuel tank is mounted at a high position.
   - **b.** Fuel flows into the carburettor float chamber solely by gravity.
   - **c.** Simple and cost-effective.
   - **d.** Primarily used in two-wheelers due to its design limitations.

2. **Pressure Feed System**
   - **a.** Utilises a sealed fuel tank where pressure is generated using the engine exhaust or a separate air pump.
   - **b.** Requires priming using a hand pump for startup.
   - **c.** Maintains pressure to facilitate fuel flow to the carburettor's float chamber.
   - **d.** Offers flexibility in the placement of the fuel tank.

3. **Pump Feed System**
   - **a.** Employs a steel pipe to transport fuel from the tank to the fuel pump.
   - **b.** The engine camshaft drives the mechanical pump.
   - **c.** Electrically operated fuel pumps are common in modern vehicles, offering placement flexibility and reducing vapour lock risks.
   - **d.** Widely used in contemporary automobiles.

4. **Fuel Injection System**
   - **a.** Replaces the carburettor with a more precise fuel injection system.
   - **b.** Achieves accurate control of the air-fuel mixture for each cylinder.
   - **c.** Atomises fuel through injector nozzles before delivering it into the air stream.
   - **d.** Allows separate fuel injection for each cylinder, offering precise control under various load and speed conditions.
   - **e.** Frequently managed electronically, making it the most accurate fuel supply system.

FOCAL AREA 2: FUEL SUPPLY SYSTEM FOR COMPRESSION IGNITION (CI) ENGINE

CI Fuel supply system

The fuel supply system for a CI (Compression Ignition) engine, like a diesel engine, ensures fuel is delivered to the combustion chamber in the correct quantity, at the right time, and with proper atomisation. The system typically includes a fuel tank, fuel transfer pump, fuel filter, injection pump (or common rail system), and injectors. See Figure 1.2.

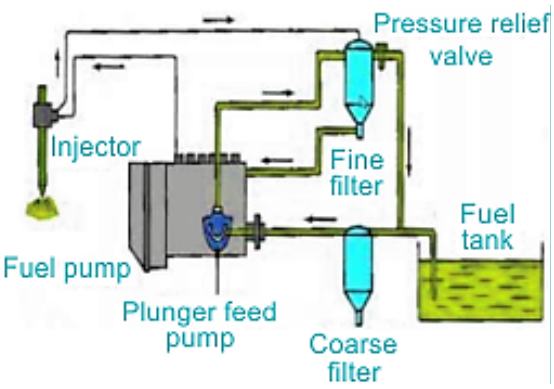


Figure 1.:2 *Compression Ignition (CI) engine*

Main Components and Their Functions

1. Fuel Tank: Stores the fuel supply.
2. Fuel Transfer Pump: Draws fuel from the tank and delivers it to the fuel filter.
3. Fuel Filter: Removes impurities from the fuel before it reaches the injection pump.
4. Injection Pump/Common Rail System: Generates high pressure fuel and controls the timing and quantity of fuel delivered to the injectors. In a common rail system, a high-pressure fuel reservoir (the rail) is used to distribute fuel to multiple injectors.
5. Injectors/Nozzles: Atomise and inject the fuel into the combustion chamber at the correct time and pressure.
6. High-Pressure Pipes: Connect the injection pump (or common rail) to the injectors, delivering the high-pressure fuel.

Working Principle

1. Fuel is drawn from the tank and filtered by the transfer pump.
2. The fuel injection pump (or common rail) then pressurises the fuel and controls its delivery to the injectors.
3. The injectors precisely inject the fuel into the combustion chamber at the optimal time and quantity for efficient combustion.
1. Excess fuel is typically bypassed back to the fuel transfer pump through a relief valve.

Types of Solid Injection Systems

Solid injection means fuel is injected directly into the engine cylinder without being mixed with air first. In diesel engines, this is how fuel gets into the combustion chamber

The various types of solid injection systems are:

1. Individual pump and nozzle system
2. Unit injector system
3. Common rail system
4. Distributor system

1. **Individual pump and nozzle system:** In this solid injection system, each cylinder is equipped with an individual pump and injector. The pump sends high-pressure fuel directly to the injector. It is common in older diesel engines and trucks. See Figure 1.3.

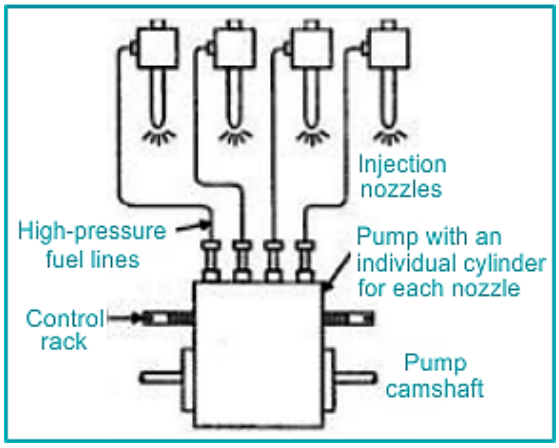


Figure 1.3: *Individual pump and nozzle system*

2. **Unit injector system:** This solid injection system incorporates a unified housing that combines the pump and injector nozzle. Each cylinder is equipped with a single unit injector, ensuring individual fuel delivery to each combustion chamber.

Figure 1.4: *Pump and injector nozzle*

3. **Common rail system:** The solid injection system relies on high-pressure pumps to deliver fuel to a header. The fuel, under intense pressure, is then distributed from the header to individual nozzles located within the cylinders of the system**.**

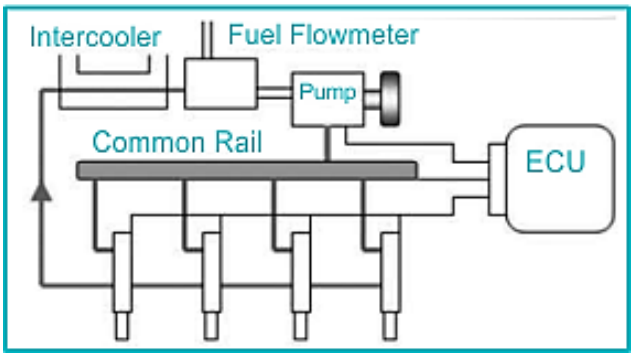


Figure 1.5: *Common rail system*

4. **Distributor system:** The solid injection system combines the functions of fuel pressurisation, metering, and timing within a single pump

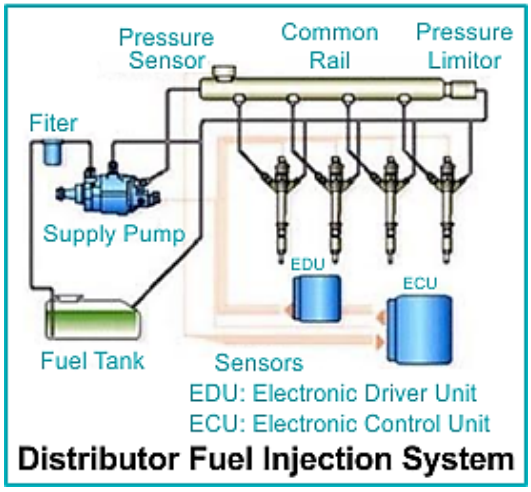


Figure 1.6: *Distributor system*

Learning Tasks

1. State the purpose of the fuel supply system in SI and CI engines?
2. List and describe the main components of the fuel supply system in a spark ignition (SI) engine.
3. List and describe the main components of the fuel supply system in a compression ignition (CI) engine.
4. Explain how the fuel supply system works in both petrol and diesel engines.

Pedagogical Exemplars

Group work/collaborative: Learners brainstorm in fair mixed groups to passionately discuss with respect to others, the layout of fuel supply system for petrol engines and present report.

Guide learners using appropriate sketches, charts or real objects to assist learners to identify and discuss the layout of the petrol injection system on a vehicle.

Learners brainstorm in fair mixed groups to discuss with respect to others the layout of fuel supply system for diesel engines and present report.

Key Assessment Level 4: Discussion and Research

1. a. Explain how a clogged fuel filter in spark ignition (SI) engines might affect engine performance. (5 marks)

b. Describe the steps you would take to diagnose and fix the problem 1 (a) above. (7 marks)

2. a. Design a simple maintenance schedule for the fuel supply system of a spark ignition engine. (6 marks)

b. Explain why each step is important for engine reliability. (6 marks)

3. a. Evaluate the impact of modern common-rail fuel injection systems compared to traditional fuel injection pumps in CI engines.

b. Propose two reasons why one might be preferred in current vehicle designs.

(10 marks).

4. Develop and justify a fault-finding procedure for diagnosing inconsistent fuel delivery in a CI engine considering mechanical components of the system.

(12 marks).

PLC Session 2

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

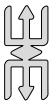
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***discussion and research***. 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

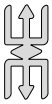
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 2 REVIEW

The lesson provided a clear and structured overview of the fuel supply systems used in both spark ignition (SI) and compression ignition (CI) engines. It began by explaining the purpose of the fuel supply system and how it differs between petrol and diesel engines. The main components such as the fuel tank, pump, filter, fuel lines, carburettor for SI engines and injectors were identified and described with simple explanations, helping learners understand their functions. The working principles of fuel supply in both engine types were covered effectively. The lesson explained how petrol engines mix fuel with air before ignition, while diesel engines compress air first, then inject fuel. This comparison helped learners see the operational differences clearly. The types of fuel supply systems in petrol engines such as gravity feed, pressure feed and fuel injection were introduced with basic features and uses. In addition, the solid injection systems used in CI engines, including the individual pump, distributor, and common rail systems, were explained in a simplified manner. In all, the lesson successfully combined theory and practical relevance, supporting learners' understanding of both systems and their real-world applications.

UNIT 3

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Be able to use selected manual and computerised machines*

Content Standard: Demonstrate understanding of use and care for engineering tools and computerised machines.

INTRODUCTION AND UNIT SUMMARY

CNC (Computer Numerical Control) machines are widely used in modern engineering because they allow for fast, accurate, and repeatable manufacturing of parts. Unlike manual machines, CNC machines follow programmed instructions to carry out cutting, drilling, or shaping operations with little human control. There are different types of CNC machines, but this lesson presents CNC lathes and milling machines, CNC lathe machines are mainly used for producing round or cylindrical parts, while CNC milling machines are used to cut flat surfaces, slots, and complex shapes. Common operations on a CNC lathe include facing, turning, thread cutting, and parting off as well as the basic components of the CNC lathe and milling machine which are also discussed. Both CNC lathes and milling machines work by following a G-code programme that tells the machine how to move the tool and workpiece. The steps to follow to use both CNC lathe and milling machines are also outlined and with the main difference being how the tool and material move during cutting. Teaching these two CNC machines requires

various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the CNC machines. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the working principle of CNC lathe and milling machines.

This unit covers only week 3:

1. ***Describe the main features and perform operations using CNC turning machines.***
2. ***Describe the main features and perform operations using CNC milling machines.***

Recap weeks

Year 2	**Week 6:** Demonstrate the use of lathe and shaping machines. **Week 8:** Demonstrate the use of the milling machine and cutting fluids.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the working principle of CNC machines requires various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate and apply basic understanding, and skills to the use these CNC machines. The teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding and the application of CNC lathe and milling machines

ASSESSMENT SUMMARY

To evaluate learners', understanding of how CNC lathe and milling machines work, along with their parts, principles, and safe operation steps assessments can span various levels to gauge learners' understanding and application of the concepts and the principles. However, by employing a DoK level 4 for assessment learners must not only understand how CNC machines work, but also evaluate, plan, and apply this knowledge in real-world or problem-solving situations. Teachers can also effectively measure learners' understanding and application, of CNC lathe and milling machine in a given task.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe the main features and perform operations using CNC turning machines	Level 3 Strategic reasoning	Group Project
Describe the main features and perform operations using CNC milling machine	Level 4 Extended critical thinking and reasoning	Discussion and Practical Assessment

WEEK 3

Learning Indicators

1. *Describe the main features and perform operations using CNC turning machines*
2. *Describe the main features and perform operations using CNC milling machine*

FOCAL AREA 1: CNC LATHE MACHINES

CNC means Computerised Numerical Control that is (computer numerical control). Numerical control is a programmable automation in which process is controlled by numbers, letters and symbols. CNC machining is a process used in the manufacturing sector that involves the use of computers to control machine tools like lathes, mills and grinders. CNC turning machine are automated machine tools that use computer systems to control the movements of the machine's parts. Unlike conventional lathes, CNC lathes can perform complex machining tasks without the need for manual intervention, improving accuracy, efficiency, and repeatability.

The need for CNC machining

CNC (Computer Numerical Control) machining is beneficial because it is:

1. High accuracy
2. Fast and saves time
3. Repeatable (produces multiple components exactly the same)
4. Reduces human error
5. Handles complex shapes
6. Safer than manual work
7. Works with many materials

Types of CNC Machines

The most common CNC machines are milling, turning (lathe), drilling, boring and grinding. Milling machines cut materials, including metal, using a cutting spindle, which can move to different positions and depths as directed by the computer instructions. Lathes use cutting tools on a rotating work piece to cut material. They are commonly used to make detailed cuts in symmetrical pieces, like cones and cylinders.

Some Basic CNC Lathe Operations

1. Turning: The workpiece rotates while a stationary cutting tool removes material to shape the piece.
2. Facing: The cutting tool moves perpendicular to the workpiece, creating a flat surface.
3. Drilling: A rotating tool is used to create holes in the workpiece.
4. Boring: Enlarging or finishing an existing hole.
5. Thread Cutting: The CNC lathe can cut internal or external threads on a workpiece.
6. Parting: The process of cutting off a piece of material from the workpiece.

Basic Components of CNC Lathe Machines

Figure 1.7 shows the basic parts of CNC lathe machines.

1. **Machine Bed:** The base structure that supports all the other components of the CNC lathe. It is made of strong materials to minimise vibrations during operation.
2. **Headstock:** it houses the main motor and spindle. It holds the workpiece in place while it rotates.
3. **Tailstock:** This provides support for the other end of the workpiece. It can be adjusted to accommodate different lengths of material.
4. **Carriage:** This holds and moves the cutting tool. The carriage is responsible for moving the tool to the correct position to cut or shape the material.
5. **Tool Post:** The component where the cutting tool is mounted. CNC lathes typically use automatic tool changers to switch tools for different operations.
6. **Control Panel:** This is where the CNC programme is entered, and it displays the machine's operational parameters and status.
7. **Chuck:** The device that holds the workpiece. It can be a 3-jaw or 4-jaw chuck, depending on the type of workpiece.

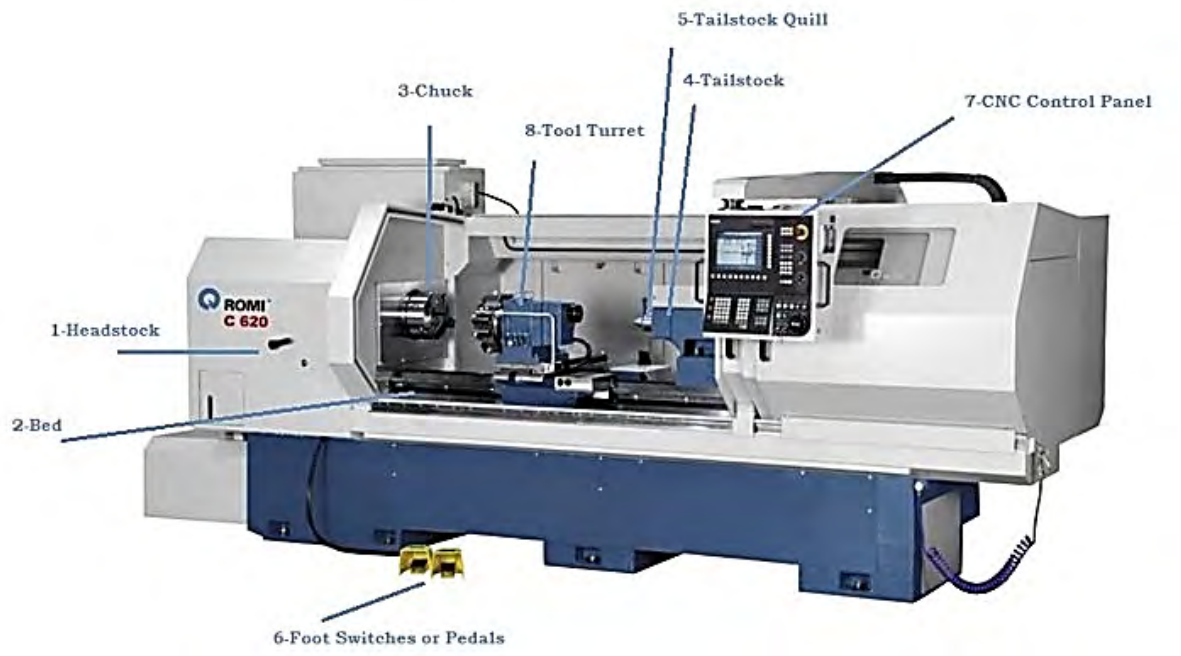


Figure 1.7: *Basic Parts of CNC Lathe Machines*

Working Principle for CNC Lathe Machines

The operator programmes the CNC machine using G-codes and M-codes. G-codes define movements while M-codes control machine functions such as starting/stopping the spindle, coolant flow, etc. The workpiece is placed in the chuck and securely clamped in position and the cutting tool is selected based on the desired operation and mounted in the tool post. The machine begins executing the programme, moving the cutting tool according to the instructions in the programme. The material is progressively shaped or cut based on the operations outlined. After the programme finishes, the workpiece is removed, and further finishing operations may be done manually or automatically.

Figure 1.8: *CNC lathe machine*

Steps to Use a CNC Lathe Machine

1. Know the Machine Parts
    a. Chuck: holds the material (workpiece).
    b. Tool turret: holds the cutting tools.
    c. Spindle: makes the workpiece spin.
    d. Control panel – where you start and stop the machine or load a programme.
2. Wear Safety Gear
    a. Put on safety glasses and proper clothing.
    b. Make sure long hair is tied back.
3. Clamp the Material
    a. Fix the round bar (metal or plastic) into the chuck.
    b. Tighten it properly so it doesn't move.
4. Choose the Right Tool
    a. Use the correct cutting tool for the job (e.g., turning or facing).
    b. Fit the tool into the tool turret.
5. Set the Zero Point: Tell the machine where the starting point is (this is called the work zero).
6. Load the CNC Programme
    a. The programme uses G-code (a special language for machines).
    b. Example: G01 means a straight cut.
7. Check with a Dry Run: Do a dry run (test run without cutting) to make sure everything works correctly.
8. Start the Machine
    a. Close the safety door.
    b. Press the cycle start button to begin cutting.

9. Watch the Process
    a. Keep an eye on the machine as it cuts.
    b. Stop the machine if there's any problem.
10. Remove and Check the Part
    a. When finished, take out the part.
    b. Measure it with a ruler or calliper to check the size.
11. Clean the Machine
    a. Remove any chips (small pieces of metal).
    b. Turn off the machine safely.

Advantages of CNC Lathe Machines

1. Provide high levels of precision with minimal human error.
2. Produce identical parts without variation, making it ideal for mass production.
3. Operate continuously, increasing the speed of production and reducing downtime.
4. Operators need to only programme the machine and monitor the process, reducing the need for manual labour.
5. Perform operations that are impossible or very difficult to do manually, such as intricate contours and profiles.

CNC Lathe Programming Codes (G-codes and M-codes)

1. G-codes (Geometric Codes):
2. G00: Rapid positioning
3. G01: Linear interpolation (cutting)
4. G02: Circular interpolation clockwise
5. G03: Circular interpolation counter clockwise
6. G04: Dwell (pause)
7. G20: Programming in inches
8. G21: Programming in millimetres
9. M-codes (Machine Codes):
10. M03: Spindle on clockwise
11. M04: Spindle on counter clockwise
12. M05: Spindle stop
13. M06: Tool change
14. M08: Coolant on
15. M09: Coolant off

FOCAL AREA 2: CNC MILLING MACHINES

A CNC milling machine is a machine that cuts flat or shaped parts out of metal, plastic, or wood using a rotating tool. The machine follows a set of instructions from a computer programme. In another word, CNC milling is a machining process that employs computerised controls and rotating multi-point cutting tools to progressively remove material from the work piece in the form of chips and produce a final part. Milling is the process of machining using rotary cutters to remove material by advancing a cutter into a work piece.

Main Parts of a CNC Milling Machine

Part	Function
Spindle	Rotates the cutting tool
Table	Holds the material (workpiece)
Tool Holder	Holds the tool in the spindle
Control Panel	Where you input or run the programme
Coolant System	Keeps the tool and workpiece cool

Types of CNC milling machines

CNC milling machines are mainly classified into three types

1. Horizontal machining centre
2. Vertical machining centre
3. Universal machining centre

Figure 1.9: *Horizontal machining centre*

Figure 1.10: *Vertical machining centre*

Figure 1.11: *Universal machining centre*

CNC Milling Operations

The main operations of CNC milling are classified into two types.

1. Planar milling. This operation involves point to point and straight cut motion control systems
2. Contour milling. This operation involves profile milling of cavities and cores, contour area machining, and machining of profile corners etc.

Simplified Steps to Use CNC Milling Machines

1. **Design the Part**: Use CAD software to create the part you want.
2. **Convert to Code**: Use CAM software to turn the design into **G-code**.
3. **Load the Material**: Place the workpiece on the machine table and clamp it.
4. **Load the Programme**: Send the G-code to the machine.
5. **Set Zero Point**: Tell the machine where to start cutting (called setting the origin).
6. **Run a Dry Test**: Make sure the programme runs correctly without cutting.
7. **Start Cutting**: Start the machine. It will cut the part automatically.

CNC Tools

A wide range of tool types and configurations are available for CNC milling machines. Below are the most commonly used tools for prototype and short run production machining.

1. End mills and Face mills
2. Corner Rounding tools
3. Slot Tools
4. Spot-Centre Drill
5. Twist Drill
6. Tap
7. Reamer
8. Counter bore

Advantages of CNC milling machines

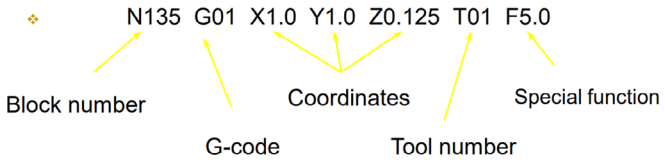
1. Follow programmed instructions very precisely. This makes the parts they produce very accurate.
2. Every part made is exactly the same. This is important when making many identical parts.
3. Work faster than manual machines and can run all day and night with little supervision.
4. Since the machine follows a programme, less chance of mistakes compared to manual.
5. Produce shapes that would be very difficult or impossible to make by hand.
6. Operators don't need to be close to moving tools, so the process is safer.
7. Once a design is programmed, it can be reused many times in the future.
8. Fewer skilled workers are needed because one operator can run several machines.

Disadvantages of CNC milling

1. High initial cost
2. Need a higher qualified operator
3. It is expensive to repair

Basic Concept of Part Programming

1. Part programming contains geometric data about the part and motion information to move the cutting tool with respect to the workpiece.
2. Basically, the machine receives instructions as a sequence of blocks containing commands to set machine parameters; speed, feed and other relevant information.
3. A block is equivalent to a line of codes in a part programme.



Learning Tasks

1. Why is CNC Machining necessary?
2. Describe the main features of a CNC turning machine.
3. Describe the main features of a CNC milling machine.
4. Describe its main steps in using CNC lathe and milling machines.

Pedagogical Exemplars

Talk for learning approaches: With video or simulation, learners are exposed to the various features of CNC lathe and milling machines used in the manufacturing industry. Assist learners to effectively identify and describe the main features of the CNC lathe and milling machines.

Guide learners in groups to demonstrate the use of CNC lathe and milling machine.

Experiential Learning: In the school workshop or local manufacturing industry with learners or simulated activities, help learners to identify, observe and perform the operations using the CNC lathe machine.

Key Assessment Level 3: Group Project

1. Using a working drawing of a turned component, plan a sequence of machining operations including tool selection and G-code considerations to produce the part accurately on a CNC lathe. (12 marks).
2. **a.** Analyse the following defects found on a CNC turned part
   i. chatter marks
   ii. taper error

iii. poor surface finish

b. Explain possible causes and specific adjustments you would make to correct each defect. (10 marks)

3. a. Design a CNC milling process to produce a component from a given working drawing include tool selection and work-holding method.

b. Give two justifications of your cutting strategy and sequence (4 marks)

4. a. Design a complete CNC milling process for producing a given part considering material selection, tooling, cutting parameters, and safety measures.

b. Provide a rationale for each decision in your process

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 3

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 ***group project***. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the group project (NTS 3k-3q).

10 minutes	Content Exploration

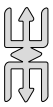
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 3 REVIEW

In modern engineering and manufacturing, CNC machines have become essential tools. The term CNC stands for Computer Numerical Control, which means the machines are operated using programmed instructions instead of being controlled manually. These machines are used to produce parts with high accuracy, faster speed, and greater consistency compared to traditional machines. There are several types of CNC machines, but two of the most commonly used in workshops and training centres are the CNC lathe machine and the CNC milling machine. A CNC lathe is mainly used for producing round or cylindrical parts. The workpiece is clamped in a chuck and rotated, while a cutting tool moves in different directions to shape the material. Unlike the lathe, a **CNC milling machine** works by keeping the workpiece still while the **rotating cutting tool** moves across it. Milling machines can produce flat surfaces, slots, holes, and even complex 3D shapes.

UNIT 4

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Analyse intake system for both spark ignition (SI) and compression ignition(C1) engines systems and identify the main components*

Content Standard: Demonstrate and apply knowledge in the working principles of fuel supply system for both spark ignition (SI) and compression ignition(C1) engines, as well air intake and exhaust systems.

INTRODUCTION AND UNIT SUMMARY

In this lesson, learners will focus on two important systems in an automotive engine: the air intake system and the exhaust system. Both systems play a vital role in engine performance, fuel efficiency, and emission control. The air intake system is responsible for bringing clean, fresh air into the engine. This air mixes with fuel and is burned in the combustion chamber to produce power. We will identify the main components of the air intake system, such as the air

filter, mass flow sensor, throttle body, intake manifold, and, in some engines supercharger and turbocharger. The exhaust system, on the other hand, removes the burnt gases from the engine after combustion. It helps reduce noise and controls harmful emissions. We will study the main components of the exhaust system, including the exhaust manifold, catalytic converter, silencer (muffler), and exhaust pipe. Understanding how these two systems work together is essential for diagnosing engine problems and improving vehicle performance. This lesson will help learners develop a clear understanding of airflow into and out of an engine. Teaching air intake and exhaust systems requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying these systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding and the functions of the main components of the two systems

This unit covers only week 4:

1. Explain the air intake system of the engine and state the functions of the main components.

2. Describe the main components of the vehicle exhaust system.

Recap weeks

Year 1	**Week 2:** Identify types of engines and describe the main components of the engine. **Week 4 and 7:** Explain the constructional and operational difference between petrol and diesel engines.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the air intake and exhaust systems in automotive engines requires the use of diverse pedagogical exemplars to ensure meaningful and effective learning. To help learners understand and apply key concepts and skills in analysing these systems, teachers should use a variety of strategies such as problem-based learning, collaborative group work, scaffold instruction, experiential activities, and project-based tasks. These teaching approaches combine practical, visual, interactive, and theoretical methods, catering to different learning styles and abilities. By engaging in these varied tasks, learners not only build a solid foundation of knowledge but also develop critical thinking and problem-solving skills. These strategies encourage students to analyse component functions, compare system types, and understand how the intake and exhaust systems work together to support engine operation.

ASSESSMENT SUMMARY

To assess learners' understanding of the air intake and exhaust systems, including their main components and working principles, a variety of assessment methods should be applied. These should go beyond simple recall of facts and include opportunities for learners to apply their knowledge in realistic and practical contexts. Using Depth of Knowledge (DOK) Level 4 assessments, learners are expected to not only describe and explain how these systems work but also to analyse, evaluate, and apply their knowledge. These assessments help determine whether learners can connect theoretical knowledge with real-world situations, such as engine maintenance or system troubleshooting. Teachers can use written tasks, group presentations, hands-on demonstrations, or project-based work to effectively measure both conceptual understanding and critical thinking. By integrating higher-order assessments, learners gain a

deeper, more practical understanding of how air intake and exhaust systems contribute to engine operation and efficiency.

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain the air intake system of the engine and state the functions of the main components.	Level 4 Extended critical thinking and reasoning	Discussion and Homework
Describe the main components of the vehicle exhaust system.	Level 3 Strategic reasoning	Discussion and Homework

WEEK 4

Learning Indicators

1. *Explain air intake system of the engine and state the functions of the main components*
2. *Describe the main components of the vehicle exhaust system*

FOCAL AREA 1: AIR INTAKE SYSTEM

Combustion requires air, fuel and heat, as such, certain ratios of all three are necessary if an engine is to operate. Air intake system deal with air as it is required to support combustion in the cylinder of the engine. Air intake system delivers oxygenated air into the combustion chambers of an engine which is an essential element for combustion within the engine. A good and proper working intake system delivers a clean and continuous amount of air into the engine. In the naturally aspirated air intake system, the engine draws in air naturally, using only the suction created by the movement of the piston.

The main components of the air intake system are:

1. **Air Filter:** Removes dust, dirt, and debris from the incoming air. There are three types of air filters
   - **a.** Paper air filter
   - **b.** Gauze air filter
   - **c.** Foam air filter

Figure 1.12: *Air filter*

2. **Air Flow Sensor**: Measures how much air is entering the engine. There are two types of mass airflow sensors in use on automotive engines.
   - **a.** Vane meter
   - **b.** Hot wire

Figure 1.13: *Air Flow Sensor*

3. **Throttle Body** – This controls how much air goes into the engine (in petrol engines). When the accelerator is depressed, the throttle plate opens and allows air into the engine. When the accelerator is released, the throttle plate closes and effectively chokes-off air flow into the combustion chamber.

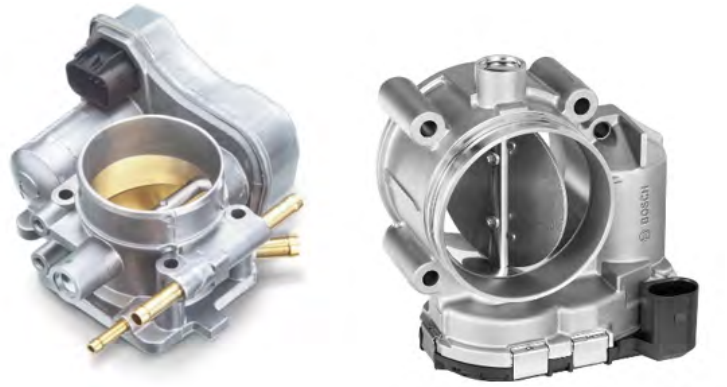


Figure 1.14: *Throttle body*

4. **Intake Manifold**: The intake manifold also known as the inlet manifold, is the component used to deliver an equal proportion of intake charge to each cylinder of the engine. It delivers an equal amount of charge to all cylinders to get higher performance from the engine. In carburetted engines, it is connected between the carburettor and cylinder head while in fuel-injected engines, it helps to connect the throttle body to the cylinder head. See Figure 1.15.

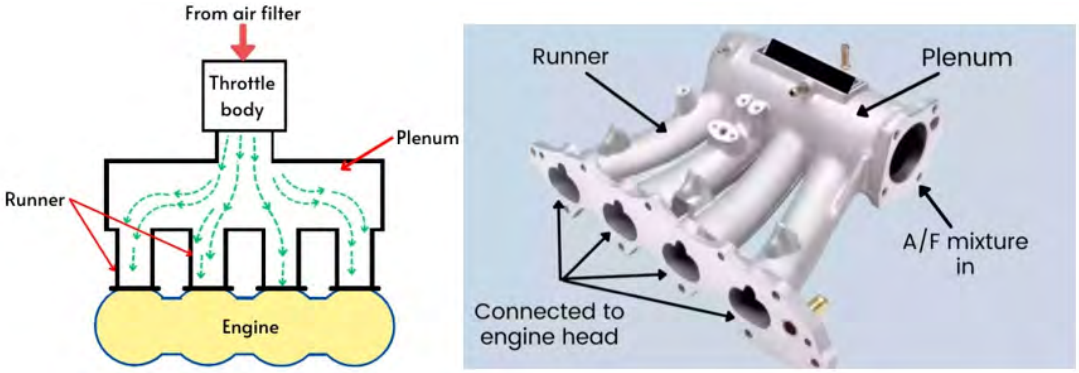


Figure 1.15: *Intake manifold*

5. **Turbocharger or Supercharger**: Increases the air pressure to allow more air into the engine cylinders for better performance. They differ in how they are powered. Superchargers are mechanically driven by the engine's crankshaft, while turbochargers utilise the energy of exhaust gases to spin a turbine and compress air.

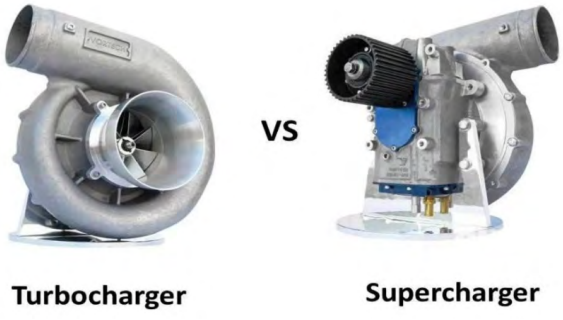


Figure 1.16: *Turbocharger or Supercharger*

FOCAL AREA 2: EXHAUST SYSTEM

The exhaust system removes burnt gases (exhaust gases) from the engine after combustion. It also helps to reduce noise and harmful emissions before releasing the gases into the air. The main functions of the exhaust system are:

1. To carry exhaust gases away from the engine.
2. To reduce engine noise.
3. To clean harmful gases before they are released into the environment.
4. To improve engine performance and fuel efficiency.

A modern automobile exhaust system has five main parts

1. Exhaust manifold
2. Oxygen sensor
3. Catalytic converter
4. Muffler or silencer
5. Exhaust pipes

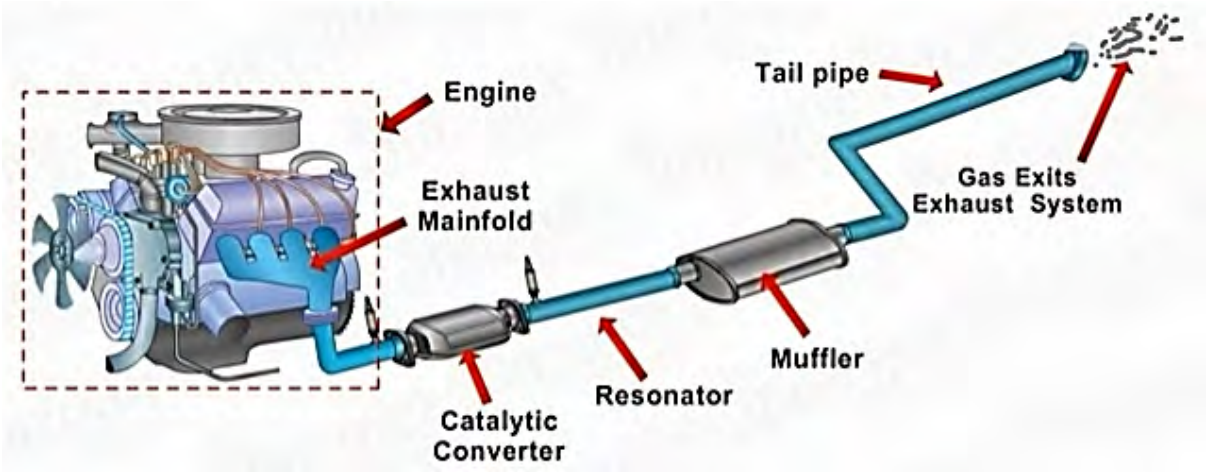


Figure 1.17: *Exhaust system*

1. **Exhaust Manifold:** The exhaust manifold attaches to the cylinder head and takes each cylinder exhaust and combines it into one pipe.

Figure 1.18: *Exhaust manifold*

2. **Oxygen sensor:** Oxygen sensor measures how much oxygen is present in the exhaust. From this the computer can add or subtract fuel to obtain the correct mixture for maximum fuel economy.

Figure 1.19: *Oxygen sensor*

3. **Catalytic converter**: The **function of a catalytic converter** is to reduce harmful gases produced by the engine before they are released into the atmosphere. It changes **carbon monoxide (CO), unburnt hydrocarbons (HC),** and **nitrogen oxides (NOx)** into **less harmful gases** such as **carbon dioxide (CO_2), water vapour (H_2O),** and **nitrogen (N_2).** This helps to lower air pollution and make vehicles more environmentally friendly.
4. **Muffler:** The muffler, also known as a silencer, is a part of the exhaust system in a vehicle. Its main function is to reduce the noise produced by the engine's exhaust gases. When fuel burns in the engine, it creates high-pressure gases that exit quickly through the exhaust pipe, making loud noise. The silencer helps to reduce this noise by slowing down and absorbing the sound waves before the gases leave the tailpipe.
5. **Exhaust Pipe:** An exhaust pipe is part of a vehicle's exhaust system. It carries hot gases from the engine to the back of the vehicle and releases them safely into the air.

Learning Tasks

1. State the purpose of the air intake and exhaust system.
2. List and describe the main components of the exhaust system.
3. List and describe the main components of the air intake system.
4. Explain what might happen if the silencer or catalytic converter fails.

Pedagogical Exemplars

Problem Based Learning

Learners work independently or in a group to identify and brainstorm how air goes in and out of an engine,

Assist learners to discuss how to get more air into the engine and present honest individual results to the class for discussion.

Research and collaboration

Organise the learners into mixed ability and gender inclusive groups, task them to research the main components of the exhaust system. Use diagrams or engine models to show each part of the air intake and exhaust system.

Play videos or sounds to demonstrate the role of the silencer and give real-life examples of what happens when the exhaust system fails

Key Assessment Level 4: Homework

1. Explain how each component of the air intake system contributes to the efficient running of the engine. (6 marks)

2. **a.** Compare three differences between naturally aspirated and turbocharged air intake systems.

b. Explain how each system affects engine performance, fuel efficiency and emissions under varying driving conditions

(6 marks)

3. Design a process to diagnose and repair a malfunctioning exhaust system in a vehicle, taking into consideration the symptoms of failure. Include safety precautions, tools required and troubleshooting steps.

(10 marks)

4 a. Compare the functions of the muffler and catalytic converter. (3 marks)

b. Describe how each contributes to the safety and efficiency of the exhaust system.

(3 marks)

PLC Session 4

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

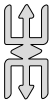
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes	Content Exploration

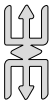
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 4 REVIEW

The lesson provided a clear and engaging introduction to the air intake and exhaust systems in automotive engines. It began by explaining the purpose of the air intake system, which is to bring clean air into the engine for combustion. Learners were introduced to the main components of the system, including the air filter, mass air flow sensor, throttle body, intake manifold, supercharger and turbocharger. These components were described in simple terms to help learners understand their functions and importance. The second part of the lesson focused on the exhaust system, which removes burnt gases from the engine and helps reduce noise and emissions. The main components discussed included the exhaust manifold, catalytic converter, silencer (muffler), and exhaust pipe. Each part was linked to its specific role in maintaining engine efficiency and environmental safety. The use of diagrams, practical examples, and group discussions helped reinforce key concepts. Overall, the lesson successfully supported learners' understanding of how these two systems work together to improve engine performance and reduce pollution.

MARKING SCHEMES/RUBRICS FOR THE KEY ASSESSMENTS

UNIT 1

1. Movement Commands (6 marks)

a. G00 (Rapid Positioning) (1 mark)

Moves the tool at maximum speed to the specified coordinates. (1 mark)

Used for non-cutting movements to quickly position the tool (1 mark)

G01 (Linear Interpolation) (1 mark)

Moves the tool in a straight line at the programmed feed rate. (1 mark)

Used for cutting operations in a straight line. (1 mark)

b. G02 (Clockwise Circular Interpolation). (1 mark)

Creates clockwise arcs at the programmed feed rate. (1 mark)

Requires centre point (I, J) or radius (R) parameters. (1 mark)

G03 (Counter-clockwise Circular Interpolation). (1 mark)

Creates counter-clockwise arcs at the programmed feed rate. (1 mark)

Requires centre point (I, J) or radius (R) parameters. (1 mark)

2. Spindle Control Commands (6 marks)

a. M03 (Spindle On - Clockwise) (1 mark)

Starts spindle rotation in the clockwise direction. (1 mark)

Used for most standard cutting operations. (1 mark)

b. M04 (Spindle On - Counter-clockwise) (1 mark)

Starts spindle rotation in the counter-clockwise direction. (1 mark)

Used for special cutting operations or left-handed tools. (1 mark)

c. M05 (Spindle Stop) (1 mark)

Stops the spindle rotation. (1 mark)

Used at the end of cutting operations or before tool changes. (1 mark)

d. S (Spindle Speed) (1 mark)

Sets the rotational speed of the spindle in RPM. (1 mark)

Must be used with M03 or M04 to activate the spindle. (1 mark)

3. A learner needs to programme a CNC machine to cut a square with 40 mm sides. The starting position is the top-left corner of the square at coordinates X10, Y10. Which sequence of G-code commands would correctly create this square with the cutting tool ending at the starting position? (10 marks)

Assessment Rubric **(10 marks)**

Excellent (8-10 marks)	**Very Good (5-7 marks)**	**Satisfactory (4-6 marks)**	**Needs improvement (1-3 marks)**
Perfect G-code sequence that: - Uses G00 for initial positioning to X10,Y10, - Uses G01 with appropriate feed rate for all cutting moves: - Correctly calculates all coordinates (X10,Y10 → X50,Y10 → X50,Y50 → X10,Y50 → X10,Y10), - Creates precise 40mm square sides.	Good G-code sequence with: - Mostly correct positioning and cutting commands. - Accurate coordinate calculations - Proper square dimensions.	Functional G-code that: - Creates a recognisable square - Has generally correct coordinates but may have minor calculation errors - Uses appropriate commands but may mix G00/G01 incorrectly.	Basic attempt that: - Shows understanding of coordinate system - Creates partial square path. - Has several coordinate errors. - May not return to start. - Contains multiple syntax errors. - Shows limited understanding of G00/G01 difference.

UNIT 2

Question 1

a. Effects of Clogged Fuel Filter on Engine Performance (5 marks)

Excellent (4-5 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive explanation of multiple effects.	Explanation of several effects.	Explanation of some key effects.	Minimal or incorrect explanation. Mentions only 1 basic effect.

b. Describe the steps you would take to diagnose and fix the problem 1 (a) above.

(7 marks)

Excellent (6-7 marks)	Very Good (4-5 marks)	Satisfactory (3-4 marks)	Needs improvement (1-2 mark)
Detailed, logical diagnostic sequence.	Good diagnostic approach.	Basic diagnostic steps.	Poor or incorrect diagnostic procedure.
Comprehensive repair sequence.	Good repair procedure.	Basic repair steps.	Poor or incorrect repair procedure.

Question 2

a. Maintenance Schedule Design (6 marks)

Excellent (5-6 marks)	Very Good (3-4 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive maintenance schedule.	Good maintenance schedule.	Adequate maintenance schedule.	Basic maintenance schedule

b. Explanation of Importance (6 marks)

Excellent (5-6 marks)	Very Good (3-4 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive explanation for each maintenance task.	Good explanation for each maintenance task.	Adequate explanation for each maintenance task.	Basic explanation for each maintenance task

c. Modern common-rail fuel injection

Excellent (9-10 marks)	Very Good (6-8 marks)	Satisfactory (3-5marks)	Needs improvement (1-2 marks)	
Demonstrates comprehensive understanding of both systems	Demonstrates good understanding with correct explanation of main components of both systems	Demonstrates adequate understanding with basic explanation of components	Demonstrates limited understanding with incomplete explanation of systems	
Preference justification.				
Provides excellent reasons with two clearly articulated, distinct reasons for preference.	Provides good reasons with two valid reasons for preference.	Provides satisfactory reasons with two basic reasons for preference.	Provides limited reasons with Vague or partially developed reasons.	Provides poor reasons with unclear or invalid reasons.

4. Fault finding Procedure

Excellent (10-12 marks)	Very Good (7-9 marks)	Satisfactory (4-6 marks)	Needs improvement (1-3 marks)
Develops a comprehensive, logically-sequenced procedure with: clear starting point.	Develops a good procedure with logical starting point.	Develops a basic procedure with identifiable starting point.	Develops a limited procedure with unclear starting point.

UNIT 3

Question 1

CNC Lathe Operation Planning (12 marks)

Excellent (10-12 marks)	Very Good (7-9 marks)	Satisfactory (4-6 marks)	Needs improvement (1-3 marks)
Thorough analysis of drawing.	Good analysis with minor omissions.	Basic analysis with significant omissions.	Limited analysis of the drawing.
Comprehensive logical sequence	Good sequence with minor inefficiencies	Basic sequence with some logical gaps.	Poor sequence with major flaws

Comprehensive tool selection.	Good tool selection.	Basic tool selection.	Poor tool selection.
Comprehensive G-code considerations	Good G-code considerations:	Basic G-code considerations:	Poor G-code considerations:

Question 2

a. Defect Analysis (4 marks)

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive analysis of all three defects.	Good analysis of all defects with minor limitations.	Basic analysis with some gaps.	Limited analysis of the three defects.

b. Causes and Corrective Adjustments (6 marks)

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs improvement (1 marks)
Comprehensive explanation of causes and corrective adjustments.	Good explanation causes and corrective adjustments.	Basic explanation causes and corrective adjustments.	Poor explanation causes and corrective adjustments.

Question 3

a. (8 marks)

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs improvement (1-2 marks)
Comprehensive and precise CNC milling process design with optimal tool selection and work-holding method. Excellent interpretation of working drawing with attention to tolerances and surface finishes.	Detailed description of CNC milling process with appropriate tool selection and suitable work-holding method. Clear interpretation of working drawing.	Adequate description of CNC milling process with appropriate but limited tool selection and basic work-holding method. Some interpretation of working drawing.	Basic description of CNC milling with minimal reference to tool selection and work-holding. Limited interpretation of working drawing.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Two comprehensive justifications demonstrating extended critical thinking about efficiency, quality, and manufacturing constraints	Two detailed justifications showing strategic reasoning	Two justifications with basic technical understanding	Single basic justification with limited technical reasoning.

Question 4 (6 marks)

a.

Excellent (5-6 marks)	Very Good (3-4 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive CNC milling process with optimal material selection, appropriate tooling sequence, well-calculated cutting parameters and thorough safety measures. Process demonstrates extended critical thinking and could be implemented without significant modification.	Good description of CNC milling process with appropriate consideration of material selection, tooling, cutting parameters and safety measures. Process is mostly complete but may have minor omissions.	Adequate description of CNC milling process with appropriate consideration of material selection, tooling, cutting parameters and basic safety measures. Process is mostly complete but may have minor omissions.	Basic description of CNC milling process with minimal consideration of material selection, tooling, cutting parameters, OR safety measures. Process lacks sufficient detail to be implementable

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Detailed and well-justified rationale for all decisions, showing extended critical thinking that considers efficiency, quality, production constraints, and industry standards.	Clear rationale provided for most decisions, demonstrating sound technical understanding and strategic reasoning.	Adequate rationale provided for some decisions, demonstrating minimal technical understanding and reasoning.	Limited rationale provided for some decisions with minimal technical understanding.

UNIT 4

Q1

Excellent (5-6 marks)	**Very Good** (4 marks)	**Satisfactory** (3 marks)	**Needs Improvement** (1-2 marks)
Correctly identifies all major components of the air intake system (air filter, intake manifold, throttle body, air flow sensor, resonator, etc.). Provides detailed explanation of each component's specific function. Clearly articulates how each component directly contributes to engine efficiency. Uses precise technical terminology throughout. Demonstrates comprehensive understanding of the relationship between air intake and engine performance.	Identifies most major components of the air intake system and explains the function of each identified component accurately. Connects most components to engine efficiency using appropriate technical terminologies to show good understanding of how air intake affects engine operation.	Identifies some components of the air intake system and provides basic explanation of component functions. Makes limited connections to engine efficiency. Uses some technical terms correctly. Demonstrates basic understanding of air intake system's role.	Identifies few components of the air intake system and provides minimal explanation of its functions. Makes little or no connection to engine efficiency. Uses minimal technical terminology or uses terms incorrectly to show limited understanding of how air intake affects engine performance

Q2

Excellent (8-10 marks)	**Very good (5-7 marks)**	**Satisfactory (3-5 marks)**	**Needs improvement (1-2 marks)**
Demonstrates comprehensive understanding of both systems with accurate technical details, clear comparisons and thorough explanation of performance implications across varying conditions.	Shows strong understanding of both systems with good technical details and explanation of performance implications.	Demonstrates adequate understanding of the systems and their effects on engine operation.	Shows basic understanding of the differences between systems with limited technical explanation.

Q3

Criteria	Excellent (8-10 marks)	Very Good (6-7 marks)	Satisfactory (4-5 marks)	Needs Improvement (1-3 marks)
Knowledge of Air Intake Systems	Accurately identifies and comprehensively explains three distinct differences between naturally aspirated and turbocharged systems with precise technical vocabulary.	Identifies and clearly explains three differences between the systems with appropriate technical terms.	Identifies at least two differences between systems with some technical understanding.	Identifies only one difference or shows major misconceptions about how the systems function.
Analysis of Performance Effects	Provides detailed analysis of how each system affects engine performance across multiple driving conditions (e.g., low-end torque, high-RPM power, altitude compensation).	Explains performance differences between systems across standard driving conditions with clear examples.	Explains basic performance differences with limited connection to driving conditions.	Minimal or incorrect explanation of performance effects.
Understanding of Fuel Efficiency	Comprehensively explains efficiency implications of both systems, including detailed discussion of power-to-fuel ratios and specific driving scenarios.	Clearly explains efficiency differences between systems with supporting examples.	Provides basic explanation of fuel efficiency differences.	Shows limited understanding of how air intake systems affect fuel efficiency.
Analysis of Emissions Impact	Provides sophisticated analysis of emissions differences, including specific pollutants and how they vary under different load conditions.	Explains emissions differences with clear understanding of environmental impacts across driving conditions.	Basic explanation of emissions differences with limited connection to driving conditions.	Minimal or incorrect explanation of emissions impact.

Technical Accuracy	All explanations demonstrate exceptional technical accuracy and depth of understanding of automotive principles.	Explanations show sound technical understanding with minor oversights.	Explanations show adequate technical understanding with some errors.	Significant technical errors throughout the response.

Q4

Criteria	Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (3 marks)	Needs Improvement (1-2 marks)
Function Comparison	Comprehensively compares functions with clear distinctions: muffler primarily reduces noise through sound wave cancellation/absorption while catalytic converter chemically converts harmful emissions (CO, HC, NOx) to less harmful substances (CO_2, H_2O, N_2). Includes precise technical explanations of operational principles.	Clearly differentiates primary functions with accurate descriptions of both components. Includes some technical explanation of how each works.	Basic comparison that identifies primary functions but with limited technical explanation of how they operate.	Minimal or incorrect comparison. May confuse the primary functions of the components or provide very superficial descriptions.
Safety Contributions	Detailed explanation of safety aspects: catalytic converter reduces toxic emissions preventing health hazards; muffler prevents excessive noise pollution protecting hearing and meeting legal requirements. Explains how backpressure management prevents engine damage.	Clear explanation of safety contributions for both components with specific examples of how they protect users and environment.	Basic explanation of safety benefits with limited detail or missing some key safety aspects.	Minimal or incorrect explanation of safety contributions. Significant safety aspects overlooked.
Efficiency Contributions	Sophisticated analysis of efficiency: explains how catalytic converter's operation affects fuel economy, how proper muffler design balances noise reduction with optimal			

SECTION 2: CNC MACHINES AND ENGINES

The section covers the following unit (strands); Metal technology and Automotive technology.

In this section learners will be able to perform operations using CNC milling machine, CNC drilling and grinding machines. In the Automotive construction technology unit, learners are expected to gain the knowledge and understanding of air intake system of the engine and describe the principle of supercharger and turbocharger. All the above are treated from unit 5 to unit 9.

UNIT 5

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines.

Learning Outcome: *Be able to use selected manual and computerised machines.*

Content Standard: Demonstrate understanding of use and care for engineering tools and computerised machines.

INTRODUCTION AND UNIT SUMMARY

CNC machines are important tools in modern engineering and manufacturing. They use computer programmes to control the movement of tools with high accuracy. Two common types of CNC machines are the CNC drilling machine and the CNC grinding machine. Each of these machines plays a key role in producing precise and high-quality parts, often used in automotive, aerospace, and industrial applications. This lesson presents a CNC drilling machine which is designed to drill holes into various materials, such as metal or plastic. It highlights the main parts of the machines, the control panel for entering the programme, the drilling head with a rotating drill bit, the worktable where the material is placed, and a clamping system to hold the material firmly. In addition, the lesion also presents a CNC grinding machine which is used to smooth or shape hard surfaces by removing small amounts of material. It also discusses its main parts include the control panel, a grinding wheel that rotates at high speed, the worktable, and a coolant system to prevent overheating. Teaching these two CNC machines requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the CNC machines. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the

learners and ensuring that the learners develop a deep understanding of the working principle of CNC drilling and grinding machines

This unit covers only week 5: ***Describe the main features and perform operations using CNC drilling and grinding machines***

Recap weeks

Year 2	**Week 4:** Describe twist drills and use drilling and grinding machines.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the main features of CNC drilling and grinding machines requires various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate and apply basic understanding and skills to the use these CNC machines, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding and the application of CNC drilling and grinding machines.

ASSESSMENT SUMMARY

To evaluate learners' understanding of how CNC drilling and grinding machines work, along with their parts, principles, and safe operation steps, assessments can span various levels to gauge learners' understanding and application of the working principle and the usage. However, by employing a DOK level 4 for assessment learners must not only understand how CNC machines work, but also evaluate, plan, and apply this knowledge in real-world or problem-solving situations. Teachers can also effectively measure learners' understanding and application, of CNC drilling and grinding machine in a given task.

Indicators	DOK Level	*Assessment Strategy and/or Mode*
Describe the main features and perform operations using CNC drilling and grinding machines	4 (Extended critical thinking and reasoning)	Discussion and Practical Assess-ment

WEEK 5

Learning Indicator: *Describe the main features and perform operations using CNC drilling and grinding machines*

FOCAL AREA 1: CNC DRILLING MACHINES

A CNC drilling machine is a computer-controlled machine used to make precise holes in materials like metal, plastic, or wood.

1. CNC = Computer Numerical Control
2. Drilling = Making round holes using a rotating drill bit

Drilling is commonly used for mass production. The drilling machine (drilling press) is used to create or enlarge holes. There are drilling machines for different jobs;

1. **The bench drill**: For drilling holes through raw materials such as wood, plastic and metal.
2. **The pillar drill:** A larger version that stands upright on the floor. As the bench drill, it can be used to drill larger pieces of materials and produce bigger holes.

Figure 2.1: *CNC Drilling Machine*

Main Parts of a CNC Drilling Machine

Part	Function
Drill Bit	Cuts the hole
Spindle	Holds and spins the drill bit
Worktable	Holds the workpiece in place
Control Panel	Input for the CNC programme (e.g., G-code)
Drive Motors	Move the machine along X, Y, Z axes

How It Works

The process begins by writing a programme using commands, such as G-code. Once the material is securely fixed on the machine's table, the drill bit starts spinning and moves into the correct positions. The machine then drills holes according to the programmed instructions.

Advantages of CNC Drilling

1. High Accuracy
2. Fast and Repeatable
3. Low Human Error
4. Can Drill Complex Patterns

Common Uses

1. Car engine parts
2. Printed circuit boards (PCBs)
3. Metal frames and plates

Safety Tips

1. Wear safety glasses at all times.
2. Keep hands away from the drill bit.
3. Make sure the material is properly clamped.
4. Never touch moving parts.

FOCAL AREA 2: CNC GRINDING MACHINE

CNC (Computer Numerical Control) grinding is a process where a computer controls a grinding machine to shape or finish metal or other hard materials. It is often used to give parts a smooth surface or to make them the exact size needed. Grinding metal process uses a coated wheel that slowly removes metal to create a part. Through the years, grinding was done on a manual machine, but with the advent of CNC technology, the grinding process has advanced

Figure 2.2: *High Precision CNC Surface Grinding Machine*

Main Parts of a CNC Grinding Machine

1. **Control panel:** Where the operator inputs the programme (e.g. G-code).
2. **Grinding wheel:** The rotating wheel that does the cutting or shaping.
3. **Worktable:** The surface where the workpiece is placed and fixed.
4. **Coolant system: Keeps the part and tool cool during grinding.**

How It Works

1. A programme is written with specific instructions for grinding.
2. The workpiece (material) is fixed onto the machine's table.
3. The grinding wheel spins at high speed.
4. The machine moves the wheel accurately to remove material.
5. The part is shaped or finished exactly as programmed.

Advantages of CNC Grinding

1. Very accurate and repeatable.
2. Can create very smooth finishes.
3. Can grind complex shapes.
4. Reduces human error.

Safety Tips

1. Always wear safety glasses.
2. Keep hands away from the moving wheel.
3. Make sure the workpiece is fixed properly.
4. Never touch the grinding wheel when it's moving.

Learning Tasks

1. What does CNC drilling and grinding machines do?
2. Describe the main parts of CNC drilling machines.
3. Describe the main parts of a CNC grinding machines.
4. Describe its main steps in using CNC drilling and grinding machines.

Pedagogical Exemplars

Talk for learning approaches: With video or simulation, learners are exposed to the various features of drilling and grinding machines in the manufacturing industry. Assist learners to effectively identify and describe the main features of the CNC drilling and grinding machines.

Experiential Learning: In the school workshop or local manufacturing industry with learners or simulated activities, help learners to identify, observe and perform the operations using the drilling and grinding machines.

Key Assessment Level 4: Discussion and Practical

1 **a.** Develop a complete process plan for machining a given part that requires both drilling and grinding include operation sequencing, tool and machine selection and quality control steps.

b. Give two justifications of using this process. (4 marks)

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

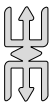
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***discussion and practical***. 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

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 la-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.

UNIT 5 REVIEW

In this lesson, we learned about two important types of computer-controlled machines used in modern manufacturing: CNC drilling machines and CNC grinding machines. First, we looked at the CNC drilling machine, which is used to drill holes accurately into materials like metal or plastic. We identified its main parts, including the control panel, drilling head (with drill bit), worktable, and clamping system. We also discussed how it works: a programme is entered into the machine, the material is fixed in place, and the drill bit spins and moves to the correct position to drill holes as programmed. We noted that the advantages of CNC drilling include high accuracy, fast operation, repeatable results, and reduced human error. We also focused on the CNC grinding machine, which is used to shape or finish surfaces by removing small amounts of material. The main parts of this machine include the control panel, grinding wheel, worktable, and coolant system. In learning how it works, we saw that the machine follows a programmed path to move the grinding wheel across the material, creating smooth and precise finishes. The advantages of CNC grinding include excellent surface quality, the ability to create complex shapes, and consistent, accurate results with less waste.

UNIT 6

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Be able to analyse fuel supply system for compression ignition(C1) engine systems*

Content Standard: Demonstrate and apply knowledge in the working principles of fuel supply system for both spark ignition (SI) and compression ignition(C1) engines as well air intake and exhaust systems

INTRODUCTION AND SECTION SUMMARY

In this lesson, learners will learn about superchargers and turbochargers, which are devices used to increase engine power by forcing more air into the combustion chamber. We will begin by identifying the main parts of both systems, such as the compressor, turbine, and shaft. Learners will explore the working principles, understanding how a supercharger is driven by the engine while a turbocharger uses exhaust gases. The lesson will also cover the different types of superchargers such as roots and centrifugal as well as for turbocharger. We will compare the advantages and disadvantages of the two systems. Learners will also examine the key differences between the two systems in terms of design, performance, and application. By the end of this lesson, learners should be able to explain how each device works, name its parts,

list its pros and cons, and identify when and why each is used in automotive and mechanical systems. Teaching these two systems requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying these systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the working principles of superchargers and turbochargers.

***This unit covers only** week 6: Describe the principle of supercharger and turbocharger*

Recap weeks

Year 1	**Week 2:** Identify types of engines and describe the main components of the engine. **Week 4 and 7**: Explain the constructional and operational difference between petrol and diesel engines.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching superchargers and turbochargers as part of the air intake and exhaust systems in automotive engines requires a blend of diverse teaching strategies to support effective learning. To help learners understand the principles, components, and functions of these systems, teachers should use problem-based learning, collaborative group work, scaffold instruction, experiential activities, and project-based tasks. These approaches combine theoretical, visual, practical, and interactive methods, addressing various learning styles and abilities. For example, learners can engage in hands-on activities to examine turbocharger parts, use diagrams to trace airflow, and work in groups to compare supercharger and turbocharger types. Scaffolded lessons can break down complex processes like forced induction, while problem-solving tasks can involve diagnosing engine performance issues. Through these methods, learners gain not only a clear understanding of how superchargers and turbochargers operate but also develop essential critical thinking and problem-solving skills. These pedagogical strategies enable learners to analyse component functions, compare system types, and appreciate how intake and exhaust systems work together to enhance engine performance.

ASSESSMENT SUMMARY

To effectively assess learners' understanding of superchargers and turbochargers within the air intake and exhaust systems, a variety of assessment methods should be used. These should move beyond simple fact recall and focus on real-world application of knowledge. Using Depth of Knowledge (DOK) Level 4 assessments, learners should be able to describe, explain, analyse, and evaluate the working principles and components of these systems. Assessments may include written tasks, where learners explain the differences between superchargers and turbochargers; group presentations comparing types and applications; hands-on demonstrations showing airflow through a turbocharger setup; or project-based assignments involving engine system analysis or fault diagnosis. These higher-order tasks ensure that learners can link theoretical concepts to practical engine functions, such as performance improvement or troubleshooting. This approach supports the development of critical thinking, problem-solving, and a deeper understanding of how forced induction systems contribute to overall engine efficiency and performance.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe the principle of supercharger and turbocharger.	Level 4 Extended critical thinking and reasoning	Mid-Semester Examination

WEEK 6

Learning Indicator: *Describe the principle of supercharger and turbocharger*

FOCAL AREA 1: SUPERCHARGER

A supercharger is a device used in engines to increase the amount of air entering the combustion chamber. This increase in air allows more fuel to be burned, resulting in more power from the engine. Superchargers are commonly used in high-performance vehicles, enhancing acceleration and overall engine efficiency. These power-enhancing devices are driven mechanically, using gears, belts, shafts, or chains connected to the engine's crankshaft. See Figure 2.3.

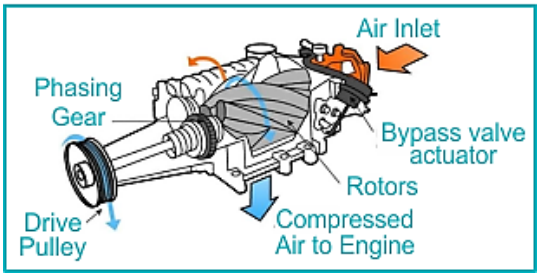


Figure 2.3: *Supercharger*

The engine's crankshaft operates a supercharger, whereas a turbocharger utilises the energy from exhaust gases generated during combustion. Both devices aim to amplify the volume of air entering the intake manifold, enabling the engine to burn more fuel and produce greater power output.

Working Principle of Supercharger

Superchargers play a vital role in compressing and pressurising air, enabling it to enter the cylinders. The initial air-fuel mixture may not achieve complete combustion during acceleration due to insufficient pressure. Superchargers address this issue by compressing air into the cylinders, increasing their density. This higher density allows for more fuel to be burned during each cycle, promoting more complete combustion and enhancing engine performance.

Types of Superchargers

1. **Roots Type**
   - **a.** Simple design with lobed rotors.
   - **b.** Provides boost at lower RPMs, good for instant power.

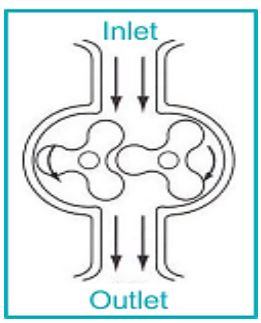


Figure 2.4: *Roots Supercharger*

2. **Centrifugal Type**
   a. Operates like a turbocharger but driven by a belt.
   b. Better efficiency at higher RPMs, providing smooth power increase.

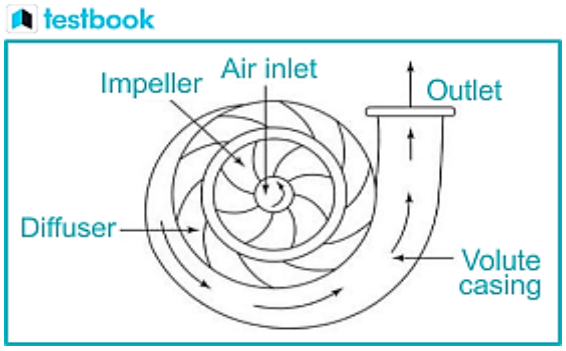


Figure 2.4: *Centrifugal*

Supercharger Advantages

A supercharger in an automotive engine offers several advantages, including:

1. Boosts engine power immediately no delay like turbo lag.
2. Driven directly by the engine usually by a belt, making it easier to understand and control.
3. Provides strong pulling power at lower engine speeds.
4. Increases air and fuel intake, leading to more powerful combustion.
5. Delivers fast acceleration, ideal for performance vehicles.

The disadvantages of a supercharger include:

1. Takes power from the engine to run, which slightly reduces efficiency.
2. Burns more fuel due to increased air and power demand.
3. Extra pressure and heat can wear out engine parts faster.
4. Compressed air gets hot; this heat must be managed properly.
5. Superchargers can be louder than turbochargers.

FOCAL AREA 2: TURBOCHARGER

A turbocharger is a device that forces more air into an engine's cylinders, resulting in increased power and efficiency. It's powered by exhaust gases, which spin a turbine connected to a compressor that sucks in and compresses air. This increased air density allows for more fuel to be burned, leading to more power and potentially better fuel economy. The main parts of a turbocharger are

1. **Turbine**: Spun by exhaust gases.
2. **Compressor**: Compresses the air going into the engine.
3. **Shaft**: Connects turbine and compressor.
4. **Intercooler**: Cools the compressed air before it enters the engine

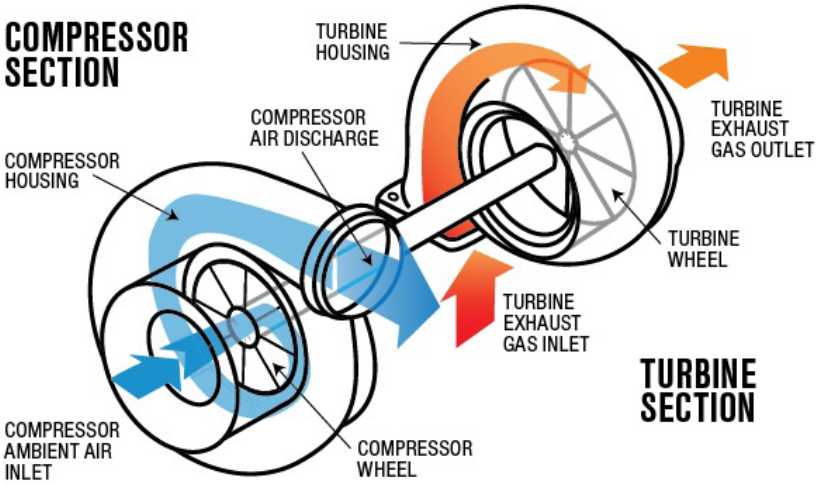


Figure 2.4: *Turbocharger*

Working principle of a turbocharger

The working of a turbocharger begins when hot exhaust gases leave the engine after combustion. These gases are directed into the turbine side of the turbocharger. As they pass through, the fast-moving exhaust gases spin the turbine wheel. This turbine is connected by a shaft to a compressor wheel on the other side of the turbocharger. So, when the turbine spins, it also causes the compressor to spin at high speed. The spinning compressor draws in fresh air from the atmosphere and compresses it. This compression increases the density of the air, meaning it contains more oxygen. The compressed air is then sent into the engine's intake system. Because there is now more air, the engine control system can also add more fuel. This creates a stronger explosion in the combustion chamber during each engine cycle. As a result, the engine burns more air and fuel together, which leads to the production of more power than a regular, naturally aspirated engine.

Advantages of Turbochargers

1. Boosts engine power without increasing engine size.
2. Smaller engines with turbochargers can be more fuel-efficient.
3. Helps burn fuel more completely.

Disadvantages of Turbochargers

1. Slight delay in power when the accelerator is pressed.
2. Exhaust heat can damage parts if not managed well.
3. Turbos work at very high speeds and temperatures.

Difference between Supercharger and Turbocharger

Superchargers and turbochargers both increase engine power but differ in their operation. Superchargers are mechanically driven by the engine, delivering instant power but using engine power. Turbochargers are exhaust-driven, providing power with less impact on fuel efficiency but suffering from "turbo lag" before boosting. Each has unique advantages depending on the application. The below table lists the difference between supercharger and turbocharger.

Supercharger	Turbocharger
Driven by the engine's crankshaft using a belt, chain, or gear drive.	Driven by the force of exhaust gases from the engine.
Provides immediate power boost at lower engine RPMs.	Power delivery is delayed due to the time needed for exhaust gas build-up.
Increases engine power output throughout the RPM range.	Power output is more prominent at higher RPMs.
Produces more heat due to mechanical drive, requiring an intercooler for efficient operation.	Exhaust gas-driven, resulting in less heat generation and often utilising an intercooler.
Generally simpler installation and requires less modification to the engine.	More complex installation, often requiring modifications to the exhaust system.
Typically results in lower overall engine efficiency due to power loss from mechanical drive.	Can improve engine efficiency by utilising waste energy from exhaust gases.
Provides immediate throttle response and linear power delivery.	Turbo lag may cause delayed throttle response and non-linear power delivery.
Usually used in applications where instant power and response are desired, such as in sports cars.	Commonly used in high-performance and diesel engines, where efficiency and power at higher RPMs are essential.

Learning Tasks

1. State the difference between the superchargers and turbocharger.
2. Describe the working principle of supercharger and turbochargers.
3. Explain the advantages and disadvantages of using superchargers and turbochargers.

Pedagogical Exemplars

Problem Based Learning

Learners work independently or in a group to identify and brainstorm the principle of supercharger and turbocharger systems.

Assist learners to discuss what goes in and out of an engine, how to get more of these things into the engine and present an honest individual results to the class for discussion**.** Use simple explanations with diagrams or videos.

Demonstrate and show actual components or working models.

Group discussion to allow students to compare systems and share ideas. Learners observe and identify forced induction systems in real or simulated engines.

Key Assessment: Mid-Semester Examination

1. Compare three advantages and disadvantages of using a supercharger versus a turbocharger in a high-performance vehicle consider factors such as engine efficiency, power delivery, fuel economy, and maintenance requirements.

(10 marks)

2. With the aid of a diagram explain the main difference between supercharger and turbocharger

(6 marks)

Hint

*Conduct **Mid-semester Examination**. It should cover contents taught from Week 1 to 5. Refer to the **Table of Specification and Structure of the Paper**. 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	Programming language for (CNC) machines	MCQs	2	2	–		4
		ESSAY	–	–	–		–
2	Fuel supply system for spark ignition (SI) engine Fuel supply system for compression ignition (CI) engine	MCQs	2	2	2		6
		ESSAY	–	–	1		1
3	CNC lathe machines CNC milling machines	MCQs	–	2	1		3
		ESSAY	–	–	–		
4	Air intake system Exhaust system	MCQs	3	2	1		6
		ESSAY					
5	CNC drilling machines CNC grinding machine	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.

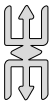
b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).

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

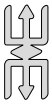
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 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 la-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.

UNIT 6 REVIEW

This lesson provided learners with a comprehensive understanding of superchargers and turbochargers, focusing on their function within an engine's air intake and exhaust system. The session began with an overview of the main components, including the compressor, turbine, shaft, and drive mechanisms. Learners explored the working principles of both systems—highlighting that superchargers are mechanically driven by the engine, while turbochargers are powered by exhaust gases. The lesson also covered the types of superchargers roots, and centrifugal helping students identify their applications in real-world contexts. Through class discussions and visual aids, learners examined the advantages and disadvantages of each system, such as turbo lag in turbochargers and increased fuel consumption in superchargers. A clear comparison of the differences between the two systems helped reinforce understanding, encouraging learners to think critically about efficiency, response time, and engine performance. Overall, the lesson was well-structured, interactive, and effectively combined theory with practical examples, supporting the development of both technical knowledge and analytical skills.

UNIT 7

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines.

Learning Outcome: *Be able to use selected manual and computerised machines.*

Content Standard: Demonstrate understanding of use and care for engineering tools and computerised machines.

INTRODUCTION AND UNIT SUMMARY

This lesson explores 3D printers and lasers the two important technologies used in modern manufacturing and engineering: These technologies have changed the way we design, create, and process materials, making production faster, more accurate, and more efficient. The lesson defines 3D printers, which are machines that build objects layer by layer from a digital design and identifies the main parts of a 3D printer, such as the extruder, filament, print bed, and control panel. It also looks at how 3D printing works, starting with a design created in CAD software, followed by slicing the model and printing it using filament material. It also highlights the basics of designing 3D models for printing and why this process allows for creativity and customisation. Learners will also learn laser technology, which is used in various fields like cutting, engraving, measuring, and communication and identify the main parts of a laser system, including the laser medium, energy source, mirrors, and focusing lens. The lesson will also introduce learners to how lasers produce a narrow, powerful beam of light and the advantages of laser technology. Teaching these 3D printers and lasers require various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying 3D printers and lasers. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding and the application of 3D printers and lasers

This unit covers only week 7:

1. ***Describe and perform operations using 3D printers.***
2. ***Describe and perform operations using lasers.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the working principles of 3D and lasers require various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate and apply basic understanding, and skills to the use of 3D printers and lasers, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding and demonstrate the use of 3D printers and lasers.

ASSESSMENT SUMMARY

To evaluate learners' understanding of how 3D printers and lasers work, along with their parts, principles, and safe operation steps, assessments can span various levels to gauge learners' understanding and application of the working principle and the usage. However, by employing a DOK level 4 for assessment learners must not only understand how 3D printers and lasers work, but also evaluate, plan, and apply this knowledge in real-world or problem-solving situations. Teachers can also effectively measure learners' understanding and application, of 3D printers and lasers in a given task.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe and perform operations using 3D printers	Level 4 Extended critical thinking and reasoning	Demonstration and Practical Assessment
Describe and perform operations using lasers	Level 4 Extended critical thinking and reasoning	Demonstration and Practical Assessment

WEEK 7

Learning Indicators

1. *Describe and perform operations using 3D printers*
2. *Describe and perform operations using lasers*

FOCAL AREA 1: 3D PRINTERS

3D printing is a modern manufacturing process that creates three-dimensional objects by building them layer by layer from a digital design. It is also known as additive manufacturing because material is added, rather than cut away as in traditional machining.

Figure 2.5: *3D Printer*

Basic Terminology

1. **Additive manufacturing** refers to technologies that create objects through sequential layering.
2. **Rapid prototyping** is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data.
3. **Subtractive processes** is the removal of material by methods such cutting or drilling.
4. **Stereolithography** is defined as the system for generating three-dimensional objects by creating aa cross-sectional pattern of the object to be formed.

3D printing methods and methodologies

The following are the three broad types of 3D printing technology:

1. **Sintering** is a technology where the material is heated, but not to the point of melting, to create high resolution items. Metal powder is used for direct metal laser sintering while thermoplastic powders are used for selective laser sintering.
2. **Melting** methods of 3D printing include powder bed fusion, electron beam melting and direct energy deposition, these use lasers, electric arcs or electron beams to print objects by melting the materials together at high temperatures.

3. **Stereolithography** utilises photo polymerisation to create parts. This technology uses the correct light source to interact with the material in a selective manner to cure and solidify a cross section of the object in thin layers.

Main Parts of a 3D Printer

1. **Control Panel:** Used to operate the printer and start the printing job.
2. **Extruder/Print Head:** Heats and pushes out the material (usually plastic).
3. **Filament:** The raw material, often in the form of a plastic wire (commonly PLA or ABS).
4. **Build Platform (Print Bed):** The surface where the object is printed.
5. **Frame:** The main body that holds all parts together.
6. **Stepper Motors:** Move the print head and platform precisely.

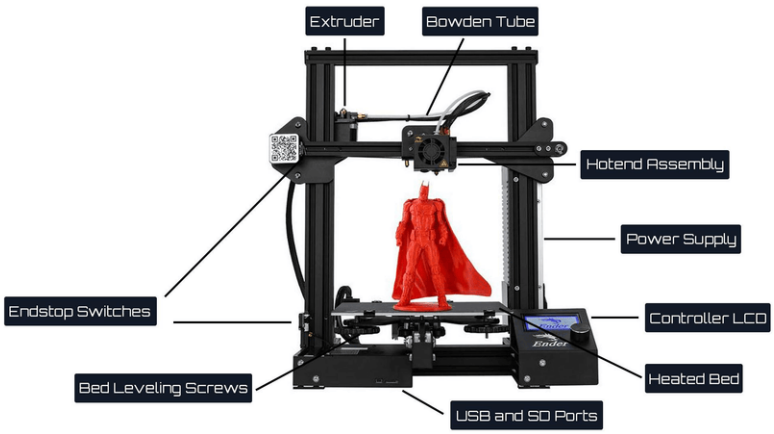


Figure 2.6: *Parts of a 3D Printer*

Working Principle of 3D Printing

To begin the 3D printing process, a design is first created using **CAD (Computer-Aided Design) software.** Once the design is complete, it is saved as a **STL file**, which is a common file format for 3D models. This file is then opened in a **slicer programme,** which breaks the model into thin layers and generates a set of instructions known as **G-code**. The G-code tells the 3D printer exactly how to move and what to do. After the G-code is uploaded to the printer, the machine heats the **filament,** usually a type of plastic, and pushes it through the **print head**. The printer then follows the instructions to build the object **layer by layer** continuing this process until the full shape is complete.

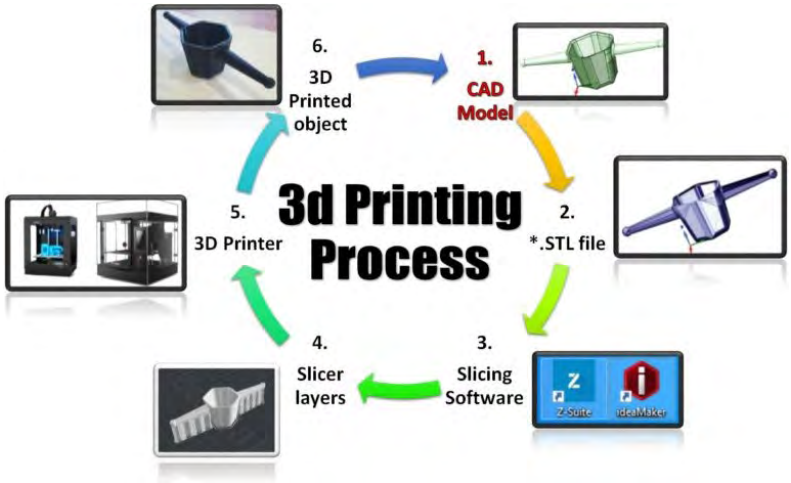


Figure 2.7: *3D printing process*

Designing 3D CAD model for 3D Printing

To develop 3D model, you will need to use a CAD (computer-aided design) programme. Cadding is the process of designing a 3D printer model in a CAD programme. There are many different CAD programmes available. Below are some of the CAD packages:

1. Tinkercad is a free browser-based CAD platform for 3D design, electronics, and coding that students and educators can access on any web-connected device.

Figure 2.8: *Tinkercad*

2. Onshape is a free browser-based CAD platform that students and educators can access on any web-connected device.

Figure 2.8: *Onshape*

3. SOLIDWORKS 3D CAD is a subscription programme that is great for engineering projects.

Figure 2.8: *SolidWorks*

4. AutoCAD is used by architects, engineers, and construction professionals.

Figure 2.8: *AutoCAD*

5. Fusion is a design and make platform that incorporates CAD as well as simulation (CAE) and manufacturing (CAM).

Figure 2.8: *Fusion*

STL File: An STL file is a simple, portable format used by computer aided design (CAD) systems to define the solid geometry for 3D printable parts. An STL file provides the input information for 3D printing by modelling the surfaces of the object as triangles that share edges and vertices with other neighbouring triangles for the build platform.

3D Printing Materials (Metals)

Popular metal 3D printing materials are

1. **Titanium** is lightweight and has excellent mechanical characteristics. It is strong, hard and highly resistant to heat, oxidation, and acid.
2. **Stainless steel** has high strength, high ductility, and is resistant to corrosion.
3. **Aluminium** is a lightweight, durable, strong, and has good thermal properties.
4. **Tool steel** is a hard, scratch-resistant material that you can use to print end-use tools and other high-strength parts.
5. **Nickel alloys** have high tensile, creep and rupture strength and are heat and corrosion resistant.

3D Printing Materials (Plastics)

FDM 3D printing materials are available in a variety of colour options. Various experimental plastic filament blends also exist to create parts with wood- or metal-like surfaces.

Figure 2.9: *3D Printing plastic materials*

Advantages of 3D Printing

1. **Fast Prototyping:** Designs can be quickly turned into physical models.
2. **Customisation:** Each print can be easily modified.
3. **Less Waste:** Only the needed material is used.
4. **Complex Shapes:** Can produce shapes that are difficult with traditional methods.
5. **Lower Costs for Small Batches:** No need for expensive moulds or tools.

The disadvantages of 3D printing include

1. **Can have a lower strength than with traditional manufacture**
2. **Increased cost at high volume**
3. **Limitations in accuracy**
4. **Post-processing requirements**

Common Applications

1. Aerospace and automotive industry
2. Prototypes for engineering and design projects
3. Robotics
4. Custom tools or parts
5. Medical models and aids
6. Educational models
7. Art and creative objects

Safety Tips

1. Keep the area well-ventilated when printing.
2. Avoid touching the hot extruder or print bed.
3. Wait for the print to cool before removing it.
4. Keep long hair and loose clothing away from moving parts.

FOCAL AREA 2: LASERS

A laser is a device that produces a strong, focused beam of light. The word LASER stands for Light Amplification by Stimulated Emission of Radiation. Laser light is very powerful, precise, and travels in a straight line. It is used in many fields such as manufacturing, medicine, and communication.

Figure 2.10: *Laser machine*

Properties of Laser Light

1. **Monochromatic:** Made of one colour or wavelength.
2. **Coherent:** The light waves move together in step.
3. **Directional:** Travels in a narrow, straight beam.
4. **Intense:** Much brighter and more focused than normal light.

Main Parts of a Laser System

1. **Laser Medium:** The material that produces the laser light (e.g., gas, crystal, or diode).
2. **Energy Source:** Supplies power to excite the medium (e.g., electrical current).
3. **Mirrors:** Reflect light to build up energy inside the laser.
4. **Focusing Lens:** Concentrates the beam for cutting or marking.
5. **Cooling System:** Keeps the laser from overheating.

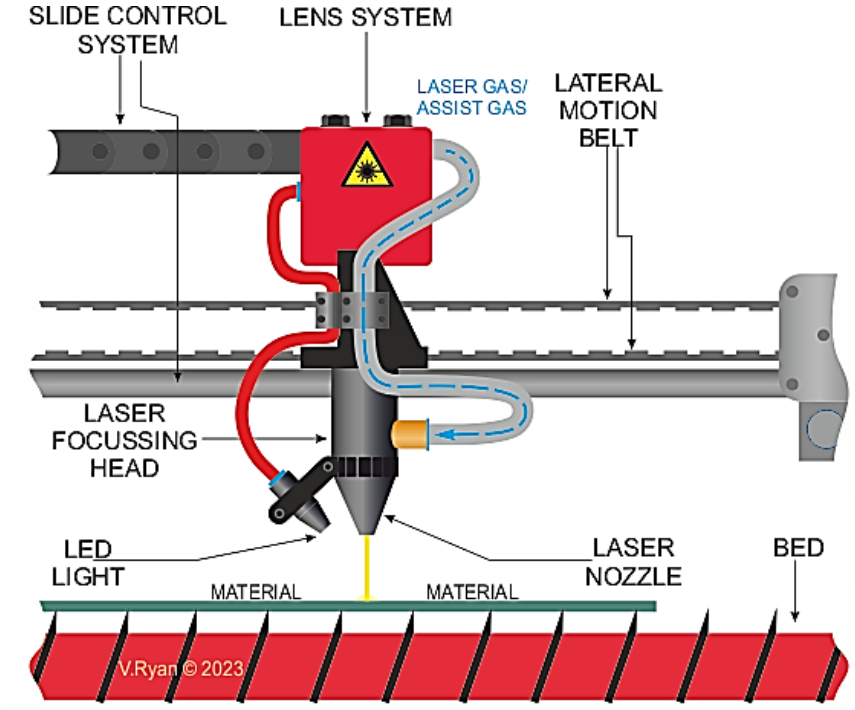


Figure 2.11: *Parts of a Laser System*

Parts of a Laser machine

How It Works

1. Energy is supplied to the laser medium.
2. The medium gets excited and emits light.
3. The light bounces between mirrors, becoming stronger.
4. One mirror lets the beam out in a straight line.
5. The focused laser beam can then be used to cut, engrave, or measure materials.

Common Uses of Lasers in Technology

1. **Cutting and Engraving:** In CNC laser machines for metals, plastics, and wood.
2. **Measuring and Alignment:** In construction and surveying tools.
3. **Communication:** In fibre optic cables for fast data transfer.
4. **Medical Applications:** In surgery, eye treatment, and dental care.
5. **Barcode Scanners and Printers:** For reading and writing data.

Advantages of Laser Technology

1. **High Precision:** Can cut or mark very small details.
2. **Speed:** Fast processing of materials.
3. **Contact-Free:** No physical touch, reducing wear and tear.
4. **Automation:** Can be controlled by computer programmes (e.g., in laser cutters).

Safety Tips When Using Lasers

1. Never look directly into a laser beam.
2. Wear proper safety goggles.
3. Use warning signs in the work area.
4. Make sure the laser machine has protective covers.
5. Follow teacher or supervisor instructions carefully.

Learning Tasks

1. Identify main parts of a 3d printer
2. Arrange printed steps of the 3D printing process in the correct order.
3. Create a Simple 3D Design Using CAD Software
4. Identifying Parts of a Laser System
5. Design a simple project using lasers and 3D printers

Pedagogical Exemplars

Group work/collaborative learning

Guide learners to perform design and manufacture incorporating CAD applications used to create the model for 3D printers in mixed ability groups

Assist learners to perform design for manufacturability incorporating CAD applications used to create the model for lasers in mixed ability groups E.g., Creating a simple design or prototype on a sheet metal or wood using lasers

Experiential Learning: In the school workshop or local manufacturing industry with learners or simulated activities, help learners to identify, observe and perform the operations using the 3D printers and lasers.

Key Assessment Level 4: Demonstration and Practical

1. **a.** Design a 3D-printed component for a mechanical assembly, specifying the material choice, print settings, and required post-processing steps. (8 marks)

b. Give two reasons based on the functional requirements of the component and the limitations of 3D printing technologies. (4 marks)

2. Propose a procedure for using a 3d printer for a given project and justify your choice.

(10 marks)

3. **a.** Design a given project that uses laser cutting or engraving to produce a functional product. (8 marks)

b. Justify your choice of material, laser settings, and design features based on safety, efficiency, and quality (4 marks).

4. Propose step by step procedure for using a laser for a given project and justify your choice.

(10 marks)

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

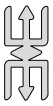
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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

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

10 minutes	Content Exploration

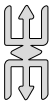
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 7 REVIEW

This lesson focused on two important modern technologies 3D printers and lasers which are widely used in industries such as engineering, manufacturing, design, and healthcare. The 3D printing machines build up objects layer by layer from a digital design. The main parts of a 3D printer include the extruder the filament the print bed, and the control panel. We then explored how 3D printing works starting with creating a 3D model using CAD (Computer-Aided Design) software and how the design is then sliced into layers using a slicer programme and sent to the printer, which builds the object step by step. The lesson also covered the advantages of 3D printing and laser technology. We also learnt how laser **technology** is used in many areas such as **cutting, engraving, measuring, and communication** also identified the **main parts of a laser system**, which include the **laser medium, energy source, mirrors**, and a **focusing lens**. With this lesson covered, learners can use 3D printers to make prototype parts, tools, models, and even small machine components as well as use Lasers d for marking parts, and cutting materials in workshops.

UNIT 8

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Be able to analyse fuel supply system for compression ignition(C1) engine systems*

Content Standard: Demonstrate and apply knowledge in the working principles of fuel supply systems for both spark ignition (SI) and compression ignition(C1) engines as well as air intake and exhaust systems

INTRODUCTION AND UNIT SUMMARY

In this lesson, learners will learn about the catalytic converter, a key component in a vehicle's exhaust system that helps reduce harmful emissions. As concerns about air pollution and vehicle emissions continue to grow, understanding how catalytic converters work is essential for anyone studying automotive technology. The lesson begins by introducing the function and purpose of the catalytic converter stating specifically how it transforms dangerous gases like carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) into safer substances such as carbon dioxide (CO_2), water (H_2O), and nitrogen (N_2). Learners will then explore the working principle, focusing on the role of the catalyst materials such as platinum, palladium, and rhodium and the chemical reactions that take place inside the converter. We will also discuss the two main types of catalytic converters: two-way and three-way, including their differences and where each is commonly used. The lesson will also cover the advantages and disadvantages of catalytic converters, helping learners evaluate their benefits and limitations in real-world vehicle operation. This knowledge will help students connect theory to practice in automotive emission. Teaching catalytic converter requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the working principle, types, and importance of catalytic converters. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of how catalytic converters work and why they are essential in modern automotive systems for reducing harmful emissions and protecting the environment.

This unit covers only week 8: ***Discuss the function and types of catalytic converter.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching catalytic converters as part of the exhaust system in automotive engines requires a blend of diverse teaching strategies to support effective and meaningful learning. To help learners understand the principles, components, and functions of catalytic converters, teachers should incorporate problem-based learning, collaborative group work, scaffolded instruction, experiential activities, and project-based tasks.

These approaches combine theoretical, visual, practical, and interactive methods, addressing various learner learning styles and needs. For example, learners can take part in hands-on activities to observe or identify the parts of a catalytic converter, use diagrams to trace exhaust gas flow, and work in groups to compare types of catalytic converters two-way and three-way. Through these varied strategies, learners gain not only a thorough understanding of how catalytic converters function but also build valuable critical thinking and problem-solving skills, enabling them to analyse the role of emissions control in overall engine efficiency and environmental protection.

ASSESSMENT SUMMARY

To effectively assess learners' understanding of catalytic converters within the exhaust system, a variety of assessment methods should be applied. These methods should go beyond basic recall and instead focus on the real-world application of knowledge. Using Depth of Knowledge (DOK) Level 4 assessments, learners should demonstrate their ability to describe, explain, analyse, and evaluate the working principles, chemical reactions, and components of catalytic converters. Assessment activities may include written tasks, where learners explain the difference between two-way and three-way converters; group presentations on how catalytic converters reduce harmful emissions; and hands-on demonstrations identifying parts and explaining how gas conversion occurs. Project-based tasks could involve diagnosing the effects of a faulty catalytic converter on engine performance or emission output. These higher-order tasks help ensure learners can connect theoretical knowledge to practical applications, such as environmental protection and compliance with emission standards. This approach supports the development of critical thinking, problem-solving, and a deeper understanding of how catalytic converters contribute to cleaner engine operation and improved vehicle performance

Indicators	DOK Level	Assessment Strategy and/or Mode
Discuss the function and types of catalytic converter.	Level 4 Extended critical thinking and reasoning.	Discussion and Homework

WEEK 8

Learning Indicator: *Discuss the function and types of catalytic converter*

FOCAL AREA: CATALYTIC CONVERTER

A catalytic converter is a device in vehicle exhaust system that reduces harmful emissions by converting them into less harmful substances. It uses a catalyst, typically a mix of precious metals, to speed up these chemical reactions. The converter is typically located near the engine to facilitate faster warming and optimal efficiency. See Figure 2.11 for an example of catalytic converter.

Figure 2.11: *Catalytic converter*

The main parts are:

1. Metal casing – protects the converter.
2. Ceramic or metallic honeycomb structure – increases surface area for reactions.
3. Catalyst coating – allows the chemical reactions to occur

Working Principle of a catalytic converter

A catalytic converter works by using a catalyst to convert harmful exhaust gases from an internal combustion engine into less harmful ones. It achieves this by utilising oxidation and reduction reactions to break down pollutants like hydrocarbons, carbon monoxide, and nitrogen oxides into less harmful substances like carbon dioxide, water, and nitrogen.

1. Catalytic converters contain a catalyst typically a honeycomb structure coated with precious metals like platinum, palladium, and rhodium.
2. These metals act as catalysts, meaning they speed up chemical reactions without being consumed themselves.
3. The catalyst facilitates the chemical reactions that convert harmful pollutants into less harmful gases.

Oxidation: This involves the loss of electrons by a substance, often involving the addition of oxygen. In a catalytic converter, unburned hydrocarbons and carbon monoxide are oxidised, meaning they react with oxygen to form carbon dioxide and water.

Reduction: This involves the gain of electrons by a substance, often involving the removal of oxygen. In the case of nitrogen oxides, the catalyst helps them to break down into nitrogen gas and oxygen gas.

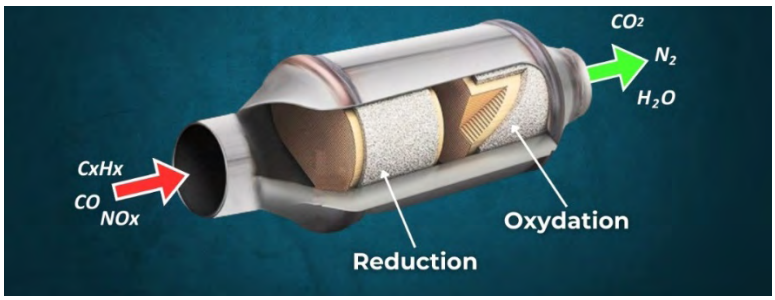


Figure 2.12: *Reduction and oxidation*

In practice, the engine's exhaust gases containing pollutants flow through the catalytic converter. The exhaust gases come into contact with the catalyst. . The catalyst facilitates the oxidation and reduction reactions, converting pollutants into less harmful gases. The now-less harmful gases, like carbon dioxide, water, and nitrogen, are released into the atmosphere through the exhaust pipe**.**

Pollutants and their Conversion

1. **Hydrocarbons (HC):** These are unburned fuel particles that are oxidised into carbon dioxide and water.
2. **Carbon Monoxide (CO):** This is a toxic gas that is oxidised into carbon dioxide.
3. **Nitrogen Oxides (NOx):** These gases are reduced into nitrogen gas and oxygen gas.
4. **Unburnt fuel and carbon monoxide:** The oxidation catalyst converts these into carbon dioxide.

Types of Catalytic Converters

Catalytic converters come in different types depending on how many pollutants they treat and the technology used.

Figure 2.13: *Different Types of Catalytic Converters*

1. **Two-Way Catalytic Converter:** A two-way catalytic converter is designed to reduce two major pollutants found in vehicle exhaust gases. It converts carbon monoxide (CO) a poisonous gas into carbon dioxide (CO_2) and changes hydrocarbons (HC) which are unburned fuel particles into carbon dioxide and water (H_2O). This type of converter is commonly found in older petrol engines and small engines such as those used in motorcycles. However, its main limitation is that it does not reduce nitrogen oxides (NOx), which are harmful to both human health and the environment.

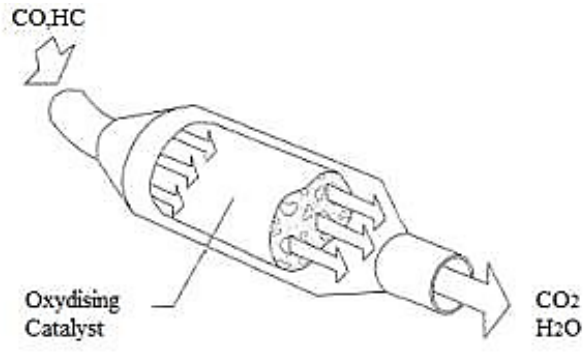


Figure 2.14: *Two-Way Catalytic converter*

2. **Three-Way Catalytic Converter (TWC):** The three-way catalytic converter (TWC) is more advanced and is used in most modern petrol vehicles. It is called "three-way" because it treats three types of pollutants at the same time. It converts carbon monoxide (CO) into carbon dioxide (CO_2), hydrocarbons (HC) into carbon dioxide and water, and nitrogen oxides (NOx) into harmless nitrogen (N_2) and oxygen (O_2). For the three-way converter to work efficiently, the engine must maintain a balanced air-fuel mixture not too rich and not too lean. This ensures the converter operates under ideal conditions to reduce emissions effectively.

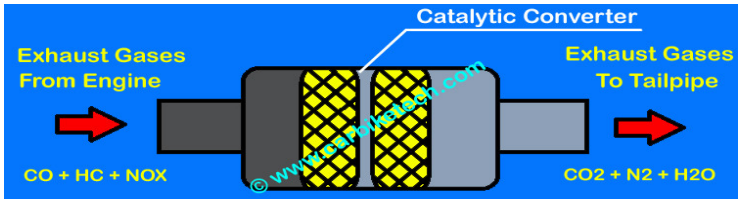


Figure 2.15: *Three-Way Catalytic Converter (TWC)*

Diesel Particulate Filters (DPFs)

Diesel particulate filters (DPFs) are specifically designed for diesel-powered vehicles. They are used to trap and remove particulate matter, such as soot, from the exhaust gases. DPFs work by physically trapping the particulate matter in a porous filter. Over time, the trapped particles accumulate and form a layer known as the "soot cake." To prevent the filter from becoming clogged, the soot cake needs to be periodically burned off, a process known as regeneration.

Advantages and Disadvantages of Catalytic Converters

Advantages	Disadvantages
Reduces harmful emissions (CO, HC, NOx)	High cost due to expensive metals
Helps protect the environment	Requires high temperature to work effectively
Improves public health by lowering air pollution	Can be damaged by leaded fuel or poor engine tuning
Helps meet legal emission standards	May slightly reduce engine performance
Works automatically when engine is hot	Risk of theft due to valuable metal content

Learning Tasks

1. State the function of a catalytic converter
2. Explain the working principle of a catalytic converter
3. Explain the difference between a two-way and a three-way catalytic converter

Pedagogical Exemplars

Project-based Learning

Guide learners and assist them to identify the position and the main parts of the catalytic converter in the real exhaust system

Assist learners to discuss the functions and the types of catalytic converter and write it down for class and group discussion.

Learners match types of converters two-way and three-way with their functions.

Assist learners to display a flowchart showing how gases (CO, HC, NOx) are converted to CO_2, H_2O, and N_2

Key Assessment Level 4: Discussion and Homework

1. Design a maintenance and inspection routine for a vehicle's exhaust system focusing on the catalytic converter. (10 marks)

2. Explain how the two- and three-way catalytic converters treat the exhaust gasses and reduce the global warming. (10 marks)

PLC Session 8

45 minutes	Planning & Reviewing the Learning Plan

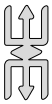
1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.

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 ***discussion and homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes	Content Exploration

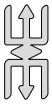
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 8 REVIEW

The lesson on catalytic converters successfully introduced learners to the essential role these components play in reducing harmful vehicle emissions. It began by explaining the working principle of a catalytic converter, highlighting how toxic gases such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) are converted into less harmful substances like carbon dioxide (CO_2), water (H_2O), and nitrogen (N_2) through chemical reactions facilitated by catalyst materials such as platinum, palladium, and rhodium. Learners explored the two main types of catalytic converters two-way and three-way, and discussed where each is commonly used and how they function. The lesson also addressed the advantages, such as environmental protection and improved air quality, and disadvantages, including high cost, the need for high operating temperatures, and vulnerability to damage or theft. Through a combination of diagrams, group activities, and guided discussions, learners were able to engage with the content and apply their understanding to real-world vehicle systems.

MARKING SCHEMES/RUBRICS FOR THE KEY ASSESSMENTS

UNIT 5

Question 1

a.

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs improvement (1-2 marks)

Sophisticated process plan with optimal operation sequencing showing efficiency considerations	Detailed process plan with logical operation sequencing. Appropriate tool and machine selection with clear justification.	Adequate process plan with reasonable operation sequencing. Basic tool and machine selection with some justification. Some quality control steps included but lacking detail.	Basic outline of process with minimal consideration of drilling and grinding operations. Limited or incorrect sequencing. Few appropriate tools or machines identified. Minimal quality control steps mentioned.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Two comprehensive justifications demonstrating extended critical thinking about manufacturing principles, material considerations, precision requirements, and process advantages compared to alternatives.	Two detailed justifications showing strategic reasoning about process efficiency, quality outcomes, or manufacturing constraints.	Two justifications with basic technical understanding but lacking depth or connection to manufacturing principles.	Single basic justification with limited technical reasoning or relevance to the specific process.

UNIT 2

Question 1

Criteria	Excellent (8-10 marks)	Very Good (6-7 marks)	Satisfactory (4-5 marks)	Needs Improvement (0-3 marks)
Technical Understanding of Forced Induction	Demonstrates comprehensive understanding of how both systems operate, including mechanical principles, drive methods, and physical differences. Uses precise technical vocabulary to describe boost generation methods.	Shows clear understanding of both systems' operations with appropriate technical vocabulary and minimal misconceptions.	Shows basic understanding of how both systems work with some technical vocabulary but may have minor misconceptions.	Demonstrates limited or incorrect understanding of how forced induction systems function.

Analysis of Power Delivery	Provides sophisticated comparison of power delivery characteristics: supercharger's immediate boost vs. turbocharger's lag, detailed explanation of power bands, and how each affects drivability across RPM ranges with specific examples.	Clearly compares power delivery differences with accurate explanation of turbo lag vs. immediate supercharger response and their effects on performance.	Basic comparison of power delivery with some mention of response differences but limited analysis of real-world implications.	Minimal or incorrect comparison of power delivery characteristics.
Efficiency and Fuel Economy Analysis	Thoroughly analyses parasitic power loss of superchargers vs. exhaust energy recovery of turbochargers with detailed explanation of how each impacts overall efficiency and fuel consumption across different driving conditions.	Clearly explains efficiency differences with accurate comparison of how each system affects fuel economy in various scenarios.	Basic explanation of efficiency differences with limited connection to real-world fuel economy impacts.	Minimal or incorrect analysis of efficiency and fuel economy implications.
Maintenance Requirements Comparison	Comprehensive comparison of maintenance needs including: belt systems vs. oil dependencies, heat management, longevity factors, and specific component vulnerabilities with associated costs and service intervals.	Clear comparison of maintenance differences with specific examples of common issues, service requirements, and reliability factors.	Basic comparison of maintenance needs with limited detail on specific service requirements or long-term considerations.	Minimal or incorrect comparison of maintenance requirements.

Overall Comparative Analysis	Exceptional balance in the comparison, presenting nuanced analysis of when each system is advantageous for specific performance goals or vehicle applications. Considers manufacturer trends and engineering trade-offs.	Well-balanced comparison that clearly identifies appropriate applications for each system based on the analysed factors.	Basic comparison that identifies some situations where one system might be preferred over the other.	Unbalanced or incomplete comparison that fails to identify appropriate applications for the different systems.

Question 2

Criteria	Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1mark)
Diagram Quality and Accuracy	Detailed, well-labelled diagram showing both systems with clear indication of power sources (belt/chain drive for supercharger vs. exhaust gas turbine for turbocharger). All major components are accurately represented with proper positioning.	Clear diagram showing both systems with most major components labelled correctly. Power source difference is clearly illustrated.	Basic diagram that shows the fundamental difference but may have minor inaccuracies or missing labels.	Incomplete, inaccurate, or missing diagram. Major components incorrectly positioned or missing.

Technical Explanation of Differences	Comprehensive explanation of the fundamental difference: superchargers are mechanically driven by the engine (typically via belt/chain from crankshaft) while turbochargers are powered by exhaust gas flow. Includes precise technical vocabulary and explains the energy transfer principles.	Clear explanation of the primary difference in power source with appropriate technical vocabulary. Correctly identifies the mechanical drive vs. exhaust gas drive distinction.	Basic explanation that identifies the main difference in power source but with limited technical detail or some minor misconceptions.	Minimal or incorrect explanation of the fundamental difference. May confuse basic operating principles of either system.
Explanation of Performance Implications	Sophisticated analysis of how the different power sources affect performance: supercharger's immediate response vs. turbocharger's lag, efficiency differences (parasitic loss vs. exhaust energy recovery), and how these characteristics manifest across different engine speeds.	Clear explanation of performance implications including response characteristics and basic efficiency considerations.	Basic mention of some performance differences with limited analysis of why these occur based on the different power sources.	Minimal or incorrect explanation of performance implications. Fails to connect the power source difference to how it affects vehicle operation.

UNIT 7

1. a.

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs improvement (1-2 marks)
Sophisticated design optimised for both 3D printing and mechanical performance.	Detailed design with clear consideration of mechanical fit and function.	Adequate design showing some understanding of mechanical assembly integration.	Basic design with minimal consideration of mechanical assembly requirements.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Two comprehensive reasons demonstrating extended critical thinking about how the design optimally addresses functional requirements while accounting for and mitigating 3D printing limitations.	Two detailed reasons showing strategic understanding of the relationship between functional requirements and 3D printing technologies.	Two reasons with basic understanding of either functional requirements or 3D printing limitations, but lacking integration of both aspects.	Single basic reason with limited connection to functional requirements or 3D printing limitations.

2.

Excellent (9-10 marks)	Very Good (7-8 marks)	Satisfactory (4-6 marks)	Needs improvement (1-4marks)
Sophisticated procedure demonstrating expert knowledge of 3D printing workflow with optimisation for the specific project.	Comprehensive procedure with specific technical details including CAD preparation, slicing parameters, printer calibration, material selection, print settings, and post-processing steps.	Detailed 3D printing procedure covering design preparation, printer setup, printing parameters, and basic post-processing.	General 3D printing procedure with some key steps identified. Basic technical understanding demonstrated.

3. a. (8 marks)

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs improvement (1-2 marks)
Sophisticated design with precise technical specifications including power settings, cutting speeds, and material-specific parameters.	Detailed design with clear technical specifications including cutting/engraving parameters.	Adequate design with basic technical specifications.	Basic design concept with minimal technical detail.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs improvement (1 mark)
Comprehensive justification with extended critical thinking about how material properties, laser settings, and design features optimise safety, efficiency, and quality simultaneously.	Detailed justification addressing all three factors (safety, efficiency, quality) with sound technical reasoning.	Adequate justification addressing at least two factors (safety, efficiency, quality) with some technical reasoning.	Basic justification with minimal connection to safety, efficiency, or quality.

4. (10 marks)

Excellent (9-10 marks)	Very Good (7-8 marks)	Satisfactory (4-6 marks)	Needs improvement (1-3 marks)
Exceptional procedure demonstrating expert knowledge of laser technology with precise specifications tailored to the project requirements	Comprehensive procedure with detailed technical specifications for each step.	Complete procedure with all necessary steps identified.	General and basic procedure covering basic laser operation. Some steps lack necessary detail.

UNIT 8

Question 1

Criteria	Excellent (8-10 marks)	Very Good (6-7 marks)	Satisfactory (4-5 marks)	Needs Improvement (1-3 marks)
Knowledge of Exhaust System Components	Demonstrates comprehensive understanding of the entire exhaust system including manifold, pipes, catalytic converter, muffler, resonator, and tailpipe. Explains their interrelationships and how they affect catalytic converter performance.	Shows clear understanding of major exhaust components with accurate description of their functions and relationship to the catalytic converter.	Demonstrates basic knowledge of exhaust components with some understanding of how they relate to the catalytic converter.	Shows limited or incorrect knowledge of exhaust system components and their relationship to the catalytic converter.
Catalytic Converter Understanding	Sophisticated understanding of catalytic converter operation including types (3-way, oxidation, reduction), conversion processes, materials (platinum, palladium, rhodium), and failure modes with specific indicators for each.	Clear understanding of catalytic converter function with accurate description of conversion processes and common failure indicators.	Basic understanding of catalytic converter purpose with some knowledge of how it processes emissions.	Minimal or incorrect understanding of catalytic converter function and importance.
Inspection Procedures	Comprehensive inspection routine including: visual inspection, performance testing (emissions testing), backpressure measurement, temperature checks, and diagnostic scanning with specific parameters and acceptable ranges for each test.	Clear inspection procedures covering visual, auditory, and performance checks with appropriate sequence and frequency recommendations.	Basic inspection procedures that include fundamental checks but may lack specific parameters or comprehensive coverage.	Incomplete or inappropriate inspection procedures that would fail to identify common catalytic converter issues.

Maintenance Recommendations	Detailed maintenance plan with preventive measures, optimal driving practices, fuel quality recommendations, and addressing upstream engine issues that affect converter life. Includes specific timelines and mileage intervals.	Clear maintenance recommendations with appropriate frequency and focus on factors that extend catalytic converter life.	Basic maintenance recommendations with some preventive measures but limited detail on implementation or scheduling.	Minimal or inappropriate maintenance recommendations that would not effectively preserve catalytic converter function.
Safety Considerations	Exceptional attention to safety including: working with cool systems, proper ventilation, PPE requirements, awareness of high temperatures, supporting vehicle properly, and environmental considerations for disposal/ recycling.	Appropriate safety considerations covering most significant hazards with clear precautions for maintenance activities.	Basic safety considerations covering obvious hazards but may omit some important precautions.	Minimal or missing safety considerations with significant hazards overlooked.
Technical Accuracy and Practicality	All procedures are technically accurate, practically feasible, and presented in a logical sequence with consideration of both professional and owner-level maintenance distinctions.	Procedures are technically sound and presented in a workable sequence with consideration of practical limitations.	Procedures are generally correct but may have minor technical inaccuracies or impractical elements.	Procedures contain significant technical errors or impractical recommendations.

Question 2

Criteria	Excellent (8-10 marks)	Very Good (6-7 marks)	Satisfactory (4-5 marks)	Needs Improvement (1-3 marks)
Understanding of Catalytic Converter Types	Demonstrates comprehensive understanding of both two-way (oxidation) and three-way catalytic converters, their structural differences, and precise catalytic materials used (platinum, palladium, rhodium). Explains why different vehicle types use different converter designs.	Clearly differentiates between two-way and three-way catalytic converters with accurate description of their basic structures and materials.	Provides basic differentiation between the two types with some knowledge of their structure but limited detail on materials or design rationales.	Shows minimal or incorrect understanding of the differences between converter types. May confuse basic functions or structures.
Chemical Conversion Processes	Sophisticated explanation of chemical processes: two-way converters' oxidation reactions ($CO \rightarrow CO_2$, $HC \rightarrow CO_2 + H_2O$) and three-way converters' additional reduction reactions ($NO_x \rightarrow N_2 + O_2$). Includes balanced chemical equations and reaction conditions (temperature, catalysts).	Clearly explains the main chemical reactions in both converter types with appropriate technical vocabulary and accurate description of outcomes.	Describes basic chemical processes with some technical vocabulary but may lack specific reactions or have minor misconceptions.	Minimal or incorrect explanation of chemical processes. Major misconceptions about how pollutants are converted.

Effectiveness and Limitations	Comprehensive analysis of effectiveness including: conversion efficiency percentages, temperature requirements (light-off temperature), aging factors, and limitations with specific pollutants. Discusses catalyst poisoning and operational constraints.	Clear explanation of effectiveness factors with appropriate discussion of temperature requirements and common limitations.	Basic explanation of effectiveness with some limitations mentioned but limited technical detail.	Minimal or incorrect analysis of effectiveness. Little understanding of operational requirements or limitations.
Global Warming Connection	Sophisticated analysis of global warming impacts: explains greenhouse potential of different emissions, quantifies warming reduction through converter use, discusses trade-offs (CO_2 increase vs. other GHG reduction), and places in context of overall vehicle emissions.	Clear explanation of how converters affect greenhouse gases with specific examples of how treated vs. untreated emissions differ in global warming potential.	Basic explanation of global warming connection with limited quantification or specific examples of greenhouse gas reduction.	Minimal or incorrect connection to global warming. May misunderstand which emissions contribute to global warming or how converters affect them.
Technical Accuracy and Depth	Exceptional technical accuracy with precise scientific vocabulary throughout. Demonstrates understanding of catalytic chemistry principles beyond basic level.	Good technical accuracy with appropriate scientific vocabulary and clear understanding of fundamental principles.	Generally accurate with some technical vocabulary but may contain minor scientific misconceptions.	Contains significant technical errors or fundamental misconceptions about catalytic conversion processes.

SECTION 3: DESIGN FOR MANUFACTURE, 3D PRINTERS, LASERS AND VEHICLE EXHAUST SYSTEM, CATALYTIC CONVERTER

The section covers the following unit (strands); Metal technology and Automotive technology.

In this section, learners will acquire knowledge and understanding of stages in design for manufacture recap weeks, entrepreneurial skills in metal work and apply a simple soldering and brazing joint design for manufacture. In the Automotive technology unit, learners are expected to gain the knowledge and understanding of *c*harging system, lighting, auxiliary and instrument panel systems of the vehicle, batteries and ignition and starting motor systems of the vehicle. All the above are treated from unit 9 to unit 13.

UNIT 9

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Outline the basic techniques applied in design for manufacture*

Content Standard: Demonstrate understanding of the principles and special welding techniques in design for manufacture and entrepreneurship.

INTRODUCTION AND UNIT SUMMARY

Design and Manufacture is a key part of learning in metal technology because it connects thinking with making. It helps learners understand how real products are planned and built, from the first idea to the finished product. The lesson explores the various design situations which is a real-world problems leaners have to analyse and devise solutions for. The lesson also shows a sample design brief which clearly explains what is to be design and manufacture taking into consideration the relevant analysis questions to help understand the problem better and guide the thinking process. Learners will also learn how to write a design specification which is a list of requirements the final product must meet as well as generate and sketch some possible design concepts choosing the best one as the final solution and how to turn this idea into working drawings. In addition, the lesson will also introduce the learners to preparation of a cutting list which will show all the materials and sizes. Then comes the manufacturing process where the learners will follow safe, practical steps to measure, cut, shape and join the

metal. Teaching design and manufacture require various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in design and making. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding and the application of the various stages in design and manufacture,

This unit covers only week 9: ***Explain and perform the stages in design for manufacture***

Recap weeks

Year 2	**Week 22:** Generate and outline the sequence of operations involved in the making of artefacts.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the stages in design and manufacture require various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate and apply basic stages in design and manufacture. The teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding and demonstrate the stages in design and marking.

ASSESSMENT SUMMARY

To evaluate learners' understanding of the full process of designing and making a product from metals, assessments can span various levels to gauge learners' understanding and application of the working principle and the usage. However, by employing a DOK level 3 for assessment learners must not only understand the stages in design and making, but also evaluate, plan, and apply this knowledge in real-world or problem-solving situations. Teachers can also effectively measure learners' understanding and application, of the various stages in the design and manufacture in a given task.

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain and perform the stages in design for manufacture	3 (Strategic reasoning)	Project-Based Assessment

WEEK 9

Learning Indicator: *Explain and perform the stages in design for manufacture*

FOCAL AREA: DESIGN AND MANUFACTURE

Design and Manufacture is the process of planning, creating, and making a product out of materials to solve a problem or meet a need. Design is the thinking and planning stage and is the practical making stage.

Stages in Design and Manufacture

Below are the various stages in in Design and Manufacture

1. **Design Situation:** This is a short description of a problem or need that the product will solve. It explains why something needs to be made. Example*:* "Students need a safe place to hang their school bags in the classroom.
2. **Design Brief:** A clear statement that tells you what you are going to design and make. It is based on the design situation. Example: "Design and make a metal wall hook that is strong, safe, and easy to use.
3. **Analysis Questions:** These are questions you ask to understand the problem better. They help you think about what the design needs to do. Examples:
    a. What size should it be?
    b. What weight must it hold?
    c. What metal is best?
4. **Investigation:** This is when you research before starting your design. You might:
    a. Look at similar products
    b. Study different materials
    c. Learn how joints or finishes are used
5. **Specification:** A list of clear rules the design must follow. It tells what the final product must and should do. Example:
    a. Must hold at least 5kg
    b. Should be rust-resistant
    c. Must have no sharp edges
6. **Possible Design Concepts:** Different ideas you draw or model to show how the product might look or work. You usually make 3 or more design sketches with notes.
7. **Final Solution:** This is the best idea you choose from your designs. You improve it and make it ready for production.
8. **Working Drawing:** These are detailed, labelled drawings that help you make the product:
    a. **Orthographic projection** – front, side, and plan views

   b. **Detail drawing** – shows a close-up of a part
   c. **Assembly drawing** – shows how parts fit together
   d. **CAD drawing** – computer drawing

9. **Cutting List:** A table that lists all the materials needed:
   a. Type of material
   b. Size
   c. Quantity

Table 3.1: Example

Material		Size (mm)	Quantity
Mild steel		300 x 25x3	2

10. **Manufacturing Process (Practical Procedures):** Step-by-step guide on how you will make the product. Include:
   a. Measuring and marking
   b. Cutting and drilling
   c. Joining (e.g., welding, riveting)
   d. Cleaning and checking

11. **Finishing / Finishes:** What you do to improve the look or protect the metal;
   a. Painting
   b. Polishing
   c. Galvanising
   d. Applying lacquer

12. **Testing and Evaluation:** After making the product, you;
   a. Test if it works (Does it hold weight? Is it safe?)
   b. Evaluate how well it meets the design brief and specification
   c. Suggest **i**mprovements

Learning Tasks

1. Identify the stages in design and manufacture.
2. Analyse design situation.
3. Write brief and design specification.
4. Produce working drawings and manufacture product.

Pedagogical Exemplars

Group work/collaborative learning

In a fair mixed ability group, assist learners to conduct various investigations/research to gather pieces of information for generating possible solutions to a design problem using pictorial or conceptual drawing.

Assists learners to consider each of their three possible solutions by given criteria and select the most appropriate solution for manufacture or making in the workshop.

Guide learners to select appropriate tools and materials for making innovative new idea artefacts to the existing artefacts.

Key Assessment Level 3: Mini-Project (Group)

1. Situation

In a senior high school, learners have difficulty accessing equipment for watering their plants at the school garden. This has affected the growth of their plants and punctuality to classes.

Design Brief

a. Design and manufacture equipment for watering plants in the school garden.

Design a folio to cover the following:

i. Design situation

ii. Brief

iii. Analysis questions

iv. Investigation

v. Specification

vi. Possible design concepts

vii. Final solution

viii. Working drawing (orthographic projections, detail drawing, assembly drawing, CAD drawing)

ix. Cutting list

x. Manufacturing process (practical procedures)

xi. Finishing/Finishes

xii. Testing and Evaluation.

b. Use the sheet metals and tools provided to manufacture the equipment using the already prepared detailed working drawings**.**

2. Situation

In a Senior High Technical School, learners place small drawing instruments haphazardly during classes due to lack of proper units to keep them leading to instrument fall and breakages.

Design Brief

a. Design and manufacture an artefact to be fixed at the side of the drawing table for safe keeping of the drawing instruments.

Design a folio to cover the following:

i. Design situation

ii. Brief

iii. Analysis questions

iv. Investigation

v. Specification

vi. Possible design concepts

vii. Final solution

viii. Working drawing (orthographic projections, detail drawing, assembly drawing, CAD drawing)

ix. Cutting list

x. Manufacturing process (practical procedures)

xi. Finishing/Finishes

xii. Testing and Evaluation.

b. Use the sheet metals and tools provided to manufacture the equipment using the already prepared detailed working drawings**.**

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 ***mini-project (group)***. 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 la-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.

UNIT 9 REVIEW

This lesson focused on guiding learners through the full design and manufacture process in metalwork, from identifying a need to creating a finished product. The project began with a clear design situation that outlined a real need, helping learners understand the purpose of the task. Each student developed a design brief, clearly stating what they planned to design and make. They then asked analysis questions to better understand the problem and carried out investigations into materials, existing products, and construction methods. From their research, learners created a specification and then produced several possible design concepts through sketches, before choosing the most suitable one as their final solution. Working drawings were developed, including orthographic projections and, in some cases, CAD models and detail drawings. Learners prepared a cutting list and began the manufacturing stage, following practical procedures for measuring, cutting, joining, and assembling metal parts. They worked safely and accurately, using appropriate tools. Once assembled, products were finished using polishing, painting, or coating techniques. Finally, each product was tested and evaluated against the original specification. Learners reflected on what worked well and suggested improvements. Overall, the lesson was successful in helping learners apply both creative thinking and hands-on skills to complete a functional metal product from idea to finished item.

UNIT 10

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform diagnosis and repair on vehicle electrical/electronic systems*

Content Standard: Demonstrate understanding and perform tasks in vehicle technology sub-systems and modern automotive electronics and air conditioning system.

INTRODUCTION AND SECTION SUMMARY

In this lesson, we will explore key electrical systems found in modern vehicles. These systems are essential for safe and efficient vehicle operation. We begin with the vehicle charging system, which keeps the battery charged and powers electrical components while the engine is running. You will learn about the main charging system components, including the alternator, voltage regulator, and drive belt, and understand how they work together to maintain a steady electrical supply. Next, we will look at the lighting system, which includes the headlamps, tail lamps, indicators, and interior lights. This system ensures the vehicle is visible and provides safe driving in different conditions. We will also cover the auxiliary system, which powers additional features such as the horn, wipers, radio, and power sockets. These systems improve driver comfort and convenience. Finally, we will examine the instrument panel, which displays important information to the driver, such as speed, fuel level, engine temperature, and warning lights. Teaching charging system, lighting, auxiliary, and instrument panel systems requires diverse pedagogical approaches to ensure effective learning. By combining these instructional methods used in the lesson, learners can gain a well-rounded understanding of automotive electrical systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor instruction to different learning needs, ensuring learners develop a deep understanding of how these components enhance vehicle performance and driver awareness.

This unit covers only week 10: ***Describe charging system, lighting, auxiliary and instrument panel systems of the vehicle***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the charging system, lighting system, auxiliary system, and instrument panel system requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in analysing these vehicle electrical systems, teachers should incorporate a range of strategies. These may include demonstration-based learning, collaborative group activities, scaffolded instruction, experiential tasks, and project-based assignments. Such approaches blend practical, visual, interactive, and theoretical methods, ensuring that different learning styles and ability levels are supported. These pedagogical exemplars not only build foundational knowledge but also promote critical thinking, diagnostic skills, and real-world application. Ultimately, they help learners develop a clear and practical understanding of the components, functions, and interconnections of the charging, lighting, auxiliary, and instrument panel systems, preparing them for further technical training or industry-based tasks.

ASSESSMENT SUMMARY

To assess learners' understanding of charging system, lighting system, auxiliary system, and instrument panel system, including their main components and working principles, a range of assessment levels can be used. These assessments should not only test basic knowledge but also evaluate how well learners can apply what they have learned in practical scenarios. By using Depth of Knowledge (DOK) Level 4, learners are expected to go beyond simple recall and explanation. They should be able to analyse, evaluate, and apply their knowledge in real-world problem-solving situations, such as diagnosing faults in charging systems, designing lighting circuits, or troubleshooting auxiliary and instrument panel malfunctions. This level of assessment ensures that learners demonstrate a deep understanding of how these electrical systems function within a vehicle. Teachers can use these tasks to effectively measure both theoretical knowledge and practical problem-solving skills, preparing learners for further technical training or industry applications. Through such assessments, learners develop critical thinking and analytical abilities, strengthening their competence in automotive electrical systems.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe charging system, lighting, auxiliary and instrument panel systems of the vehicle.	4 (Extended Strategic reasoning)	Discussion and Project work

WEEK 10

Learning Indicator: *Describe charging system, lighting, auxiliary and instrument panel systems of the vehicle*

FOCAL AREA 1: CHARGING SYSTEM

The function of the charging system is to maintain the state of change of the battery. Two types of generators are used to charge the battery. These are:

1. Dynamo: The magnetic field is fixed and the conductor is moved and rectifies AC to DC by using a commutator. This is not used currently on modern vehicles.
2. Alternator: The conductor is fixed and the magnetic is moved and uses semiconductor (diodes) to rectifier AC to DC.

The alternator is shorter than a dynamo and larger in diameter than a dynamo. The alternator is lighter in weight and simpler in construction. It has fewer parts to wear.

Charging system component

These components make up the charging system:

1. Alternator
2. Voltage regulator
3. Battery
4. Charging Indicator or warning lamp

The Alternator

The alternator contains the following:

1. Rotor to form the magnetic poles
2. Stator to carry the windings in which the current is generated
3. Rectifier pack to convert AC to DC.
4. Regulator to limit the output voltage

1. **Rotor:** The rotor is the rotating part of the alternator. It has winding placed between two poles (magnetic) pieces. When current is fed to the windings through the brushes and slip rings magnetism is produced. The magnetism in the winding turns the points on the pole pieces into north and south poles. Magnetic lines of force exist between the north and south poles. Figure 3.1 shows a rotor.

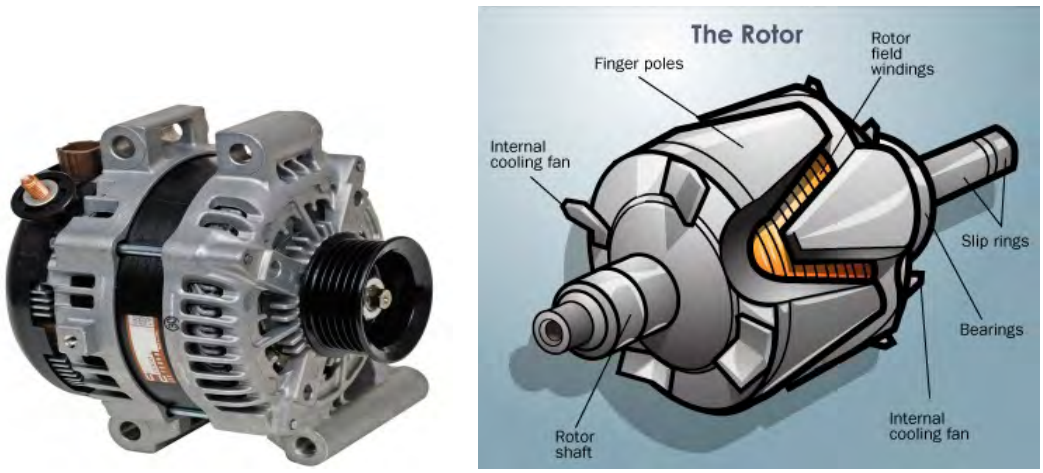


Figure 3.1: *Rotor*

2. **Stator:** This is a laminated soft iron member attached rigidly to the casing that carries three sets of stator windings. The coils of comparatively heavy enamelled copper wire forming the stator are arranged so that separate AC waveforms are induced in each winding as they are cut by the changing magnetic flux. Figure 3.2 shows a stator assembly.

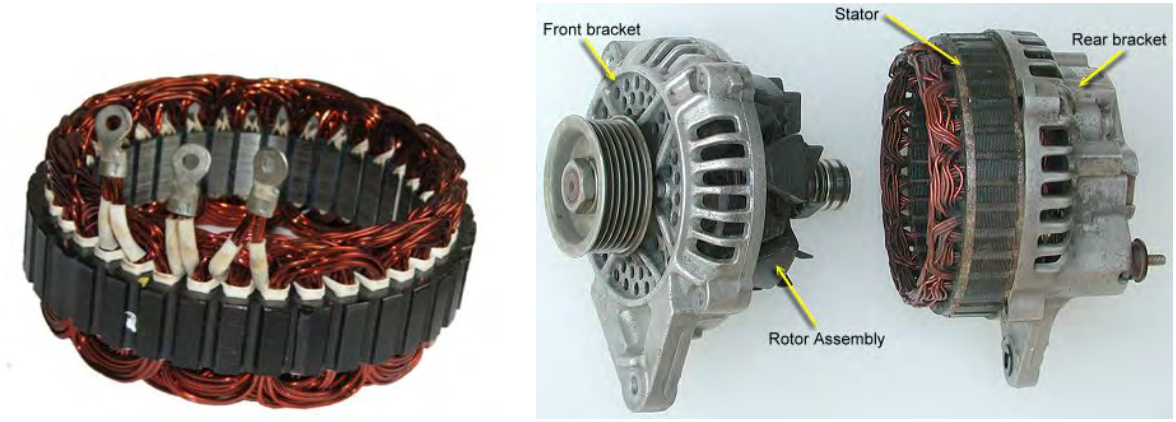


Figure 3.2: *Stator assembly*

3. **Rectifier:** The rectifier is a semiconductor device that changes alternating current to direct current. In the alternator, the rectifier allows the direct current to flow to the battery. The circuit for the diodes and the stator in a three-phase alternator is shown in Fig, 3.3. There are six diodes which make up the diode rectifier. They work together to change the AC flowing through the stator windings to DC needed to charge the battery. Figure 3.3 shows a rectifier assembly.

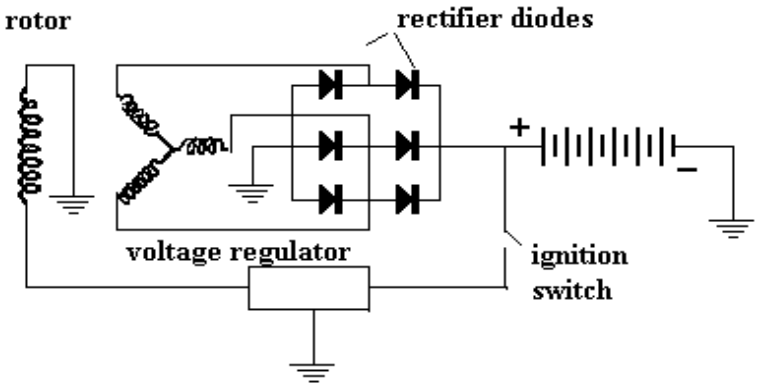


Figure 3.3: *Rectifier assembly*

4. **Regulator:** The alternator regulator limits the output voltage from the alternator and prevents the battery from being overcharged. It also protects the electrical equipment from excessive voltage. Figure 3.5 shows an exploded view of the alternator.
5. **Charging Indicator:** The charging indicator is usually an ON /OFF warning lamp. When the system is running, the light should be off. The lamp lights when the charging system is not providing sufficient charge.

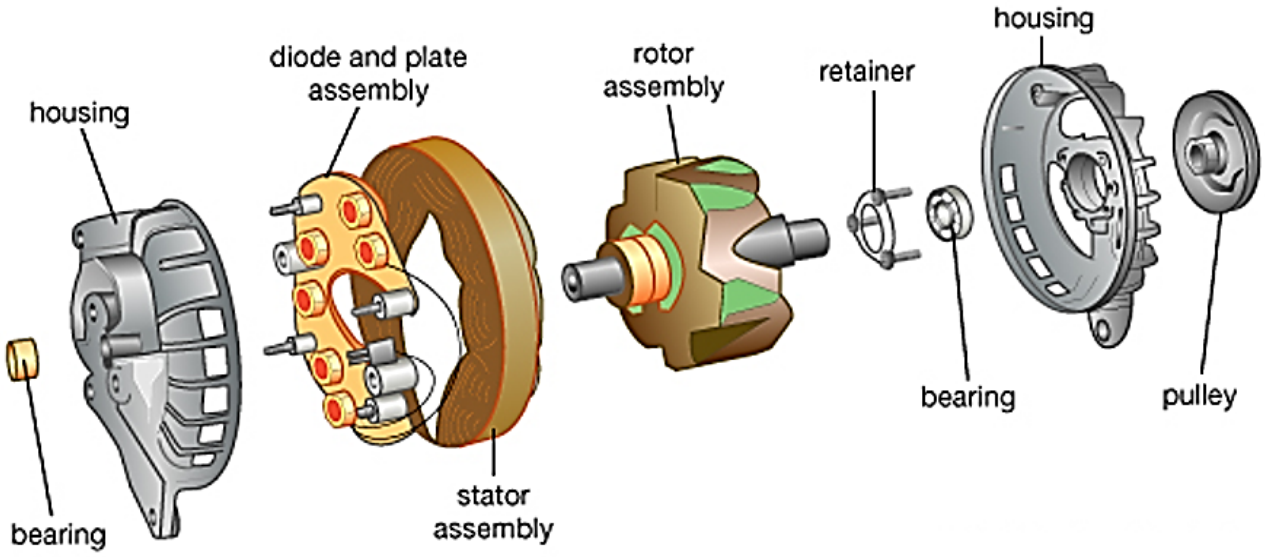


Figure 3.4: *Exploded view of alternator*

FOCAL AREA 2: LIGHTING, AUXILIARY AND INSTRUMENT PANEL

Lights are needed on a vehicle to allow the driver to see and be seen in conditions of darkness and poor visibility. Statutory regulations dictate the number, position and specifications of many external lights fitted to a vehicle. In some countries, especially in the UK, there are legal requirements for the lights that must be fitted. In summary, these requirements are

1. headlights (minimum of two, one on each side)
2. Side, rear and number plate lights
3. direction indicator lamps (flashers)
4. stop lamps (brake lights)
5. rear fog lamp (at least one).

All these lights must be maintained in good working conditions including proper alignment. In addition to obligatory lights, vehicles owners often fit supplementary lights to fulfil other purposes. These are mostly interior lights which include instrument panel lights, various warning and indicator lights and courtesy lights which turn on when the door is opened. The various lights in a typical automobile are shown in Figure 3.5 which shows vehicle lights.

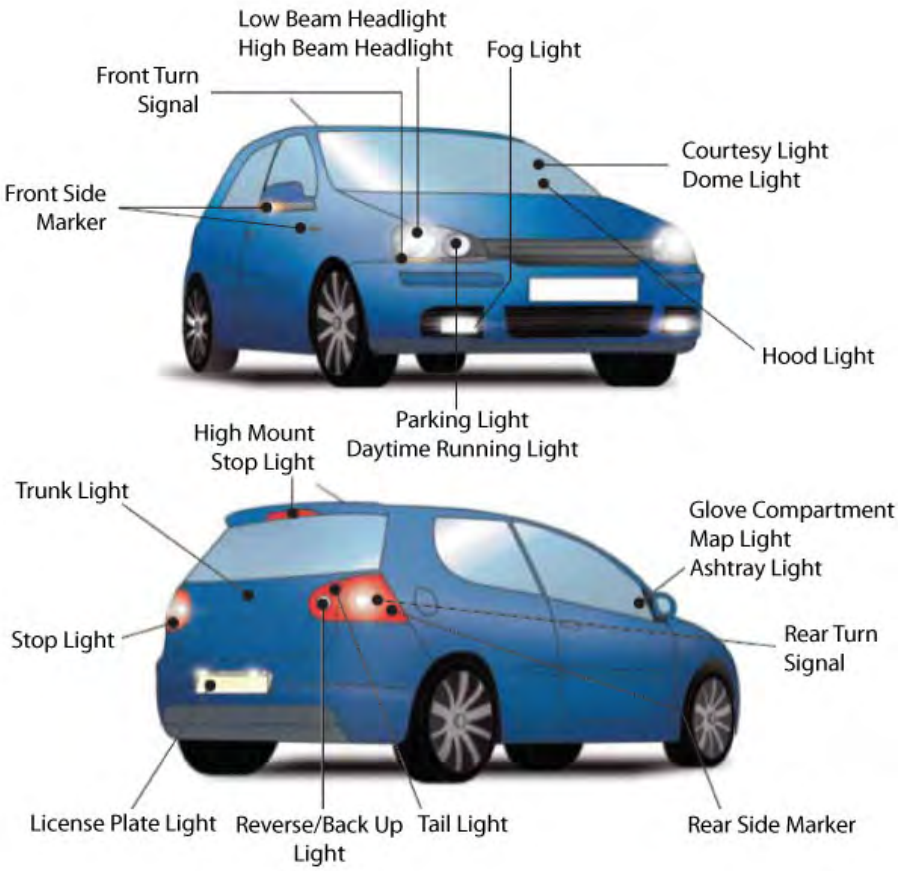


Figure 3.5: *Vehicle lights*

1. **Headlights** include two sets of lamps, a dip beam to avoid dazzle to oncoming drivers and a main beam to provide a powerful light while driving in darkness.
2. **Reverse lights** come on when the driver shifts to reverse. It is required by law.
3. **Hazard warning light** is used or designed to warn the impending danger of a parked or stalled vehicle and usually used when the vehicle has broken down.
4. **Directional indicator lights** permit the driver to signal an intention to make a left turn or right turn. They are operated by a switch on the steering column and it is an obligatory light.
5. **Brake lights** operate at the rear of the car to warn the driver behind that the brakes are being applied and it is required by law. It is a mechanical switch that is operated by the brake pedal. When the brakes are applied the switch contacts close and the brake lights come on.
6. **Auxiliary driving lamps** including front fog lamp which provide additional light to the driver in adverse conditions usually mounted below the front bumper and rear fog lamps to guide the rear of the vehicle in conditions of poor visibility e.g., fog, snow etc.

Auxiliary systems

Auxiliary systems in vehicles support various functions that enhance comfort, convenience, and safety. These systems go beyond essential driving components and improve the overall driving experience.

Some of the auxiliary systems on the vehicle are

1. **Climate Control System** – Includes air conditioning, heating, and ventilation to regulate cabin temperature.
2. **Power Windows** – Allows electronic control of window movement for convenience.
3. **Wiper and Washer System** – Clears the windshield for visibility during rain or dirt accumulation.
4. **Sound and Entertainment System** – Includes radios, speakers, infotainment screens, and Bluetooth connectivity.
5. **Navigation System** – Provides GPS-based directions and route assistance.
6. **Parking Assistance Systems** – Uses sensors and cameras to help with parking and obstacle detection.
7. **Seat Adjustment and Heating** – Electronic seats that adjust for comfort, some including heating or cooling features.
8. **Charging and Power Outlets** – USB ports and power sockets for charging electronic devices.
9. **Interior and Ambient Lighting** – Enhances visibility and aesthetics inside the vehicle.
10. **Sunroof Operation** – Power-controlled opening and closing of the sunroof for fresh air and light.

Instrumentation System

The instrument panel, commonly called the dashboard, is located in front of the driver and displays important information about the vehicle. It helps the driver monitor how the car is functioning and alerts them to any issues. It provides the driver with real-time information about the vehicle's performance and condition. Figure 3.6 shows an instrument panel

The instrument panel consists of:

1. **Speedometer** – Displays the vehicle's speed in miles per hour (mph) or kilometres per hour (km/h).
2. **Tachometer** – Measures engine speed in revolutions per minute (RPM).
3. **Fuel Gauge** – Indicates the level of fuel in the tank.
4. **Temperature Gauge** – Monitors engine coolant temperature to prevent overheating.
5. **Warning Lights** – Includes indicators for oil pressure, battery charge, check engine, and other system alerts.
6. **Odometer** – Tracks the total distance the vehicle has travelled.
7. **Trip Meter** – Records short-distance mileage for individual trips.
8. **Indicator Lights** – Includes signals for turn indicators, high beams, and hazard warnings.
9. **Digital Displays** – Found in modern vehicles, showing navigation, entertainment, and vehicle diagnostics.
10. **Control Switches** – Includes buttons and knobs for climate control, audio settings, and other features.

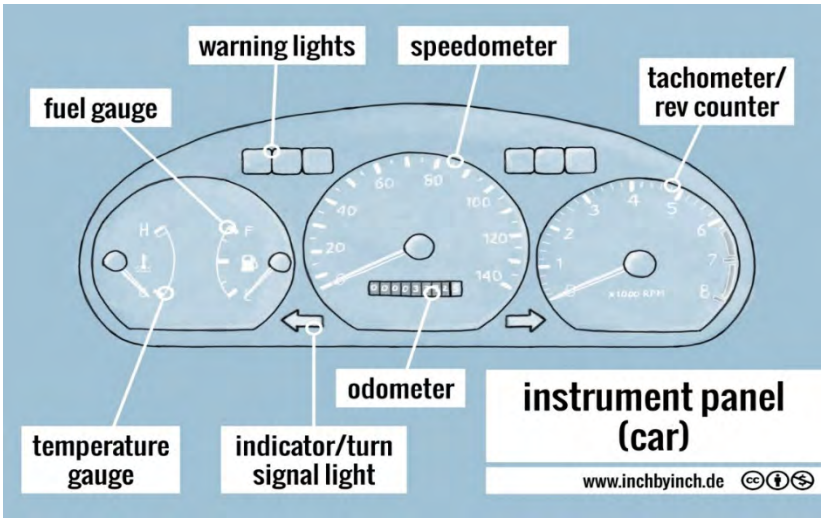


Figure 3.6: *Instrument panel*

Learning Tasks

1. State the function of the charging system
2. Describe the main components of the alternator
3. Describe obligatory and supplementary lights required on the motor vehicle.
4. Explain and interpret signs and lights on the instrument panel.

Pedagogical Exemplars

Experiential learning

Learners visit a local repair or school workshop to observe and discuss charging, lighting, auxiliary, and instrument panel systems on the vehicle, and write out a short description to keep as evidence.

Use actual vehicle components to show how alternators work and charge batteries.

Assist learners to identify the various lights on the vehicle and demonstrate their functionality.

Allow learners to interact with instrument panels in a controlled environment and present individual or group report

Key Assessment Level 3: Discussion

1. a. Explain how a failure in the charging system could affect both the auxiliary and lighting systems during a night-time journey. (5 marks)

b. Suggest two steps to diagnose the problem. (2 marks)

2. a. Design a maintenance checklist that includes tasks for inspecting the charging, lighting, and instrument panel systems. (8 marks)

b. Justify why each item is important for road safety. (4 marks)

3. Analyse the relationship between the battery, alternator, and instrument panel in the vehicle electrical system. (6 marks)

b. Illustrate the warning signs that might appear on the dashboard if the battery and alternator are not functioning. (4 marks)

c. How should a driver respond to this sign? (4 marks)

PLC Session 10

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.

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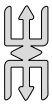


Note

- *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 ***discussion***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the discussion (NTS 3k-3q).

10 minutes	Content Exploration

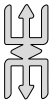
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

Unit 10 Review

The lesson on charging system, lighting system, auxiliary system, and instrument panel offers a well-structured approach to understanding essential automotive electrical components. It begins with an in-depth breakdown of the charging system, explaining how alternators, voltage regulators, and batteries work together to maintain electrical power. Clear

demonstrations of charging system components enhance comprehension, allowing learners to visualise how energy flows within a vehicle. The lighting system section effectively covers various lighting components, including headlights, brake lights, and interior illumination, emphasising their roles in visibility and safety. Diagrams and real-world examples aid understanding, making the content relatable. The lesson further explores auxiliary systems, such as windshield wipers, power windows, and climate control, demonstrating their impact on driver comfort and convenience. Interactive discussions ensure learners grasp how these systems integrate into modern vehicles. Finally, the instrument panel system is covered comprehensively, detailing speedometers, fuel gauges, warning lights, and digital displays. Practical exercises allow learners to analyse panel functions and diagnostic indicators. While the lesson successfully presents key concepts, incorporating more hands-on activities would enhance engagement. Overall, it is an informative and well-structured lesson, equipping learners with foundational knowledge in vehicle electrical systems.

UNIT 11

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Outline the basic techniques applied in design for manufacture*

Content Standard: Demonstrate understanding of the principles and special welding techniques in design for manufacture and entrepreneurship

INTRODUCTION AND SECTION SUMMARY

In today's competitive world, having technical ability alone is not enough; to succeed in the workplace or start a business, students must also develop strong entrepreneurial skills. This lesson introduces the concept of entrepreneurship and focuses on how it applies to metalwork technology. Students will begin by understanding what entrepreneurial skills are and why they are important in technical and vocational fields. The lesson also highlights the general principles of entrepreneurial skills development, such as creativity, innovation, planning, effective communication, and continuous learning. Emphasis will be placed on the key entrepreneurial skills required in metalwork technology, including technical skills for welding, cutting, and fabrication; marketing skills for promoting and selling products or services; management skills for organising time, resources, and finances; and problem-solving skills for handling both technical and business-related challenges. By exploring real-world examples and practical applications, students will gain a deeper appreciation for how these skills can be used to start and run a small metalwork business or improve career success. By the end of the lesson, learners will understand how to combine their metalwork knowledge with entrepreneurial thinking, preparing them for opportunities in self-employment, industry leadership, or further technical education. Teaching entrepreneurial skills in metalwork Technology requires diverse

pedagogical approaches to ensure effective learning. By combining instructional methods such as project-based learning, group discussions, role-play activities, case studies, and hands-on product design tasks, learners can develop a well-rounded understanding of how technical skills can be applied within a business context. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different student abilities and interests, ensuring that learners develop a deep understanding of how entrepreneurial thinking supports career growth and business sustainability in metalwork.

This unit covers only week 11: ***Describe the entrepreneurial skills in metal work***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching Entrepreneurial Skills in Metalwork Technology requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in combining technical metalwork with entrepreneurial thinking, teachers should incorporate a range of strategies. These may include demonstration-based learning of metal fabrication processes, scaffolded instruction on business planning and management, collaborative group tasks involving the design and costing of metal products, role-play exercises on customer interaction and pricing negotiation, and project-based activities where students simulate running a small metalwork enterprise. These pedagogical exemplars not only build a strong foundation in technical production such as welding, cutting, and assembling but also promote problem-solving, financial awareness, innovation, and communication within real-life business contexts. Ultimately, they help learners develop a practical understanding of how entrepreneurial skills like marketing, management, and customer service enhance the success of metalwork ventures. This prepares students for advanced technical training, self-employment opportunities, and responsible, career-ready participation in the workforce or small-scale manufacturing environments.

ASSESSMENT SUMMARY

To assess learners' understanding of Entrepreneurial Skills in Metalwork Technology, including key skill areas such as technical ability, marketing, management, and problem-solving, a range of assessment levels can be applied. These assessments should not only test basic knowledge but also evaluate learners' ability to apply entrepreneurial concepts in realistic business and workshop scenarios. By incorporating Depth of Knowledge (DoK) Level 3, students are expected to move beyond simple recall and explanation. They should be able to plan and execute a small metalwork project, calculate costs and set selling prices, propose marketing strategies, and solve business-related challenges such as customer complaints or material shortages. Assessment tasks may include practical exercises such as designing and fabricating a basic metal product, simulating customer interactions, preparing a simple business plan, or analysing a case study involving the success or failure of a small workshop. These tasks require students to demonstrate applied understanding of how technical and entrepreneurial skills work together to support business sustainability. Teachers can use these assessments to evaluate both theoretical knowledge and real-world decision-making, helping students develop critical thinking, innovation, and readiness for the workforce or future self-employment.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe the entrepreneurial skills in metal work	3 (Strategic reasoning)	Discussion and project work

WEEK 11

Learning Indicator: *Describe the entrepreneurial skills in metal work*

FOCAL AREA 1: ENTREPRENEURIAL SKILLS IN METAL WORK

An entrepreneurial skill is a skill used to start, manage, or grow a business and entrepreneurial skills in metal work refer to the abilities and mindset needed to start, manage, and grow a small business or service in the field of metal fabrication, repair, or production. These skills help students apply their technical training in real-world business situations and become self-reliant.

General Principles in Entrepreneurial Skills Development

Developing entrepreneurial skills is not only about starting a business. It is about learning how to think, act, and work productively and independently. Whether in metal work, automotive, carpentry, or any other trade, the following general principles guide entrepreneurial skills development:

1. **Start with a Vision**: Understand what you want to achieve and set clear business or career goals.
2. **Identify Opportunities**: Look for gaps in the market or problems that you can solve with your skills or products.
3. **Develop Practical Skills**: Combine technical knowledge with soft skills like communication, decision-making, and teamwork.
4. **Be Innovative and Creative**: Think of new ideas, improve existing products, or find better ways to do tasks.
5. **Take Initiative**: Be proactive, take responsibility, and don't wait for others to act first.
6. **Learn from Mistakes**: See failures as learning opportunities and use feedback to improve.
7. **Manage Resources Wisely**: Use your time, tools, materials, and money efficiently.
8. **Build Good Relationships**: Respect customers, suppliers, and team members-good relationships build trust and success.
9. **Keep Learning**: Stay updated with new methods, technologies, and business trends.
10. **Deliver Quality and Value**: Always focus on providing good service or products that satisfy customer needs.

Entrepreneurial skills in metalwork technology

Some of the entrepreneurial skills required by metalwork technology students for workforce sustainability are below with specific skills in the table.

1. The technical skills: These are the hands-on skills needed to cut, shape, join, and finish metal accurately and safely
2. The marketing skills: This is the ability to promote and sell metalwork services or products.
3. The management skills: These involve planning, organising, and controlling the use of time, money, tools, and materials.

4. The problem-solving skills: The ability to find solutions to challenges or faults in work or business.

Table 3.2: *Technical skills required by metal work technology students*

1.	Handle tools, materials correctly
2.	Read and interpret drawings / blue print accurately.
3.	Use of hydraulic press.
4.	Quality checks & quality control procedures.
5.	Classify metals correctly.
6.	Identify different uses of metals.
7.	Identify metalwork safety practices.
8.	Inspect and diagnose leakages in gas welding equipment using. computers
9.	Store hazardous substances and awareness of safety.
10.	Operate computer numerical control (CNC).
11.	Maintain correct welding position.
12.	Able to set up machine tools and dismantle them after the job is complete.
13.	Have basic knowledge of machining process such as turning, boring etc.
14.	Identify and utilise sheet metals tools.
15.	Know how to cast into any shape.

Table 3.3: *Marketing skills required by metal work technology students*

1.	Identify channels of goods distribution.
2.	Know about buying situations.
3.	Organise a sales promotion to motivate customers.
4.	Device strategies for profit-making.
5.	Capture and retain the attention of customers.
6.	Keep proper records of all transactions.
7.	Use social media platforms for marketing.
8.	Define the right products and services for meeting customer's needs.
9.	Determine the availability of goods/raw materials for production
10.	Source for market information about current prices.
11.	Identify the target market for sales of product.
12.	Advertise products/services to customers.
13.	Determine and interpret factors/strength of competition.
14.	Advertise products for sale through appropriate media.

15	Understand what customer wants.

Table 3.4: *Management skills required by metal work technology students*

1.	Meet job schedules.
2.	Have good human relationships.
3.	Conduct effective meetings.
4.	Demonstrate a strong work ethic.
5.	Display a sense of honesty and integrity.
6.	Develop organisation policies.
7.	Manage time.
8.	Set attainable goals for the organisation.
9.	Direct the affairs of the establishment.
10.	Know how to be in command.
11.	Appraise the employee's performance.
12.	Supervise effectively.
13.	Carry out Inventory control.
14.	Evaluate all activities/operations in the process of goal attainment.
15.	Produce the demanded items before the collection.

Table 3.5: *Problem-solving skills required by metal work technology students*

1.	Understand the technical aspect of metalwork and manufacturing process.
2.	To analyse complex information and data to identify problem, patterns, and trends.
3.	To create innovative designs for metalwork product and solution that meet the needs of customers.
4.	To ensure that all metalwork product meet the required quality standard.
5.	To manage the supply chain effectively, including sourcing raw material, managing inventory.
6.	To adjust to changing situation and environments and find solutions to new problem.
7.	To calculate risk in pursuit of business goal.
8.	To understand the needs and preference of customers and to design metalwork. product.
9.	To understand and use technology to solve problems and improve business operation.
10.	The ability to generate new ideas and concept for metalwork product and solution that meet the evolving needs of customers.

Learning Tasks

1. State technical skills required in metalwork and their important for entrepreneurship.
2. Explain ways a metalworker can market their products to attract customers.
3. Describe a situation in which a metalworker would need to use problem-solving skills.
4. Explain some examples of a management skill used in a small metal workshop.

Pedagogical Exemplars

Group work/collaborative learning/Project-based Learning

In a fair mixed ability group assist learners to conduct various investigations/research to gather pieces of information about entrepreneurial skills in metal work.

Guide learners to consider each entrepreneurial skill in metal work and put all the skills required in entrepreneurship into practice.

With a given project, assist learners to make artefacts in groups or individually and demonstrate all the entrepreneurial skills.

Pair students to research local metalwork businesses and present their findings on how those businesses attract customers and manage their operations.

Project-based learning

With a given project, assist learners to make artefacts in groups or individual and demonstrate all the entrepreneurial skills

Key Assessment Level 3: Discussion

1. a. Describe how you would market a metal product like a custom gate in your local community (5 marks)

b. What steps would you take to attract customers? (4 marks)

2. Imagine a customer wants a product urgently but you are short of material and manpower. How would you handle the situation while maintaining quality and customer trust? (6 marks)

3. a. Compare three benefits and financial risks and of starting a small metalwork business (6 mark)

b. What would you do to reduce the risks? (2 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

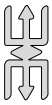
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***discussion***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the discussion (NTS 3k-3q).

10 minutes	Content Exploration

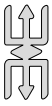
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

Unit 11 Review

This lesson effectively introduced students to the concept of entrepreneurial skills and their application in the field of metalwork technology. Beginning with a clear explanation of what entrepreneurship means, the lesson highlighted its importance for self-employment, small business creation, and career advancement in the technical trades. Learners explored the general principles of entrepreneurial skill development, including creativity, innovation, planning, and the ability to take initiative. The lesson was well-structured around four key entrepreneurial skills: technical, marketing, management, and problem-solving. Students demonstrated understanding of technical skills through hands-on metalwork tasks, while marketing skills were explored through discussions on pricing, customer targeting, and advertising. Management skills were introduced via resource planning and basic record-keeping tasks, and problem-solving skills were addressed through real-life case studies and fault-based scenarios. The use of group work, discussions, and project-based activities allowed learners to apply these skills in simulated business situations, reinforcing both practical competence and entrepreneurial thinking. Overall, the lesson provided a strong foundation for understanding how metalwork skills can be transformed into sustainable business opportunities, while promoting critical thinking, creativity, and real-world readiness.

UNIT 12

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform diagnosis and repair on vehicle electrical/electronic systems.*

Content Standard: Demonstrate understanding and perform tasks in vehicle technology sub-systems and modern automotive electronics and air conditioning system.

INTRODUCTION AND SECTION SUMMARY

In modern vehicles, the battery, ignition, and starting systems work together to ensure reliable engine operation. This lesson focuses on understanding these vital components and their functions. We begin with batteries, which supply the electrical energy needed to start the engine and power various systems. You'll learn the difference between primary and secondary batteries, the types of secondary batteries, and the conventional lead-acid battery commonly used in vehicles. We will also explore how to test batteries to ensure they are in good condition. Next, we will cover the ignition system, which ignites the air-fuel mixture in the engine. This section will explain the operation of the coil ignition system and the more advanced electronic ignition system, highlighting their importance in efficient engine performance. In addition, we will discuss the starting system, which turns the engine over to begin operation. You will learn about the different types of starter motors used in light vehicles and their roles in ensuring a smooth start. Teaching the battery, ignition system, and starting system in motor vehicle technology requires various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying these automotive electrical systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a strong and practical understanding of the battery, ignition, and starting systems, preparing them for further study or entry-level work in the automotive field.

This unit covers only week 12: ***Describe batteries, ignition and starting motor systems of the vehicle***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the battery, ignition, and starting systems in motor vehicles requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills related to these systems, teachers should adopt a range of teaching strategies. These may include demonstration-based learning, guided practical tasks, collaborative group discussions, scaffolded instruction, and interactive simulations. Such approaches combine hands-on experience, visual aids, peer learning, and theoretical explanations, catering to varied learning styles and abilities. These pedagogical exemplars not only help learners build foundational knowledge of battery types, ignition systems, and starter motor functions but also encourage analytical thinking and real-world application. Exploring starter motor types through models and workshop activities further reinforces learning. Teaching strategies ultimately,

support learners in developing a strong and practical understanding of the components, operation, and interrelationship of the battery, ignition, and starting systems, preparing them for both assessments and real-life automotive service tasks.

ASSESSMENT SUMMARY

To assess learners' understanding of the battery, ignition, and starting systems, including their components, functions, and interrelationships, a range of assessment levels should be used. These assessments should go beyond testing basic facts and instead focus on how well learners can apply their knowledge in real-world automotive contexts. By using Depth of Knowledge (DoK) Level 3, learners are expected to demonstrate higher-order thinking skills such as analysing circuit diagrams, evaluating different ignition systems, and diagnosing faults in starting systems. Tasks may include identifying causes of starting failure, comparing conventional and electronic ignition systems, or planning basic maintenance procedures for lead-acid batteries. This level of assessment ensures that learners not only recall and describe system parts but also apply and transfer their knowledge to solve problems and make informed decisions. Teachers can use practical assessments, structured group tasks, written tests, and oral questioning to measure both theoretical understanding and hands-on skill.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe batteries, ignition and starting systems of the vehicle	3 (Strategic reasoning)	Practice Paper 1 Discussion and Homework

WEEK 12

Learning Indicator: *Describe batteries, ignition and starting motor systems of the vehicle*

FOCAL AREA 1: BATTERY

A battery is required to supply electrical energy to meet the electrical requirements when the engine is not running. It must store electrical energy and then deliver the energy when it is needed at a later time. Batteries produce electricity by converting chemical energy into electrical energy. The battery supplies current to operate the starting motor and ignition system when the engine is being started. It also supplies current for the lights, radio, and other electrical accessories when the alternator is not supplying current to the electrical load. Current supplied to the battery is called a charge, while current delivered from the battery is called a discharge.

Primary and Secondary Batteries

A battery which cannot be reversed or recharged after it has been used is called a primary battery or cell. A battery which can be recharged or reversed after it has discharged is called secondary battery or accumulator.

Types of Secondary Battery

There are two main types used on the motor vehicle

1. Lead- acid
2. Nickel- alkaline

Lead-Acid Battery: This type of secondary (reversible charge and discharge) battery has lead plate immersed in an electrolyte. Electrolyte is a liquid solution of sulphuric acid (H2SO4) and distilled water. This battery is sometimes referred to as a wet battery.

The various types are;

1. Conventional lead-acid battery (original basic type)
2. Low maintenance
3. Maintenance-free

The name given to each type indicates the work needed to service the battery

Conventional Lead- Acid Battery

This type of lead-acid battery consists of a polypropylene or black hard rubber container which contains a number of separate cells (compartments), each with a normal voltage of 2 volts. A 12-volt battery has six cells connected in series by lead strips. Each cell is made up of two sets of lead plates positive and negative which are placed alternately and separated by a porous insulating material. The separator permits free circulation of the electrolyte and allows the chemical action between the plates to take place. The materials used for the separators are treated wood, porous rubber and porous plastic usually P. V. C. Figure 3.7 shows the Interlacing of positive and negative plates.

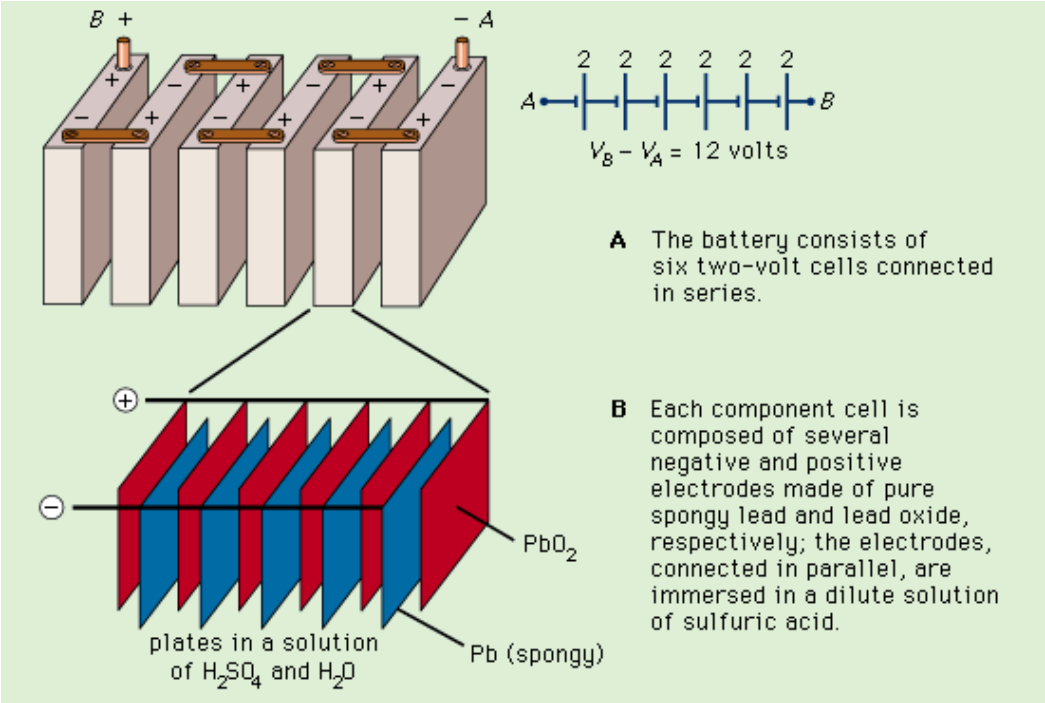


Figure 3.7: *Interlacing of positive and negative plates*

Cell action during charge and discharge: When the battery is fully charged and ready for use the positive plates comprise lead peroxide (PbO2) and the negative plates are spongy lead (Pb). As the battery discharge through an external circuit, the sulphuric acid reacts with both plates and this changes both plate materials to lead sulphate (PbSO4). The loss of sulphate from the electrolyte to the plates during the discharge process decreases the density of the electrolyte. .i.e. reduces the specific gravity. Figure 3.8 shows charging of battery with terminal connection

Figure 3.8: *Charging of battery with terminal connection*

To charge a battery requires a DC supply at a potential sufficient to force an adequate current through the battery in a direction opposite to the direction of the discharge current. To achieve this, the positive terminal of the battery charger must be connected to the battery's positive terminal. During the charging period, the plate materials will return to their original forms and the electrolyte density will increase. When the battery is fully charged, the continuous charge current will lead to excessive gassing of the cell. This gas consists of hydrogen and oxygen a highly explosive mixture, so naked flame or electric spark must not be produced in the vicinity of a battery at any time. Whilst charging remove and dry the vent plugs and ensure that all electrical connections are clean and tight. Two types of charging are usually carried out. These are slow-charge method and the quick-charge method.

Capacity of Battery

The capacity of a battery is expressed in ampere hours (Ah). This represents the current that a battery will deliver for a given time. It is generally based on a time of 10 hours or in some cases 20 hours. E.g. A battery capacity of 38 Ah based on a 10-hour rate should supply a steady current of 3.8A for 10 hours, at a temperature of 25 °C before the cell voltage drops to 1.8v.

Battery Tests

Personal safety must be observed when batteries are handled or tested. A fully equipped medical kit including eye-wash facilities should be available and protective clothing worm. Acid splashes in the eye should be treated immediately with plenty of clean water and medical attention sought. Acid on skin should be washed off with water and neutralise with sodium bicarbonate solution. Acid splashes on clothing must be treated with an alkali such as ammonia if holes are to be avoided.

There are three basic tests or checks which are performed on a conventional battery. These are:

1. Visual inspection
2. Relative density check
3. Electrical load (high-rate discharge) test

Table 3.6: Battery faults

Fault	Cause
Undercharging	Low alternator output, perhaps due to a slipping drive belt Excessive drain on the battery which may be due to short circuit Faulty alternative regulator Terminal corrosion
Overcharging (excessive gassing)	Defective cell in battery Faulty alternator regulator.
Low battery capacity	Internal or external short circuit Sulphation Loss of active material form plates Low electrolyte level Incorrect electrolyte strength Terminal corrosion

FOCAL AREA 2: IGNITION SYSTEM

The function of the ignition system is to supply or introduce electric sparks that will ignite or set fire to the compressed air and fuel mixture at the end of the compression stroke. This burning of mixture produces high pressure, which pushes the piston down.

The complete system consists

1. A battery which supplies voltage (6 volt or 12 volts) to force a small current through the primary winding of the ignition coil.

2. A contact breaker or engine operated switch which converts or interrupts the flow of battery current through the primary winding of the coil at regular and predetermined intervals.
3. An ignition coil or transformer which converts the battery voltage into a voltage high enough to cause a spark to jump the gap between the points of a spark plug in a highly compressed mixture of air and fuel.
4. A condenser which helps to provide a stronger spark and also reduce the arcing or burning of the points of the contact breaker.
5. A distributor which directs the high voltage current to the spark plug of whichever cylinder is nearing TDC on its compression stroke.
6. A spark plug for each engine cylinder. This introduces the spark into the compressed mixture of air and fuel in the cylinder.
7. An ignition switch which controls the flow of battery current through the contact breaker and the primary winding of the ignition coil.
8. An ignition warning lamp fitted inside the vehicle to indicate when the current is flowing through the circuit and when the charging circuit is not charging the battery.

See Figure 3.9 for a coil ignition system.

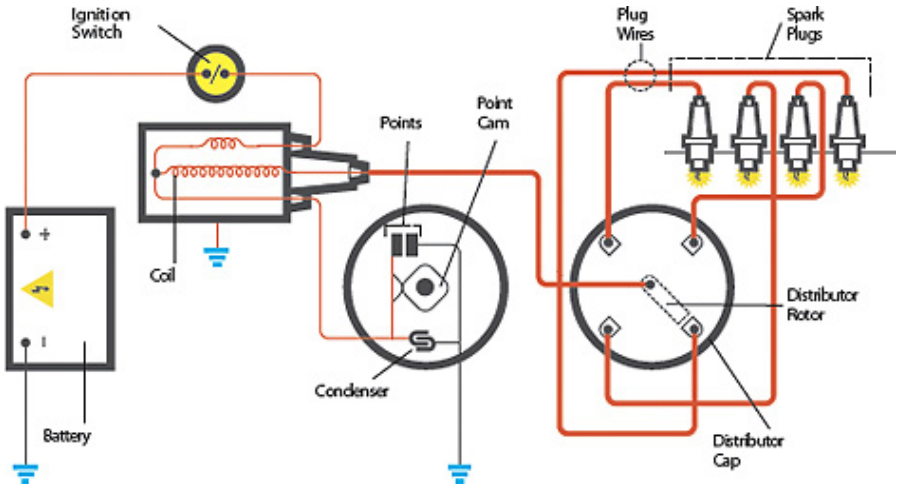


Figure 3.9: *Coil ignition system*

Operation of Coil Ignition System

The ignition coil has two windings a primary winding and a secondary winding. When the contact points are closed current flows in the coil primary winding. The current flowing through this winding causes a magnetic field to build up in the coil. When the contact points open and break the circuit, the current flow stops and the magnets field collapses. The collapsed magnetic field induces a very high voltage in the secondary winding. This sends high voltage to the spark plug, causing the spark to jump the spark plug of gap to ignite the mixture.

Advantages of a Coil Ignition System

1. Low initial cost.
2. Better spark at low speeds and better starting than magneto system.
3. Reliable system.

4. No problems due to adjustment of spark timings.
5. Simpler than magneto system.

Disadvantages of a Coil Ignition System

1. Battery requires periodical maintenance.
2. In case of battery malfunction, engine cannot be started.

The Ignition Coil

The function of ignition coil is to produce a high voltage necessary to cause a spark at the spark plug. It transforms the battery voltage of 12V to low current high voltage charge that is required to jump the plug gap. Inside the case of the ignition coil has two windings (primary and secondary) connected to three external electrical terminals. One from the

1. Low tension (LT) to the battery via the ignition switch
2. Low tension (CB) to the contact breaker
3. High intension (HT) to the spark plug via the distributor primary and secondary circuits of ignition.

Fig. 3.10 shows the ignition coil.

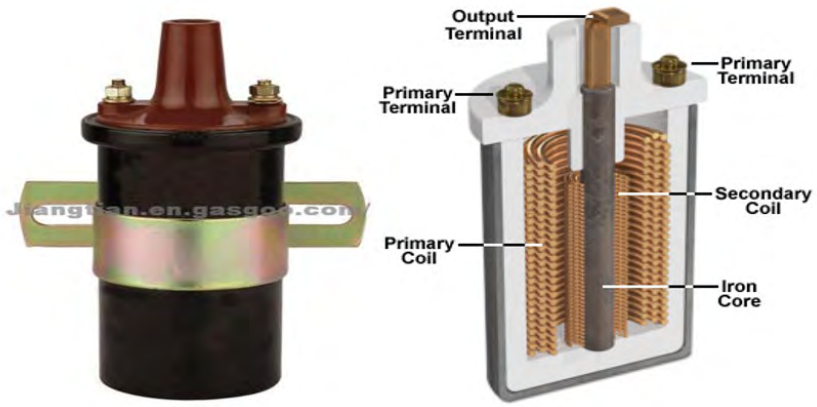


Figure 3.10: *The ignition coil*

Contact Breaker (CB)

The contact breaker (CB) is a mechanical switch consisting of two contact points, a fixed contacts screwed down to a base plate and a movable contact. Figure 3.11 shows Contact Breaker (CB).

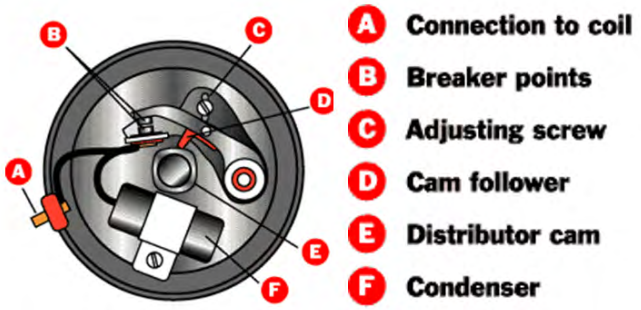


Figure 3.11: *Contact Breaker (CB)*

Capacitor (or Condenser)

The capacitor is connected in the circuit across the contact breaker points (i.e., parallel to CB). The condenser has two purposes.

1. To bring the primary current to a quick stop which helps collapse the magnetic field and
2. To prevent or greatly reduce arcing across the points there by ensuring longer contact-point life.

Distributor

This is the unit in the ignition system which directs the high-voltage current produced in the secondary winding of the coil to the spark plugs in the correct firing orders. The higher-tension cable (HT) which is insulated with PVC or thick rubber connects the ignition coil to the distributor and to the spark plugs. Figure 3.12 shows a distributor assembly.

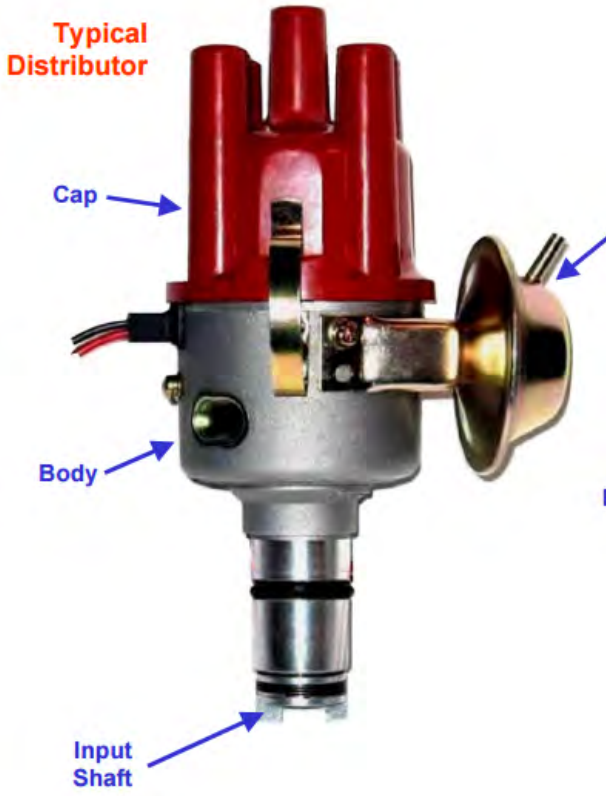


Figure 3.12: *Distributor assembly*

Spark Plug

The function of the spark plug is to introduce a high voltage and intense electric spark into the highly compressed and heated charge of mixture in the combustion chamber of the engine cylinder. The plug consists of a highly insulated centre electrode and an earth electrode which is welded to the metal body of the spark plug. The gaps between the centre electrode and the earth electrode must be set and maintained accurately. Fig. 3.13 shows a Spark Plug.

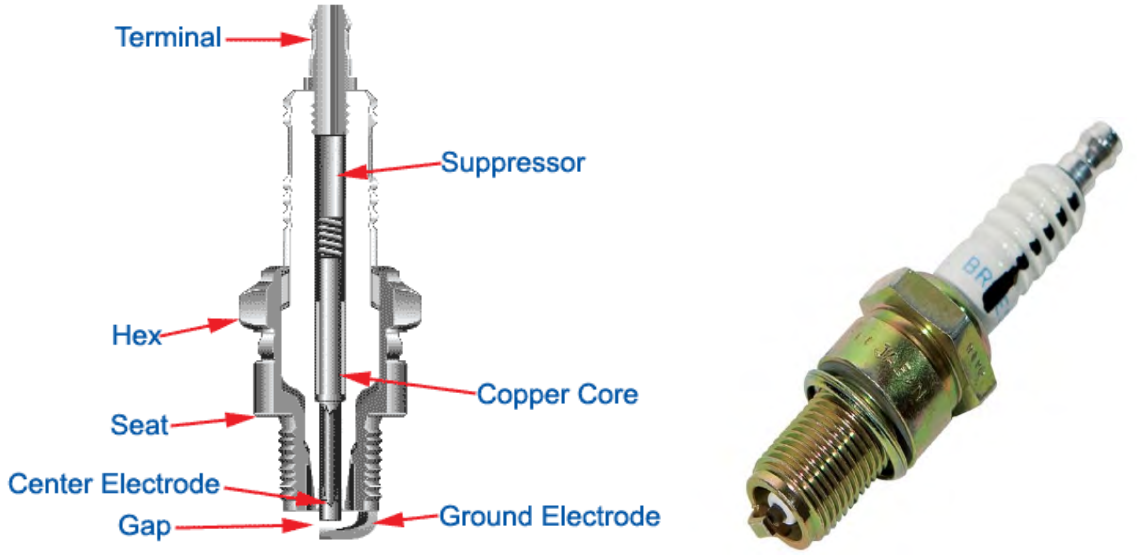


Figure 3.13: *Spark Plug*

Electronic Ignition System

In order to overcome the problems associated with conventional ignition systems, modern ignition systems use electronic components to open and close the circuit between the battery and the ignition coil. The electronic ignition system has essentially the same components as the contact-point system. Both include the battery or alternator, ignition switch, ignition coil, wiring and spark plugs. In addition, the electronic ignition system has an electronic control unit (ECU). Instead of contact points, the electronic ignition distributor has magnetic pulsing or triggering systems which signal the electronic control unit. The electronic control unit then interrupts the primary current flow. Then the coil produces a high voltage surge which is led through the wiring, distributor cap and rotor to the spark plug. Figure 3.14 shows simple electronic ignition system

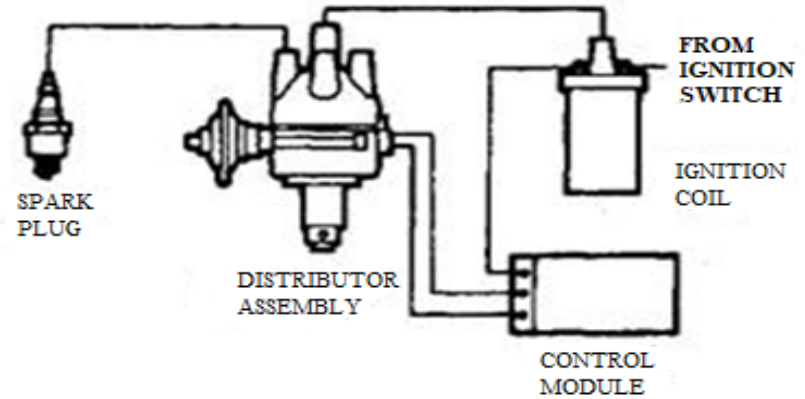


Figure 3.14: *Simple electronic ignition system*

The following types of the electronic-ignition systems are getting popular.

1. Transistorised-coil ignition (TCI),
2. Capacitive-discharge ignition (CDI) and
3. Distributor less (wasted spark and direct ignition, or coil **on** plug) systems

Electronic Control Unit

The duty of the control module is to switch the primary circuit current on and off in accordance with the signal it receives form **the** pulse generator. It may be fitted externally to the distributor or within the distributor. Locating the module within the distributor simplifies the wiring and improves reliability.

Advantages of Electronic Ignition System

1. Electronic ignitions have no moving parts that wear against each other to cause mechanical wear.
2. Dwell and timing do not change during several thousand miles operation because there is no rubbing block to wear down
3. Electronic switching devices cannot 'bounce 'at high speeds. Switching is uniform from idle to maximum revolutions per minutes
4. The triggering devices in electronic distributors do not carry primary current.

Direct Ignition

Direct ignition is from the wasted spark distributorless ignition system. This system utilises an inductive coil for each cylinder. These coils are mounted directly on the spark plugs as shown in Figure 3.15. The use of an individual coil for each plug ensures that the rise time for the low inductance primary winding is very fast. This ensures that a very high voltage, high energy sparks is produced. Figure 3.15 shows a direct ignition.

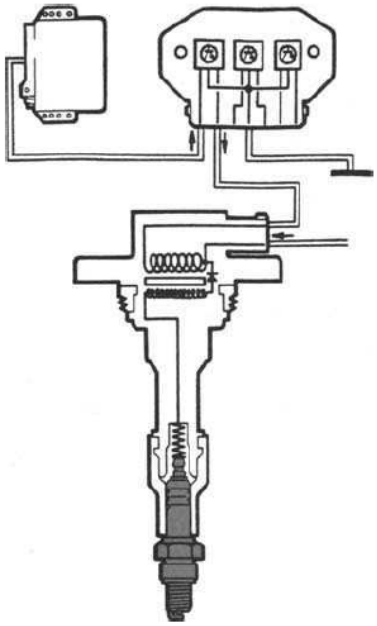


Figure 3.15: *Direct Ignition*

FOCAL AREA 3: STARTING SYSTEM

A starting motor (starter or cranking motor) converts electrical energy supplied from the battery into mechanical power. The system must supply sufficient power to enable an engine to be cranked (turned over).

Starting-Motor Construction

The basic parts of the starting motor are the armature and the field-frame or winding assembly. The armature has a series of wire loops or conductors mounted in a circle around the supporting shaft. The ends of the conductors are connected to the commutator. The purpose of the commutator is to connect the loops (through the brush) to the battery as the loops rotate. The field frame assembly has windings. They produce the magnetic field in which the loops more. The field windings are connected in series or series parallel with the main circuit or armature. The starting motor also has support for the two ends of the armature shaft. It again has a drive gear to mesh with the flywheel ring gear, solenoid switch, overrunning clutch and brushes as shown in **Figure 3.15.**

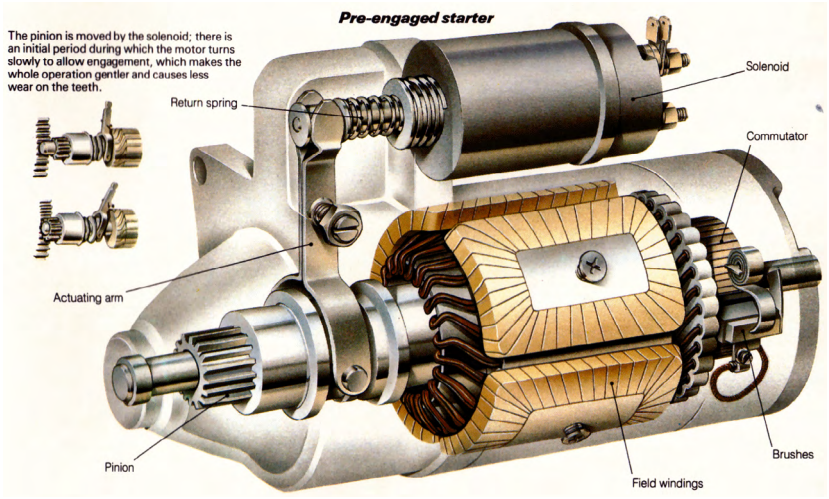


Figure 3.15: *Starting-motor parts*

Types of Light Vehicle Starter Motors

1. **Series Motor:** This type of motor has the thick field coils arranged in series with the armature windings and all current that passes to the armature also goes through the field. These give the strongest field. The current flows into the motor terminal and through the field windings, from there, it goes through one brush and then through the commutator to the other brush. This brush is connected to the ground which is the return circuit to the battery. Figure 3.16 shows a series starter motor.

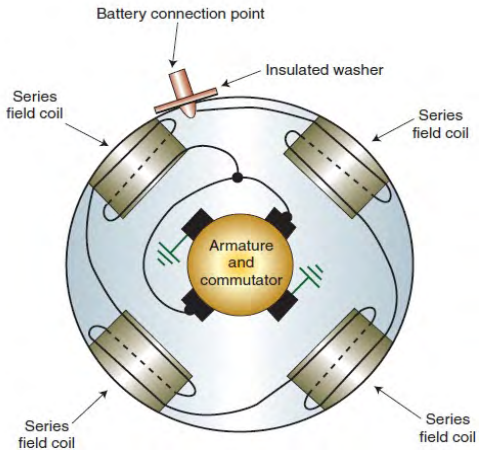


Figure 3.16: *Series starter motor*

2. **Series-Parallel Motor:** This has the field coils in series with the armature but connects the two pairs of field coils in parallel. Current flowing to the armature divides as it enters

the motor, half passes through one pair of field coils and the remainder flows to the other pair. Figure 3.17 shows a series-parallel motor.

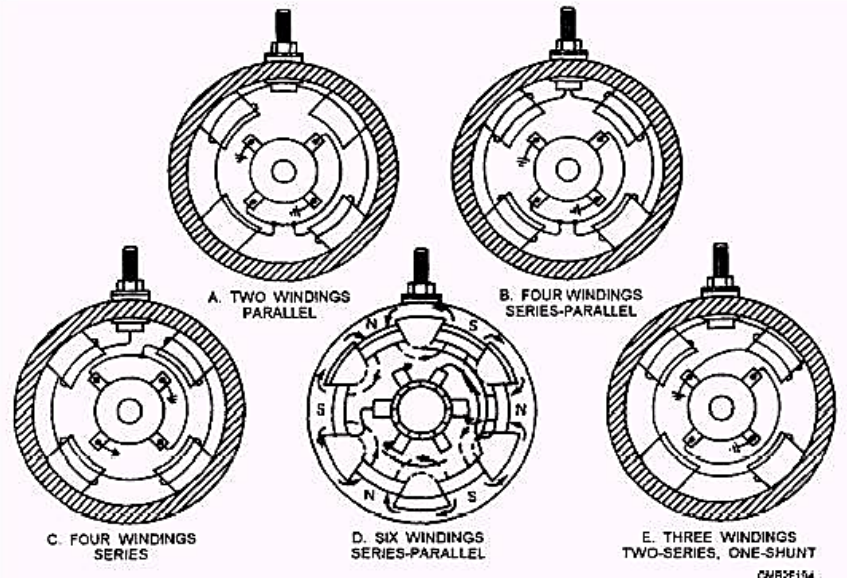


Figure 3.17: *Series-parallel motor*

3. **Pinion Engagement:** The pinion is meshed with the flywheel run gear only when the starting motor is operated. Engagement can be made of two ways inertia engagement and pre-engagement.
4. **Starter Solenoid:** There are two windings in the solenoid. These are closing coil and hold-on coil. The hold-on coil has many turns of relatively fine wire. The closing coil winding takes a high current through it and produces a strong magnetic field.
5. **Overrunning Clutch:** The overrunning clutch is a drive unit that transmits rotary motion in only one direction. This drive is from the starting motor armature to the engine flywheel. When the engine starts and begins picking up speed, the teeth on the flywheel ring gear try to turn the overrunning clutch pinion backwards. But as the rotary motion attempts to pass through the overrunning clutch, the pinion spins freely and fails to lock up.
6. **Starter switch:** An Ignition (or starter) switch is a switch in the control system of an internal combustion engine that activates the main electrical systems for the vehicle. Besides providing power to the starter solenoid and the ignition system components (including the engine control unit and ignition coil), it also usually switches on power to many "accessories" (radio, power windows, etc.). The ignition switch usually requires a key be inserted that works a lock built into the switch mechanism. It is frequently combined with the starter switch which activates the starter motor. Fig. 3.18 shows an exploded view of starter motor.

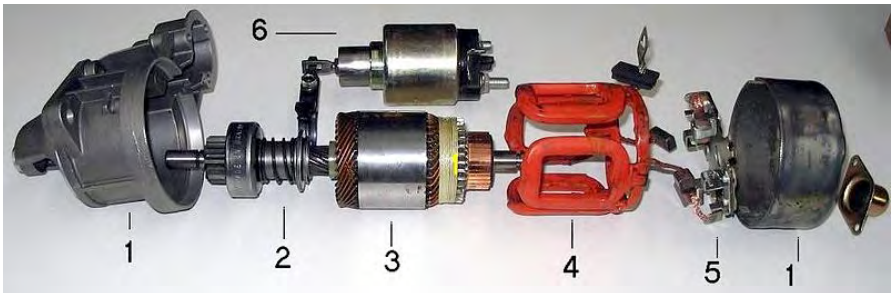


Figure 3.18: *Exploded view of starter motor*

1. Main housing (yoke)
2. Overrunning clutch and pinion gear assembly
3. Armature
4. Field coils with brushes attached
5. Brush-carrier
6. Solenoid

Learning Tasks

1. State the function of a battery in the motor vehicle.
2. Explain the function and the main components of coil ignition system.
3. Explain the basic difference between contact- point and electronic ignition systems.
4. Describe the main parts of a starter motor.

Pedagogical Exemplars

Experiential learning

Learners visit a local repair or school workshop to observe and discuss the main electrical systems on the vehicle and write out a short description to keep as evidence.

Demonstrate how to test a lead-acid battery using a voltmeter or hydrometer.

Show learners a working model of a coil ignition system and a starter motor in action.

Assign groups to research and present the differences between conventional and electronic ignition systems

Key Assessment Level 3: Practice Paper 1

1. a. Explain what might happen if the battery terminals are corroded. (4 marks)

b. How would this affect the ignition and starting systems? (4 marks)

2. a. Compare the functions of the ignition coil and the starter motor. (2 marks)

b. Why are both important for engine starting as in Q2a? (4 marks)

3. a. Describe how you would test whether the battery is the cause of an engine that will not start. (6 marks)

b. What tools or methods would you use as in Q3a? (4 marks)

4. a. Describe how you would test if the starter motor is the cause of an engine that will not start. (6 marks)

b. What tools or methods would you use as in Q4a? (4 marks)

Hint

*Conduct **Practice Paper 1**. It should cover the contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section. Learners' papers should be marked immediately and scores entered into the SAP.*

PRACTICE PAPER 1
TABLE OF SPECIFICATION
PAPER 1 (Multiple Choice Questions)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive technology	Demonstrate safety measures applied to servicing, repair and maintenance of engine systems		1	1		2
	Explain the constructional and operational differences between petrol and diesel engines	1				1
	Describe the construction and operation of the thermostat and pressurized water-cooling systems		1			1
	Examine the parts of the lubrication systems and the components to be lubricated		1			1
	Describe the main components of fuel supply for spark ignition (SI).			1		1
	Identify the components of vehicle transmission system and explain their functions	1				1
	Evaluate the components of braking system and state their functions		1	1		2
	Differentiate between mechanical, hydraulic and pneumatic braking systems		1			1
	Describe the layout of vehicle suspension systems	1	1			2
	Describe charging system, lighting, auxiliary and instrument panel systems of the vehicle	1				1
	Explain offboard and onboard diagnostics (OBD I & II) and the use of the scan tools.			1		1
	Describe the basic operation of the automotive HVAC system and safe motoring.	1		1		2

Metal technology	Describe various heat treatment processes with engineering examples		1	1		2
	Describe the twist drill and use drilling and grinding machines	1		1		2
	Demonstrate the use of lathe and shaping machines.		1			1
	Apply the principles of sand casting to produce articles	1	1			2
	Describe computing coding language used in Computer Numerical Control (CNC) machines		1			1
	Describe and perform operations using 3D printers.	1				1
	Identify and explain the use of various tools and equipment for gas welding			1		1
	Describe various tools and equipment for electric arc welding			1		1
	Demonstrate forging, rolling and extrusion operations in sheet metal.	1	1			2
	Perform basic cutting and bending operations in sheet metal fabrication	1				1
	Describe and apply a simple soldering and brazing joint in design for manufacture.		1	1		2
Building construction technology	Explain what setting out is	1				1
	Describe the roles of Professionals in building Construction projects	1				1
Woodwork technology	Classify the two main types of wood species.		1			**1**
	Outline the processing phases of timber in the woodwork industry		1			**1**
Electrical technology	Discuss safety in the use of electricity			**2**		**2**
Electronics technology	Describe the principles and operation of the various Diodes		**2**			
		12	**16**	**12**		**40**
		30%	**40%**	**30%**		**100%**

PAPER 2 (Essay)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive Technology	Explain the constructional and operational differences between petrol and diesel engines.					
	Examine the parts of the lubrication systems and the components to be lubricated.	**3**				**3**
	Describe the main components of the steering system and explain steering geometry and the angles involved.					
Metal Technology	Apply the principles of sand casting to produce articles.	**3**				**3**
	Describe and apply mechanical fasteners and finishes in design for manufacture.					
	Demonstrate the use of lathe and shaping machines.					
Total		**6**				**6**
						100%

PAPER 3 (Practical Test)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive Technology (Alternative to practical)	Describe the main components of fuel supply for spark ignition (SI).	**3**				**3**
Metal Technology	Explain and perform the stages in design for manufacture	**3**				**3**
Total		**6**				**6**
						100%

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.

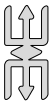
b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).

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

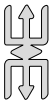
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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

6. Enact a teaching activity based on your learning plan (NTS la-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.

UNIT 12 REVIEW

The lesson on Battery, Ignition and Starting Systems provided a well-structured and practical introduction to key vehicle electrical components. It began with a clear explanation of the battery, distinguishing between primary and secondary types, followed by a focus on the lead-acid battery, its construction, and common testing methods such as voltage and electrolyte checks. The second part of the lesson addressed the ignition system, with clear comparisons between the coil ignition system and the electronic ignition system. Learners were able to identify the main components and understand how each system functions to produce the spark necessary for combustion. Finally, the starting system was introduced, with a focus on the types of starter motors used in light vehicles. Practical demonstrations and diagrams supported learning and encouraged student engagement. Throughout the lesson, a range of teaching methods such as demonstration, questioning, and group discussions supported different learning styles. Learners actively participated and showed improved understanding through practical tasks and oral feedback. Overall, the lesson successfully met its objectives by combining theory with practical skills, helping learners develop foundational knowledge and diagnostic thinking related to essential vehicle systems.

UNIT 13

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Outline the basic techniques applied in design for manufacture*

Content Standard: Demonstrate understanding of the principles and special welding techniques in design for manufacture and entrepreneurship

INTRODUCTION AND SECTION SUMMARY

Welcome to this lesson on soldering and brazing in design and manufacture two critical joining processes that play a pivotal role in modern product assembly, especially where traditional welding is not practical or efficient. Unlike welding, which melts base metals, soldering and brazing rely on filler metals with lower melting points to form strong, functional joints without altering the base materials' properties. We will begin by exploring the **soldering process**, including the tools and equipment required, such as soldering irons, fluxes, and filler wires. Then we will transition to brazing, a similar but higher-temperature method, discussing its unique process and applications. Through this lesson, you will compare the advantages and limitations of both techniques such as soldering's suitability for electronics and delicate components, versus brazing's strength in HVAC, automotive, and high-strength joints. You will also understand how these methods compare to welding in terms of thermal impact, joint strength, and manufacturing feasibility. In addition, we will examine practical applications of soldered and brazed joints in design for manufacture, where efficiency, aesthetics, and material compatibility shape the choice of joining process. Teaching Soldering and Brazing requires diverse pedagogical approaches to ensure effective learning. By combining instructional methods such as project-based learning, group discussions, role-play activities, case studies, and hands-on product design tasks, learners can develop a well-rounded understanding of how soldering and brazing can be applied in given design for manufacture project. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different student abilities and interests, ensuring that learners develop a deep understanding and application of soldering and brazing in design and manufacture

This unit covers only week 13: ***Describe and apply a simple soldering and brazing joint design for manufacture***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching Soldering and Brazing in Design and Manufacture requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in metal joining techniques, teachers should incorporate a range of strategies. These may include demonstration-based learning using soldering and brazing tools, scaffolded instruction on joint preparation, heat application, and filler material selection. These pedagogical exemplars not only build a strong foundation in the technical aspects of joining metals covering processes like capillary action, joint strength, and safety precautions but also promote innovation, problem-solving, and business awareness through real-life enterprise

contexts. Ultimately, they help learners develop a practical understanding of how soldering and brazing can be applied in product development and small-scale manufacturing. This prepares learners for more advanced technical training, entrepreneurial ventures, or productive engagement in the metalwork and fabrication industry.

ASSESSMENT SUMMARY

To assess learners' understanding of the soldering and brazing process, including joint types, material compatibility, equipment handling, and real-life application in design and manufacture, a range of assessment levels can be applied. These assessments should not only measure basic technical knowledge but also evaluate learners' ability to apply joining methods effectively in practical metalwork and entrepreneurial contexts. By incorporating Depth of Knowledge (DoK) Level 4, learners are expected to move beyond recall and simple demonstration. They should be able to analyse appropriate joining methods for different materials and designs, evaluate joint quality, select suitable filler materials, and solve problems related to heat control, joint fit-up, or material distortion. Assessment tasks may include practical exercises such as fabricating and inspecting a soldered or brazed product, comparing the suitability of different joining methods for a given application, or completing a mini project involving design, costing, and presentation of a product using soldering or brazing. Learners may also interpret defects in joints, suggest improvements, or analyse a case where joint failure affected product performance. This approach ensures learners demonstrate a deep and applied understanding of both technical processes and entrepreneurial considerations. Teachers can use these assessments to measure critical thinking, problem-solving, and readiness for real-world manufacturing or small business environments.

Indicators	DOK Level	Assessment Strategy and/or Mode
Describe and apply a simple soldering and brazing joint design for manufacture	3 (Strategic reasoning)	Demonstration and Discussion

WEEK 13

Learning Indicator: *Describe and apply a simple soldering and brazing joint design for manufacture*

FOCAL AREA 1: SOLDERING AND BRAZING JOINTS IN DESIGN AND MANUFACTURE

Soldering and brazing can be used to join metals that are difficult to weld together, such as copper, brass, aluminium, and stainless steel.

Soldering: Soldering is a joining process that uses a filler metal to join two base metals together at temperatures below 840°F (450°C). The solder melts and flows into the gap between the base metals by capillary action, creating a bond when it solidifies. Soldering is most commonly known for use in electric circuits, where it provides electrical conductivity and mechanical strength. Soldering can also be used for plumbing, jewellery making, and other applications that require low-temperature joining. Soldering involves joining similar or dissimilar metals using a filler material known as solder, typically made of a Lead-Tin alloy. Soldering necessitates the use of flux, a mixture of Zinc Chloride, Ammonium Chloride, and resin, to facilitate the process. Figure 3.19 shows a Soldering.

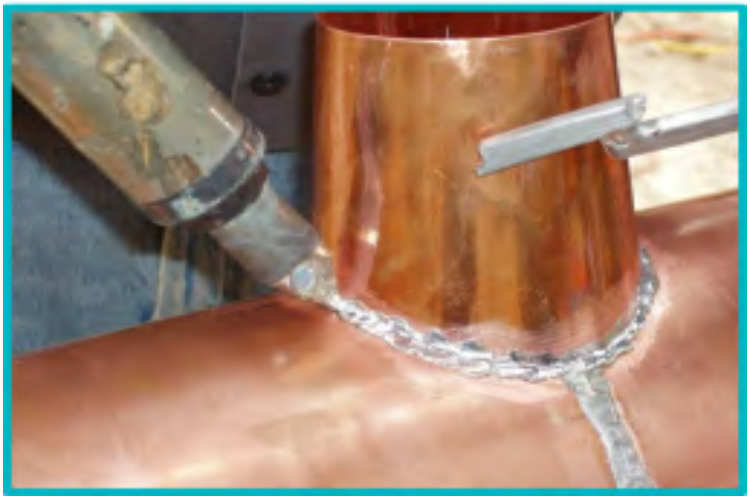


Figure 3.19: *Soldering*

Soldering Process: Soldering is a process that employs a lower melting point filler material, solder, to create a connection between two metal workpieces. It is widely used in electronics and plumbing for its versatility.

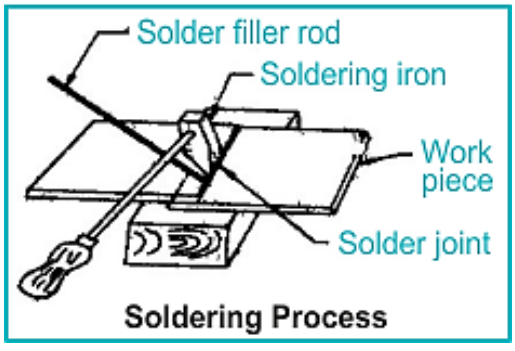


Figure 3.19: *Soldering process*

Soldering equipment comprises a soldering iron, solder or filler rod, and a power supply. The soldering process involves the following steps:

1. Prior to soldering, it is crucial to clean the workpieces thoroughly, removing any contaminants like oil, grease, dust, moisture, or rust, as their presence can weaken joints and reduce joint strength. Flux, such as borax **or resin, is often used as a cleaning agent to eliminate unwanted materials from the workpiece surfaces, ensuring a strong bond.**
2. The soldering iron tip, typically made of copper, is cleaned and heated, and then solder is applied using resin, creating a thin solder film on the iron tip known as 'tinning.'
3. With solder taken on the soldering iron tip, the tip is heated, causing the solder to melt. The molten solder is then applied to the joint area, filling any gaps. Subsequently, the joint is allowed to cool slowly. After soldering, cleaning any remaining flux using an appropriate chemical or cotton waste is essential.

Brazing is a metal-joining process that uses heat to melt a filler material, often a brass or silver alloy, which flows into the joint between two metal workpieces. Once cooled, it creates a strong and permanent bond, making it useful in various applications like plumbing and metal fabrication. Figure 3.19 shows a brazing.

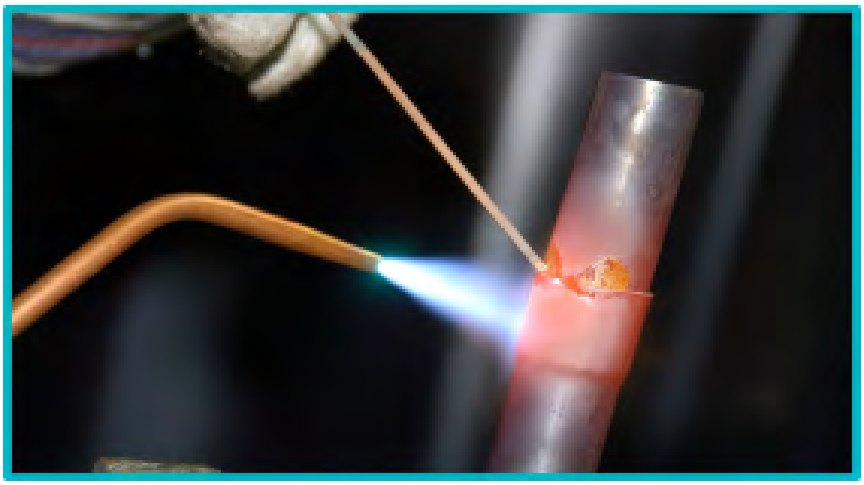


Figure 3.19: *Brazing*

Brazing is the process of joining two metals without the need for a prepared joint, relying on mechanisms like wetting and surface alloying. This method requires a joint temperature exceeding 450 degrees Celsius. The brazing process is carried out in the temperature range of approximately 1100 to 2000 °F (600 to 1100 °C). The function of flux in the brazing process is to facilitate the cleaning of metal surfaces, prevent oxidation or contamination during heating, and promote the flow and adhesion of the brazing filler material to the joint surfaces by reducing surface tension. The temperature **range for the soldering process is typically between 350 to 850°F (180 to 450°C), although it can vary depending on the specific solder and application.**

Brazing Process

Brazing is a metal-joining technique that employs heat to melt a filler material, typically brass or silver alloys, to create a strong, durable bond between two metal workpieces. This process finds use in various industries, including manufacturing and construction. **Figure 3.19 shows a brazing process.**

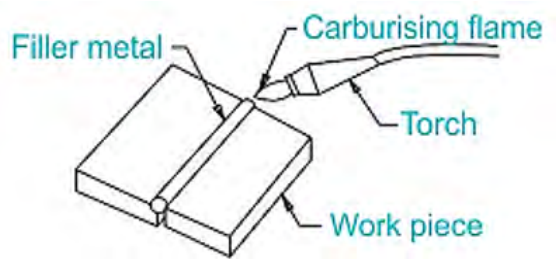


Figure 3.19: *Brazing Process*

To perform the brazing process, you will need a brazing torch, filler rod, flux, and gaseous fuels like oxygen and acetylene to create a carburising flame. The procedure for brazing is as follows:

1. At first, surfaces to be joined are thoroughly cleaned to remove any dust, oil, grease, oxide layers, or foreign substances.
2. Apply an appropriate flux at the brazing location to prevent oxidation of the base metal and facilitate the smooth flow of the filler material through capillary action.
3. Place the filler material in the designated brazing area.
4. Use a carburising flame to raise the temperature above the melting point of the filler material.
5. As the temperature of the filler material increases, it becomes molten and flows into the gap via capillary action.
6. Allow both the filler material and base metals to solidify.
7. Gradually cool the base metals to achieve a strong bond.
8. Immediately clean any remaining flux, as it has corrosive properties.

Advantages and Disadvantages of Brazing

Brazing offers several advantages, including:

1. Ability to join dissimilar metals.
2. Suitable for metals that may not be weldable due to differences in thickness, such as radiators, pipe fittings, containers, and heat exchangers.
3. Capability to create leak-proof joints through the brazing process.

The Brazing process has its drawbacks or advantages, including:

1. Requires skilled labour to perform brazing.
2. Joints created through brazing tend to have lower strength compared to welding.

Advantages and Disadvantages of Soldering

The benefits of the Soldering process include:

1. Easily dismantled joints.
2. Lower operating temperatures compared to brazing.
3. Cost-effective soldering.
4. Simple and economical design.

The drawbacks of the Soldering process include:

1. Need for skilled workers to create strong pipe joints.
2. Higher cost of solders.
3. Limited applicability to small joints, unsuitable for heavy parts.

Application of Brazing and Soldering

Some important applications of the two processes are discussed bellow:

Applications of Brazing

1. Fastening pipe fittings, attaching carbide tips to tools, and joining heat exchangers, electrical parts, radiators, and axles.
2. Joining cast metals to wrought, dissimilar, and porous metal components.
3. Assembling bicycle parts like frames and rims.

Applications of Soldering

Primarily employed for soldering wires onto Printed Circuit Boards (PCBs).

The following table compares between brazing and soldering processes**:**

Table 3.7: *Difference between Brazing and Soldering*

Aspect	Brazing	Soldering
Temperature	Higher temperature (above 450°C)	Lower temperature (below 450°C)
Filler Material	Filler metal with a high melting point	Solder with a lower melting point
Joint Strength	Stronger joints	Weaker joints
Skill Required	Skilled labour is often required	Requires less skill
Disassembly	Joints are not easily dismantled	Joints can be easily dismantled
Cost	Generally, more expensive	Economical
Applications	Used for heavier or thicker parts	Typically for smaller joints

Some of the challenges of soldering and brazing are:

1. They produce weaker joints than welding, which may not withstand high stresses or temperatures.
2. They require careful cleaning and preparation of the surfaces to ensure good wetting and adhesion of the filler metal.
3. They may introduce contaminants or impurities into the joint, which can affect its performance or reliability.
4. They may require additional steps or materials, such as fluxes or protective atmospheres, to prevent oxidation or corrosion of the filler metal or the base metals**.**

Table 3.8: *Comparison of soldering and brazing, to welding*

Feature	Soldering	Brazing	Welding
Heat required	Low (below 450°C)	Medium (above 450°C but below 900°C)	High (often above 1000°C)
Base metal melted?	No	No	Yes
Filler metal used?	Yes (soft solder)	Yes (braze alloy)	Sometimes (welding rod or wire)
Joint strength	Low to medium	Medium to high	High
Equipment cost	Low	Moderate	High
Typical applications	Electronics, plumbing (copper pipes)	Bicycles, air conditioning, tools	Car bodies, bridges, metal structures
Skill required	Basic	Moderate	High
Appearance of joint	Clean, smooth	Neat with capillary flow	May need cleaning or grinding
Ease of learning	Easy for beginners	Moderate difficulty	More complex to learn

Application of soldering and brazing joint in design for manufacture

Design and make a small metal-framed desk lamp with a working LED light. The frame will be brazed, and the electrical circuit (switch, LED, resistor, battery holder) will be soldered.

Materials Needed

For Brazing (Lamp Frame):

1. Mild steel rods or copper tubes (6–8 mm diameter)
2. Silver brazing rod
3. Flux
4. Torch or brazing hearth

For Soldering (Electrical Parts):

1. LED light or bulb
2. Resistor (if using LED)
3. Battery holder (2x AA batteries)
4. Toggle switch
5. Connecting wires
6. Solder and soldering iron

Project Steps

1. Design the Frame:
   a. Sketch the shape of the lamp frame (e.g. L-shape or U-shape stand)
   b. Measure and cut the metal rods or tubes
2. Brazing the Frame:
   a. Clean and prepare the metal surfaces
   b. Apply flux to joints
   c. Heat and apply brazing rod to join parts
   d. Cool and clean the joints
3. Soldering the Circuit:
   a. Plan a simple on/off circuit using a switch, LED, resistor, and batteries.
   b. Solder the components onto a small circuit board or piece of plywood.
   c. Connect the circuit to the lamp head (where LED will sit)
4. Assembly:
   a. Attach the electrical circuit to the brazed frame
   b. Secure all parts and test the light
5. Finishing:
   a. Paint or polish the frame
   b. Label and present the project

Learning Tasks

1. Define soldering and brazing.
2. Explain the difference between brazing and soldering.
3. Compare soldering, brazing and welding processes.
4. Explain and perform soldering and brazing in a given design and manufacture project.

Pedagogical Exemplars

Project-based Learning

Guide learners using charts, pictures, models, videos (YouTube), and real objects to discuss, observe and practice. various ways of applying soldering to artefacts.

Assist learners to apply brazing and soldering to make artefacts in groups or individuals.

Assist learners to prepare different soldered and brazed joints in groups test their strengths under load or heat, and analyse the results.

Key Assessment Level 3: Demonstrations and Discussions

1. **a** Explain the difference between a soldered and a brazed joint. (6 marks)

b. Why would you choose one method over the other in design and manufacturing of a given project? (7 marks)

2. Describe how you prepared the metal and tools before making your soldering or brazing joint in the workshop. (8 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

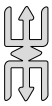
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***demonstrations and discussions***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the discussions (NTS 3k-3q).

10 minutes	Content Exploration

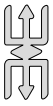
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

MARKING SCHEMES/RUBRICS FOR THE KEY ASSESSMENTS

UNIT 9

Design Folio Element	Excellent (30-40 marks)	Very Good (20-30 marks)	Satisfactory (10-20 marks)	Needs Improvement (0-10 marks)
Design Situation	Comprehensively articulates the problem with detailed analysis of causes, effects and context. Includes specific examples of instrument damage, classroom disruption, and financial implications. Clearly identifies stakeholders affected.	Clearly explains the problem with appropriate detail on effects and context. Identifies key stakeholders and primary concerns.	Basic explanation of the problem with some context but limited analysis of broader implications.	Minimal or unclear explanation of the problem context. Fails to establish the need for the solution.
Design Brief	Precisely worded brief that clearly defines scope, constraints and objectives. Demonstrates exceptional understanding of design purpose and user needs.	Well-formulated brief that outlines the main objectives and constraints. Shows clear understanding of design purpose.	Adequate brief that states the basic design goal but may lack precision in defining constraints or scope.	Poorly worded or overly vague brief that fails to provide clear direction for the design process.
Analysis Questions	Comprehensive set of thoughtful questions covering all relevant aspects: ergonomics, materials, dimensions, attachment methods, capacity, accessibility, durability, aesthetics and cost considerations. Questions show depth of critical thinking.	Well-developed questions covering most important aspects of the design challenge. Questions demonstrate good understanding of design requirements.	Basic questions covering fundamental design requirements but lacking depth in some important areas.	Minimal or irrelevant questions that don't effectively guide the design process.

Investigation	Thorough research including: existing solutions, material properties, user dimensions, classroom constraints, appropriate manufacturing techniques and relevant standards. Includes primary research (surveys, measurements) and secondary research with proper citations.	Good research covering most relevant areas with appropriate depth. Shows evidence of both primary and secondary sources.	Basic research covering fundamental information but limited in scope or depth. May rely too heavily on limited sources.	Insufficient research lacking important information needed to inform design decisions.
Specification	Comprehensive, detailed specification with measurable criteria for all relevant aspects: dimensions, materials, load capacity, durability, safety, aesthetics, manufacturability and cost. Specifications directly address user needs and environmental constraints.	Clear specifications covering most important design requirements with measurable criteria. Specifications address key user needs.	Basic specifications covering fundamental requirements but may lack measurability or detail in some areas.	Vague or incomplete specifications that provide insufficient guidance for design development.
Possible Design Concepts	Multiple creative and diverse concepts (3+ distinctly different approaches) with detailed sketches, annotations and preliminary evaluation against specifications. Each concept shows originality and thoughtful problem-solving.	Several distinct concepts (at least 3) with clear sketches and annotations. Concepts show creativity and consideration of specifications.	Basic concepts (2-3) that address the fundamental requirements but may lack originality or detail in presentation.	Minimal or underdeveloped concepts (1-2) showing little variation or creativity.

Final Solution	Exceptional final design clearly evolved from evaluation of concepts. Includes comprehensive justification for all design decisions referenced to specifications. Design demonstrates innovation, practicality and thorough understanding of user needs.	Well-developed final solution with clear rationale for design decisions. Design is practical and addresses most specifications effectively.	Adequate final solution that meets basic requirements but with limited justification for some design decisions.	Weak final solution with significant flaws or missing justification for key design decisions.
Working Drawings	Comprehensive, precise technical drawings including: multiple orthographic views, sectional views, detailed dimensioning, assembly drawings and professional CAD representations. All drawings follow technical drawing conventions perfectly.	Complete technical drawings with accurate orthographic projections, dimensions and assembly details. Drawings follow most technical drawing conventions.	Basic technical drawings that communicate the design but may have minor errors in projection, dimensioning, or conventions.	Incomplete or inaccurate technical drawings with significant errors that would impede manufacturing.
Cutting List	Detailed, comprehensive cutting list with precise measurements, materials, quantities and cost estimates. Optimised for material efficiency and manufacturing process.	Complete cutting list with appropriate measurements, materials and quantities. Good consideration of material requirements.	Basic cutting list with essential information but may lack detail or optimisation considerations.	Incomplete or inaccurate cutting list with missing or incorrect information.

Manufacturing Process	Exceptional detailed manufacturing plan with logical sequence, appropriate tools, safety considerations, quality control checks and time estimates for each stage. Demonstrates thorough understanding of workshop processes.	Clear manufacturing plan with appropriate sequence, tools, and safety considerations. Demonstrates good understanding of required processes.	Basic manufacturing plan that outlines the fundamental steps but may lack detail in some areas or optimal sequencing.	Inadequate manufacturing plan with missing critical steps or unsafe procedures.
Finishing/ Finishes	Comprehensive finishing specification with detailed surface preparation, appropriate finish selection for durability and aesthetics, application methods and environmental considerations. Includes justification for finish choices.	Clear finishing specification with appropriate finish selection and application methods. Good consideration of durability requirements.	Basic finishing information with standard finish options but limited detail on application or justification.	Minimal or inappropriate finishing information that would result in poor durability or appearance.
Testing and Evaluation	Sophisticated testing and evaluation plan with specific criteria linked to specifications, quantitative and qualitative methods, user testing protocols and detailed improvement recommendations based on anticipated results.	Well-developed testing plan with clear criteria and methods. Includes consideration of user feedback and potential improvements.	Basic testing approach that covers fundamental functionality but may lack comprehensive evaluation criteria.	Minimal or inappropriate testing plan that would not effectively validate the design.

UNIT 10

Question 1

a.

Excellent (5 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive explanation of how charging system failure affects both systems, with detailed analysis of voltage-dependent behaviour of different components and progressive symptoms as battery discharge occurs.	Clear explanation of major impacts on both systems with good understanding of voltage dependency and battery discharge effects.	Basic understanding that both systems are affected but limited detail on specific impacts or progression of symptoms.	Poor or incorrect explanation of system impacts showing limited understanding of electrical dependencies.

b.

Excellent (2 marks)	Very Good (1.5 marks)	Satisfactory (1 mark)	Needs Improvement (½ mark)
Two excellent diagnostic steps that are logically sequenced, technically appropriate, and specifically targeted at charging system diagnosis with clear procedural details.	Two good diagnostic steps that are appropriate for charging system diagnosis with reasonable procedural clarity.	Two basic steps that are generally relevant but lack specific details or optimal sequencing.	Suggested steps are inappropriate, insufficient, or incorrectly focused for charging system diagnosis.

Question 2

a.

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs Improvement (2 marks)
Checklist is exceptionally comprehensive, covering all critical components of charging system (battery, alternator, connections), lighting system (headlights, indicators, brake lights, interior lights), and instrument panel systems (gauges, warning lights) with specific inspection tasks for each.	Checklist covers most components of the three systems with clear inspection tasks. Minor components may be missing.	Checklist covers basic components of each system but lacks detail in some areas. Some important items might be missing.	Checklist is incomplete with significant gaps in one or more systems. Many critical components are missing.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Provides comprehensive justifications that clearly link each maintenance item to specific safety outcomes, showing excellent understanding of how vehicle systems affect road safety.	Provides good justifications for most items, clearly explaining their safety implications with specific examples.	Provides basic justifications that connect items to safety but may lack specific examples or depth.	Justifications are superficial or missing for many items, showing limited understanding of safety implications.

Question 3

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Provides comprehensive analysis of how the three components work together as an integrated system, with detailed explanation of electrical flow, dependencies, and feedback loops.	Explains the relationship between components clearly with good understanding of how they interact in the electrical system.	Basic understanding of component relationships demonstrated but lacks some details on system integration.	Poor understanding of how components relate to each other with significant misconceptions about system integration.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Accurately illustrates all relevant warning indicators (battery light, charging system warning, voltage indicator) with precise description of their appearance and meaning.	Accurately illustrates most warning indicators with good description of their appearance and meaning.	Illustrates basic warning indicators but may miss some or provide incomplete descriptions.	Few or inaccurate warning signs illustrated with major omissions or errors.

c.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive and prioritised list of immediate actions (reducing electrical load, safe stopping procedure, avoiding sudden shutoff) with clear rationale.	Good list of immediate actions with logical sequence and rationale.	Basic immediate actions identified but may lack prioritisation or complete rationale.	Few or inappropriate immediate actions with little understanding of safety priorities.

UNIT 11

Question 1

a.

Excellent (5 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive marketing strategy with detailed explanation of target audience, product positioning, and unique selling propositions specific to custom metal gates.	Well-developed marketing strategy covering target audience and product positioning with good understanding of local market needs.	Basic marketing strategy with some consideration of target audience but limited depth in product positioning.	Vague or inappropriate marketing strategy showing little understanding of marketing principles or local market needs.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive, well-sequenced steps for customer acquisition with innovative approaches specific to metalwork products.	Clear, logical steps for customer acquisition with good understanding of customer journey.	Basic steps for customer acquisition that follow standard practices but lack innovation.	Vague or illogical steps showing poor understanding of customer acquisition.

Question 2

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Excellent assessment of the situation with detailed analysis of material shortages, manpower limitations, and time constraints specific to metalwork.	Good assessment of the situation with clear understanding of resource limitations and their implications.	Basic assessment that identifies main constraints but lacks thorough analysis.	Poor or superficial assessment showing limited understanding of the business challenge.

Question 3

a

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive analysis of three relevant benefits with detailed explanation and examples specific to metalwork business context.	Good analysis of three benefits with clear explanation and some specific examples.	Basic description of three benefits with limited depth or metalwork-specific context.	Vague or irrelevant benefits with little understanding of business advantages

b.

Excellent (2 marks)	Very Good (1.5 marks)	Satisfactory (1 mark)	Needs Improvement (½ mark)
Comprehensive, practical strategies for reducing identified risks with specific actions tailored to metalwork business context.	Good risk reduction strategies that address the main financial risks with reasonable approaches.	Basic risk reduction approaches that are generally applicable but lack specificity or depth.	Vague or inappropriate risk reduction strategies showing poor understanding of business risk management.

UNIT 12

QUESTION 1

a.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive explanation of how corrosion creates high electrical resistance, reduces current flow, and causes voltage drop with specific technical details.	Clear explanation of how corrosion affects electrical conductivity and current flow with good technical understanding.	Basic explanation of resistance and reduced current flow but lacks technical depth.	Minimal or incorrect explanation of electrical effects showing poor understanding of basic electrical principles.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive explanation of how reduced current affects starter solenoid engagement, starter motor torque, cranking speed, and overall starting capability with specific voltage/amperage details.	Clear explanation of major effects on starter system components with good understanding of electrical requirements.	Basic explanation of reduced starting power but limited detail on specific components or electrical requirements.	Poor or incorrect explanation of starting system effects showing limited understanding of system operation.

Question 2

a.

Excellent (2 marks)	Very Good (1½ mark)	Satisfactory (1 mark)	Needs Improvement (½ mark)
Excellent comparison highlighting primary functions (coil: voltage multiplication for spark; starter: mechanical force for cranking) with clear distinctions and similarities in their roles.	Good comparison of primary functions with clear understanding of their different roles in the starting process.	Basic comparison that identifies main functions but lacks clarity on distinctions or similarities.	Poor or incorrect comparison showing fundamental misunderstanding of component functions.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 mark)
Comprehensive explanation of the complete starting sequence showing how both components work in coordinated sequence with precise timing relationships.	Clear explanation of starting sequence with good understanding of component timing and coordination.	Basic explanation of starting sequence but limited detail on timing or coordination between components.	Poor or incorrect explanation of starting sequence showing fundamental misunderstanding of engine starting process.

Question 3

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive, logically sequenced testing methodology covering visual inspection, voltage testing (both rest and under load), specific gravity testing for conventional batteries, and CCA testing with specific parameters for pass/fail.	Clear testing methodology with logical sequence covering main tests (visual, voltage, load) with appropriate parameters.	Basic testing approach that includes some key tests but lacks comprehensive sequence or specific parameters.	Poor or illogical testing methodology showing limited understanding of battery diagnostics.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive list of appropriate tools (multimetre, battery load tester, hydrometer, battery analyser) with specific brands/types and their advantages/limitations.	Good selection of appropriate tools with explanation of their functions and uses.	Basic list of common tools but limited explanation of their specific applications or advantages.	Incomplete or inappropriate tool selection showing limited knowledge of battery testing equipment.

Question 4

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive testing methodology including auditory assessment, current draw testing, voltage drop testing, direct activation testing, and bench testing if needed, with logical sequence and clear parameters.	Clear testing methodology covering main tests (current draw, voltage drop, direct activation) with appropriate sequence.	Basic testing approach that includes some key tests but lacks comprehensive sequence or specific parameters.	Poor or illogical testing methodology showing limited understanding of starter diagnostics.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive list of appropriate tools (multimeter, amp clamp, test light, jumper wires, starter test bench) with specific types and their advantages for starter diagnosis.	Good selection of appropriate tools with explanation of their functions in starter testing.	Basic list of common tools but limited explanation of their specific applications for starter testing.	Incomplete or inappropriate tool selection showing limited knowledge of starter testing equipment.

UNIT 13

Question 1

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
	Clear explanation of temperature differences with good approximate ranges and understanding of temperature impacts on the process.	Basic understanding that brazing uses higher temperatures than soldering but limited specific temperature ranges or impacts.	Minimal or incorrect explanation of temperature differences showing poor understanding of thermal aspects

b.

Excellent (6-7 marks)	Very Good (4-5 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive analysis of base material compatibility considerations with specific examples of compatible and incompatible materials for each process and metallurgical explanations.	Good explanation of material compatibility issues with appropriate examples for both processes.	Basic understanding that material compatibility matters but limited specific examples or explanations.	Poor or incorrect understanding of material compatibility showing limited knowledge of metallurgical factors.

Question 2

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs Improvement (1-2 marks)
Comprehensive description of surface preparation including mechanical cleaning (filing, sanding, wire brushing), chemical cleaning (degreasing, flux application), and specific techniques for different metal types with attention to surface quality standards.	Clear description of surface preparation methods with good understanding of cleaning requirements and appropriate techniques.	Basic description of cleaning methods but limited understanding of specific requirements for different metals or surface quality standards.	Poor or incorrect description of surface preparation showing limited understanding of its importance.

UNIT 13 REVIEW

The lesson on soldering and brazing effectively introduced learners to essential metal joining techniques used in design and manufacture. It began with a clear explanation of the soldering process, including the use of low-melting-point filler metals and relevant equipment such as soldering irons, flux, and wire. The brazing process was then explored, highlighting its use of higher temperatures and capillary action. A comparative approach was employed to deepen understanding. Learners discussed the differences between soldering and brazing, along with their respective advantages and disadvantages in terms of strength, cost, temperature, and precision. The comparison extended to welding, enabling learners to distinguish between fusion three joining methods. Through guided discussions and examples, learners explored real-life applications of soldering and brazing in product design such as in electrical components, decorative items, HVAC systems, and light structural assemblies. The lesson was reinforced with visual aids and group analysis, encouraging learner participation. Overall, the lesson successfully combined technical content with practical relevance, building a solid foundation for learners to apply these joining techniques in future design and manufacturing projects.

SECTION 4: MECHANICAL FASTENERS, WELDING TECHNIQUES, AND ENGINE, ELECTRIC VEHICLE, HVAC SYSTEM

The section covers the following unit (strands); Metal technology and Automotive technology.

In this section, learners will acquire knowledge and understanding of apply mechanical fasteners and finishes in design for manufacture, welding techniques used in design and manufacture, and welding techniques used in oil and gas industry. In the Automotive technology unit, learners are expected to gain the knowledge and understanding of automotive electronics and engine management systems, offboard and onboard diagnostics (OBD I & II), Examine and describe the operation of the electric vehicle (EV) and basic operation of the automotive HVAC system and safe motoring. All the above are treated from unit 14 to unit 18.

UNIT 14

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform diagnosis and repair on vehicle electrical/electronic systems and the use of the scan tools.*

Content Standard: Demonstrate understanding and perform tasks in vehicle technology sub-systems **in** modern automotive electronics and air conditioning system.

INTRODUCTION AND SECTION SUMMARY

Welcome to today's lesson on Automotive Electronics and Engine Management Systems. In modern vehicles, the Engine Management System plays a crucial role in optimising engine performance and efficiency. It achieves this by precisely controlling fuel injection, ignition timing, and other critical parameters. The main components include the Electronic Control Unit (ECU), which acts as the system's brain, interpreting data from various sensors and sending commands to actuators. Sensors, such as those for temperature, oxygen levels, and engine speed, provide real-time data to the ECU, enabling it to adjust settings in both closed-loop (feedback-based) and open-loop (preset) configurations. On-board diagnostics (OBD) systems further enhance maintenance and troubleshooting capabilities. These systems monitor vehicle health and emissions, with OBD scanners used to retrieve diagnostic trouble codes (DTCs) and access system status information. Understanding these fundamentals will equip you with essential knowledge for exploring the intricacies of automotive electronics and engine management systems. Teaching automotive electronics and engine management systems requires diverse pedagogical approaches to ensure effective learning. By combining these instructional methods used in the lesson, learners can gain a well-rounded understanding of

automotive electronics systems. By incorporating the highest DoK level for this learning indicator, teachers can tailor instruction to different learning needs, ensuring learners develop a deep understanding of how engine management systems enhance fuel efficiency, reduce emissions, and improve overall vehicle performance.

This unit covers only week 14:

1. ***Explain basic automotive electronics and engine management systems.***
2. ***Explain offboard and onboard diagnostics (OBD I & II) and the use of the scan tools.***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the engine management system requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in analysing engine control and electronic systems, teachers should incorporate a range of strategies. These may include demonstration-based learning, interactive use of diagnostic tools, scaffolded instruction on system components, collaborative group problem-solving, and project-based tasks involving real or simulated faults. Such approaches blend theoretical, practical, visual, and hands-on methods, catering to different learning styles and ability levels. These pedagogical exemplars not only establish a strong foundation in engine management principles but also promote analytical thinking, fault diagnosis, and system integration skills. Ultimately, they help learners develop a practical understanding of how engine management systems through components like the ECU, sensors, actuators, and OBD work together to enhance vehicle performance, efficiency, and reliability, preparing learners for more advanced technical roles or workplace demands.

ASSESSMENT SUMMARY

To assess learners' understanding of the engine management system, including its main components and working principles, a range of assessment levels can be applied. These assessments should not only measure basic knowledge but also evaluate the ability of learners to apply concepts in realistic automotive scenarios. By incorporating Depth of Knowledge (DoK) Level 4, learners are expected to move beyond recall and simple explanation. They should be able to analyse engine data, evaluate sensor inputs, interpret fault codes, and troubleshoot issues using diagnostic tools. Assessment tasks may include practical exercises such as diagnosing faults using an OBD scanner, analysing the operation of sensors and actuators, or comparing open-loop and closed-loop system behaviour under different engine conditions. This approach ensures that learners demonstrate a deep and applied understanding of engine management functions and system integration. Teachers can use these assessments to measure both theoretical knowledge and hands-on diagnostic ability, preparing learners for advanced technical studies or real-world automotive service tasks. Through this method, learners strengthen their problem-solving, critical thinking, and analytical skills within the context of modern engine management systems.

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain basic automotive electronics and engine management systems.	3 (Strategic Reasoning)	Discussion and Project work
Explain offboard and onboard diagnostics (OBD I & II) and the use of the scan tools	4 (Extended Strategic reasoning)	Discussion and Project work

WEEK 14

Learning Indicators

1. *Explain basic automotive electronics and engine management systems*
2. *Explain offboard and onboard diagnostics (OBD I & II) and the use of the scan tools*

FOCAL AREA 1: AUTOMOTIVE ELECTRONICS AND ENGINE MANAGEMENT SYSTEMS

The automotive electronics system refers to the electronic components, sensors, and control units that support the operation, safety, comfort, and efficiency of a modern vehicle. These systems have become increasingly important as vehicles move towards automation, electrification, and improved performance.

Key Areas of Automotive Electronics

1. **Engine Control System (ECU/ECM)**: Controls fuel injection, ignition timing, emissions, and overall engine performance. It relies on sensors (e.g., oxygen, temperature, airflow) and actuators.
2. **Transmission Control Module (TCM)**: Manages automatic gear shifting and optimises fuel economy and performance.
3. **Anti-lock Braking System (ABS)**: Prevents wheels from locking during braking, improving control and safety.
4. **Airbag and Safety Systems**: Includes crash sensors, airbag control modules, and seatbelt pretensioners.
5. **Infotainment System**: Covers audio, navigation, touchscreens, Bluetooth, and voice controls.
6. **Body Control Module (BCM)**: Controls interior electronics such as lights, power windows, wipers, and central locking.
7. **Advanced Driver Assistance Systems (ADAS)**: Includes lane-keeping assist, adaptive cruise control, parking sensors, and collision warning systems.
8. **Electronic Stability Control (ESC)**: Enhances vehicle stability during sudden manoeuvres.
9. **Lighting and Signalling System**: Includes headlights, brake lights, turn indicators, and interior lighting.
10. **Climate Control System**: Manages heating, air conditioning, and ventilation.
11. **Battery Management System (BMS)**: Ensures optimal charging and energy distribution.
12. **Instrument Panel and Display Systems**: Provides real-time vehicle status information through digital or analogue gauges.

An Engine Management System (EMS) is an electronic system that controls and monitors the performance of an internal combustion engine. It ensures that the engine operates efficiently, safely, and with minimal emissions by managing fuel delivery, ignition timing, air intake, and exhaust systems. EMS is a self-manipulative system that checks and regulates the proper

functioning of all the operations carried out by the engine. It checks all the factors related to engine operations,

Functions of the Engine Management System

1. Regulates the amount of fuel delivered to the engine based on operating conditions.
2. Adjusts spark timing for optimal combustion and power output.
3. Maintains the correct balance of air and fuel for efficient combustion.
4. Monitors and reduces harmful pollutants through exhaust gas treatment.
5. Maintains stable engine speed when the vehicle is stationary.
6. Regulates engine temperature by controlling coolant flow.
7. Adjusts engine response based on acceleration demands.
8. Identifies and records system errors for troubleshooting.
9. Ensures smooth operation and fuel efficiency under different driving conditions.
10. Interfaces with transmission, stability control, and other electronic systems for coordinated operation.

Electronic Engine Control

The engine control system is responsible for controlling fuel and ignition for all possible engine operating conditions

Main Components of an Engine Management System

1. **Electronic Control Unit (ECU)**: An Electronic Control Unit (ECU), also known as an Electronic Control Module (ECM), is a computer system that controls various electrical systems in a vehicle. It acts as the "brain" of the engine and other vehicle systems, managing functions like fuel delivery, ignition timing, and emissions. Figure 4.1 shows an **Electronic Control Unit (ECU).**

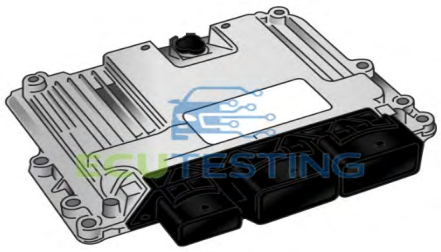


Figure 4.1: *Electronic Control Unit (ECU)*

Principles of ECU Operation: The Electronic Control Unit (ECU) operates by following three main principles: data input, data processing, and command output. First, the ECU collects data from various sensors located throughout the vehicle. These sensors include the oxygen (O_2) sensor, throttle position sensor (TPS), engine coolant temperature sensor, mass air flow (MAF) sensor, and crankshaft and camshaft position sensors. Next, the ECU processes this data using built-in software and pre-programmed maps (lookup tables), comparing the input values against standard parameters. Based on this analysis, the ECU determines the appropriate

adjustments required for optimal engine performance, such as the amount of fuel to inject or the timing of ignition. Finally, in the command output stage, the ECU sends electrical signals to actuators to carry out specific actions. These actions include controlling fuel injection, adjusting ignition timing, regulating idle speed, and managing emission control systems. Through this continuous process, the ECU ensures the engine runs efficiently, safely, and with minimal emissions.

2. **Sensors:** Sensors are devices used in vehicles to monitor various physical conditions and send signals to the Electronic Control Unit (ECU). These sensors help manage engine performance, improve safety, increase fuel efficiency, and reduce emissions. Some of the common sensors are;

   a. **Oxygen Sensor** – Monitors exhaust gases to maintain correct air-fuel mixture.

   b. **Throttle Position Sensor (TPS)** – Measures how far the throttle is open.

   c. **Engine Temperature Sensor** – Detects coolant temperature for warm-up adjustments.

   d. **Mass Air Flow Sensor (MAF)** – Measures the amount of air entering the engine.

   e. **Crankshaft and Camshaft Position Sensors** – Monitor engine speed and position for correct ignition and fuel timing. Figure 4.2 shows various sensors.

Figure 4.2 Types of Sensors

3. **Actuators**: Actuators are devices that receive signals from the Electronic Control Unit (ECU) and perform physical actions in response. Some common types of automotive actuators:

   a. **Fuel Injectors**: Deliver precise amounts of fuel.

   b. **Ignition Coils**: Provide spark for combustion.

   c. **Idle Control Valve**: Maintains correct engine idle speed.

Closed loop and open loop

In an **Engine Management System (EMS), open loop** and **closed loop** refer to two different modes of operation used by the **Electronic Control Unit (ECU)** to manage the air-fuel mixture based on available data. In open loop mode, the ECU controls the fuel injection without using feedback from the oxygen (O2) sensor in the exhaust. Figure 4.3 and 4.4 show an open loop and closed loop respectively.

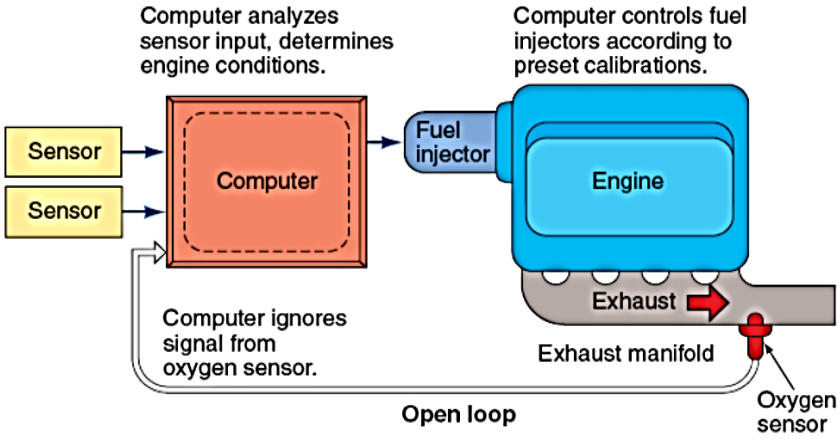


Figure 4.3: *Open loop*

In closed loop mode, the ECU adjusts the air-fuel mixture continuously using feedback from the oxygen sensor.

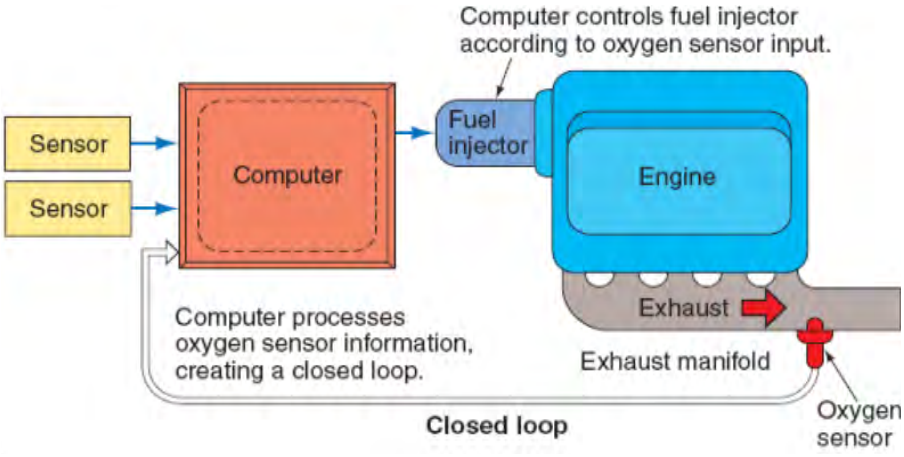


Figure 4.4: *Closed loop*

FOCAL AREA 2: ON-BOARD DIAGNOSTICS

Onboard Diagnostics (OBD) is a system in modern vehicles that monitors the performance of key engine and emission components. It helps detect faults, stores error codes, and alerts the driver when something is wrong usually through a warning light on the dashboard. A basic OBD system consists of an ECU (Electronic Control Unit), which uses input from various sensors (e.g., oxygen sensors) to control the actuators (e.g., fuel injectors) to get the desired performance. The "Check Engine" light, also known as the MIL (Malfunction Indicator Light), provides an early warning of malfunctions to the vehicle owner. A modern vehicle can support hundreds of parameters, which can be accessed via the DLC (Diagnostic Link Connector) using a device called a scan tool. See Figure 4.5.

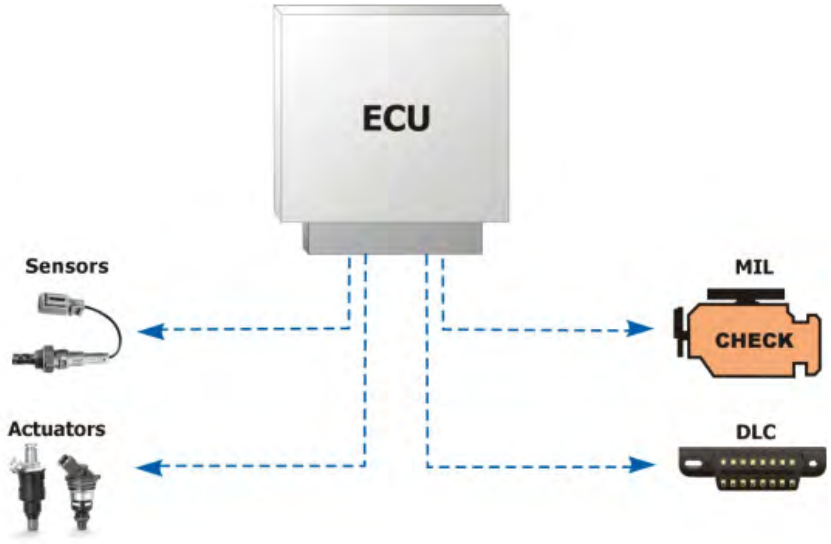


Figure 4.5: *Closed loop*

Importance of OBD

1. Helps detect problems early.
2. Saves time and cost during repairs.
3. Ensures the vehicle runs efficiently and within emission limits.
4. Essential for vehicle inspection and maintenance.

Types of OBD

There are two kinds of on-board diagnostic systems: OBD-I and OBD-II**.**

1. **OBD-I:**
   - **a.** Early version (used in vehicles before the mid-1990s).
   - **b.** Limited and manufacturer-specific.
2. **OBD-II:**
   - **a.** Standardised version used in most vehicles from 1996 onwards.
   - **b.** Allows universal scanners to read codes across different makes.

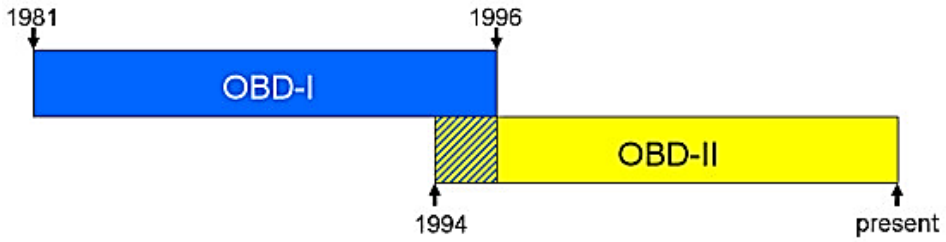


Figure 4.6: *OBD-1 and OBD-11*

OBD scanner

An OBD (On-Board Diagnostics) scanner is a device that connects to a vehicle's diagnostic port and retrieves data from the onboard computer system, allowing you to diagnose potential issues

and monitor the car's performance. It essentially allows you to access and interpret the data stored by the car's computer.

Figure 4.7 OBD-II scanner

A fault code, also known as a **Diagnostic Trouble Code (DTC),** is a standardised alphanumeric code that indicates a problem detected by a vehicle's computer. These codes help technicians and owners identify the location and nature of a malfunction. When a vehicle's on-board diagnostics (OBD) system detects a problem, it activates the corresponding trouble code.

Common DTCs include

1. P0300 (Random/Multiple Cylinder Misfire)
2. P0335 (Crankshaft Position Sensor "A" Circuit Malfunction)
3. B1300 (Air Conditioning System Fault).

To use an OBD-II scanner, locate the OBD-II port (usually under the steering wheel), plug in the scanner, turn on the ignition (but don't start the car), and follow the scanner's prompts to read codes. The scanner will display a diagnostic trouble code (DTC), which can be researched online or in a code book to understand the issue.

Learning Tasks

1. State the purpose of automotive electronics in modern vehicles.
2. Describe the main components in an engine management system.
3. Explain the difference between open loop and closed loop operation.
4. Explain the difference between OBD-I and OBD-II and the use of the scan tool.

Pedagogical Exemplars

Environmental observation

Using charts, models and videos (YouTube), and real vehicle in the school workshop, engage learners in an inclusive class discussion to explain electronics systems in the vehicle.

Using charts, models and videos (YouTube), and real vehicle in the school workshop, engage learners in an inclusive class discussion to explain offboard and onboard diagnostics (OBD I & II) used in vehicle diagnosis.

Help learners visually understand how the ECU, sensors, and actuators interact.

Discuss the use of OBD scan tools for vehicle diagnosis and present report for discussion.

Assist learners to use an OBD-II scanner to retrieve and interpret diagnostic trouble codes (DTC).

Key Assessment Level 3: Discussion and Mini-Project

1. a. Explain how the ECU uses information from sensors to control the engine's fuel supply and ignition. (6 marks)

2. a. Describe what might happen to engine performance if the oxygen sensor is faulty.

(6 marks)

b. How could this effect fuel use? (4 marks)

3. a. Analyse the relationship between the battery, alternator, and instrument panel in the vehicle electrical system. (6 marks)

b. Design a step-by-step process for using a scan tool to diagnose a car that shows a check engine light. Include how to read, interpret and respond to the fault code.

(10 marks)

4. a. Explain how using a scan tool can help a mechanic find a fault in the engine faster than using manual methods. (10 marks)

b. Describe two differences between OBD I and OBD II. (4 marks)

c. Why is OBD II more useful for modern vehicles? (3 marks)

PLC Session 14

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

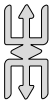
b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

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 ***discussion and mini-project***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessments (NTS 3k-3q).

10 minutes	Content Exploration

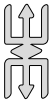
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 14 REVIEW

The lesson on Automotive Electronics and Engine Management Systems was well-structured and effectively delivered, covering key concepts essential for learners' understanding of modern vehicle operation. The session began with a clear explanation of the functions of the Engine Management System (EMS), focusing on its role in fuel efficiency, emissions control, and engine performance. The main components—including the Electronic Control Unit (ECU), sensors, and actuators were introduced through visual aids and real-world examples, making the content accessible and engaging. The distinction between closed-loop and open-loop systems was explained using simple diagrams and class discussions, helping learners understand how feedback mechanisms influence engine control. The introduction to On-Board Diagnostics (OBD), including types of OBD and the use of an OBD scanner, was particularly effective. Learners were shown how diagnostic codes are retrieved and interpreted, reinforcing the importance of fault detection and system monitoring. Overall, the lesson successfully combined theory with practical insight, using interactive teaching strategies to meet different learning needs. Learners were actively engaged and demonstrated improved understanding through questioning and practical tasks.

UNIT 15

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Outline the basic techniques applied in design for manufacture*

Content Standard: Demonstrate understanding of the principles and special welding techniques in design for manufacture and entrepreneurship.

INTRODUCTION AND SECTION SUMMARY

This lesson introduces learners to mechanical fasteners and finishers, essential elements in assembling and protecting metal products. Mechanical fasteners are devices used to join two or more parts without permanent deformation. They are widely used in manufacturing, construction, automotive, and metalwork industries due to their reliability and ease of disassembly. The lesson begins by exploring the types of mechanical fasteners, focusing on two main categories: threaded and non-threaded fasteners. Threaded fasteners include bolts, screws, nuts, and studs, all of which require a clear understanding of thread standards and definitions, as well as internal and external threads. Learners will also examine the various types of bolts and screws used in metal assembly. In the non-threaded category, the focus will be on rivets, including solid, blind, and pop rivets, commonly used where access is limited to one side of the material. Finally, the lesson covers finishes, which are applied to protect fasteners and enhance their appearance or corrosion resistance. Common types of finishes such as painting, galvanising, and electroplating will be discussed. This foundational knowledge prepares learners for effective design, selection, and application of fasteners and finishers in metalwork. Teaching mechanical fasteners and finishes in metalwork technology requires diverse pedagogical approaches to ensure effective learning. By combining instructional methods such as demonstration-based learning, hands-on fastening and finishing exercises as well as group projects learners can develop a comprehensive understanding of both technical application and design decision-making. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different student abilities and interests, ensuring that learners develop a deep understanding of how to apply fasteners and finishes in design and manufacture situation.

This unit covers only week 15: ***Describe and apply mechanical fasteners and finishes in design for manufacture***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching mechanical fasteners and finishes requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply key concepts in fastening and surface protection, teachers should incorporate a range of strategies. These may include demonstration-based learning of threaded and non-threaded fasteners, scaffolded instruction on thread standards and types of finishes, collaborative group activities involving product assembly using bolts, screws, and rivets, role-play exercises on material selection and customer consultation, and project-based learning where students design, assemble, and finish a simple

metal product. These pedagogical exemplars not only build a strong foundation in the technical aspects of joining and protecting metal parts but also encourage analytical thinking, teamwork, and problem-solving. By linking classroom activities to real-life design and manufacturing contexts, learners gain practical experience in making informed choices about fastening methods and finishes based on function, cost, and aesthetics. Ultimately, this approach equips students with both the technical skills and applied knowledge needed for further training.

ASSESSMENT SUMMARY

To assess learners' understanding of mechanical fasteners and finishes in metalwork technology, including key areas such as fastener types, thread standards, joint selection, and surface finishing methods, a range of assessment levels can be applied. These assessments should not only test basic theoretical knowledge but also evaluate learners' ability to apply fastening and finishing techniques in realistic design and manufacturing scenarios. By incorporating Depth of Knowledge (DoK) Level 3, students are expected to move beyond recall and identification. They should be able to select appropriate fasteners for specific applications, justify the use of particular thread types or finishes, and demonstrate correct assembly and finishing procedures. Assessment tasks may include practical exercises such as assembling a metal product using bolts, screws, or rivets, applying a protective finish, or interpreting technical drawings with specified fasteners and coatings. Learners may also be asked to analyse a case study involving fastener failure, propose suitable alternatives, or calculate the cost implications of different finishing options. These tasks ensure students demonstrate an applied understanding of how fasteners and finishes contribute to product strength, durability, and appearance. Teachers can use these assessments to evaluate both technical competence and design-related decision-making, preparing learners for further training or industry roles.

Indicator	DOK Level	*Assessment Strategy and/or Mode*
Describe and apply mechanical fasteners and finishes in design for manufacture	3 (Strategic reasoning)	*Practical Assessments*

WEEK 15

Learning Indicator: *Describe and apply mechanical fasteners and finishes in design for manufacture*

FOCAL AREA 1. MECHANICAL FASTENERS AND FINISHES

Mechanical fasteners are components used to join two or more parts together without permanently changing the parts. They can be removed or replaced.

Figure 4.8: *Various types of mechanical fasteners*

Types of Mechanical Fasteners

There are many different types of mechanical fasteners, but in general fasteners can be divided into two main categories: non-permanent and permanent fasteners. Non-permanent fasteners which enable parts to be assembled and disassembled repeatedly can be divided into two groups

1. General fasteners such as keys, pins, retaining rings etc. They are often associated with shafts.
2. Threaded fasteners such as bolts, screw, studs, setscrews. They are the most widely used type of non-permanent fasteners since they can easily be removed then reused, on the other hand, rivets are considered to be permanent fastener since removing rivets will destroy them.

Figure 4.9: *Types of Mechanical Fasteners*

Threaded Fasteners

1. Bolts: Cylindrical rods with a head at one end and threads at the other, used with nuts for clamping.
2. Screws: Similar to bolts, but they create their own threads in the material they are screwed into. Screws usually have longer threads than bolts and also they can be made with slotted heads. Screws are sometimes divided into two sub-categories: Cap screws and machine screws. Machine screws are generally smaller in size than the cap screws and they are used for screwing into thin materials.
3. Studs: Threaded rods with threads on both ends, often used to mount components.

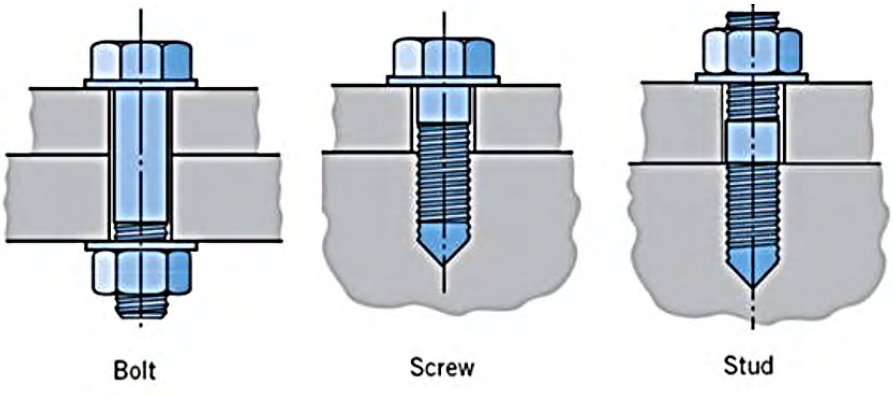


Figure 4.10: *Threaded Fasteners*

In practice, the basic difference between a bolt and screw is that a bolt is usually intended to be used in conjunction with a nut where it will be tightened or loosened using the nut while a screw is usually intended to be mated with an internally threaded hole and the screw head is used for tightening or loosening.

Threads Standards and Definitions

Bolt and screw threads are standardised and there are two major standards **ISO Metric and (ANSI Unified)**. In both standards the thread angle is 60^0

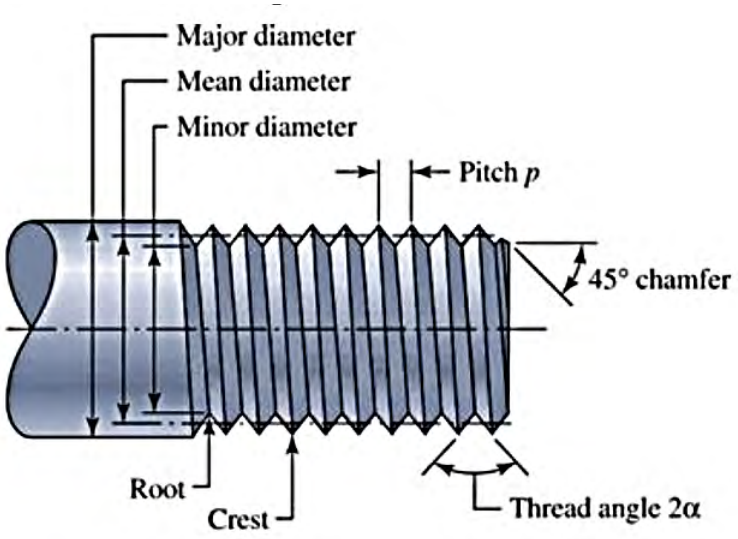


Figure 4.11: *Threads standards*

Table 4.1

Term	Meaning
Thread	The spiral groove on a screw or bolt
Pitch	The distance between each thread (measured in mm for metric threads).
Major diameter	The outer diameter of a thread (widest point).
Minor diameter	The inner diameter (narrowest part between threads)
Thread angle	The angle between the sides of the thread (usually 60° for metric).
TPI (Threads Per Inch)	Used in imperial threads to count how many threads fit into 1 inch.

Threads can be either external or internal

a. External Thread: A thread on the outside of a part. Example screw or bolt. An external thread is usually cut by using a die

Figure 4.12: *Die*

b. Internal Thread: A thread on the inside of a hole. Example, threads of nuts and holes. An internal thread is usually cut by using a tap

Figure 4.13: *Tap*

Types of Bolts and Screws

There are many different types of bolts and screws where each is suitable for different types of applications. The figure shows some of the most commonly used types of bolts and screws

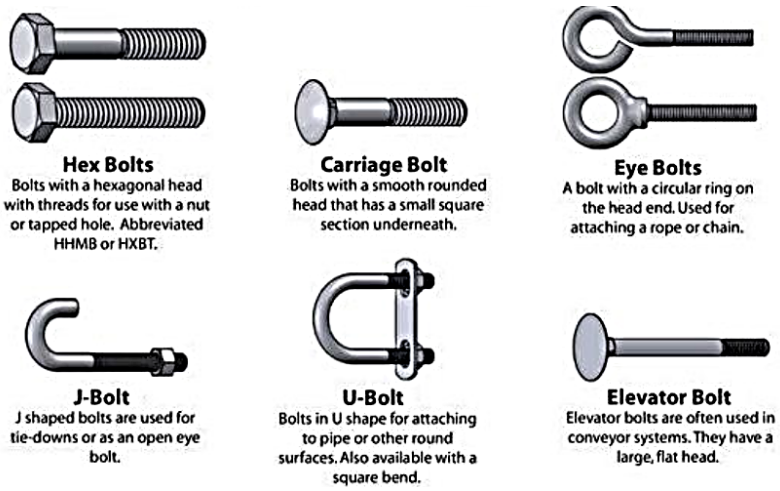


Figure 4.14: *Types of Bolts*

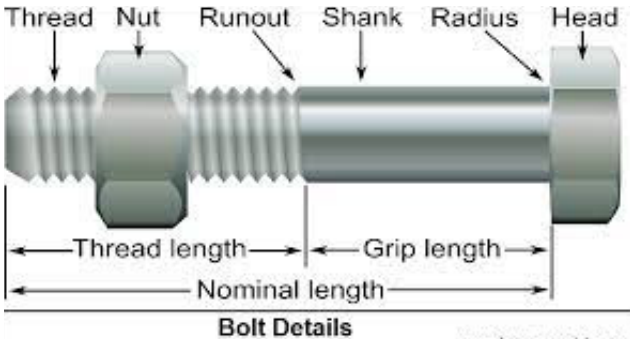


Figure 4.15 Bolts details

Figure 4.16: *Types of Screws*

Setscrew

A setscrew is a type of short screw used to hold one part tightly on another without using a nut. Most setscrews have no external head; they sit flush or inside the part. They are turned using an Allen key or screwdriver and often used to stop a gear or pulley from **slipping** on a shaft.

Figure 4.17: *Setscrew*

Nuts

A nut is the counter part of a bolt. Bolt and nut are used together to clamp two or more parts having unthreaded holes together. The most common used type of nuts are the regular hexagonal nuts. The figure below shoes some of the common types of nuts

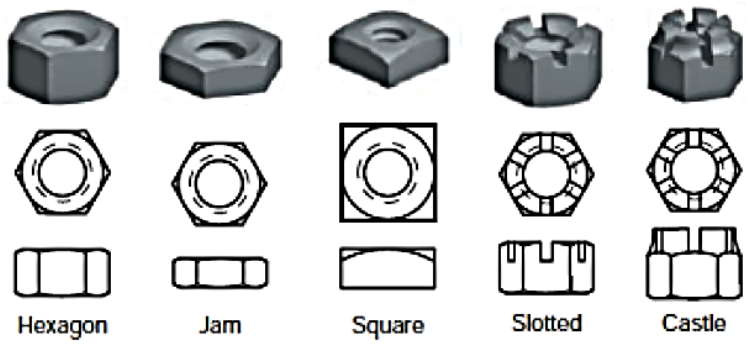


Figure 4.18: *Types of nuts*

Non-Threaded Fasteners

1. Rivets: These are metal pins that are deformed to create a head, providing a permanent mechanical connection.

Table 4.2: Types of Rivets

Type	Description	Common Use
Solid rivet	Needs hammering to fix	Aircraft, bridges
Pop rivet (blind rivet)	Fixed using a special tool from one side only	Sheet metal, car panels
Tubular rivet	Hollow shank, easier to deform	Light-duty uses (e.g. leather, soft plastics)
Snap head rivet	Has a rounded head	General-purpose metalwork

Figure 4.19: *Types of nuts*

2. Nails: Similar to rivets but typically used in wood or other softer materials.
3. Pins: Used to join components together, often with a retaining ring or clip.

Retaining Devices

1. Washers: A washer is a thin, flat disc with a hole in the middle. It is placed under a bolt or nut to help spread the load and protect the surface. It is used to distribute load, prevent damage to surfaces, or provide a locking mechanism.

Figure 4.20: *Types of nuts*

2. Locking Washers: Designed to prevent loosening due to vibration. Some of the common types of lock washers are shown below

Figure 4.21: *Types of nuts*

3. Clips: Used to hold components together, often with a spring or snap-lock mechanism.
4. Retaining Rings: Used to prevent components from sliding out of a groove

Finishes: are treatments or coatings applied to a product's surface to protect it or improve its appearance.

Table 4.3: Common Types of Finishes

Finish	Purpose	Example
Painting	Adds colour and protects from rust	Bicycles, tools
Plating	Covers metal with another metal (e.g. chrome, zinc)	Car parts, taps
Polishing	Makes the surface shiny and smooth	Cutlery, ornaments
Galvanising	Coats steel with zinc to stop rust	Fences, buckets
Anodising	Adds colour and protection to aluminium	Phone cases, torches

Learning Tasks

1. Differentiate between permanent and non-permanent fasteners.
2. Explain the difference between threaded and non-threaded fasteners.
3. Describe the most common threaded fasteners.
4. Differentiate with application the common types of finishes.

Pedagogical Exemplars

Group work/collaborative and Project-based learning

In a fair mixed ability group assist learners to brainstorm and identify the various fasteners and finishes.

Guide learners to select and use the appropriate fasteners and finishes for a given design for manufacture.

Project-based learning

With a given project, assist learners to make artefacts in groups or individually and apply mechanical fasteners and finishes.

Key Assessment Level 3: Practical

1. a. Explain why a designer might choose bolts instead of welding to join two metal parts in a product. (5 marks)

b. What are the advantages of using rivet in a given design than bolt and nuts?

(5 marks)

2. a. Describe how you would apply a finish to protect a metal product from rust.

(6 marks)

b. What safety precautions would you take in applying this finish in the workshop?

(6 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).

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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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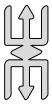


Note

- *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 ***discussion and mini-project***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessments (NTS 3k-3q).

10 minutes	Content Exploration

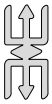
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

Unit 15 Review

The lesson on mechanical fasteners and finishers provided learners with a comprehensive introduction to essential components used in metal assembly and surface protection. It began with a clear explanation of mechanical fasteners, covering their function in joining parts without permanent deformation. Learners were introduced to threaded fasteners, including bolts, screws, and nuts, with emphasis on thread standards, internal and external threads, and how they apply in practical design situations. The lesson also explored non-threaded fasteners, focusing particularly on types of rivets such as solid and blind rivets, and their use in situations where only one side of the work piece is accessible. Learners engaged with visual aids and real fastener samples, helping them connect theoretical content with hands-on understanding. The second part of the lesson addressed common types of finishes, including painting, galvanising, and electroplating. These were discussed in relation to their protective, functional, and aesthetic roles in product design and manufacturing. Overall, the lesson was well-structured and interactive. It effectively built foundational knowledge while promoting practical awareness of fastening and finishing choices in metalwork. This provided learners with valuable skills applicable in both technical tasks and real-world manufacturing scenarios.

UNIT 16

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform diagnosis and repair on vehicle electrical/electronic systems*

Content Standard: Demonstrate understanding and perform tasks in vehicle technology sub-systems and modern automotive electronics and air conditioning system.

INTRODUCTION AND SECTION SUMMARY

Welcome to today's lesson on Electric Vehicles (EVs). As the automotive industry moves towards cleaner and more sustainable technology, electric vehicles are becoming increasingly common on our roads. Understanding how these vehicles work is essential for any modern automotive technician. In this lesson, we will explore the basic components of an EV, including the electric motor, battery pack, power inverter, and control systems. You will learn how these components work together to power the vehicle without using traditional fuels like petrol or diesel. We will also look at how an electric vehicle operates, from energy storage in the battery to how power is delivered to the wheels. In addition, we will examine the different types of electric vehicles, such as battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). The lesson will also highlight the advantages of EVs, such as lower emissions, reduced fuel costs, and quieter operation, along with some disadvantages compared to internal combustion engine vehicles, like limited range, longer charging times, and higher initial costs. Teaching electric vehicles (EVs) requires diverse pedagogical approaches to ensure effective learning. By combining instructional methods used in the lesson such as visual demonstrations, hands-on activities, group discussions, and multimedia presentations learners can gain a well-rounded understanding of electric vehicle technology. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different learning needs, ensuring that learners move beyond simple recall to deeper analysis and application. Through this approach, learners develop a deeper understanding of how electric vehicle systems contribute to energy efficiency, environmental sustainability, and modern vehicle performance, preparing them for future training and industry expectations.

This unit covers only week 16: ***Examine and describe the operation of the electric vehicle (EV)***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching electric vehicles (EVs) requires the use of diverse pedagogical exemplars to support meaningful learning. To help learners understand and apply basic concepts and skills in analysing EV systems, teachers should incorporate a range of strategies. These may include demonstration-based learning using EV components, collaborative group activities for exploring different EV types, scaffolded instruction on system operations, experiential tasks such as virtual simulations, and project-based assignments focused on EV design or comparison with internal combustion engine vehicles.

Such approaches blend practical, visual, interactive, and theoretical methods, ensuring that different learning styles and ability levels are supported. These pedagogical exemplars not only build foundational knowledge of electric motors, batteries, inverters, and control systems, but also promote critical thinking, system analysis, and real-world application. Ultimately, they help learners develop a clear and practical understanding of how EVs operate, the benefits and limitations of electric mobility, and the key differences between electric and conventional vehicles. This prepares learners for further technical training, industry tasks, and emerging roles in the automotive field.

ASSESSMENT SUMMARY

To assess learners' understanding of electric vehicles (EVs), including their main components and operational principles, a range of assessment levels can be used. These assessments should not only test basic knowledge but also evaluate how well learners can apply what they have learned in practical and real-world contexts. By using Depth of Knowledge (DoK) Level 4, learners are expected to move beyond simple recall and explanation. They should be able to analyse, evaluate, and apply their knowledge in problem-solving situations such as comparing different types of EVs, assessing the performance of electric drivetrains, diagnosing energy efficiency issues, or designing basic EV system layouts. Learners might also evaluate the advantages and disadvantages of EVs versus internal combustion engine vehicles in terms of cost, maintenance, and environmental impact. This level of assessment ensures that learners demonstrate a thorough understanding of how EV systems function, interact, and perform in real conditions. Teachers can use these tasks to effectively measure both theoretical understanding and advanced application skills, preparing learners for future technical training or careers in the automotive industry. Such assessments help learners develop critical thinking, analytical reasoning, and systems-based problem-solving skills essential for working with modern electric vehicles.

Indicators	DOK Level	*Assessment Strategy and/or Mode*
Examine and describe the operation of the electric vehicle (EV).	4 (Extended Strategic reasoning)	*Discussion and Research*

WEEK 16

Learning Indicator: *Examine and describe the operation of the electric vehicle (EV)*

FOCAL AREA 1: ELECTRIC VEHICLE (EV)

An electric vehicle (EV) is a type of vehicle that operates using electrical energy stored in a battery, rather than fuel such as petrol or diesel. The energy powers an electric motor, which drives the wheels and moves the vehicle.

Basic Components of an EV

1. **Battery Pack**
   a. Stores electrical energy (usually lithium-ion).
   b. Supplies power to the electric motor and other systems.
2. **Electric Motor**
   a. Converts electrical energy into mechanical energy to rotate the wheels.
   b. Works efficiently with fewer moving parts than an internal combustion engine.
3. **Inverter:** Changes the **direct current (DC)** from the battery into **alternating current (AC)** used by the motor.
4. **Controller**
   a. Acts like the vehicle's brain.
   b. Receives input from the driver (e.g., accelerator pedal) and regulates the power sent to the motor.
5. **Charging Port:** Allows the battery to be recharged from an external power source.
6. **Electric Drivetrain:** Delivers power from the motor to the wheels efficiently and with fewer moving parts than traditional drivetrains.

Working Principle of an EV

An electric vehicle (EV) operates through a coordinated system of electrical components working together to drive the vehicle efficiently. When the driver presses the accelerator pedal, the controller receives this input and sends a signal to the inverter. The inverter then converts the battery's direct current (DC) into alternating current (AC) and delivers the correct type and amount of electricity to the electric motor. Once powered, the motor begins to rotate and drives the wheels, propelling the vehicle forward. As the vehicle slows down, regenerative braking comes into action. This system recovers some of the kinetic energy that would otherwise be lost during braking and converts it back into electrical energy, which is then stored in the battery for later use. Throughout the drive, the battery pack acts as the main energy source for the entire vehicle. In addition to powering the motor, it also supplies electricity for all onboard systems, including lighting, climate control, and infotainment features. This fully electric operation makes EVs highly efficient and environmentally friendly, with minimal reliance on mechanical parts compared to traditional vehicles.

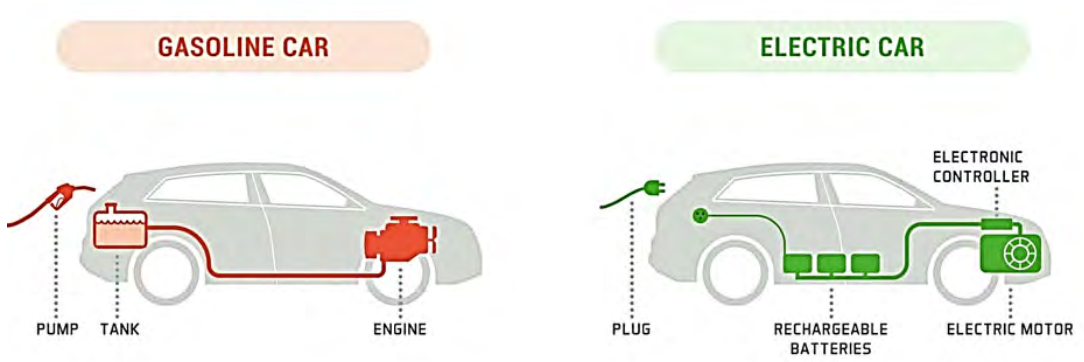


Figure 4. 22: *Working Principle of an EV*

Types of Electric Vehicles

There are currently **three main types of electric vehicles (EVs)** available on the market each with different levels of electrification and fuel use:

1. **Battery Electric Vehicles (BEVs):** These vehicles run entirely on electricity and do not have a petrol or diesel engine. They are powered by large battery packs that need to be recharged using an external power source. BEVs produce zero tailpipe emissions and are fully electric. *Example: Tesla Model 3, Nissan Leaf.*
2. **Plug-in Hybrid Electric Vehicles (PHEVs):** PHEVs have both an electric motor and a petrol or diesel engine. They can run on electric power for shorter distances and switch to the internal combustion engine when the battery runs low. The battery can be recharged by plugging into an external power source. *Example: Toyota Prius Plug-in, Mitsubishi Outlander PHEV.*
3. **Hybrid Electric Vehicles (HEVs):** HEVs also use both an electric motor and a combustion engine, but their batteries are charged through regenerative braking and the engine itself, not by plugging in. They typically start in electric mode and then switch to the engine when needed. *Example: Toyota Corolla Hybrid, Honda Insight.*

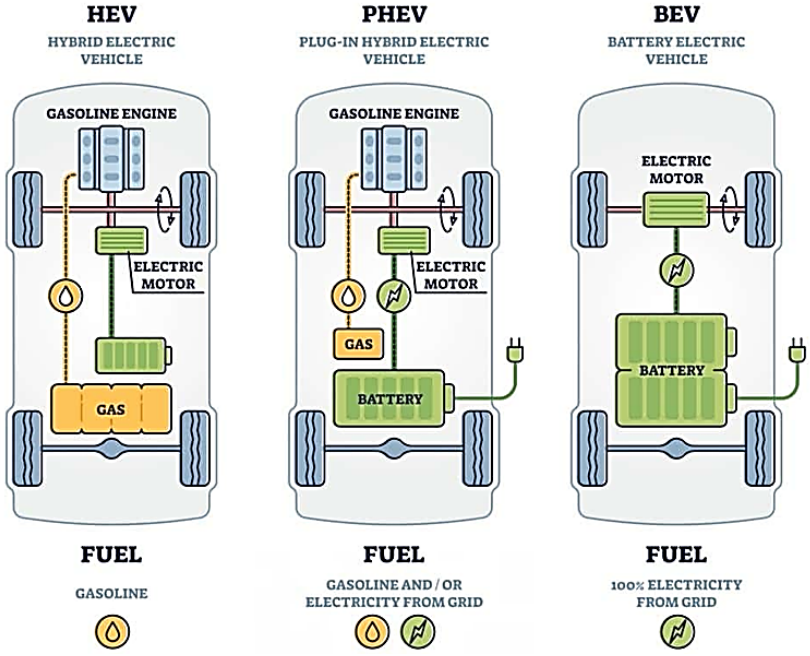


Figure 4.23: *Types of* **Electric vehicles**

Advantages of Electric Vehicles (EVs) Over Internal Combustion Engines (ICEs)

1. EVs produce zero tailpipe emissions, reducing air pollution and greenhouse gases.
2. Electricity is generally cheaper than gasoline or diesel, and EVs have fewer moving parts, reducing maintenance expenses.
3. EVs convert more energy from their source into usable power compared to ICEs.
4. Electric motors operate silently, enhancing driving comfort and reducing noise pollution.
5. EVs recover energy during braking, improving efficiency and extending driving range.
6. Many governments offer subsidies, tax benefits, and reduced registration fees for EV purchases. EVs deliver immediate power, improving driving performance.

Disadvantages of Electric Vehicles Over Internal Combustion Engines

1. EVs are generally more expensive upfront due to battery technology.
2. Charging stations are not as widespread as fuel stations, making long-distance travel challenging in some regions.
3. Charging an EV can take hours, compared to a few minutes for refuelling an ICE vehicle.
4. EV batteries degrade over time, affecting range and performance.
5. Most EVs have shorter ranges compared to ICE vehicles, especially without fast-charging support.
6. Battery production requires lithium, cobalt, and other materials, which pose environmental and ethical concerns.
7. Charging relies on electricity availability, which may be affected by grid outages or energy shortages.

Learning Tasks

1. State the main source of power for a Battery Electric Vehicle (BEV).
2. Describe the main components used in electric vehicle.
3. Explain the principle of operation of an electric vehicle.
4. Differentiate between battery electric vehicles (BEVs), hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs).

Pedagogical Exemplars

Group work and collaborative Learning

Using charts, models and videos (YouTube), and real vehicle in the school workshop, learners **should** identify and describe the main components of the electric vehicle.

Engage learners in an inclusive class discussion to explain the operation of the electric vehicle.

Assign each group a type of electric vehicle (BEV, PHEV, HEV) to research

Provide diagrams of an EV and ask groups to label and describe functions of key components

Key Assessment

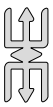
1. Design a basic diagram or flowchart showing how energy moves through an electric vehicle from the battery to the wheels. (12 marks)
2. How does the inverter help the electric motor work in an EV? (4 marks)
3. Suppose you are designing a new electric vehicle (EV) for exhibition before manufacturing companies. What systems or features would you include to improve efficiency and reliability, and why? (8 marks)
4. **a.** Explain how full electric vehicle differ from hybrid electric vehicle. (6 marks)

   b. State three advantages and one disadvantage of using EV over internal combustion engines. (4 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).



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 ***discussion and research***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessments (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

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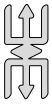

Note

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- 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 la-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.

UNIT 16 REVIEW

The lesson on charging system, lighting system, auxiliary system, and instrument panel offers a well-structured approach to understanding essential automotive electrical components. It begins with an in-depth breakdown of the charging system, explaining how alternators, voltage regulators, and batteries work together to maintain electrical power. Clear demonstrations of charging system components enhance comprehension, allowing learners to visualise how energy flows within a vehicle. The lighting system section effectively covers various lighting components, including headlights, brake lights, and interior illumination, emphasizing their roles in visibility and safety. Diagrams and real-world examples aid understanding, making the content relatable. The lesson further explores auxiliary systems, such as windshield wipers, power windows, and climate control, demonstrating their impact on driver comfort and convenience. Interactive discussions ensure students grasp how these systems integrate into modern vehicles. Finally, the instrument panel system is covered comprehensively, detailing speedometers, fuel gauges, warning lights, and digital displays. Practical exercises allow learners to analyse panel functions and diagnostic indicators. While the lesson successfully presents key concepts, incorporating more hands-on activities would enhance engagement. Overall, it is an informative and well-structured lesson, equipping learners with foundational knowledge in vehicle electrical systems.

UNIT 17

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Outline the basic techniques applied in design for manufacture*

Content Standard: Demonstrate understanding of the principles and special welding techniques in design for manufacture and entrepreneurship.

INTRODUCTION AND SECTION SUMMARY

This lesson introduces learners to special welding techniques that play a vital role in modern metal joining, especially in high-precision industries such as design and manufacturing, as well as the oil and gas sector. Unlike conventional welding, special welding processes offer enhanced control, strength, and suitability for a wide range of materials and applications. Learners will explore the advantages of special welding processes, such as cleaner welds, improved precision, and reduced material distortion. Key techniques covered in this lesson include TIG welding (Gas Tungsten Arc Welding – GTAW) and MIG welding (Gas Metal Arc Welding – GMAW). The lesson will explain how TIG welding works, focusing on the use of a non-consumable tungsten electrode, shielding gas, and filler material. Learners will also be introduced to TIG equipment and its applications in thin-gauge metals and aerospace components. For MIG welding, the lesson will describe its operation using a consumable wire electrode and shielding gas, along with the equipment required. The advantages of MIG welding, such as high speed and ease of automation, and its limitations, including poor performance on thick materials without proper preparation, will be discussed. This foundation prepares learners for advanced training and real-world welding applications. Teaching special welding techniques requires diverse pedagogical approaches to ensure effective learning. By combining instructional methods such as project-based learning, group discussions, and hands-on design tasks, learners can develop a well-rounded understanding of a well-rounded understanding of advanced welding applications. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different student abilities and interests, ensuring that learners develop a deep understanding of how special welding techniques are used in precision manufacturing and high-demand industries such oil and gas.

This unit covers only week 17:

1. ***Explain special welding techniques used in design and manufacture.***
2. ***Explain special welding techniques used in oil and gas industry***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching special welding techniques in metalwork technology requires the use of diverse pedagogical exemplars to promote deep and applied learning. To help learners understand and apply processes such as TIG (GTAW) and MIG (GMAW) welding, teachers should incorporate a range of strategies. These may include demonstration-based instruction using actual welding equipment, scaffolded lessons on process selection and safety procedures, project-based tasks

where learners fabricate metal components using TIG or MIG welding, group analysis of case studies from the oil and gas industry, and comparative discussions on the advantages and limitations of each process.

These pedagogical exemplars not only build technical competence in advanced welding methods but also promote problem-solving, decision-making, and process evaluation skills. Learners gain practical insights into how special welding processes improve quality, precision, and material compatibility in design and manufacturing. By applying these techniques to real-life contexts learners are better prepared for industry standards and expectations. Ultimately, these approaches support learners in developing both technical expertise and entrepreneurial thinking, equipping them for further training, employment, or small-scale welding enterprises.

ASSESSMENT SUMMARY

To assess learners' understanding of special welding techniques, including processes such as TIG and MIG, a variety of assessment levels can be applied. These assessments should not only evaluate theoretical knowledge but also test learners' ability to apply advanced welding methods in realistic fabrication and industrial scenarios. By incorporating **Depth of Knowledge (DoK) Level 3**, students are expected to move beyond simple recall and demonstration. They should be able to select suitable welding techniques for specific materials or design requirements, explain process advantages and limitations, and apply safe welding procedures in practical settings. Assessment tasks may include practical exercises such as performing TIG or MIG welds on assigned joints, identifying and assembling appropriate welding equipment, or evaluating weld quality based on industry standards. Learners may also complete written tasks comparing welding methods, analysing case studies from industries like oil and gas, or proposing suitable techniques for given manufacturing challenges. These assessments help measure both technical skill and decision-making abilities. Teachers can use them to assess learners' readiness for advanced training, industry practice, or entrepreneurship in metal fabrication, ensuring they can meet modern design and manufacturing demands.

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain special welding techniques used in design and manufacture	3 (Strategic reasoning)	Discussion and Class Exercise
Explain special welding techniques used in oil and gas industry	3 (Strategic reasoning)	Discussion and Class Exercise

.

WEEK 17

Learning Indicators

1. *Explain special welding techniques used in design and manufacture*
2. *Explain special welding techniques used in oil and gas industry*

FOCAL AREA 1. SPECIAL WELDING TECHNIQUES

Special welding processes refer to advanced welding techniques beyond the common methods like MIG, TIG, and arc welding. These include processes like ultrasonic welding, friction welding, laser beam welding, and electron beam welding, which offer precise, high-quality welds suitable for specialised applications.

Advantages of Special Welding Processes

1. High precision and accuracy
2. Reduced heat-affected zone (HAZ)
3. Joining dissimilar metals
4. Automated and controlled processes
5. High-speed welding:

Special welding processes widely used in **design and manufacturing** to meet demands for precision, strength, and innovation are

1. **Laser Beam Welding (LBW)**: Used in **automotive body design**, electronics, and fine metal fabrication where minimal distortion and high-speed welding are essential.
2. **Electron Beam Welding (EBW):** Ideal for **aerospace components, turbine blades, and precision instruments** requiring ultra-clean, high-strength welds in vacuum environments.
3. **Friction Stir Welding (FSW)**: Applied in **lightweight structural design**, such as aluminium panels for aircraft, trains, and electric vehicle battery enclosures.
4. **Ultrasonic Welding**: Common in **plastic product design**, including medical devices, packaging, and consumer electronics, where heat-sensitive materials must be joined without melting.
5. **Explosion Welding**: Used to **bond dissimilar metals** in cladding applications, such as heat exchangers or corrosion-resistant panels in industrial equipment.
6. **Plasma Arc Welding (PAW):** Employed in **precision manufacturing** of stainless steel and titanium parts, especially in medical and aerospace sectors.
7. **Orbital Welding**: Automated TIG welding used in **piping systems** for food processing, pharmaceuticals, and cleanroom manufacturing.
8. **Submerged Arc Welding (SAW):** Utilised in **heavy fabrication**, such as pressure vessels, structural beams, and large machine components.
9. **Thermit Welding**: Occasionally used in **tool and die manufacturing** or for joining large steel components in custom machinery.

10. **Electroslag Welding (ESW):** Applied in **vertical welding of thick sections**, such as moulds, dies, and heavy-duty structural parts.

Special welding processes are vital in the oil and gas industry due to the extreme environments, high-pressure systems, and critical safety requirements. Below is a list of key applications:

1. **Submerged Arc Welding (SAW):** Used for welding **pressure vessels, storage tanks, and long pipeline sections** due to its deep penetration and high deposition rate.
2. **Orbital Welding** – Ensures **precise, repeatable welds** in pipeline joints and tubing systems, especially in offshore and subsea installations.
3. **Electron Beam Welding (EBW)**: Applied in **critical components** like valves and high-pressure fittings where ultra-clean, high-strength welds are needed.
4. **Laser Beam Welding (LBW)**: Used in **refinery equipment and instrumentation** for its precision and minimal heat-affected zones.
5. **Friction Stir Welding (FSW)**: Ideal for **joining aluminium components** in offshore structures and lightweight transport systems.
6. **Explosion Welding**: Used to **bond dissimilar metals**, such as cladding corrosion-resistant alloys onto steel for pipelines and pressure vessels.
7. **Thermit Welding**: Common in **repairing or joining large steel structures**, like pipelines and rail systems in remote areas.
8. **Electroslag Welding (ESW)**: Suitable for **vertical welding of thick sections**, such as structural supports in offshore platforms.
9. **Hyperbaric Welding**: A specialised underwater technique used for **subsea pipeline repairs and offshore platform maintenance.**
10. **Ultrasonic Welding**: Occasionally used for **non-metallic components** in control systems and sensors where heat must be minimised.

TIG Welding (Gas Tungsten Arc Welding – GTAW)

Gas Tungsten Arc Welding (GTAW) also known as Tungsten Inert Gas welding (TIG) is an electric arc welding process that produces an arc between a non-consumable electrode (tungsten which does not melt due to its high melting point) and the work piece to be welded. The weld is shielded from the atmosphere by a shielding gas that forms an envelope around the weld area. However, a filler metal is usually used in the process. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used**.** TIG is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys.

Figure 4.24: *How TIG Welding Works*

1. A **non-consumable tungsten electrode** creates an electric arc between itself and the workpiece.
2. This arc generates intense heat, melting the base metal.
3. A **shielding gas** (usually argon or a mix of argon and helium) flows around the weld area to protect it from atmospheric contamination like oxygen or nitrogen.
4. A **filler rod** may be manually added to the weld pool, depending on the joint type and strength required.

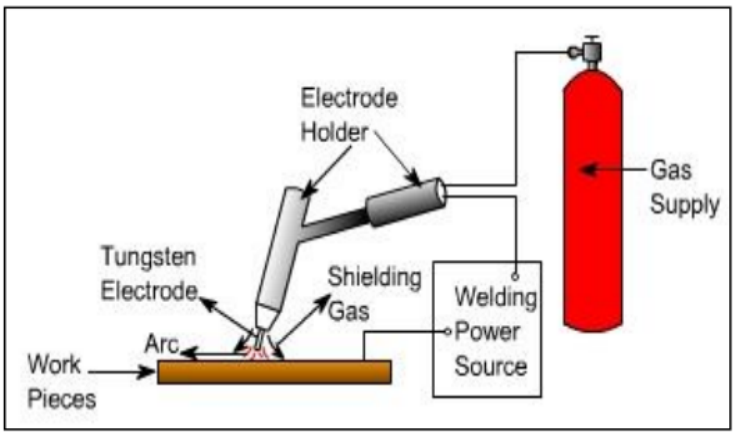


Figure 4.25: *TIG Welding Works*

Equipment

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

1. Welding torch
2. Power supply
3. Electrode
4. Shielding gas
5. Filler Rod

1. **Tungsten Electrode**: Doesn't melt during welding; it can be sharpened to control arc shape and penetration.

   Tungsten electrode types:

   1. Pure tungsten electrodes -GREEN
   2. Thoriated tungsten electrodes - RED
   3. Ceriated tungsten electrodes - ORANGE
   4. Lanthanated tungsten electrodes – GOLD
   5. Zirconiated tungsten electrodes – BROWN

2. **TIG Torch**: Holds the electrode and directs shielding gas.

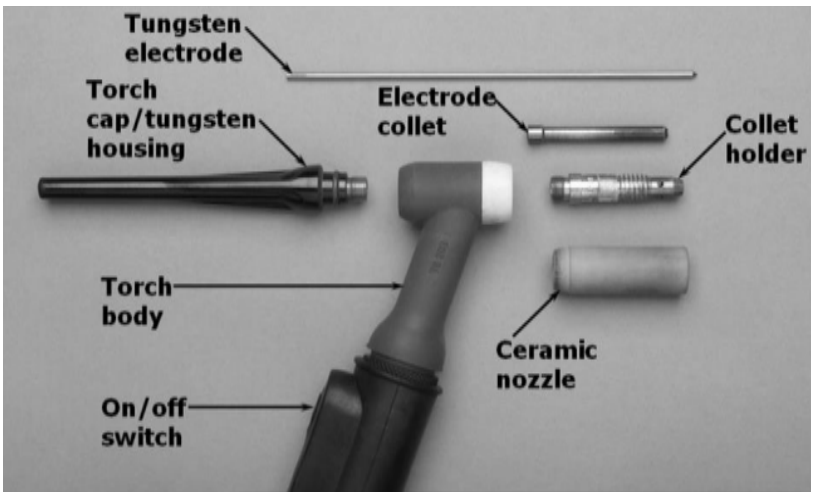


Figure 4.26: *TIG torch*

3. **Power Source**: Can be AC or DC depending on the metal; AC for aluminium, DC for steel and stainless steel.
4. **Shielding Gas Supply**: Prevents oxidation and ensures a clean weld.
5. **Filler Rod**: Added by hand for stronger joints or when welding thicker materials.

TIG welding applications in design and manufacturing

1. Aerospace: TIG welding is used in the construction of aircraft and spacecraft.
2. Pipeline and Container Construction: TIG welding is used in the construction of pipelines and containers.
3. Thin Sheet Metal Welding: TIG is suitable for welding thin sheet metal, especially aluminium and stainless steel.
4. Specialty Metal Welding: TIG welding is used for welding reactive metals like titanium, magnesium, and certain alloys.
5. **Medical Device Manufacturing**: Fabricating surgical instruments, implants, and stainless-steel housings.
6. **Electronics Enclosures**: Welding delicate casings and connectors for sensors and control systems.
7. **Welding of Dissimilar Metals**: Joining materials like stainless steel to copper or titanium in specialised products.

TIG welding applications in the oil and gas industry

1. **Pipeline Welding**: For high-pressure pipelines transporting oil and gas, especially when working with stainless steel or exotic alloys.
2. **Pressure Vessel Fabrication**: Used to weld tanks and vessels that must withstand extreme pressure and temperature.
3. **Refinery Equipment**: TIG is ideal for welding heat exchangers, reactors, and separators where precision and corrosion resistance are critical.
4. **Offshore Platform Construction**: For structural components exposed to harsh marine environments, requiring strong, clean welds.

5. **Storage Tank Manufacturing**: Ensures leak-proof, durable welds in large tanks used for oil and gas storage.
6. **Valve and Flange Assembly**: Precision welding of components that control flow and pressure in pipelines and processing systems.
7. **Maintenance and Repair**: TIG is used for repairing cracks or corrosion in critical infrastructure without compromising integrity.
8. **Instrumentation and Control Systems**: Welding of small, delicate components like sensor housings and tubing in control systems.

MIG Welding (Gas Metal Arc Welding – GMAW)

MIG welding, also known as Gas Metal Arc Welding (GMAW), is a process where an electric arc forms between a continuously fed wire electrode and the workpiece, creating a weld. This arc, shielded by a gas, melts both the wire and the base metal, joining them together. MIG welding can be semi-automatic or fully automatic, making it a versatile and efficient welding method.

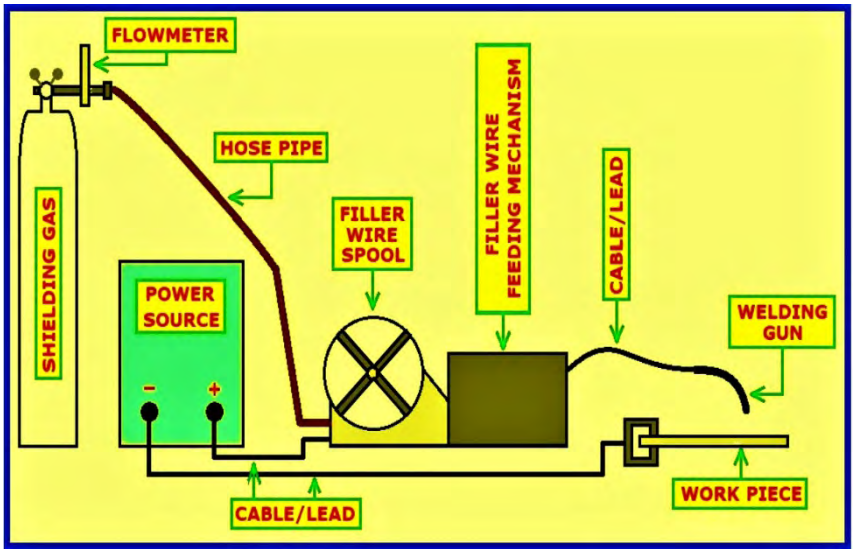


Figure 4.27: *MIG Welding – Gas Metal Arc Welding (GMAW)*

In MIG welding process, consumable electrode is used in the form of filler wire and a shielding gas such as Argon, Helium, Carbon dioxide or a mixture of these gases are used. These gases shield the molten weld pool from atmospheric contamination. The shielding gas is allowed to flow through the weld gun. The electrode or filler metal of MIG welding (which comes in wire form) is fed continuously, at a fixed rate, by a feeding mechanism. The filler wire gets consumed during the process and thereby provides the required filler metal.

The equipment needed for GMAW set up are shown above

1. Power Source
2. Filler metal feeding Mechanism
3. Welding Gun
4. Shielding Gas
5. Welding cables or leads and gas hose pipes

In MIG welding, Voltage, Current, and wire feed speed must be controlled for producing sound welding.

Advantages of GMAW (MIG Welding)

1. GMAW can be used to weld all commercial metals and alloys
2. No restriction of limited electrode length as we face in shielded metal arc welding (SMAW).
3. Due to the gas shielding, no additional flux is required for the protection of the molten pool
4. It can be used to weld in all positions.
5. Higher deposition rates than shielded metal arc welding (SMAW)
6. Due to the continuous electrode feeding mechanism, we can achieve higher welding speeds and higher filler metal deposition rates than shielded metal arc welding (SMAW)
7. Due to the continuous electrode (wire feed) feed, longer welds can be deposited without intermediate stops and starts;
8. Very less post-weld cleaning is required due to the absence of any heavy slag;
9. Comparatively easy to learn and less skilled welders can also do the MIG welding.
10. This process can be easily automated

Limitations of GMAW (MIG Welding)

1. The GMAW equipment is more complex, costlier, and less portable than that for shielded metal arc welding (SMAW)
2. Due to the absence of flux covering, chances of faster cooling rates exists which may affect badly
3. Shielding of the molten weld pool is quite difficult during windy and drafty environments. High chances of porosity in the weld metal during windy environments.
4. MIG welding requires moderate cleaning of joints before welding

Learning Tasks

1. Review TIG and MIG welding and explain special welding process
2. Explain some types of special welding processes.
3. Describe some applications of special welding processes in the oil and gas industry.
4. Describe a design and manufacturing situation where especial welding process is preferred.

Pedagogical Exemplars

Experiential and Project-based learning: Learners embark on educational visits to local welding shops, manufacturing industry and observe special welding techniques and present a report in the class.

With a given project in groups or individual, assist learners to identify and use the appropriate special welding technique to make artefacts.

Assist learners to develop a welding procedure specification (WPS) for joining stainless steel pipes using TIG welding, as used in oil and gas pipelines.

Guide learners in a missed ability groups to design and fabricate a structural frame using MIG welding techniques for a workshop trolley or metal stand.

Learners embark on educational visits to a local oil and gas industry and observe the use of special welding processes and present a report to class

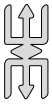
Key Assessment Level 3: Discussion and Class Exercise

1. Why might a car manufacturer choose special welding technique instead of normal arc welding? (5 marks)
2. How could using any special welding technique improve the quality of an aluminium body? (6 marks)
3. Describe two problems that might happen if TIG welding is done without shielding gas, and why? (8 marks)

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 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 ***discussion and class exercise***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessments (NTS 3k-3q).

10 minutes	Content Exploration

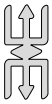
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

Unit 17 Review

The lesson on special welding techniques provided learners with a focused and practical introduction to advanced welding processes commonly used in manufacturing and the oil and gas industry. It began with an overview of the importance and advantages of special welding processes, particularly in high-precision and high-strength applications. Key attention was given to TIG (Gas Tungsten Arc Welding) and MIG (Gas Metal Arc Welding) techniques. The lesson clearly explained how each process works, including the required equipment setup, shielding gases, and filler materials. Learners explored the benefits of TIG welding such as clean, high-quality welds for thin materials and the advantages and limitations of MIG welding, including its speed and ease of automation versus its challenges with thicker materials. Through diagrams, equipment demonstrations, and industry-based examples, the teacher successfully linked theoretical content to real-life applications, especially in pipeline construction, structural fabrication, and light manufacturing. Learners also discussed safety considerations and the role of these techniques in oil and gas infrastructure. Overall, the lesson was well-structured and engaging, combining theory with applied knowledge. It effectively built learner confidence in identifying, comparing, and selecting special welding processes for different design and industrial needs.

UNIT 18

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform diagnosis and repair on vehicle electrical/electronic systems and air conditioning system and safe motoring.*

Content Standard: Demonstrate understanding and perform tasks in vehicle technology sub-systems and modern automotive electronics, air conditioning system and safe motoring

INTRODUCTION AND SECTION SUMMARY

In this lesson, we will explore two important areas of automotive knowledge: the Automotive HVAC (Heating, Ventilation, and Air Conditioning) system and the principles of Safe Motoring. Understanding these systems is essential for both vehicle performance and road safety. We will begin by stating the function and examining the parts of an automotive Air Conditioning (AC) system, such as the compressor, condenser, evaporator, and expansion valve. You will also learn the working principle of the AC system, which includes how refrigerant flows and helps cool the cabin. In addition, we will look at different types of refrigerants, including the eco-friendlier options used in modern vehicles. The second part of the lesson focuses on safe motoring practices. We'll discuss the key elements of safe motoring, including regular vehicle checks, driver awareness, and avoiding distractions. You will also be introduced to defensive driving techniques that help prevent accidents and protect all road users. Lastly, we'll look at some common road signs and their meanings to reinforce good driving habits. Teaching the Automotive HVAC System and Safe Motoring requires diverse pedagogical approaches to ensure effective learning. By combining instructional methods such as hands-on demonstrations, visual aids, group discussions, and real-life case studies, learners can gain a well-rounded understanding of vehicle climate control systems and road safety practices. By incorporating the highest Depth of Knowledge (DoK) level for this learning indicator, teachers can tailor instruction to different learning needs, ensuring leaners develop a deep understanding of how HVAC systems improve driver comfort and visibility, while safe motoring habits reduce accidents and promote responsible vehicle operation. This approach prepares leaners not only for technical training but also for real-world automotive tasks that require both mechanical knowledge and road safety awareness.

This unit covers only week 18: ***Describe the basic operation of the automotive HVAC system and safe motoring***

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the Automotive HVAC System and Safe Motoring requires the use of diverse pedagogical exemplars to support meaningful learning**.** To help learners understand and apply basic concepts and skills in analysing vehicle climate control and road safety systems, teachers should incorporate a range of strategies. These may include demonstration-based learning using HVAC components, scaffolded instruction on system operation and refrigerant flow,

collaborative group analysis of safe driving scenarios, role-play on defensive driving, and experiential activities like identifying road signs or conducting vehicle checks. These pedagogical exemplars not only build a strong foundation in how HVAC systems function covering parts like the compressor, evaporator, and expansion valve but also promote critical thinking, hazard awareness, and responsible driving habits through real-life context. Ultimately, they help learners develop a practical understanding of how climate control systems and motoring safety practices contribute to vehicle comfort, visibility, and accident prevention. This prepares leaners for more advanced technical training and safe, professional behaviour in automotive service or road-use environments.

ASSESSMENT SUMMARY

To assess learners' understanding of the Automotive HVAC System and Safe Motoring, including key components, system functions, and road safety principles, a range of assessment levels can be applied. These assessments should not only measure basic knowledge but also evaluate learners' ability to apply concepts in realistic automotive and driving scenarios. By incorporating Depth of Knowledge (DoK) Level 4, leaners are expected to move beyond simple recall and explanation. They should be able to analyse HVAC system operation, evaluate the flow and effects of refrigerants, interpret AC performance under different conditions, and troubleshoot climate control issues using basic diagnostic methods. In relation to safe motoring, learners should apply defensive driving strategies, assess the causes of road hazards, interpret road signs, and evaluate vehicle readiness for safe operation. Assessment tasks may include practical exercises such as identifying and explaining the function of HVAC components, simulating safe driving decisions in various scenarios, or analysing a case study involving a vehicle breakdown or AC system fault. This approach ensures learners demonstrate a deep and applied understanding of both technical and safety-related systems. Teachers can use these assessments to measure both theoretical understanding and real-world application, helping leaners develop essential critical thinking and decision-making skills for the automotive field.

Indicators	DOK Level	*Assessment Strategy and/or Mode*
Describe the basic operation of the automotive HVAC system and safe motoring.	4 (Extended Strategic reasoning)	*Practice Paper 2* *Discussion and homework*

.

WEEK 18

Learning Indicator: *Describe the basic operation of the automotive HVAC system and safe motoring*

FOCAL AREA 1: AUTOMOTIVE HVAC SYSTEM

The HVAC system in a vehicle stands for Heating, Ventilation, and Air Conditioning. It helps to control the temperature, airflow, and air quality inside the passenger cabin for comfort and safety. The main functions of the automotive HVAC system are

1. Warms the interior using heat from the engine's coolant.
2. Moves fresh or recirculated air into the cabin.
3. Cools and dries the air using a refrigeration system.

Automotive AC System Parts

Automotive air conditioning systems have a few key components. Figure 4.28 shows the main parts and their roles:

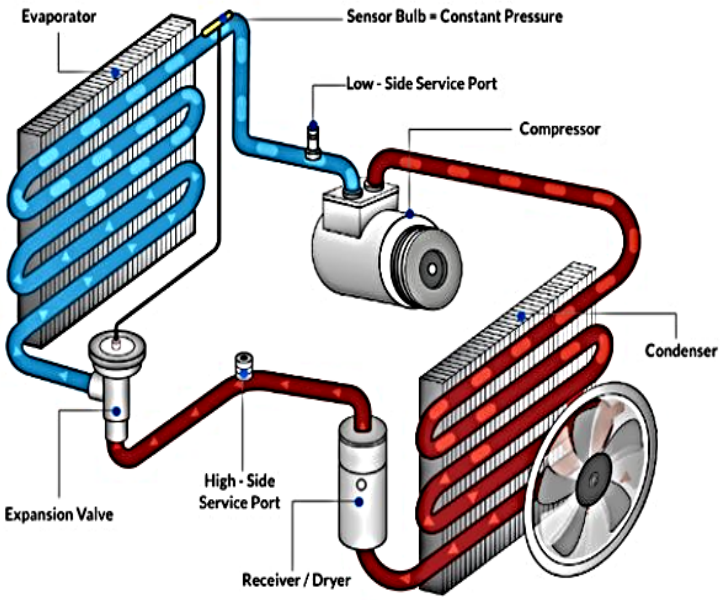


Figure 4.28: *Automotive AC System Parts*

Compressor

1. Power unit of the system that separates the low-pressure side from the high-pressure side.
2. Takes in low-pressure gas and compresses it into high-temperature/high-pressure gas.
3. Mounted to the front of the engine and driven by the serpentine belt.

Condenser

1. Reduces the temperature of refrigerant while it maintains high pressure.
2. Refrigerant changes from a gaseous state to a liquid state as it cools.

3. Like the engine radiator, it uses forced air (fan or vehicle movement) to transfer heat.
4. Mounted in front of the vehicle, behind the grill.

Dryer

1. Removes water from the refrigerant using a desiccant (drying agent).
2. Has some system-filtering properties.
3. Mounted on the high-pressure side of the system, between the condenser and metering device.

Metering device

1. Either expansion valve or fixed orifice tube.
2. Lowers refrigerant pressure, which quickly drops the refrigerant temperature.
3. Refrigerant is still in liquid form after leaving the metering device.
4. Mounted on the high-pressure side of the system, between the dryer and firewall.

Evaporator

1. Refrigerant changes back to a gaseous state in the evaporator, causing a cooling effect.
2. Cabin air is cooled and dried as it blows across the evaporator.
3. Only component mounted inside the passenger compartment, behind the dashboard.

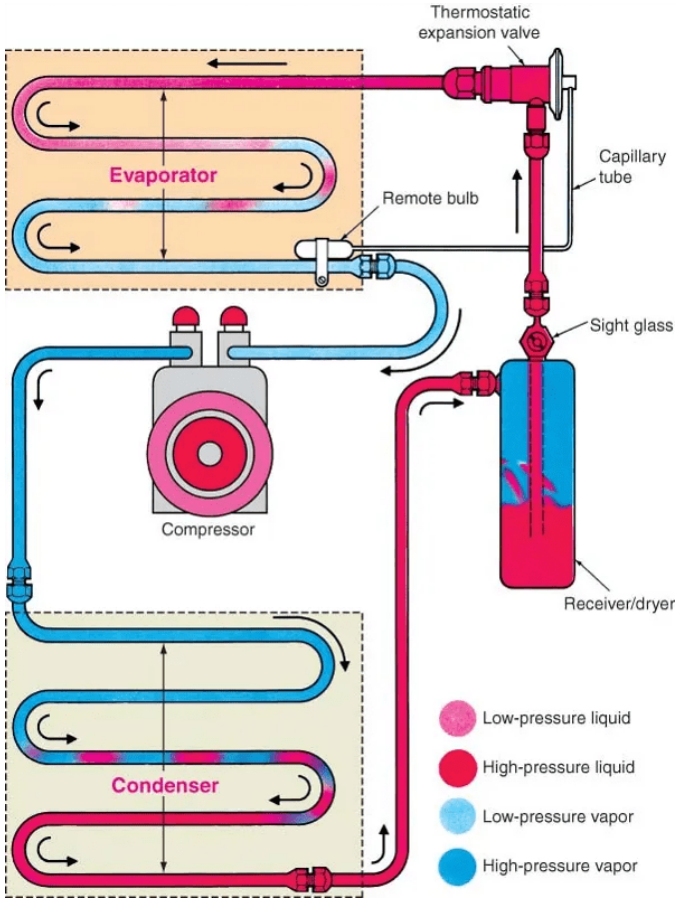


Figure 4.29: *AC working diagram*

Refrigerant Used in Automotive Air Conditioning

AC refrigerant is a gaseous substance used in air conditioning systems to absorb and release heat, enabling the air conditioner to produce and push cooled air into the vehicle cabin. It circulates through the entire system, changing from a liquid to a gas and back again as it repeats the process.

Types of Car AC Refrigerant

1. **R-12**: Used in older vehicles; no longer allowed due to ozone damage.
2. **R-134a**: Common in vehicles made from the 1990s to early 2010s.
3. **R-1234yf**: Used in most modern cars; more environmentally friendly.

Path and characteristics of refrigerant

1. Low-temperature/low-pressure refrigerant enters the compressor (gas).
2. High-temperature/high-pressure refrigerant leaves the compressor (gas).
3. Refrigerant cools and converts to liquid in the condenser.
4. Still under high pressure.
5. The receiver/dryer removes water from the refrigerant.
6. Expansion valve reduces refrigerant pressure.
7. Refrigerant converts back to a gaseous state in the evaporator.
8. Absorbs heat; when air blows across the evaporator, it is cool and dry.

FOCAL AREA 2: SAFE MOTORING

Safe motoring also known as safe driving means driving a vehicle in a way that protects the driver, passengers, other road users, and the vehicle itself. It involves the following road rules, maintaining the vehicle properly, and being alert and responsible on the road**.** Safe motoring is not just about following rules; it's about having a mindset that prioritises the safety of everyone on the road. By understanding and practicing these principles, drivers can significantly reduce the risk of accidents and contribute to a safer driving environment for all.

Key Elements of Safe Motoring

1. **Vehicle Condition**
   - Check brakes, tyres, lights, steering, and fluid levels regularly.
   - Ensure windscreen wipers and mirrors are clean and working.
2. **Driver Behaviour**
   - Always wear a seatbelt.
   - Avoid distractions (like mobile phones).
   - Do not drive under the influence of alcohol or drugs.
   - Obey speed limits and traffic signals.

3. **Awareness and Observation**
   - Use mirrors regularly and check blind spots.
   - Keep a safe distance from the vehicle in front.
   - Be aware of pedestrians, cyclists, and motorcyclists.
4. **Weather and Road Conditions**
   - Adjust speed and following distance in rain, fog, or poor visibility.
   - Use headlights correctly in low light or bad weather.
5. **Emergency Preparedness**
   - Know how to respond in a breakdown or accident.
   - Keep a basic first aid kit, warning triangle, and torch in the vehicle.
6. **Adopting a defensive driving attitude:** Anticipating potential hazards and reacting accordingly, even if other drivers are not behaving safely, is essential.

Defensive driving

Defensive driving is a set of driving practices that help you lower the risk of accidents and enhance road safety. It involves being aware of what's happening around you, spotting potential hazards early, and making informed decisions to protect yourself and others on the road.

Learning Tasks

1. State the purpose of Automotive HVAC system
2. Describe the main components of the automotive AC system.
3. Explain the working principle of automotive AC system.
4. Explain safe motoring and the key elements involved.

Pedagogical Exemplars

Problem-Based and Group work/collaborative Learning

Group learners to discuss automotive HVAC systems and safe motoring and present group report on the problem.

Guide learners to discuss the main components of air condition system.

In a fair mixed ability group assist learners to conduct various investigations/research to gather pieces of information regarding safe motoring

Assist learners to discuss and identify each of the safety devices on the vehicle for the driver and other road users,

Assist learners to discuss highway codes and causes of road accidents and present individual report

Table 4.4: Some of the common road signs in use

	SIGN	MEANING	ORIGIN		SIGN	MEANING	ORIGIN
1		Right-curve ahead	Norway	17		Unguarded level crossing ahead	Ireland
2		Road works ahead	Romania	18		Accident hot spot	Bulgaria
3		Caution, children	Slovakia	19		End of road pavement	Belarus
4		Motorway ahead	Sweden	20		Fog	Czech Republic
5		National speed limit applies	UK	21		Road block	Hungary
6		Pedestrian crossing	France	22		Built-up-area	Denmark
7		Cross-over	UK	23		Dangerous Curves	Kosovo
8		Level crossing	Germany	24		Stop-Wrong way	Norway
9		Priority to oncoming vehicles	Poland	25		Wrong-way driver	Austria
10		Go straight or right	Greece	26		U-Turn mandatory	Austria
11		Elderly people	UK	27		Reduced visibility because of snow etc.	Nether-lands
12		No right turn	France	28		Accident hot spot	Czech Republic
13		Two-way traffic ahead	UK	29		No entry	Ireland
14		Lane grooves	Poland	30		Maximum curve speed	Denmark
15		Advisory speed	Germany	31		Priority road	France

Key Assessment: Practice Paper 2

1. How does the air conditioning section of a car's HVAC system keep the inside cool?

(6 marks)

2. What could happen if a driver uses the heater but the ventilation system is not working properly? (4 marks)

3. Explain how a working automobile HVAC system contributes to safe motoring in cold or rainy weather. (10 marks)

Hint

*Conduct **Practice Paper 2**. It should cover the contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section. Learners' papers should be marked immediately and scores entered into the SAP.*

Practice Paper 2

TABLE OF SPECIFICATION

PAPER 1 (Multiple Choice Questions)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive technology	Explain engine cooling system and describe the construction and operation of the air-cooling systems		**1**			1
	Describe the construction and operation of the thermosyphon and pump assisted water-cooling systems	1				1
	Describe types of lubrication systems, oil pumps and filters.		1	**1**		2
	Explain the properties and classification of engine lubricating oils and crankcase ventilation.		1	**1**		2
	Describe the main components of fuel supply for compression ignition (C1) engines.			1		1
	Describe the main components of the steering system and explain steering geometry and the angles involve.		**1**			1
	Explain front axle and stub axle, types and their functions		1			1
	Describe vehicle wheels and tyres	**1**				1
	Explain leaf, coil and air suspension systems.	1	1			2
	Describe the principle of supercharger and turbocharger.	1				1
	Describe batteries, ignition and starting motor systems of the vehicle.			1		1
	Examine and describe the operation of the electric vehicle (EV).	1		1		2

Metal Technology	Describe computing coding language used in Computer Numerical Control (CNC) machines.		1			1
	Demonstrate the use of the milling machine and cutting fluids.	1				1
	Explain the various machining processes and relate them to manufacturing industry.		1	1		2
	Explain basic metal forming processes with engineering products.		1	1		2
	Perform basic cutting and bending operations in sheet metal fabrication.		1	1		2
	Perform drawing, die and presses operation in sheet metal fabrication	1				1
	Generate and outline the sequence of operations involved in the making of artefacts.			1		1
	Explain and use the various tools and equipment for soft and hard soldering.	1	1			2
	Describe and perform operations using 3D printers.	1		1		2
	Describe and perform operations using lasers.		1			1
	Explain special welding techniques used in oil and gas industry.	1				1
Building construction technology	Discuss methods of excavating foundation trenches	1				
	Explain what setting out is	1				
Woodwork technology	Classify the two main types of wood species.		1			
	Outline the processing phases of timber in the woodwork industry		1			
Electrical technology	Discuss safety in the use of electricity			**2**		**2**
Electronics technology	Describe the principles and operation of the various Diodes		**2**			
		12	**16**	**12**		**40**
		30%	**40%**	**30%**		**100%**

Paper 2 (Essay)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive Technology	Describe types of lubrication systems, oil pumps and oil filters.					
	Describe batteries, ignition and starting motor systems of the vehicle.	**3**				**3**
	Explain front axle and stub axle, types and their functions.					
Metal Technology	Describe various heat treatment processes with engineering examples and explain equilibrium diagrams.	**3**				**3**
	Demonstrate the use of the milling machine and cutting fluids.					
	Explain basic metal forming processes with engineering products.					
Total		**6**				**6**
						100%

Paper 3 (Practical test)

STRAND	LEARNING INDICATORS	LEVEL OF ASSESSMENT				TOTAL
		1	2	3	4	
Automotive Technology (Alternative to practical)	Describe types of lubrication systems, oil pumps and oil filters.	**3**				**3**
Metal Technology	Explain and perform the stages in design for manufacture	**3**				**3**
Total						**100%**

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.

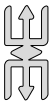
b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).

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

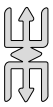
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

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 la-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.

UNIT 18 REVIEW

The lesson on Automotive Electronics and Engine Management Systems was well-structured and effectively delivered, covering key concepts essential for learners' understanding of modern vehicle operation. The session began with a clear explanation of the functions of the Engine Management System (EMS), focusing on its role in fuel efficiency, emissions control, and engine performance. The main components—including the Electronic Control Unit (ECU), sensors, and actuators were introduced through visual aids and real-world examples, making the content accessible and engaging. The distinction between closed-loop and open-loop systems was explained using simple diagrams and class discussions, helping leaners understand how feedback mechanisms influence engine control. The introduction to On-Board Diagnostics (OBD), including types of OBD and the use of an OBD scanner, was particularly effective. Learners were shown how diagnostic codes are retrieved and interpreted, reinforcing the importance of fault detection and system monitoring. Overall, the lesson successfully combined theory with practical insight, using interactive teaching strategies to meet different learning needs. Leaners were actively engaged and demonstrated improved understanding through questioning and practical tasks.

MARKING SCHEMES/RUBRICS FOR THE KEY ASSESSMENTS

UNIT 14

Question 1

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive explanation of key sensors (MAF/MAP, oxygen, coolant temperature, throttle position, knock, crankshaft position) with specific parameters measured and signal characteristics.	Clear explanation of major sensors with good understanding of their function and parameters measured.	Basic identification of some sensors but limited explanation of their specific parameters or signals.	Poor or incorrect identification of sensors showing limited understanding of input systems.

Question 2

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive identification of performance symptoms (rough idle, hesitation, surging, power loss, stalling) with detailed explanation of their relationship to oxygen sensor failure modes.	Clear identification of major performance symptoms with good understanding of their connection to oxygen sensor failure.	Basic identification of some symptoms but limited explanation of how they relate to oxygen sensor failure.	Poor or incorrect identification of symptoms showing limited understanding of oxygen sensor's role.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive analysis of fuel economy impact with specific percentage ranges for different failure modes, driving conditions, and vehicle types with technical explanation.	Clear explanation of fuel economy impact with reasonable estimates of consumption increases and good technical understanding.	Basic understanding that fuel economy worsens but limited specific estimates or technical explanation.	Minimal or incorrect explanation of fuel economy impact showing poor understanding of consumption factors.

Question 3

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive analysis of how these three components form an integrated monitoring and power system with detailed explanation of electrical flow, dependencies, and feedback loops.	Clear explanation of the relationship between components with good understanding of how they interact as a system.	Basic understanding of component relationships demonstrated but lacks detail on system integration.	Poor understanding of how components relate to each other with significant misconceptions about system integration

b.

Excellent (9-10 marks)	Very Good (7-8 marks)	Satisfactory (5-6 marks)	Needs Improvement (1-4 marks)
Comprehensive preparation steps including vehicle identification, ensuring proper operating conditions (engine temperature, battery voltage), selecting appropriate scan tool and adapters, and safety precautions.	Clear preparation steps covering major requirements including proper connection and basic operating conditions.	Basic preparation steps but missing some important preliminary checks or conditions.	Minimal or incorrect preparation steps showing poor understanding of diagnostic prerequisites.

Question 4

a.

Excellent (9-10 marks)	Very Good (7-8 marks)	Satisfactory (5-6 marks)	Needs Improvement (1-4 marks)
Comprehensive analysis of time savings with specific examples of diagnostic scenarios, comparative time estimates, and explanation of how electronic diagnosis eliminates trial-and-error approaches.	Clear explanation of time advantages with good examples of how scan tools accelerate the diagnostic process.	Basic understanding that scan tools are faster but limited specific examples or time-saving mechanisms.	Minimal or incorrect explanation of speed advantages showing poor understanding of diagnostic efficiency.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 mark)
Comprehensive comparison of standardisation aspects including connector design, communication protocols, code formats, and manufacturer-specific variations with technical details.	Clear comparison of standardisation differences with good understanding of connector and protocol standardisation in OBD II.	Basic understanding that OBD II is more standardised but limited specific examples or technical details.	Minimal or incorrect explanation of standardisation differences showing poor understanding of diagnostic evolution.

c.

Excellent (3 marks)	Very Good (2 marks)	Satisfactory (1 mark)	Needs Improvement (½ mark)
Excellent explanation of how OBD II accommodates modern vehicle complexity including network communications, multiple electronic modules, drive-by-wire systems, and advanced emission controls.	Good explanation of compatibility with modern systems with understanding of network and multiple module advantages.	Basic understanding that OBD II works better with newer systems but limited specific examples or technical details.	Poor or incorrect explanation of modern system compatibility showing limited understanding of contemporary vehicle electronics

UNIT 15

Question 1

a.

Excellent (5 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive analysis of design factors including disassembly requirements, load types, material compatibility, thermal effects and vibration resistance with specific design scenarios.	Clear explanation of major design considerations with good understanding of when bolted connections are preferable to welding.	Basic understanding of some design factors but limited depth in explaining specific design scenarios or requirements.	Poor or incorrect explanation of design factors showing limited understanding of joining method selection

b.

Excellent (5 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive explanation of weight reduction and low-profile advantages including specific weight comparisons, aerodynamic benefits, space savings, and design implications with quantitative examples.	Clear explanation of weight and profile advantages with good understanding of their importance in specific applications.	Basic mention of weight or profile benefits but limited specific examples or quantitative analysis.	Poor or incorrect explanation of weight/profile advantages showing limited understanding of design optimisation

Question 2

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive description of surface preparation including cleaning methods (degreasing, solvent cleaning), mechanical preparation (sanding, wire brushing, blasting), chemical treatments (phosphating, acid etching), and quality verification with specific standards.	Clear description of surface preparation with good understanding of cleaning, mechanical preparation, and basic treatments.	Basic description of cleaning and preparation but limited detail on specific methods or quality standards.	Poor or incorrect description of surface preparation showing limited understanding of its critical importance.

b.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive description of appropriate PPE including respiratory protection (specific mask types), eye protection, skin protection (gloves, coveralls), and hearing protection with specific standards and selection criteria.	Clear description of major PPE requirements with good understanding of appropriate protection for different finishing processes.	Basic identification of some PPE items but limited explanation of specific types or standards.	Minimal or incorrect PPE identification showing poor understanding of personal protection requirements.

UNIT 16

Question 1

Excellent (10-12 marks)	Very Good (7-9 marks)	Satisfactory (4-6 marks)	Needs Improvement (1-3 marks)
Comprehensive inclusion of all key components in correct sequence: battery pack, battery management system (BMS), main contactors/switches, DC-DC converter, inverter, motor controller, electric motor, transmission/gearing (if applicable), differential, wheels, with regenerative braking pathway clearly shown.	Good inclusion of most key components in logical sequence with main power flow and regenerative braking pathway shown.	Basic inclusion of essential components (battery, controller, motor, wheels) but missing some important intermediate components or connections.	Minimal or incorrect component inclusion showing poor understanding of EV power systems

Question 2

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Comprehensive explanation of the inverter's primary function in converting DC power from batteries to AC power required by the motor, with excellent explanation of why this conversion is necessary.	Clear explanation of the inverter's DC to AC conversion function with good understanding of why electric motors typically require AC power.	Basic understanding that the inverter converts power but limited explanation of why this conversion is necessary.	Poor or incorrect explanation of inverter function showing fundamental misconceptions about power conversion.

Question 3

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs Improvement (2 marks)
Comprehensive selection of innovative and relevant systems/features targeting both efficiency and reliability, with excellent balance between cutting-edge and proven technologies.	Good selection of appropriate systems/features addressing both efficiency and reliability with reasonable technological balance.	Basic selection of some relevant systems but limited innovation or imbalance between efficiency and reliability features.	Poor or inappropriate system selection showing limited understanding of EV design priorities

Question 4

a.

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive comparison of powertrain configurations with excellent explanation of full electric (battery-only) versus hybrid (combined ICE and electric) architectures, including different hybrid types (series, parallel, plug-in).	Clear comparison of basic powertrain differences with good understanding of the fundamental architectural differences between full electric and hybrid vehicles.	Basic understanding that hybrids combine electric and combustion engines but limited explanation of specific configurations or types.	Poor or incorrect explanation of powertrain differences showing fundamental misconceptions about vehicle architectures.

b.

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 marks)
Excellent identification of three significant, relevant advantages with precise explanation of each, showing exceptional understanding of EV benefits across multiple dimensions (environmental, economic, performance).	Good identification of three relevant advantages with clear explanation showing understanding of key EV benefits.	Basic identification of three advantages but explanations lack depth or specificity, or advantages are somewhat superficial.	Identification of fewer than three advantages, or advantages listed are incorrect or insignificant.

UNIT 17

Question 1

Excellent (5 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive explanation of how special welding techniques address specific material challenges in automotive manufacturing (thin high-strength steel, aluminium alloys, advanced materials) with excellent technical detail on material properties and weldability issues.	Clear explanation of material-specific challenges with good understanding of how special techniques accommodate different automotive materials.	Basic mention of material differences but limited explanation of specific material properties or weldability challenges.	Poor or incorrect explanation of material considerations showing limited understanding of automotive materials.

Question 2

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 marks)
Comprehensive analysis of aluminium-specific welding challenges including high thermal conductivity, low melting point, oxide layer issues, high coefficient of thermal expansion, and alloy sensitivity with excellent technical explanation.	Clear explanation of major aluminium welding challenges with good understanding of thermal properties and oxide issues.	Basic identification of some aluminium challenges but limited technical explanation of why this affects welding quality.	Poor or incorrect identification of aluminium challenges showing limited understanding of material properties.

Question 3

Excellent (7-8 marks)	Very Good (5-6 marks)	Satisfactory (3-4 marks)	Needs Improvement (2 marks)
Comprehensive identification of two significant, relevant problems (oxidation/contamination, electrode degradation, arc instability, porosity formation, etc.) with precise technical description of each problem's nature and manifestation.	Clear identification of two relevant problems with good technical description of their nature and appearance.	Basic identification of two problems but descriptions lack technical depth or precision.	Identification of fewer than two problems, or problems identified are incorrect or insignificant.

UNIT 18

Question 1

Excellent (5-6 marks)	Very Good (4 marks)	Satisfactory (2-3 marks)	Needs Improvement (1 mark)
Comprehensive explanation of the complete refrigeration cycle including compression, condensation, expansion, and evaporation phases with precise technical detail on pressure and state changes of the refrigerant.	Clear explanation of the main refrigeration cycle phases with good understanding of refrigerant state changes.	Basic explanation of some cycle phases but limited understanding of the complete cycle or state changes.	Poor or incorrect explanation of the refrigeration cycle showing fundamental misconceptions about cooling principles.

Question 2

Excellent (4 marks)	Very Good (3 marks)	Satisfactory (2 marks)	Needs Improvement (1 mark)
Comprehensive identification of safety hazards including carbon monoxide accumulation, reduced oxygen levels, potential for exhaust gas intrusion, and driver impairment with excellent explanation of physiological effects and risks.	Clear identification of major safety hazards with good understanding of gas accumulation risks and potential health effects.	Basic identification of some safety concerns but limited explanation of specific hazards or their severity.	Poor or incorrect identification of safety hazards showing limited understanding of ventilation importance.

Question 3

Excellent (9-10 marks)	Very Good (7-8 marks)	Satisfactory (5-6 marks)	Needs Improvement (1-4 marks)
Comprehensive explanation of visibility enhancement including windshield defrosting/defogging mechanisms, side/rear window clearing, mirror defrosting, headlight condensation prevention and specific technical details of how the HVAC system accomplishes each function.	Clear explanation of major visibility functions with good understanding of defrosting/defogging processes and their importance for safe driving.	Basic explanation of some visibility aspects but limited technical detail on specific HVAC functions or their safety importance.	Poor or incorrect explanation of visibility enhancement showing limited understanding of critical safety functions.

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