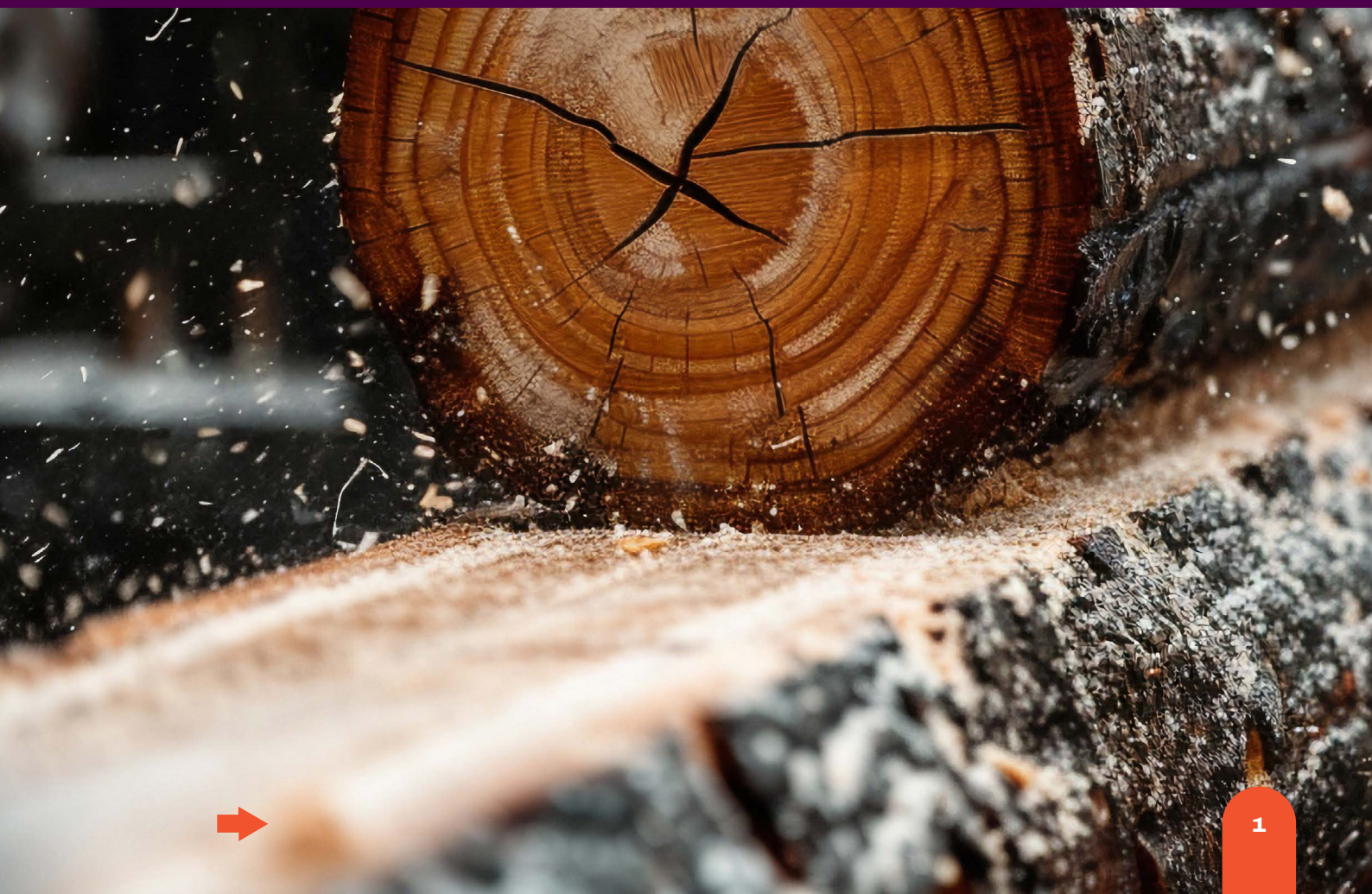
SECTION

2

TIMBER, METALS, PETROL AND DIESEL ENGINES, BUILDING CONSTRUCTION STAKEHOLDERS AND ELECTRICAL POWER GENERATION



UNIT 1

WOODWORK TECHNOLOGY

Material and Artefacts Production Woodwork Industry in Ghana

INTRODUCTION

Timber plays a vital role in woodwork technology, with two primary varieties to consider. First, let's explore hardwood. These trees grow slowly, resulting in dense, durable wood that is perfect for creating robust structures and fine furnishings.

On the other hand, we have softwood. These trees grow quickly, making them ideal for building frames and structures in woodworking projects, as well as for everyday items like cardboard and paper. Understanding the difference between hardwood and softwood is crucial in woodworking technology. It's akin to selecting the right tool for the task at hand; having this knowledge enables you to approach each project with confidence.

At the end of this unit, you should be able to:

Classify the two main types of timber

Key Ideas

- The solid wood that comes from fully developed tree trunks is called timber. It is essential for producing goods like buildings and furnishings.
- The two primary kinds are softwood and hardwood. Softwood is derived from coniferous trees with needles, while hardwood is derived from deciduous leafy trees.
- We can select the best wood for our projects by being aware of these sorts.

Key words: Timber, Hardwood, Softwood, Deciduous, Coniferous, Trees, Properties

TIMBER

Timber is a vital natural resource used across various industries, especially in construction and woodworking. It comes from trees and is processed into materials like planks and boards for use in building, furniture making, and many other applications. Timber can be classified into hardwood and softwood, each offering unique qualities. **Hardwoods**, being denser and more durable, are ideal for high-quality furniture and long-lasting structures.

Softwoods, on the other hand, grow faster and are widely used for general construction, paper production, and everyday wood items. Understanding timber and its varieties is essential for making informed decisions in woodwork and construction.

The Living Tree

The live tree that yields the timber is the first place to analyse a timber type. As illustrated in Fig. 2.1.1, a living tree consists of three main sections: *the roots, the trunk (*stem or bole), and *the crown*, which is made up of the branches and leaves.

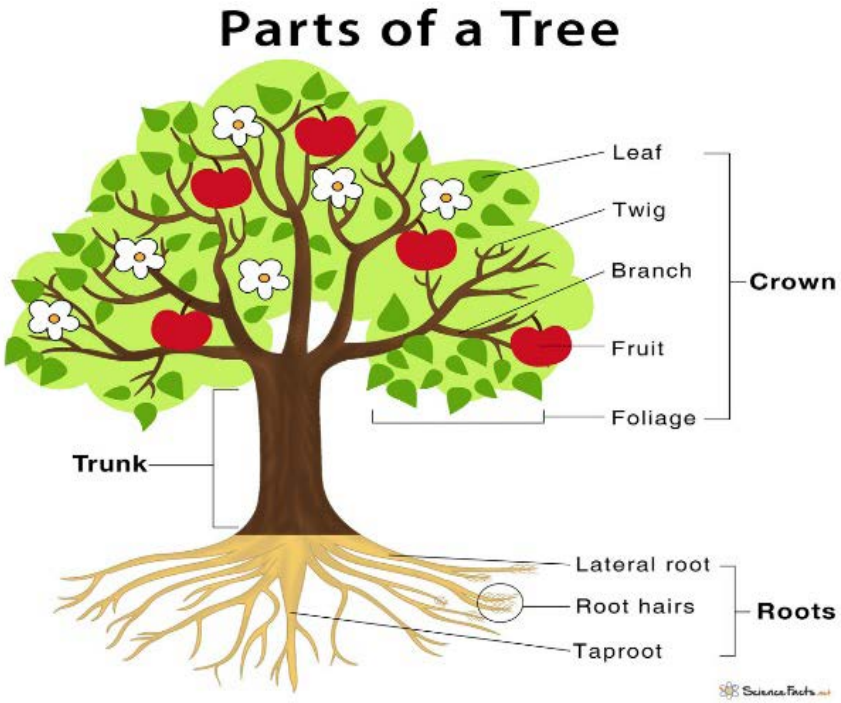


Fig. 2.1.1: Parts of a tree

Fig. 2.1.2 below shows the structurally labelled parts of the tree.

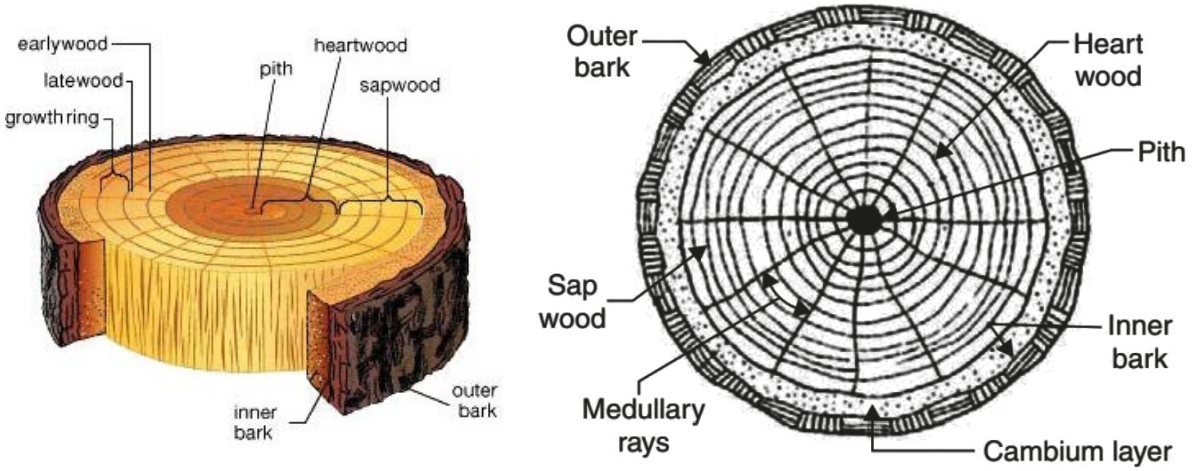


Fig. 21.2: Structurally labelled parts of a tree [sourced from the teacher's manual]

Activity 2.1.1

Working with your partner, describe each of the following parts of a tree using the table provided.

Table 2.1.1: Parts of a tree and their descriptions

Part	Description
Bark	
Phloem (layer beneath bark)	
Vascular (Cambium) layer	
Sapwood	
Heartwood	
Pith	
Medullary rays	

Classification of Timber

The basic material derived from trees, known as timber, is essential to many industries, including furniture manufacturing and construction. Timber is primarily classified into two main categories: hardwood and softwood, each with distinct qualities.

1. Hardwood

Source: Hardwood timber comes from deciduous trees, also known as angiosperms in botanical terms. These trees are characterised by their broad trunks, an abundance of flowers, and fruit-containing seeds (also called dicotyledonous seeds). Deciduous trees have broad leaves that usually shed seasonally. There are approximately 30,000 species within this category.

Examples: Hardwood species include trees such as Odum, sapele, teak, mahogany, and Wawa.

Characteristics: Hardwood timber is typically denser and heavier than softwood. It is known for its excellent strength, durability, and resistance to wear and tear.

Application: Due to its durability, hardwood is often used in the production of high-quality furniture, flooring, cabinetry, and architectural components.

The following descriptions cover some useful and popular hard- and softwood trees.

Types of Hardwood and Their Applications

1. Odum

- **Characteristics**: Odum has a reddish-brown colour and a straight grain.
- **Workability**: It is relatively easy to work with both power and hand tools.
- **Average Dried Weight**: Approximately 800 kg/m³.
- **Common Uses**: Odum is commonly used in boat building, flooring, construction, and general building work.
- **Finishing**: It finishes well and polishes to a smooth surface.

2. Sapele

- **Characteristics**: This reddish-brown wood features a ribbon-like pattern and straight grain.
- **Workability**: Though the grain may be interlocked, it is generally easy to work with both hand and power tools.
- **Average Dried Weight**: Around 640 kg/m².
- **Common Uses**: Sapele is used for decorative veneers, cabinets, and furniture.
- **Finishing**: It takes a good finish and looks attractive when polished or stained.

3. Teak

- **Characteristics**: Teak has a golden-brown colour and a high natural oil content.
- **Workability**: Due to its high silica content, it can dull tools but is generally workable with hand and power tools.
- **Average Dried Weight**: About 660 kg/m².
- **Common Uses**: Teak is often used for decking, boats, outdoor furniture, and interior trim.
- **Finishing**: It acquires a natural patina over time and polishes beautifully.

4. Mahogany

- **Characteristics**: Mahogany has a reddish-brown hue with a fine grain.
- **Workability**: Although some species may have interlocking grain, it is easy to work with hand and power tools.
- **Average Dried Weight**: Approximately 560 kg/m².
- **Common Uses**: Mahogany is commonly used for interior trim, cabinets, and furniture.
- **Finishing**: It finishes well and can be polished or stained to a smooth surface.

5. Wawa

- **Characteristics**: Wawa has a straight grain and a creamy white to pale yellow colour.
- **Workability**: It is relatively easy to work with both power and hand tools.
- **Average Dried Weight**: Around 390 kg/m².

- **Common Uses**: Wawa is used in woodworking, furniture making, and decorative veneers.
- **Finishing**: It finishes nicely and can be painted or stained to achieve different looks.

Note: It is important to remember that not all softwoods are evergreen (such as ebony), and not all hardwoods are deciduous (like Wawa).

2. Softwood

Source: Softwood comes from coniferous trees, also known as gymnosperms in botanical terms. These trees, such as pine and spruce, remain evergreen throughout the year and take approximately 25 to 30 years to mature, about half the time of hardwood. Conifers and pines are neither monocotyledonous nor dicotyledonous plants. This category includes around 650 species.

Examples: Softwoods include species such as Scots pine, Western red cedar, and Paraná pine.

Characteristics: Contrary to the name, softwoods are not always softer than hardwoods. For instance, balsa wood, which is a hardwood, is softer than most softwoods, whereas longleaf pine, Douglas fir, and yew softwoods are harder than many hardwoods.

Application: Softwood is widely used in the construction industry and for producing paper pulp and card products.

Understanding the characteristics of each wood type allows woodworkers to choose the most suitable material for their projects.

1. **Colour**: This refers to the natural tone or hue of the wood, such as the pale yellow of pine or the deep brown of mahogany.
2. **Grain**: This is the pattern created by the arrangement of wood fibres, such as the swirling grain of burl wood or the straight grain of oak.
3. **Texture**: This refers to the feel or appearance of the wood's surface, for example, the roughness of cedar or the smoothness of maple.
4. **Figure**: The figure in wood refers to a distinctive pattern or feature, such as the tiger-stripe pattern in maple or the wavy figure in walnut.

Types of Softwood and Their Applications

1. Ofram

- **Characteristics**: Ofram is pale yellow to pinkish-brown in colour with a straight grain.
- **Workability**: It is relatively easy to work with both power and hand tools.
- **Average Dried Weight**: Approximately 600 kg/m².
- **Common Uses**: Ofram is commonly used for interior finishing, plywood production, and construction.
- **Finishing**: It finishes well and can be painted or stained to achieve different looks.

2. Cedar

- **Characteristics**: Cedar has a pleasant fragrance and a distinctive reddish-brown hue.
- **Workability**: It offers good dimensional stability and is easy to work with.
- **Average Dried Weight**: 370 kg/m².
- **Common Uses**: Cedar is often used in closets, chests, and outdoor projects such as decking, siding, and fencing, due to its aromatic qualities.
- **Finishing**: Over time, cedar develops a natural patina and polishes well.

3. Cypress

- **Characteristics**: Cypress has a straight grain and ranges in colour from pale white to yellowish.
- **Workability**: It is relatively easy to work with both power and hand tools.
- **Average Dried Weight**: 510 kg/m².
- **Common Uses**: Cypress is used for roof trusses, sheathing, and framing in construction.
- **Finishing**: Cypress can be painted or stained to enhance its appearance and takes finishes well.

4. Akom (Obeche or Samba)

- **Characteristics**: Akom has a homogenous texture and a pale, creamy colour.
- **Workability**: It is easy to work with both power and hand tools.
- **Average Dried Weight**: 320 kg/m².
- **Common Uses**: Akom is used in joinery, decorative millwork, and plywood manufacturing.
- **Finishing**: It finishes nicely and can be painted or stained to create various styles.

5. Lignum Vitae

- **Characteristics**: Lignum Vitae is a robust, dense wood with a deep greenish-brown hue.
- **Workability**: Due to its hardness, it is difficult to work with.
- **Average Dried Weight**: 1,300 kg/m³.
- **Common Uses**: Lignum Vitae is used for bearings, tool handles, and other parts requiring extreme strength and resistance to wear.
- **Finishing**: It develops a natural lustre over time and has a good finish.

6. Pine

- **Characteristics**: Pine ranges in colour from pale yellow to reddish-brown and has a straight grain.
- **Workability**: It is soft and easy to work with using both power and hand tools.
- **Average Dried Weight**: 450 kg/m².
- **Common Uses**: Pine is used for interior trim, furniture making, and construction.

- **Finishing**: Pine finishes well and can be painted or stained to create various looks.

7. Spruce

- **Characteristics**: Spruce has a straight grain and ranges from pale white to yellowish in colour.
- **Workability**: It is strong yet lightweight, making it easy to work with both power and hand tools.
- **Average Dried Weight**: 420 kg/m².
- **Common Uses**: Spruce is used for roof trusses, sheathing, and framing in construction.
- **Finishing**: Spruce can be painted or stained to improve its appearance and takes finishes well.

8. Ebony

- **Characteristics**: Ebony has a dense, fine texture and a rich black colour.
- **Workability**: It is challenging to work with using both power and hand tools.
- **Average Dried Weight**: 1,100 kg/m³.
- **Common Uses**: Ebony is used in decorative furniture, musical instruments, and carvings.
- **Finishing**: When polished, it takes on a natural sheen and finishes well.

Importance of Understanding Hardwood and Softwood:

1. **Selection**: Knowing the characteristics of each wood type helps make informed decisions when choosing wood for specific purposes.
2. **Usage**: Different projects require different types of timber, considering factors such as strength, durability, and aesthetic appeal.
3. **Quality**: Understanding various wood types contributes to the durability and quality of the final products.

Activity 2.1.2

1. You are part of a group of high school students participating in an exciting woodworking workshop. Today, your task is to choose the perfect type of wood for a specific project. Below are six fun project options to choose from:
   a. Building a birdhouse.
   b. Crafting a picture frame or small shelf.
   c. Designing a compact bookcase.
   d. Creating a wooden bench.
   e. Hand-making a wooden key holder.

f. Constructing a unique wooden coffee table.

2. Each group will be assigned one of these projects and provided with a variety of materials, including different types of hardwood and softwood (like pine, cedar, mahogany, and teak), as well as tools such as saws, glasspaper, wood glue, finishing oil or varnish, rulers, and tape measures.

Assignment Steps:

a. **Research and Design**: Each group will research the types of wood available, focusing on the differences between hardwoods and softwoods. You will also design your project, sketching it out and determining the measurements and sizes for each part.

b. **Choosing the Wood**: Based on your research, decide which type of wood (hardwood or softwood) best suits each part of your project. Consider factors such as workability, colour, grain, texture, and hardness.

c. **Measuring and Cutting**: Once your design is finalised, measure, cut, and shape the wood according to your project plan. Be sure to follow all safety precautions while handling tools.

d. **Sanding**: Smooth the wood using glasspaper, preparing the pieces for assembly and finishing.

e. **Assembly**: Use wood glue to carefully assemble the parts of your project. Ensure the pieces fit together well.

f. **Finishing**: Apply varnish or finishing oil to preserve the wood and bring out its natural beauty.

g. **Project Display**: Once your project is complete, your group will display the finished work. During the presentation, you will answer the following questions:

   i. What factors influenced your choice of wood for the different parts of your project?

   ii. Why did you select specific tools and materials, and how did they contribute to the project?

   iii. What key aspects should be considered when selecting the ideal wood for a woodworking project?

   iv. How do the characteristics of wood types—such as colour, grain, texture, and pattern—affect your decision-making process?

   v. Why might some wood species be more suitable for certain projects, such as building a birdhouse versus making a picture frame?

   vi. What challenges did you face while working with different types of wood, and how did you overcome them?

   vii. How does the wood material you selected fit the design and functional needs of your woodworking project?

Activity 2.1.3

Using ICT tools, obtain sample species of timber to complete the task below. In your group, carry out research and create charts comparing softwoods and hardwoods.

Hardwood Chart

S/n	Sample species	Name	Botanical name	Characteristics	Uses
1					
2					
3					
4					
5					

Softwood Chart

S/n	Sample species	Name	Botanical name	Characteristics	Uses
1					
2					
3					
4					
5					

Characteristics of Timber

Based on the presence or absence of pores in the wood's structure, timber can be divided into two major categories. This classification provides valuable insights into the characteristics and properties of different types of wood.

1. **Pored Wood**: Commonly referred to as hardwood, pored wood is characterised by visible pores or vessels, fibres, parenchyma (soft tissue), and rays, as illustrated in Fig. 2.1.3. These elements give living trees their unique appearance and function by releasing sap. Long cells, known as fibres, run vertically through the tree, providing strength and structural support. Parenchyma, a soft layer, stores nutrients, while rays, which are microscopic tubes, carry sap and water laterally, maintaining the tree's health.

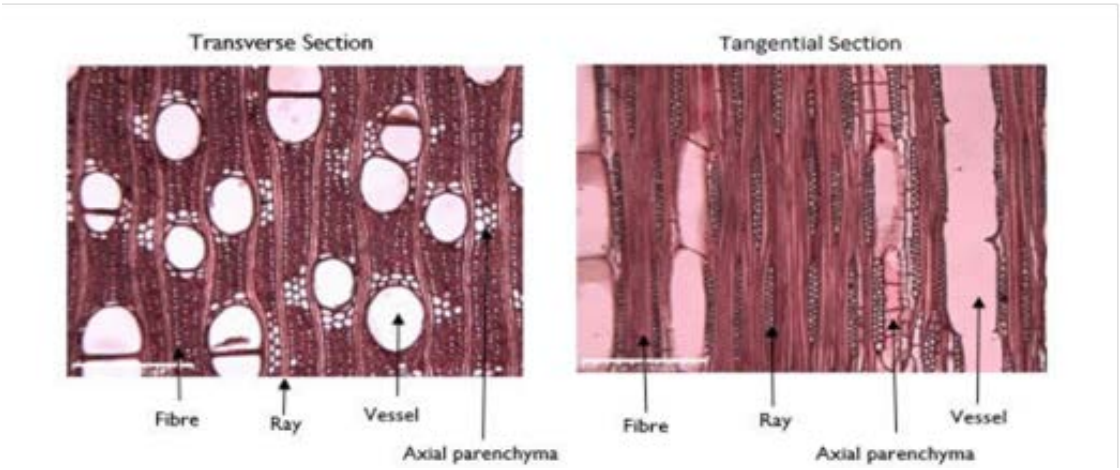


Fig. 2.1.3: Structure of ring-porous or diffuse-porous hardwood [Sourced from teacher's manual]

Examples: The following are typical instances of pored wood:

- Odum (Excellent Mary)
- Khaya spp. Mahogany
- Entandrophragma cylindricum, or Sapele,
- Mahogany from Africa (Khaya ivorensis)
- Pterocarpus spp. rosewood
- Teak (Tectona grandis)

Characteristics: Denser and more durable than non-pored wood, pored wood is highly valued for its striking textures and grain patterns. Its visual appeal makes it ideal for use in cabinetry, flooring, furniture making, and decorative applications.

Properties: Pored wood is known for its durability, strength, and resistance to abrasion. It is also less susceptible to damage from moisture and insects compared to non-pored wood.

2. **Non-Pored Wood**: Commonly referred to as softwood, this type of wood lacks visible pores or channels, as shown in Fig. 2.1.4. Instead, it contains *rays* and *tracheids*. Tracheids are long cells that transport nutrients and water vertically through the tree. Rays, which extend from the tree's core to its outer layers like tiny channels, assist in the lateral movement of nutrients and water. These rays also provide structural support and strength to the timber.

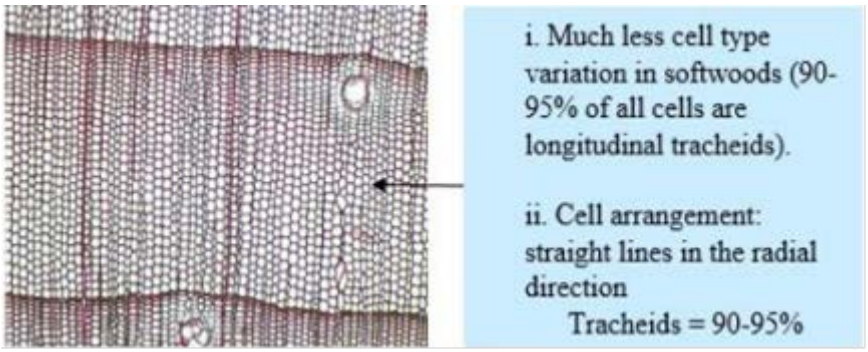


Fig. 2.1.4: Tangential section of softwood [sourced from teacher's manual]

Examples: Typical illustrations of non-pored wood are as follows:

- Terminalia ivorensis, or Ofram
- Triplochiton scleroxylon, or Akom,
- Cypress (family Cupressaceae).
- Lignum Vitae (Guaiacum spp.)

Characteristics: Generally, non-pored wood is less dense and lighter than pored wood. It often has a more uniform appearance and texture, with less pronounced grain patterns.

Properties: Non-pored wood is valued for its versatility and ease of use. It is commonly used in construction, framing, decking, and the production of cardboard and paper. Although it is less strong and more flexible than pored wood, non-pored wood is more readily available and affordable, making it suitable for a wide range of applications.

Understanding the distinction between pored and non-pored wood enhances our knowledge of the various wood species. Each type of wood serves a specific purpose, whether it's the robust texture of pored hardwood or the flexibility of non-pored softwood. By recognising these differences, we can select the right wood for our projects, ensuring the outcomes meet our expectations in both appearance and functionality.

Conclusion

In conclusion, understanding the two primary types of timber—hardwood and softwood—is essential for woodworking and construction tasks. While hardwood is ideal for durable furniture and large structures, softwood, which grows quickly, is more practical for everyday items like frames and building materials. Recognising the differences between hardwood and softwood will equip you to handle any woodworking project with confidence.

Activity 2.1.4

1. a. Using the diagrams provided in your workbook, draw and label the three main parts of a living tree. After labelling, write a brief description (3-4 sentences) of the function of each part. For example, explain how the roots anchor the tree and absorb nutrients from the soil. Use your own words to enhance understanding and retention.

   b. Consider a tree in your local area that you often see. Describe its characteristics and how each part contributes to its overall health and growth.

   Questions:

   i. How do the roots help the tree during dry seasons?

   ii. In what ways do the leaves contribute to the tree's energy production?

2. a. Write a short paragraph (5-6 sentences) explaining the terms “pored woods” and “non-pored woods.” Use examples to illustrate your points. You may refer to the information provided in class about the characteristics of each type. Additionally, create a simple table that lists at least three types of pored woods and three types of non-pored woods, including their uses.

   b. Imagine a carpenter choosing wood for a specific project. If they need a strong, decorative table, which type of wood would they select? Explain your reasoning based on the characteristics of pored and non-pored woods.

   Questions:

   i. What advantages do pored woods have over non-pored woods?

   ii. Why might someone choose non-pored wood for building a shed?

3. a. Create a visual chart that differentiates between the anatomical structures of hardwoods and softwoods. Use drawings, labels, and brief descriptions to illustrate the key features of each type. Identify at least three examples of hardwoods (like mahogany, teak, and oak) and three examples of softwoods (such as pine, cedar, and spruce). Make sure to include characteristics such as grain patterns and density.

   b. You are tasked with choosing wood for a school project that requires durability and aesthetic appeal. Based on your chart, decide which type of wood you would select and explain why.

   Questions:

   i. How does the grain pattern in hardwoods differ from that in softwoods?

   ii. What might be some challenges you face if you choose softwood for your project?

Extended Reading

1. Albert Jackson, David Day (1989), Woodworker’s Manual, HarperCollins Publishers, pages 10-34
2. Walton, John A. (1947), Woodwork in Theory and Practice, Fifth Edition (Metricated), Australasian Publishing Company, London, pages 191-203.
3. Aidoo, Frank Fabian et al. (2022), Essential Career Technology Learner’s Book for Basic 7, pages 42-43, 52. Cambridge University Press & Assessment UK and NNF Esquire Ltd, Accra, Ghana.

Review Questions for Section 2, Unit 1

1. You have been assigned to oversee a Ghanaian timber plantation. One of your tasks is to meet the demand for timber products while preserving the health of the forest ecosystem. How would you ensure the sustainable harvesting of both hardwood and softwood trees?
2. As a budding architect in Ghana, your goal is to create sustainable structures using locally harvested wood. For various structural components, how would you decide between hardwood and softwood to maximise sustainability and reduce environmental impact?
3. A community woodworking project is being organised by your school to make furniture for a nearby charity. How would you choose the type of wood (hardwood or softwood) for each piece of furniture, considering factors such as affordability, aesthetic appeal, and longevity?
4. You are involved in an initiative led by learners to support forest conservation in Ghana. How would you effectively spread the word to your classmates and the local community about the significance of protecting both hardwood and softwood tree species for their ecological and economic benefits?
5. The government of Ghana is contemplating the introduction of new regulations regarding timber exports to safeguard the nation's forest reserves. As a youthful advocate for sustainable development, how would you propose enacting laws that strike a balance between the timber industry's financial interests and the need to protect softwood and hardwood species?
6. As a member of a student innovation team, your role is to create novel and unique timber products from hardwood and softwood species found in Ghana. How would you collaborate with local craftspeople and business leaders to develop innovative products that showcase the distinctive qualities and versatility of each type of wood?

References

Owusu, F. W., Adam, K.A., Seidu, H., Mensah, P., & Govina, J. (2020). Lesser-Known Species; Utilising Ghana's Sustainable Timber Resources. BVRio, Forestry Commission, CSIR-Forestry Research Institute of Ghana: Responsible Timber Exchange.

Rundmo, T. & Hale, A. R. (2003). Managers' attitudes towards safety and accident prevention. Safety Science, 41(7), 557-574. https://doi.org/10.1016/S0925-7535(01)00091-1

Walton, J. (1970). Woodwork in Theory and Practice (metric edition). www.booktopia.com.au www.en.wikipedia.org

UNIT 2

AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

INTRODUCTION

This unit will explore how the two engine types are constructed and the different ways in which they operate to deliver power to the road wheels. Some of the technological advancements that have been made to improve the efficiency of the two engine types will also be covered. Understanding how these engine types operate can help us explain why some cars are manufactured with petrol engines while others are made with diesel engines.

This unit will focus on the four-stroke engine cycle and the two-stroke cycle.

At the end of this unit, you should be able to:

Explain the constructional and operational differences between petrol and diesel engines.

Key Ideas

- Every system requires the working together of all individual parts to achieve the purpose for which that system was made.
- As a system, the automotive engine is designed to run on petrol or diesel but not both.
- There are unique principles underlying the workings of internal combustion engines that must be strictly followed to make them work efficiently and last longer.

CONSTRUCTION AND OPERATIONAL DIFFERENCES BETWEEN PETROL AND DIESEL

Petrol engines are mostly used in cars, scooters, and machines. It is an internal combustion engine with spark ignition, also known as a petrol engine. It was invented in Europe in 1876. In petrol engines, air and fuel are mixed before compression and then an electric spark is used for ignition. Ignition temperature is the lowest temperature at which a fuel or combustible substance, when heated, catches fire. It works on the Otto cycle. The Otto cycle explains how in petrol engines, chemical energy is converted into thermal energy and then into motion.

The Four-stroke Engine Cycle

Different engines operate differently. The main difference between a petrol and a diesel engine is that in a petrol engine, a mixture of petrol and air is compressed in the combustion chamber before an electric spark is applied to burn the fuel. In the case of a diesel engine, only air is compressed in the combustion chamber, after which the diesel fuel is sprayed into the hot air for burning to take place. The two engine types, however, undergo the same stages of operation to complete a cycle, which are induction, compression, power and exhaust strokes.

Construction of a Four-Stroke Spark Ignition (Petrol) Engine

Spark ignition engines run on petrol (or gasoline) and other highly volatile fuels. Petrol is volatile, but it achieves better combustion only when it is properly vaporised, made lighter, or spread over a wider surface area. The process of mechanically breaking up the liquid fuel into tiny particles to obtain a mist or fine spray is termed *atomisation.* Petrol engines therefore require a carburettor or an injector to break up the liquid fuel into very fine droplets. Old petrol engines made use of a carburettor to meter (or measure) the air and petrol in their correct proportions and then deliver the mixture into the intake manifold or combustion chamber. Newer engines, however, make use of an injector to achieve the same purpose as a carburettor.

Operation of A Spark Ignition Engine

The operation of a **spark ignition** engine involves a precise sequence of events that convert fuel into mechanical energy. This process is driven by the ignition of an air-fuel mixture within the engine's cylinders, triggered by a spark. The engine operates through a series of strokes, creating a cycle that powers various types of vehicles and machinery. Efficient performance and power output rely on the timing and coordination of these events, making spark ignition engines a fundamental part of modern internal combustion technology.

1. Induction Stroke

This is the first stroke of the four-stroke internal combustion engine. The starter motor cranks or drives the flywheel, which in turn rotates the crankshaft. The rotational motion of the crankshaft through an angle of 180° translates into a linear motion of the piston in the combustion chamber. The piston travels from the top dead centre (TDC) to the bottom dead centre. While the piston is moving, the camshaft opens the inlet valve to allow a fresh air-fuel mixture to enter the combustion chamber through the inlet port.

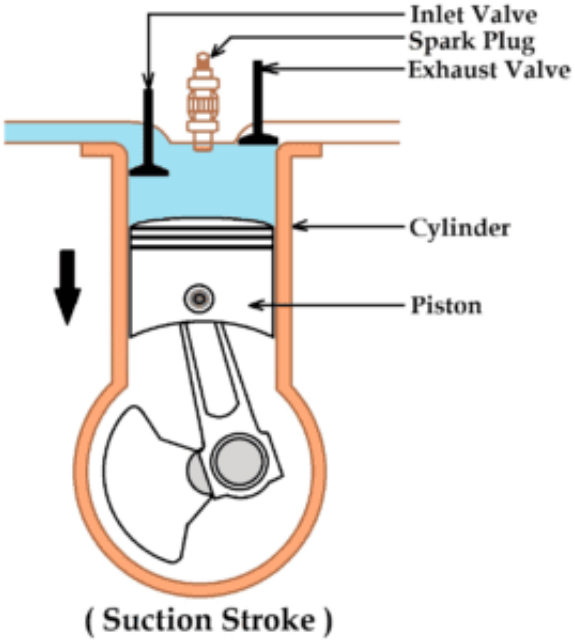


Fig. 2.2.7: Induction stroke (Source: specbee.net)

2. Compression Stroke

This is the second stroke. The piston returns from BDC to TDC, compressing the air-fuel mixture in the combustion chamber. The movement of the piston corresponds to the next 180° turn or a total of 360° turn of the crankshaft. During the compression stroke, both inlet and exhaust valves are closed to ensure a gastight chamber is achieved. The highly compressed air-fuel mixture attains a very high temperature. Near the end of this stroke, an electric spark is released from the spark plug to ignite the highly volatile mixture in the combustion chamber. The valves remain completely closed to prevent loss of pressure during this stage of the engine's power cycle.

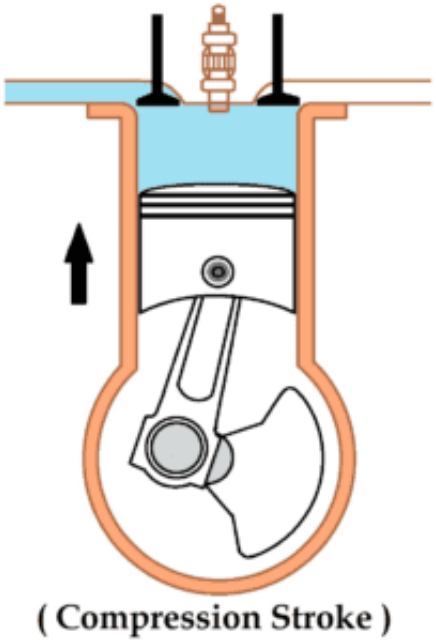


Fig. 2.2.8: Compression stroke (Source: specbee.net)

3. Power Stroke

The power stroke is the third and working stroke of the piston, which corresponds to a 540° turn of the crankshaft. The spark from the spark plug ignites the highly compressed air-fuel mixture. The combustion instantly causes the air-fuel mixture to explode inside the combustion chamber. The expansion forcefully pushes the piston away from TDC to BDC. The force or thrust of the piston is transferred to the crankshaft through the connecting rod. The crankshaft then converts the linear motion of the piston into rotational motion that drives the flywheel attached to it. The engine power is then transmitted from the flywheel through the transmission system to the road wheels. Both inlet and exhaust valves remain closed during the power stroke.

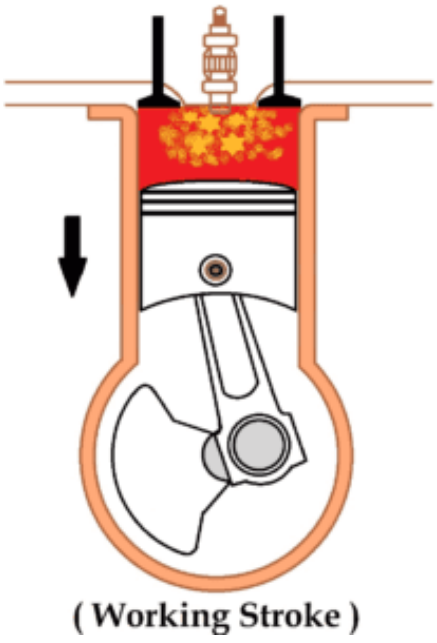


Fig. 2.2.9: Power stroke (Source: specbee.net)

4. Exhaust Stroke

This is the last stroke of the four-stroke engine cycle. During this stage, the piston makes its last travel from BDC to TDC. The exhaust valve opens to allow the burnt gases to exit the combustion chamber. Just before the piston reaches TDC, the inlet valve opens to begin the next cycle of operation. The incoming fresh air assists in the cleaning of the combustion chamber of exhaust gases. The fourth stroke of the piston corresponds to 720°, or two complete revolutions of the crankshaft.

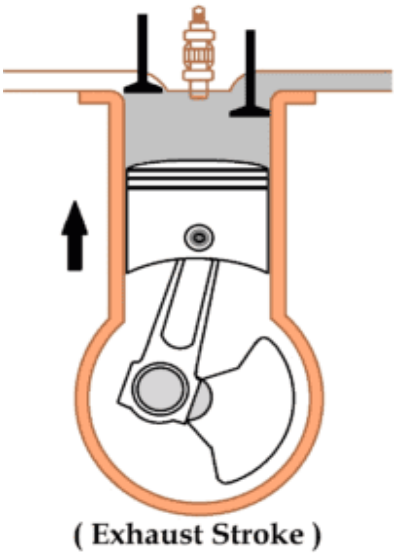


Fig. 2.2.10: Exhaust stroke (Source: specbee.net)

Activity 2.2.2

Watch the video titled *"Petrol Engine Working"* using the link below: https://youtu.be/BdXM6SkGUMU

After watching, work together in your group to discuss how a four-stroke petrol engine operates. Focus on identifying key stages in the engine cycle—such as intake, compression, etc. As you discuss, think about where problems might occur, like when air cannot enter the ignition chamber to mix with the fuel, or if the spark fails to ignite the mixture.

Consider questions such as:

a. What might happen if there is no air in the ignition chamber?
b. How could faulty components affect the performance of the engine?
c. What solutions can be found for common issues in the working cycle?

Remember to share your ideas openly and think critically about how each part of the engine contributes to its smooth operation.

Construction of a Four-Stroke Compression (Diesel) Ignition Engine

The **compression ignition** four-stroke engine differs from the **spark ignition** engine only in the type of fuel used and the process of igniting the fuel in the combustion chamber. In the diesel engine, only air is drawn or pushed into the combustion chamber and compressed to a very high temperature. Because diesel is less volatile than petrol, this engine requires a higher compression ratio to create a high pressure in the combustion chamber before the fuel is delivered. Burning the fuel is accomplished by the hot compressed air in the combustion chamber. Diesel engines use injectors to deliver the fuel into the combustion chamber. An injection pump supplies fuel to the injector at very high pressure. In a mechanical system,

the fuel injector's pulses are created by the injection pump controlled by a cam on the camshaft.

Fig. 2.2.11: A mechanical diesel injection pump (source: goldfarbinc.com)

Fig. 2.2.12: Diesel fuel injector (Source: www.sdsonlinestore.com)

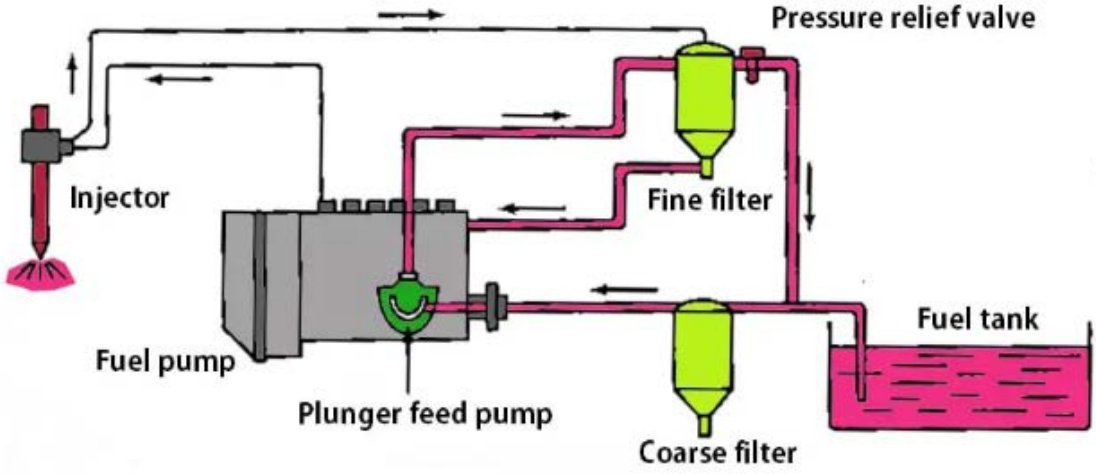


Fig. 2.2.13: A diagram of the diesel fuel injection system (source: extrudesign.com)

Again, due to the less volatile nature of diesel, it is difficult to achieve proper ignition, especially when the engine is cold. To assist cold staring, compression ignition engines are equipped with a glow plug in every combustion chamber. A glow plug is an electrical

device that lights up and warms up the compressed air and the diesel fuel that is sprayed into the combustion chamber. It is installed on the cylinder head with the tip in the combustion chamber.

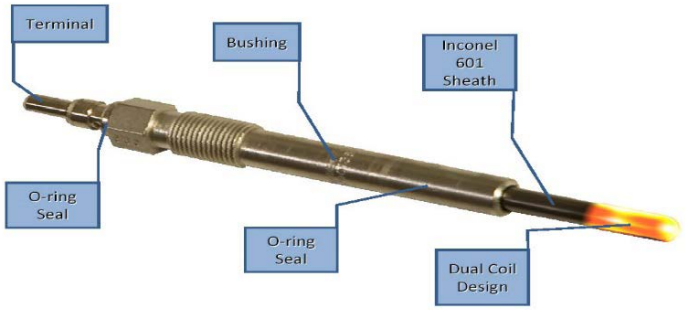


Fig. 2.2.14: Parts of a glow plug (Source: www.dieselrxproducts.com)

Diesel fuel is denser and has a higher viscosity than petrol, which often results in incomplete combustion. This leads to visible smoke being emitted from the exhaust. To address the issue of high carbon emissions, advanced technologies such as direct injection, turbocharging, and electronic control systems have been introduced. Additionally, fuel additives are available that enhance the combustion of diesel, helping to reduce smoke and improve efficiency.

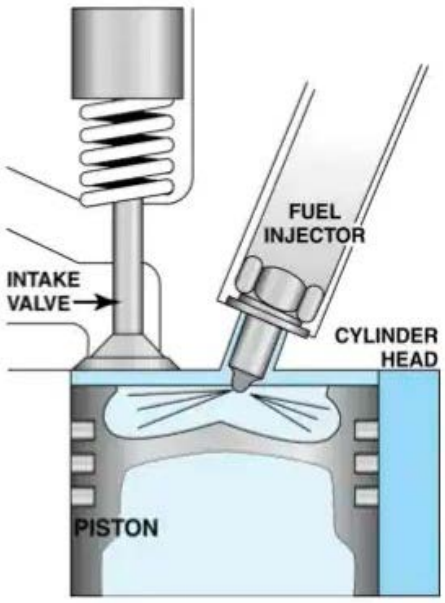


Fig. 2.2.15: Diesel direct injection system

Methods of Diesel Fuel Injection

Similar to spark ignition, compression ignition engines also employ direct injection and indirect injection methods. In the direct injection, the fuel is sprayed directly into the combustion chamber, whereas in the indirect injection, the fuel is first sprayed into a pre-chamber (or swirl chamber). The purpose of the pre-chamber is to achieve a better mixing of the fuel and air before the charge is further released through a small passage into the main combustion chamber.

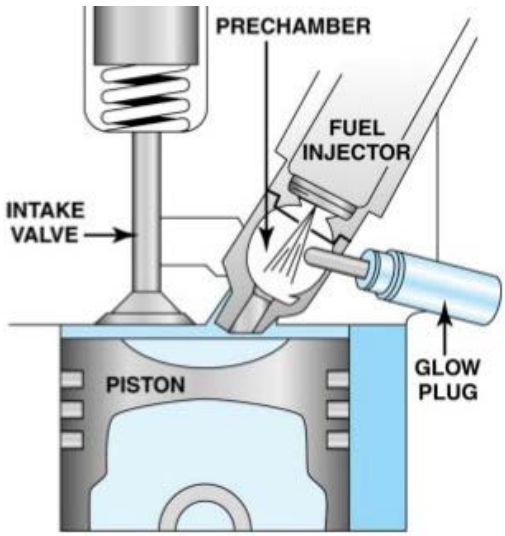


Fig. 2.2.16: Diesel indirect injection system

Turbochargers/Superchargers

Many modern diesel engines use a turbocharger or supercharger to increase the flow of air and improve upon the compression ratios of the cylinders. Chargers are common to many high-performance petrol engines as well.

Fig. 2.2.17 A turbocharger

Activity 2.2.3

1. Watch 'How Diesel Engines Work—Part 1 (Four Stroke Combustion Cycle)' https://youtu.be/fTAUq6G9apg
2. Briefly explain how the diesel four-stroke engine works. Again, like the petrol engine, try to identify where problems could occur with this engine, for example, dirty fuel being used.

Activity 2.2.4

1. Watch 'Turbochargers vs. Superchargers: Which Is Better?' at https://youtu.be/UUFf4n0MUq8
2. Why would you prefer a turbocharger to a supercharger, and vice versa?
3. Which of the two devices would you recommend to an automaker who manufactures cars for the Ghanaian market?
4. Imagine you are an automaker. Educate your class about the pros and cons of each of the two types of chargers.

Operation of a Compression Ignition Engine

Compression ignition engines possess similar features and undergo the same cycle of operation as their spark-ignition counterparts. However, in the case of compression ignition, only air is compressed in the combustion chamber, after which the diesel fuel is sprayed into

the hot air for burning to take place. As the name suggests, compression ignition engines achieve ignition by the highly compressed hot air inside the combustion chamber.

1. Induction Stroke

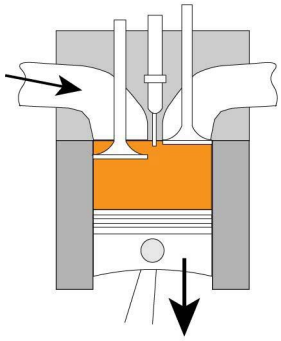


Fig. 2.2.19: Induction stroke

During the induction stroke, the piston moves down from the top dead centre (TDC) to the bottom dead centre (BDC). The inlet valve opens, and fresh air is drawn or sucked into the combustion chamber by the downward movement of the piston.

2. Compression Stroke

After the air has been drawn into the combustion chamber, the piston travels back up from BDC to TDC and compresses the air inside the combustion chamber. The inlet and exhaust valves are both closed to prevent loss of pressure in the combustion chamber.

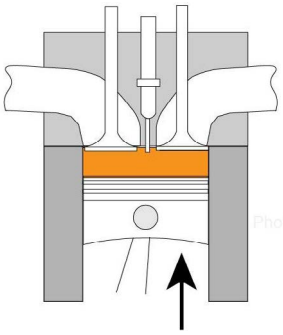


Fig. 2.2.20: Compression stroke

3. Power Stroke

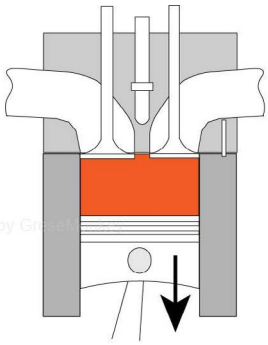


Fig. 2.2.21 Power stroke

This third stroke is the working stroke that transmits engine power to the road wheels. Near the end of the compression stroke, the fuel injector sprays a highly atomised fuel into the combustion chamber. The heat of the compressed air instantly ignites the fuel, and combustion takes place. The expansion created by the burning fuel forces the piston downwards, and the force of the piston is transmitted through the connecting rod to the crankshaft, which in turn rotates to drive the flywheel attached to it.

4. Exhaust Stroke

During the final stroke of the engine's power cycle, the piston returns from BDC to TDC. The exhaust valve opens as the piton pushes the burnt gases out of the combustion chamber. The inlet valve also opens before the piston reaches TDC to allow fresh air to enter the combustion chamber to assist in pushing out the exhaust gases and to prepare the combustion chamber for the next cycle of operation.

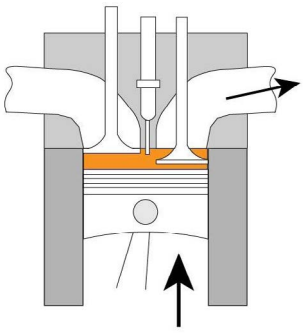


Fig. 2.2.22: Exhaust stroke

Conclusion

Both spark ignition and compression ignition four-stroke engines operate on the same principle, except for the fact that in spark ignition engines, the fuel, forming a mixture with air, is compressed in the combustion chamber before the mixture is ignited by the spark plug to produce power.

Two stroke engines

Two-stroke engines, as the name suggests, are internal combustion reciprocating engines, which complete a power cycle in just two piston strokes. Remember, four-stroke engines require four different strokes of the piston to complete a cycle. So, the main difference between two-stroke and four-stroke engines lies in the number of piston strokes required to complete a power cycle. Even though there are only two piston strokes in a cycle, all four processes of the engine's operation, namely induction, compression, power and exhaust are adequately taken care of.

Some applications of two-stroke engines:

1. motorbikes
2. portable generators
3. outboard motors
4. lawn mowers
5. chainsaw
6. marine engines

Activity 2.2.5

Identify some basic differences between two-stroke and four-stroke engines

Steps

1. Study the characteristics and features of two-stroke and four –stroke engines as shown in the table below.
2. Explore different internet sites or read other books on the differences between two-stroke and four-stroke engines.
3. Fill in the blank spaces to complete the table of differences between the two engine types.
4. Compare your answers with those of your colleagues.
5. Discuss in detail each of the differences identified.

Two-stroke engines	Four-stroke engines
There is one revolution of the crankshaft during one operational cycle.	

Two-stroke engines	Four-stroke engines
	Completes power cycle in four piston strokes.
They have fewer parts.	
They deliver more power.	
They are simple in construction.	
They produce higher emissions.	They produce lower emissions.
	They have less power-to-weight ratio.
They are suitable for motorcycles and smaller machines like chainsaw and lawnmowers.	
They are less fuel-efficient.	
Fuel combustion is complete.	Fuel combustion is partially complete.
	They are quieter in operation
	They are difficulty to service and maintain.
They are less expensive.	

Constructional features of the two-stroke petrol engine

The two stroke petrol engine uses the piston to perform the work usually done by the valves found on four-stroke engines. A typical two-stroke petrol engine has three ports. These are inlet, exhaust and transfer ports. These ports are generally located in the walls of the engine's cylinder and are closed and opened by the piston as it moves up and down.

Two stroke petrol engines have the disadvantage of higher emission levels due to the overlapping of exhaust and intake processes. To overcome this problem, some pistons are designed with deflective crowns to restrict the fresh incoming charge from being swept along with the exiting exhaust gases.

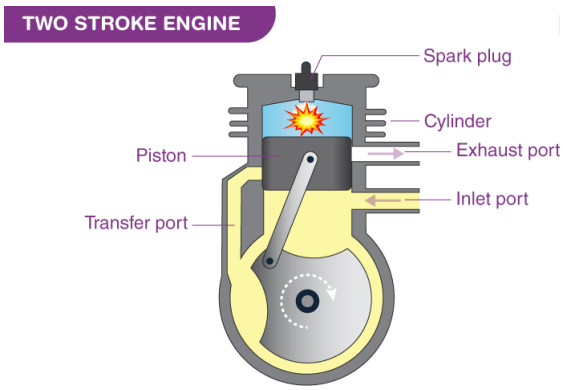


Fig. 2.2.23: Parts of a two-stroke petrol engine

Working principle of two-stroke petrol engines

In two-stroke petrol engines, induction and compression are combined in a single stroke of the piston, and power and exhaust are also combined in another single stroke of the piston.

Induction and Compression Stroke

During this stroke, the piston moves up from bottom dead centre (BDC) to top dead centre (TDC). As the piston travels upward, it compresses the air-fuel mixture (or charge) in the combustion chamber. At the same time, it uncovers the inlet port or a reed valve is opened for a fresh air-fuel mixture to enter the crankcase. The upward movement of the piston creates a partial vacuum in the crankcase below the piston that sucks in the air-fuel mixture.

Power and exhaust stroke

The second stroke completes the power cycle. Just before the piston reaches the top of its travel during the compression stroke, the spark plug releases an electric spark that instantaneously ignites the highly compressed air-fuel mixture in the combustion chamber. The expansion of the burning gases pushes the piston downwards, exerting force on the crankshaft. During this stroke, the piston, first, uncovers the exhaust port for the *scavenging* process to begin.

A further downward movement of the piston uncovers the transfer port to allow a partially compressed air-fuel mixture from the crankcase into the combustion chamber to begin another cycle. The incoming fresh charge helps in pushing the burnt gases out of the combustion chamber to complete the scavenging process.

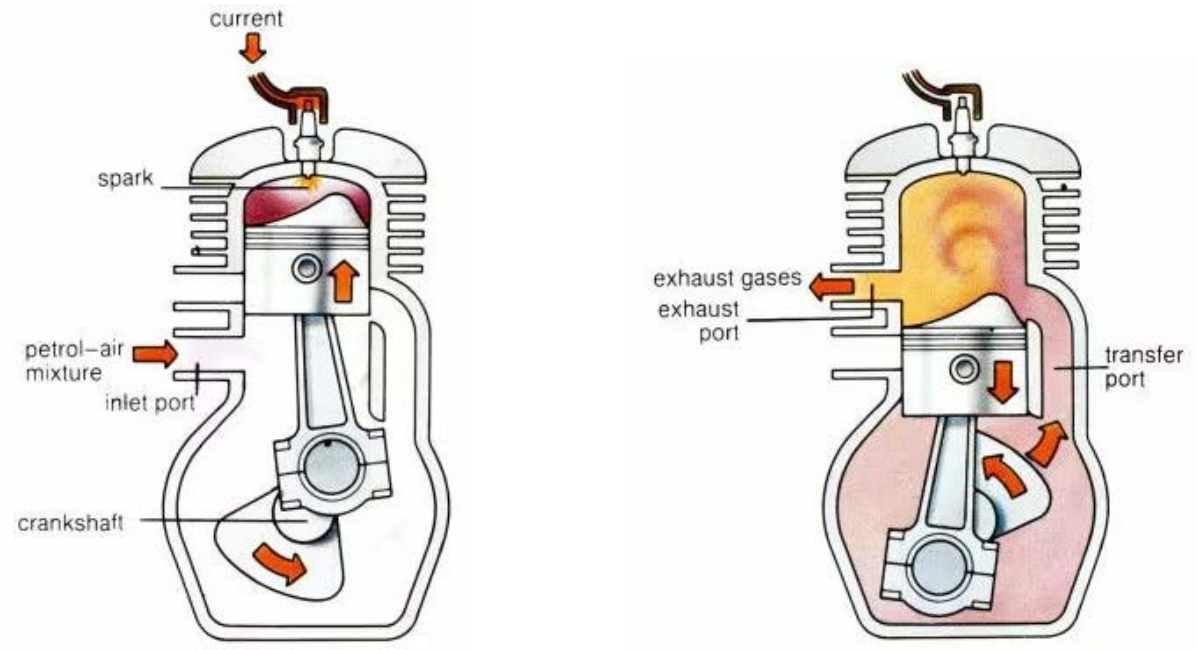


Fig. 2.2.24: Construction and operation of a two-stroke petrol engine

Activity 2.2.6

Briefly explain the working principle of the two-stroke petrol engine.

Steps

1. Watch a cutout model explaining the working principle of a two-stroke petrol engine at https://www.youtube.com/shorts/-ksCBfABA7I?feature=share
2. pause the video intermittently to critically take note of the various parts of the engine.
3. Watch another video at https://youtu.be/kWRRHRWuduk to observe how power is delivered in the two-stroke petrol engine.
4. Explain why the three ports are located at different levels in the cylinder wall.
5. Read out your observations to the class.

Constructional features of two-stroke diesel engines

The two-stroke diesel engine is designed to compress air only. Because it is a compression ignition (CI) engine, it relies on the temperature of the compressed air to ignite the diesel fuel. Apart from this, two-stroke diesel engines have similar parts to those of two-stroke petrol engines.

Two stroke diesel engines have only two sets of ports: intake port and exhaust port. Like their two-stroke petrol counterparts, two-stroke diesel engines designed with uniflow scavenging systems use exhaust valves to open and close exhaust ports located in the cylinder head.

All diesel engines are noted for their high power efficiency and so depend on a good supply of fresh air for a higher level of engine performance. To achieve this purpose, two stroke diesel engines are designed with air intake systems to ensure adequate supply of air for compression and for scavenging purposes. The air intake systems used in two-stroke diesel engines include turbochargers, superchargers (discussed under four-stroke diesel engines), blowers and naturally aspirated air. Apart from naturally aspirated air system, which relies solely on atmospheric pressure to supply the combustion chamber with fresh air, all the other systems rely on mechanically driven components (compressors) to supply pressurized air to the combustion chamber.

Working principle of two-stroke diesel engines

Two–stroke diesel engines, unlike their petrol counterparts, accomplish compression during the upward stroke and complete power, exhaust and induction during the downward stroke. There is, however, an overlap between the exhaust and intake, and between the intake and compression in this type of engine.

Induction and compression

The first stroke is the compression stroke. The inlet port which opens to scavenge the combustion chamber remains open till the start of compression. The blower or turbocharger continues to push more air into the cylinder until the inlet port is closed by the piston as it moves from bottom dead centre (BDC) to top dead centre (TDC). The compression of air takes place during the upward movement of the piston. Fresh air used for scavenging continues to flow into the cylinder during this stage. The piston seals off the inlet port and then compresses the remaining air in the top of the cylinder. The exhaust valve is closed to ensure a gas tight cylinder. As the piston nears the top of its travel, the diesel fuel is injected into the highly compressed, hot air that causes the burning of the fuel. The force of expansion from the combustion pushes the piston down. At the same time, the exhaust ports are opened by valves in the cylinder head or uncovered by the piston to allow the burnt gases to exit the chamber. As the piston moves further down, it uncovers the intake port to allow fresh air to be forced into the combustion chamber by a turbocharger or a blower. The incoming fresh air assists in expelling the burnt gases from the combustion for the next cycle to begin.

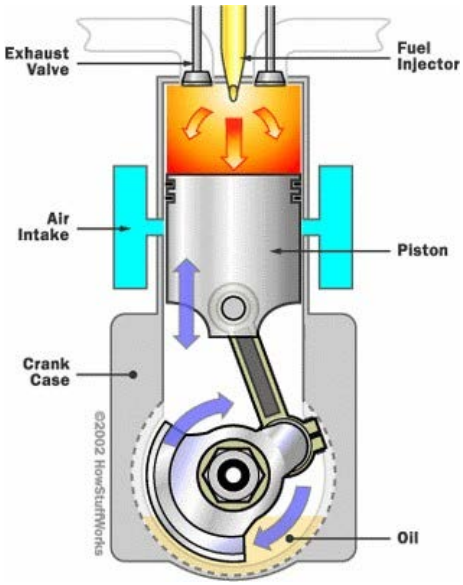


Fig. 2.2.25: Construction and operation of a simple two-stroke diesel engine

Activity 2.2.7

Describe how burning is initiated in a two-stroke diesel engine.

Resources Needed

- YouTube Video
- Writing materials

Steps

1. watch a video on the working principle of a two-stroke diesel engine at the link below:
   https://youtu.be/znBTQvy28f8
2. observe the movement pattern of the piston and the valve.
3. Pause the video at the point where fuel is injected into the cylinder.
4. Make a sketch of the engine showing the position of the piston at the following stages:
   a. compression
   b. power
   c. exhaust and
   d. induction

5. Label the main parts of the engine that work together to deliver power.
6. Summarise in writing the process of the burning of fuel in a two-stroke diesel engine.
7. Display your sketch on the board and explain to the entire class how burning of fuel occurs in a two-stroke diesel engine.
8. Compare your answer with responses from other members of the class.
9. Discuss in class some disadvantages of the two-stroke diesel engine and suggest ways of c overcoming them.

Activity 2.2.8

Illustrate with sketches the operation of four-stroke cycle compression ignition engines.

Resources Needed

- Video
- Pictures from textbooks and the internet
- Cardboard
- Marker pen (Different colours)
- Writing materials

Steps

1. WATCH 'How Diesel Engines Work - Part - 1 (Four Stroke Combustion Cycle)' at https://youtu.be/fTAUq6G9apg

   OR Surf the internet to find pictures on the four stages of the compression ignition power cycle.
2. Pause video intermittently to observe each of the four strokes of the power cycle or look for similar stages in the textbook or on the internet.
3. Draw the four distinct stages on your cardboard.
4. Use different colours to show the air intake, compressed air, power and exhaust.
5. Use annotations to describe each of the stages.
6. Identify the various strokes with arrows.
7. Label the other parts of the engine that contribute to the performance of the four-stroke diesel engine.
8. Display your group's work on the board and explain it to the whole class.
9. Compare your chart with the solution of other groups.
10. Discuss how the four-stroke diesel engine differs from their two-stroke counterparts.

Activity 2.2.9

Illustrate, with sketches, the operation of two-stroke cycle spark ignition engine.

Resources needed

- Engine of a motorbike, lawnmower, or generator
- Writing materials
- Sketch pad

Caution: Wear your personal protective equipment and observe all workshop safety rules.

Activity Steps

1. Visit the school's auto mechanics shop or a nearby mechanic shop to observe and learn about two stroke engines.
2. Pay critical attention to the kinds of machines that operate on two-stroke petrol engines.
3. Observe the engine block design and the various components attached to it.
4. Watch how they operate, noting down any significant characteristics.
5. Watch a video on 'Petrol Engine Working' at the link below
   https://youtu.be/BdXM6SkGUMU
6. Compare the video with what you observed at the mechanic shop.
7. Outline engine features on the two-stroke petrol engine that are different from its diesel counterpart.
8. Prepare a step-by-step procedure with sketches showing the four stages of the two-stroke spark ignition engine.
9. compare your work with other groups' work.
10. Discuss with the entire class differences and similarities between four-stroke petrol and diesel engines.

ANNEX 2: FURTHER INFORMATION AND ACTIVITIES

Compression ignition engines, on the other hand, compress only air in the combustion chamber and ignite the fuel with the hot compressed air. Spark ignition engines use either a carburettor or injector to deliver fuel to the combustion chamber, whereas compression ignition engines rely solely on injectors to spray highly atomised fuel into the combustion chamber.

Both engine types may be designed to deliver the fuel into the combustion chamber by either direct or indirect method.

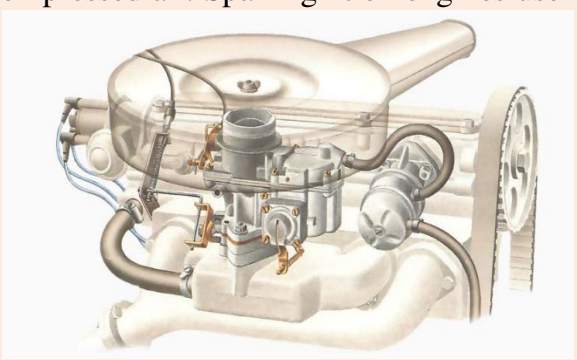


Fig. 2.2.1: A carburettor-installed engine

Carburettor System

Carburettors are manufactured in several sizes and configurations. There are two types of carburettors:

1. **Fixed venturi:** The velocity of the airflow is used to regulate the flow of the fuel.
2. **Variable venturi:** The flow of raw fuel is controlled mechanically, and airflow is regulated with fuel flow.

An engine's efficiency is controlled by three main factors: **fuel, air (oxygen), and heat**. The air used by the petrol engine is drawn from the air cleaner (a component that usually sits atop or close to the top of the carburettor that contains an air filter). The air filter traps particles and dirt from entering the combustion chamber. When the driver depresses the accelerator pedal, it opens a throttle valve (butterfly) inside the carburettor to increase the airflow into the combustion chamber. The flow of air draws petrol from the float chamber of the carburettor into the mixing chamber. The air pressure atomises the fuel and sends it into the combustion chamber through the intake manifold.

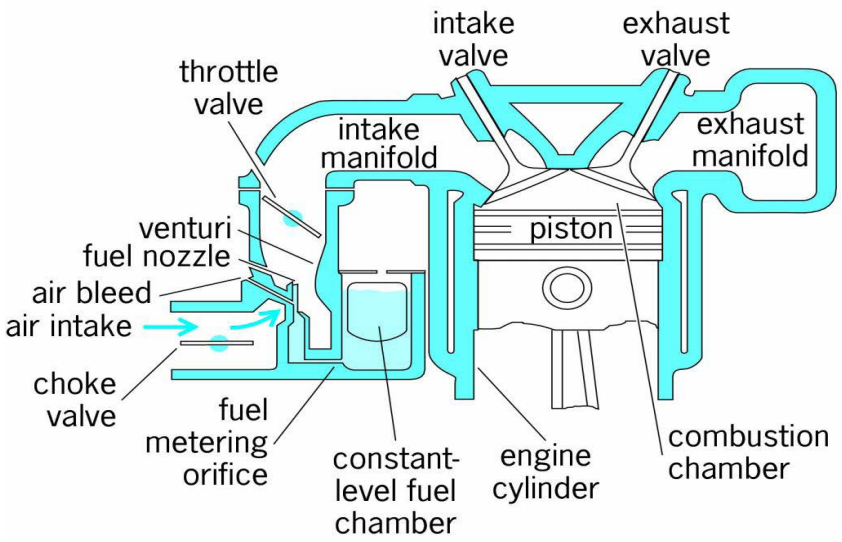


Fig. 2.2.2: Parts of a carburettor engine

Petrol Fuel Injection System

A petrol-injection system is designed to deliver the correct quantity of highly atomised fuel into the engine's combustion chamber. Fuel injection systems have the following advantages:

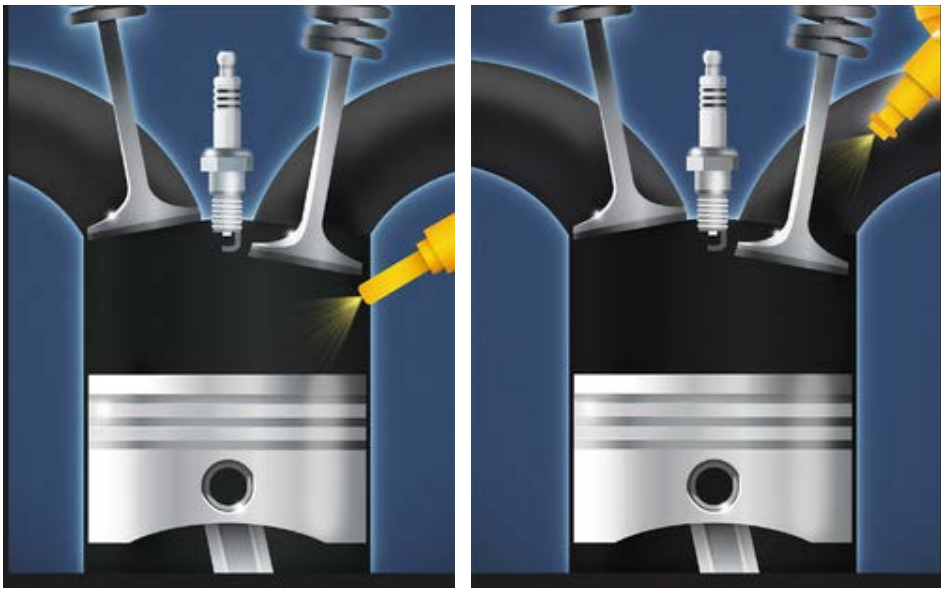
1. lower exhaust pollution.
2. lower fuel consumption.
3. higher power output.
4. automatic adjustment of the air/fuel ratio to suit operating conditions.

Methods of Fuel Injection

There are two methods by which the fuel is delivered into the combustion chamber. They are **direct injection** and **indirect injection.**

a. **Direct injection:** In direct injection, the fuel is delivered directly into the combustion chamber.

b. **Indirect Injection:** In indirect injection, the fuel is delivered into the intake manifold or throttle body.



(a) (b)

Fig. 2.2.3: Petrol injection system (a) direct and (b) indirect

Types of Fuel Injection Systems

Fuel injection systems can be classified into two: **single-point injection** and **multi-point injection.**

1. **Single-point injection system:** A single-point injection system (also called throttle body injection) uses only one injector that is mounted on the intake manifold or throttle body to discharge fuel into the airstream.

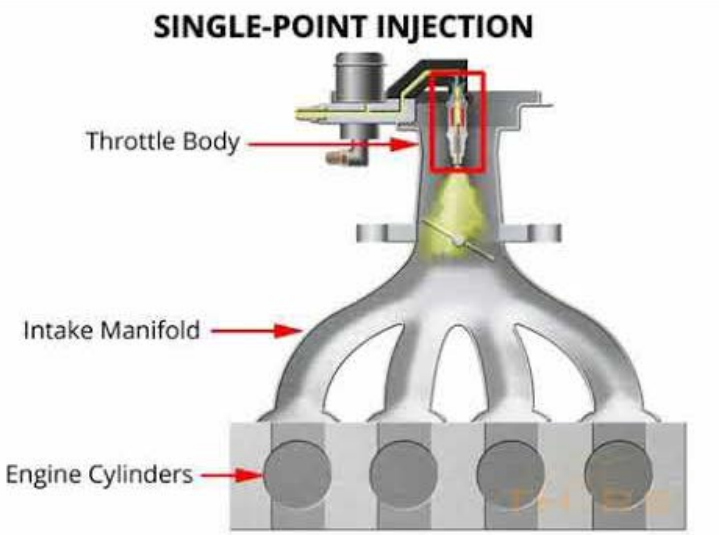


Fig. 2.2.4: A single-point injection system (source: www.youtube.com)

2. **Multi-point injection system:** A multi-point injection system uses separate injectors for each cylinder. The injectors are positioned just close to and behind the inlet valve of the engine.

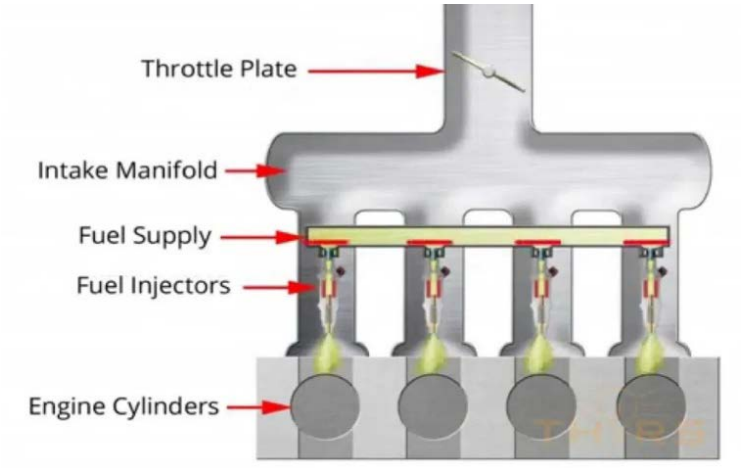


Fig. 2.2.5: A single-point injection system (source: www.spinny.com)

3. **Electronic Fuel Injection (EFI) System:** The more advanced engines are designed with an electronic fuel injection (EFI) system, which is more reliable and more efficient by offering a higher performance and improved emissions from the engine. An electronic fuel injection system uses a computer-controlled device called an electronic control unit (ECU) to measure the amount of fuel and air that suits the operating condition of the engine at a particular point in time.

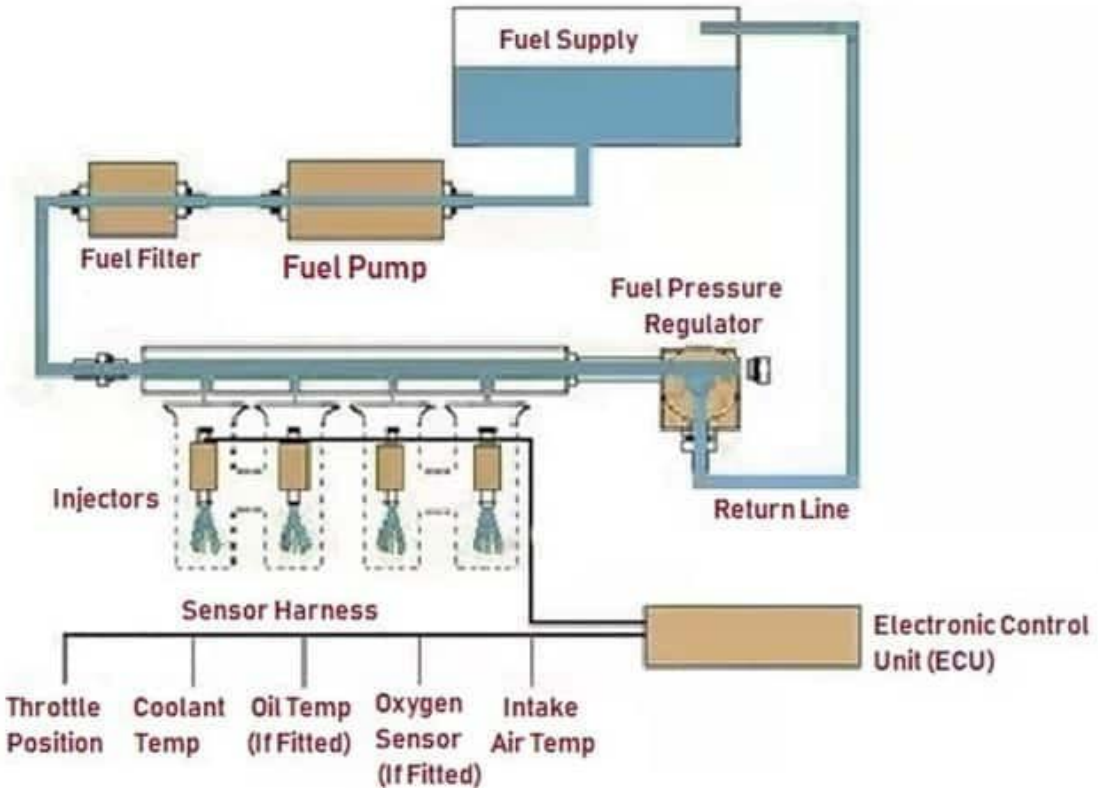


Fig. 2.2.6: Multi-point fuel injection (Source: Northern Technical College—Nortec)

Activity 2.2.10

1. a. Visit an auto mechanic shop or watch an online resource to explore the parts of different four-stroke spark ignition engines. You can also use maintenance manuals for cars and other vehicles if available.

   b. Discuss in groups how the different parts work together to achieve power from the engine.

   c. Present your list of parts and compare with the list of other members in class.

Note: Remember, if you visit a workshop or garage, be sure to always follow the safety instructions and signs provided.

Review Questions for Section 2, Unit 2

1. a. Make a neatly labelled sketch of a simple carburettor on paper or cardboard and bring it to class at your next lesson.

   b. Use the drawing to explain to your colleagues the working principle of the carburettor.

2. The majority of vehicles we find today run on fossil fuel, which is composed of hydrocarbons. One of the end products of this fuel is carbon monoxide, which is dangerous to life. Suggest a policy statement to your local authority that can be adopted to deal with carbon emissions from vehicles.

3. Prepare a one-page debate for or against the following topic: 'Compression Ignition Engines are better than Spark-Ignition Engines'. Make it as interesting as possible, and you can include a picture if there is space.

4. Discuss with illustrations the four strokes of the spark-ignition engine operating cycle.

5. Suggest any two modifications each for spark-ignition and compression ignition engines that you would like auto manufacturers to include in their engine designs to make them perform more efficiently in the near future.

6. a. As an owner of a fuel station in your community, what safety measures would you recommend for your pump attendants to ensure they do not mistakenly dispense the wrong fuel into a vehicle, whether it runs on petrol or diesel?

   b. Discuss any three (3) consequences that may result from supplying an engine with the wrong type of fuel.

7. Your neighbour visited your auto mechanics shop and complained about the low performance of their lawnmower. Suggest possible causes of low engine performance and discuss with him/her how the problem can be remedied.

8. a. Using internet resources and additional books, illustrate and explain the three scavenging methods used in two-stroke petrol engines?

   b. i. How does scavenging contribute to the overall engine performance?

      ii. Which of the three scavenging methods would you recommend for auto makers to include in future two-stroke engine designs? Explain why.

9. a. It is a fact that two-stroke engines deliver more power than four-stroke engines. a) Analyse why modern automobiles use four-stroke engines whilst machines like chainsaw and lawnmowers use two-stroke engines.

   b. Also suggest ways in which the deficiencies of two-stroke engines, which make them unpopular in automobile applications, can be rectified.

Extended Reading

1. Click the link to read more on crankshaft technology: https://media.defense.gov/2014/Jun/20/2002655897/-1/-1/1/140620-N-ZZ182-6546.pdf
2. Hillier, V. A. W. (2012) Fundamentals of Motor Vehicle Technology (6th edition), Nelson Thornes Ltd, Cheltenham, United Kingdom. pp. 143-145; 236-250.
3. Nunney, M. J. (2007) Light and Heavy Vehicle Technology (4th edition), Elsevier Ltd., pp. 4-6; 71-73.
4. Two Stroke Engine: Main Parts, Principle, Working, Application, Advantages and Disadvantages (mech4study.com)
5. The two-stroke cycle in Fundamentals of Motor Vehicle Technology by Hillier, V. A. W. (6th edition), pp. 37, 38.

References

1. Halderman, J. D. (2012) Automotive Technology: Principles, Diagnosis and Service (4th edition) Pearson Education, Inc., New Jersey, USA.
2. Hillier, V. A. W. (2012) Fundamentals of Motor Vehicle Technology (6th edition), Nelson Thornes Ltd, Cheltenham, United Kingdom.
3. Nunney, M. J. (2007) Light and Heavy Vehicle Technology (4th edition), Elsevier Ltd.

UNIT 3

BUILDING CONSTRUCTION

Pre-construction Activities

INTRODUCTION

This unit provides you with a detailed insight into stakeholder's forum and its importance for the roles of stakeholders involved in building construction projects. This knowledge of stakeholders' forum and its link to the various stakeholders in construction project and their roles is of great importance for the success of construction projects. The study will enable you to appreciate the efforts that stakeholders put in, to achieve the desired aim of the construction project. In the following discussion, you will be introduced to the stakeholder's forum and the subsequent roles of the various stakeholders in the construction project. Take a critical look at how the stakeholders forum can enhance the roles of the various stakeholders in performing their roles as expected in a construction project.

At the end of this unit, you should be able to:

- Describe the roles of Stakeholders involved in building construction project.

Key Ideas

- The roles of the various stakeholders involved in building construction projects are diverse but are necessary.
- They contribute to the effective and efficient execution of works at the construction site.

STAKEHOLDERS FORUM

The stakeholder's forum is a meeting of all key players involved in the building construction project. It is a platform for all stakeholders to explore or examine all the available opportunities or avenues possible to achieve the ultimate goal of achieving successful undertaking of the project.

Usually, stakeholder forums for building construction projects serve as an important strategy for ensuring good pricing, quality, and time duration for the project.

Importance of a Stakeholders forum

A stakeholders' forum in building construction projects is crucial for ensuring a good price, competitive pricing for goods and services and quality control as it facilitates communication, collaboration, and transparency among all parties involved. By bringing together various stakeholders, such as clients, contractors, suppliers, designers, and regulatory authorities, the forum can address and resolve issues that affect the project's cost-effectiveness. Listed below are some of the keyways in which a stakeholders forum contributes to achieving a high-quality, cost-effective end result are:

1. Enhanced Communication and Collaboration
2. Transparent Cost Management
3. Efficient Resource Allocation
4. Risk Mitigation
5. Quality Assurance and Value Engineering
6. Regulatory and Compliance Efficiency

Also, a stakeholders' forum in building construction projects is instrumental in ensuring good time duration, as it facilitates coordination, communication, and collaboration among all parties involved. Time management is crucial in construction projects to ensure timely completion, avoid delays, and minimize costs. Here are several ways in which a stakeholders' forum contributes to ensuring good time duration in building construction:

1. Collaborative Planning**:** Stakeholders from various disciplines collaborate to develop comprehensive project plans and schedules.
2. Alignment of Objectives**:** Forum discussions ensure that all stakeholders understand project timelines and are committed to achieving project milestones.
3. Proactive Problem-Solving**:** Regular meetings allow stakeholders to identify potential delays or obstacles early in the project lifecycle.
4. Timely Decision-Making**:** Collaborative problem-solving enables quick decision-making to address issues and keep the project on track.
5. Efficient Resource Management**:** Stakeholders coordinate resource allocation, including labour, equipment, and materials, to optimize productivity and minimize downtime.
6. Synchronized Workflows: Forum discussions help synchronize workflows between different trades and project phases to minimize idle time and maximize efficiency.
7. Effective Communication Channels**:** The forum serves as a centralized platform for communication, ensuring that information flows smoothly between all stakeholders.
8. Timely Information Sharing: Regular updates and progress reports keep stakeholders informed of project status, allowing for timely adjustments as needed.
9. Shared Responsibility**:** Stakeholders work together to address challenges and find creative solutions to keep the project on schedule.
10. Risk Mitigation**:** Collaborative risk management efforts help identify potential delays and implement strategies to mitigate their impact.

11. Clear Expectations**:** Forum discussions ensure that all parties understand their roles and responsibilities as outlined in the project contracts.
12. Contract Compliance**:** Regular reviews of contract terms and deliverables help ensure that all stakeholders are fulfilling their contractual obligations to prevent delays.
13. First-Time Quality**:** Ensuring quality workmanship and materials from the outset minimizes rework and delays due to defects.
14. Inspection and Monitoring**:** Forum discussions include monitoring project quality and addressing any issues that arise promptly to prevent delays.

Activity 2.3.1

1. Study in detail, the key issues of the importance of stakeholders' forum for building construction projects.
2. Note down the key issues of importance of stakeholders' forum that you have observed during the school organised field trip to a construction site. In your classroom groups, discuss your notes on the key issues of the importance of the stakeholders' forum.

ROLES OF STAKEHOLDERS INVOLVED IN BUILDING CONSTRUCTION PROJECT

The three client groups play key roles in building construction projects. The discussions about client groups will enrich your knowledge and understanding of why it is usually believed that the commencement, continuation and completion of every building construction project depends mostly on the ability of the client.

1. **Roles of the client:** Clients, whether an individual, a corporate entity or a government body, provide the financial resources necessary for the project and are responsible for ensuring that funds are available and properly managed. Throughout the construction phase, clients monitor progress, provide feedback, and ensure that the project aligns with their expectations and standards.
2. **The Roles of the Design Team**: The design team in a building construction project is responsible for the planning, conceptualization, and detailed design of the project. The design team typically includes architects, engineers, interior designers, landscape architects, and other specialists. Fig. 1 shows the members of the design team.

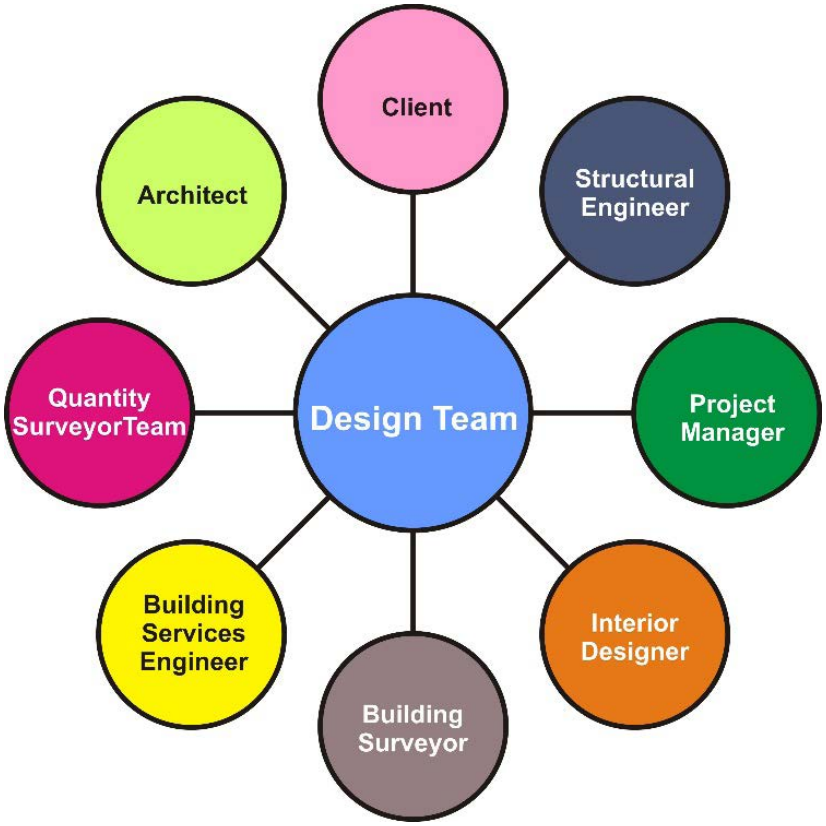


Fig 2.3.1: The Design Team

The key roles of the members of the design team are presented in Table 2.3.1.

Table 2.3.1: Key roles of the Design Team

Job title	Key words
Architect	Concept, Design, Aesthetic, Regulation, Compliance, Coordination
Structural Engineers	Structure, Framework, Calculations, Simulations, Materials, Specifications, Collaboration
Mechanical, Electrical, and Plumbing (MEP) Engineers	System Design, Integration, efficiency and regulatory compliance.
Interior Designers	Space Planning, Material and Finish Selection, Lighting and Colour Schemes, Accessibility and Ergonomics.
Landscape Architects	Site Analysis, Environmental Considerations, Aesthetic and Functional Design
Civil Engineers	Site Development, Stormwater Management, Roads and Parking.
Acoustic Engineers	Sound Design, Testing and Analysis.
Fire Protection Engineers	Fire Safety Design, Code Compliance.

Sustainability Consultants	Green Building Design, Certification.
Project Manager (Design Phase)	Coordination and Oversight, Client Communication.

3. **Roles of the Building Team:** The building team as shown in the diagram below indicates all the stakeholders who play various roles as per their specialized areas. Take a thorough look at each of the specific stakeholders and read about the roles that they play. In building construction projects, the building team is a crucial stakeholder group, encompassing various stakeholders and entities responsible for planning, designing, and executing the construction of the project. The building team and their roles are shown in Table 2.3.2.

Table 2.3.2: The Building Team and their roles

Job title	Description of roles
Clients/Owners	The individuals or organizations who commission the project, provide funding, make critical decisions on project's direction.
Architects	Design and aesthetics of the building; ensure project meets client's needs and complies with building codes and regulations.
Structural Engineer	Ensures the building's structural integrity.
Civil Engineer	Oversee site development, including grading, drainage, and roadways.
Mechanical, Electrical and Plumbing Engineers (MEP)	Design and oversee the installation of mechanical, electrical, and plumbing systems.
Project Managers	Coordinate project schedule and ensures project meets budget.
General Contractors	Oversee the day-to-day operations on the construction site.
Subcontractors	Undertake specific tasks such as electrical work, plumbing, roofing, and more.
Quantity Surveyors	Manage all costs and ensure the project meets quality and regulatory standards.
Construction Workers	Physically build project under contractors and site managers' supervision.
Interior Designers	Ensure interior aesthetics and functionality of the spaces within the building.
Suppliers and Vendors	Provide materials, equipment, and other resources necessary for the construction project.

Inspectors and Code Officials	Ensure construction complies with relevant building codes, safety regulations, and standards.
Environmental Consultants	Ensure project complies with environmental regulations, and address sustainability and environmental issues.
Legal Advisors	Handle contracts, permits, and legal issues arising during project.

4. **Roles of statutory authorities or agencies:** Among the statutory authorities or agencies for building construction projects are the District /Municipal/ Metropolitan assemblies, Survey Department, architectural and Engineering Services Limited (AESL) and Town and country planning.
5. **The Roles of Civil Societies as Stakeholders:** There are several civil society organizations (CSOs) in Ghana that are actively involved in construction-related activities. They contribute to the development of sustainable and equitable construction sector in Ghana. The following are examples of CSOs in Ghana that are actively engaged in construction-related activities:

Activity 2.3.2

1. Follow the links below to watch videos on the roles of the various stakeholders involved in building construction projects
   a. https://youtu.be/gHsclsEqdJU
   b. https://youtu.be/lNDlT7NrL6Q
2. Discuss with a colleague some roles of the various stakeholders mentioned in the videos watched.

Review Questions Section 2 Unit 3

1. Explain the relevance of the stakeholders forum for building construction projects.
2. Categorise the stakeholders into the groups of those who function directly on design and construction and those that do not function directly.
3. Describe the strategies the Client, Design and Building teams can put in place to achieve good price, good quality and good time duration for a building construction project.

Extended Reading

1. Establishes Site Podium. "Indirect Stakeholders in the Construction Industry." https://www.sitepodium.com/blog/indirect-stakeholders-in-the-construction-industry/
2. Site Podium. "Who Are the Stakeholders in a Construction Project?" https://www.sitepodium.com/blog/who-are-the-stakeholders-in-a-construction-project/
3. Designing Buildings Wiki. "Stakeholder management for building design and construction." https://www.designingbuildings.co.uk/wiki/Stakeholder_management_for_building_design_and_construction

References

Chinyio, E. A., & Olomolaiye, P. (Eds.). (2010). Construction stakeholder management.

Olander, S. (2007). Stakeholder impact analysis in construction project management. Construction management and economics, 25(3), 277-287.

Jepsen, A. L., & Eskerod, P. (2009). Stakeholder analysis in projects: Challenges in using current guidelines in the real world. International Journal of Project Management, 27(4), 335-343.

UNIT 4

STRAND: ELECTRICAL AND ELECTRONIC TECHNOLOGY

Electrical Systems Design

INTRODUCTION

Electric power is generated by power producing stations, and the power produced is transported over long distances to sub-stations and supplied to industrial, commercial and domestic consumers by processes referred to as transmission and distribution. In this unit you will learn about the generation and transmission of electricity.

At the end of this unit, you should be able to:

Describe the process of electrical power generation, transmission and distribution.

Key Ideas

- Methods of electric power, transmission and distribution to consumers.
- Process of transmission and distribution of electric power to industrial, commercial and domestic consumers.

ELECTRICITY GENERATION IN GHANA

In Ghana, electricity generation involves the combination of different sources to meet the country's energy needs. We will look at different sources both conventional and unconventional in the generation of electricity.

Electricity Generation

Electricity does not just exist on its own, other forms of energy must be converted into electrical energy. These include:

1. **Electrochemistry:** The conversion of chemical energy *into electricity, as in a cell or* battery and finds wide applications in portable devices like mobile phones and lamps.
2. **Photovoltaic effect:** The conversion of light energy into electrical energy, as in solar cells. Photovoltaic panels *convert sunlight directly into DC electricity. If AC is required,* inverters *are employed for that purpose.*

3. **Generator:** The generator converts mechanical energy into electrical energy. Its operation is based on Faraday's laws of electromagnetic induction and achieved by rotating a magnet within closed loops of conductors or rotating a conductor within the magnetic a field.

   The generator is the most commonly device used in electricity generation and almost all commercial electricity generation utilises it. A number of methods are employed in producing the mechanical energy required by the generator to produce the electricity. They include **Thermal, Hydro**, Renewal energy sources (**Solar Power**, **Biomass and wastewater systems**), etc.

Thermal Power Plants

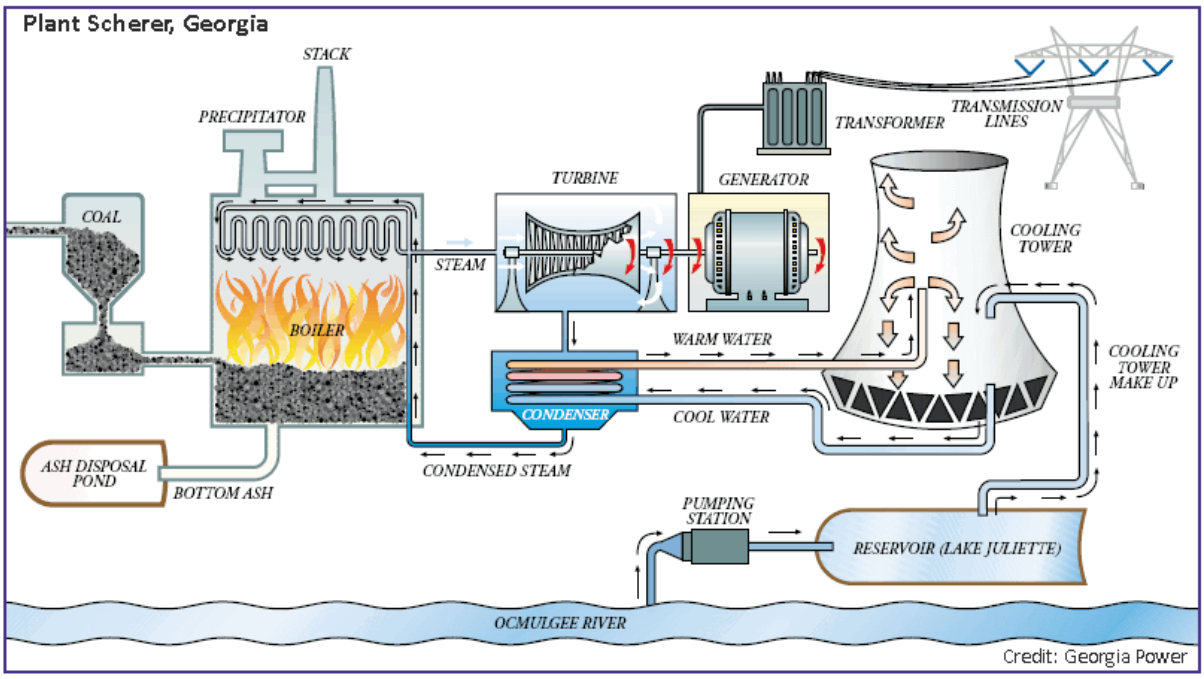


Fig 2.4.1: A Thermal Power Plant

Thermal power plants primarily rely on fossil fuels, including crude oil, natural gas, and diesel. These power plants generate electricity by burning the fossil fuels to produce steam, which drives turbines connected to generators.

Hydroelectric Power

Ghana has significant hydroelectric power generation capacity. The country has several hydropower dams, including the Akosombo Dam on the Volta River, which is the largest hydropower facility in Ghana. Hydropower plants harness the potential energy of water stored in reservoirs behind the dams. The water is released, and its kinetic energy drives turbines to generate electricity.

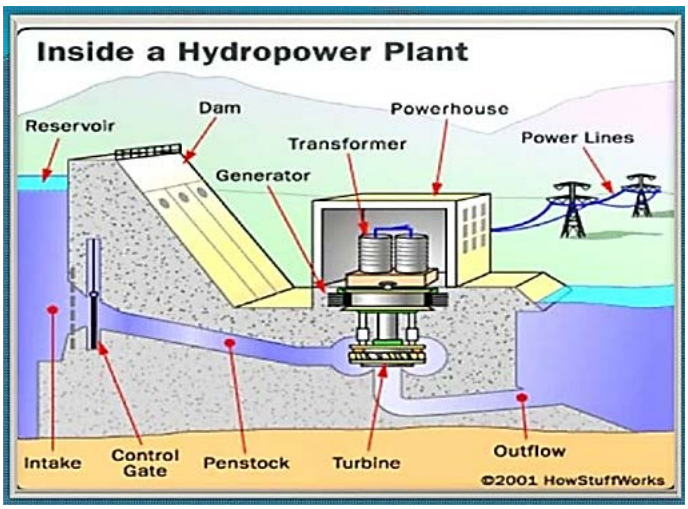


Fig. 2.4.2: Hydroelectric Power Station

Renewable Energy Sources

1. Solar Power:

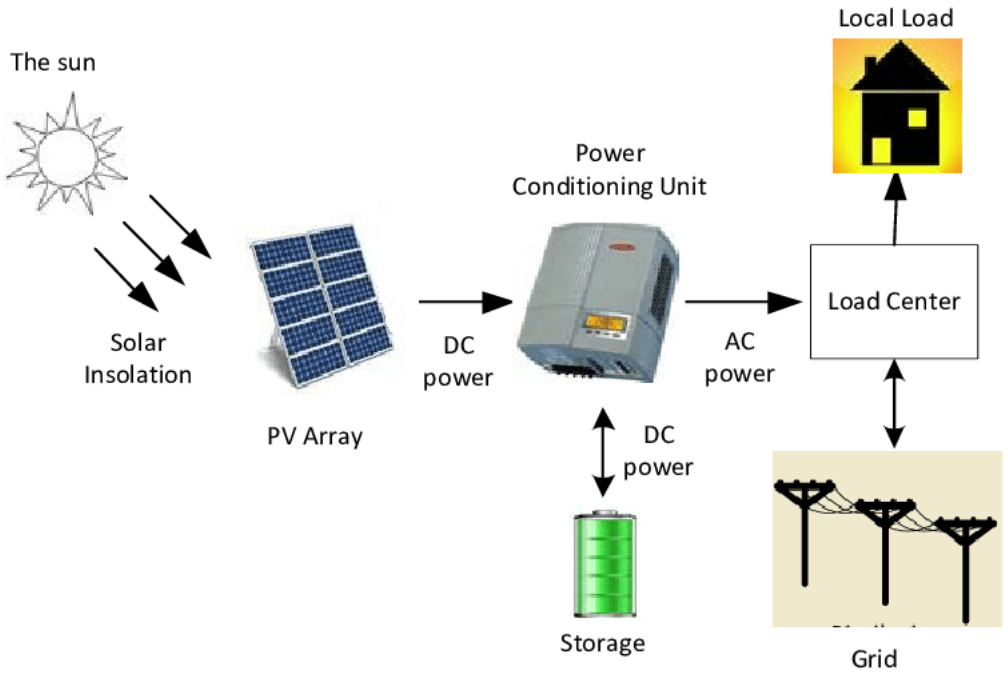


Fig. 2.4.3: Solar Power Plant

Ghana has been making efforts to harness solar power. Solar energy is mostly used in off-grid and distributed systems, such as solar home systems and solar lanterns, to provide electricity to rural areas without access to the national grid.

2. Biomass:

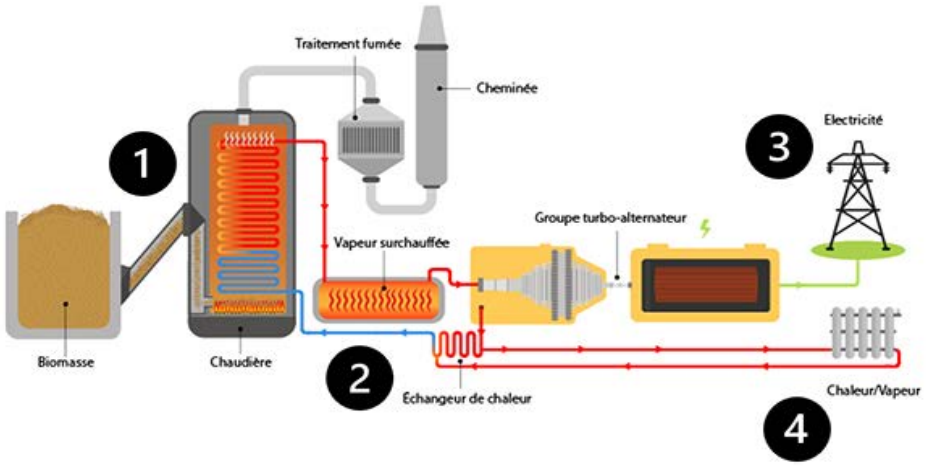


Fig. 2.4.4: Biomass Generation Station

Biomass is another renewable energy source used for electricity generation in Ghana. It involves the combustion of organic materials such as agricultural residues, wood, and palm kernel shells. The Kwame Nkrumah University of Science and Technology (KNUST) has a biomass power plant that produces electricity from cocoa pod husks.

3. **Waste-to-Energy:**

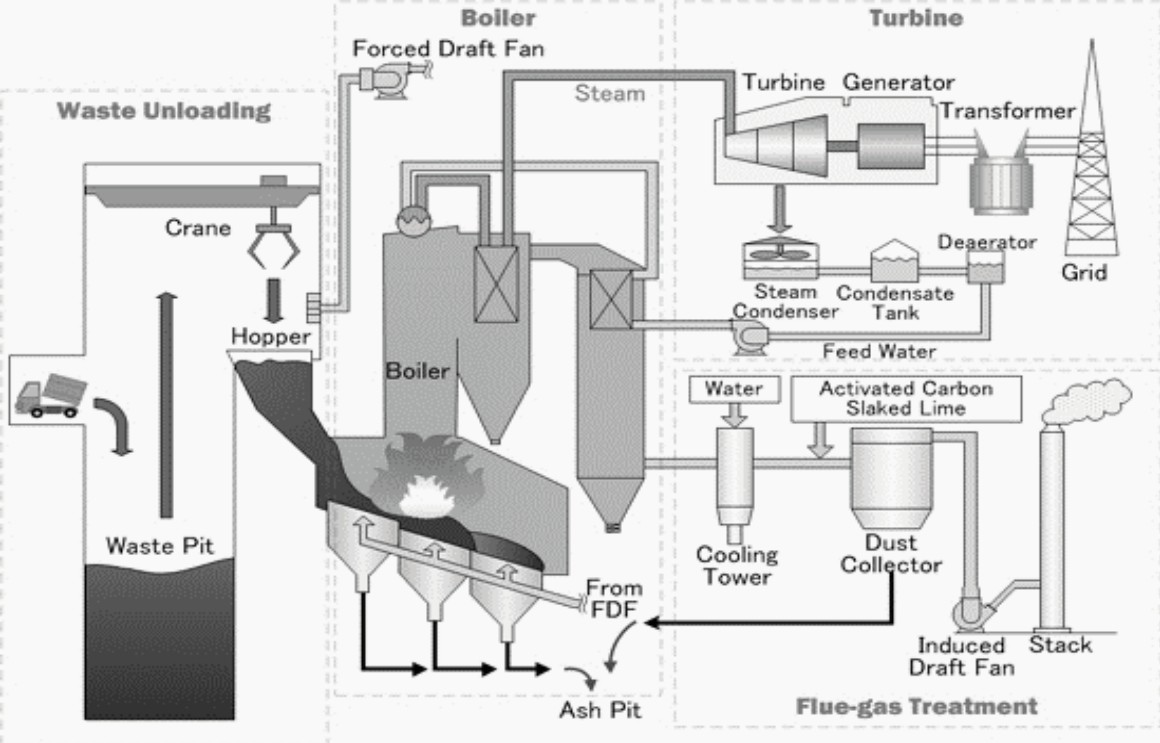


Fig 2.4.5: Waste Energy Generation Station

Ghana is exploring waste-to-energy technologies to generate electricity from municipal solid waste. The Accra Compost and Recycling Plant is an example where organic waste is converted into biogas, which is then used to generate electricity.

Pause and Discuss: Look at each of the energy generation types and discuss as a group which ones are more efficient at producing electricity and which ones are more environmentally friendly. Are they both the same? Which ones do you think are more damaging to the environment and why?

ELECTRICITY TRANSMISSION IN GHANA

In Ghana, the Ghana Grid Company Limited (GRIDCo), which operates and maintains the national transmission grid, supervises electricity transmission.

The system by which electric power is conveyed from a generating station to the consumers premises is divided into two diverse parts

a. Transmission
b. Distribution.

The bulk transfer of electric power from the generating station to power sub-stations near the consumers is called **power transmission**.

Electricity Transmission

The transmission voltages in Ghana are typically categorised into three levels. These are:

1. **High-voltage Transmission (400 kV and 330 kV):**

Fig 2.4.6: High-voltage Transmission Line (33 kV)

The highest voltage level used in Ghana's transmission system is 400 kilovolts (kV), although some sections operate at 330 kV. This voltage level is employed for long-distance transmission of electricity over major power corridors.

2. **Medium Voltage Transmission (161 kV and 132 kV):**

Fig 2.4.7: Medium Voltage Transmission Line

Medium voltage transmission in Ghana operates at 161 kilovolts (kV) and 132 kilovolts (kV). It is used to distribute electricity from major substations to regional or local distribution networks.

3. **Low-voltage Transmission (33 kV and 11 kV):**

Fig 2.4.8: Low-voltage Transmission Line

Involves the delivery of electricity from distribution substations to industrial, commercial, and residential areas. It is important to note that these voltage levels can vary depending on specific projects, locations, and system requirements.

NOTE: The tall steel structures / towers known as **pylons** are used to support the main overhead transmission power lines.

Fig 2.4.9: Pylon

Why power transmission is done on high voltage and low current:

Transmission of electrical power is normally done using high-voltages and low currents for several reasons which include:

1. Reduced power losses
2. Increased efficiency
3. Voltage regulation
4. Cost-effectiveness (considering weight, size and cost of transmission lines)
5. Flexibility and interconnection

ELECTRIC POWER DISTRIBUTION IN GHANA

Electric power distribution is the final stage in the delivery of electricity. Electricity is carried from the transmission system to individual consumers by the Electricity Company of Ghana (ECG) for the southern sector and the Northern Electricity Distribution Company (NEDCo) for the northern sector.

Electric Power Distribution

In Ghana, the power distribution voltage levels are standardised and regulated by the Energy Commission and the Public Utilities Regulatory Commission (PURC). The primary distribution voltage levels used in Ghana's electrical power system are as follows:

1. **High-voltage Distribution (HV):**

The high-voltage level in Ghana refers to voltages above 33kV. These voltages are primarily used for long-distance transmission of electricity from power generation plants to primary substations. High-voltage transmission lines are designed to minimise power losses during transmission over extended distances.

Fig 2.4.10: High-voltage Distribution Substation)

2. **Medium distribution network:**

The medium voltage level in Ghana is typically categorised as voltages between 11kV and 33kV. This level is used for distributing power from the primary substations to secondary substations, industrial areas, and larger commercial establishments. The medium voltage distribution system plays a crucial role in supplying power to the bulk of consumers and supporting the overall power infrastructure.

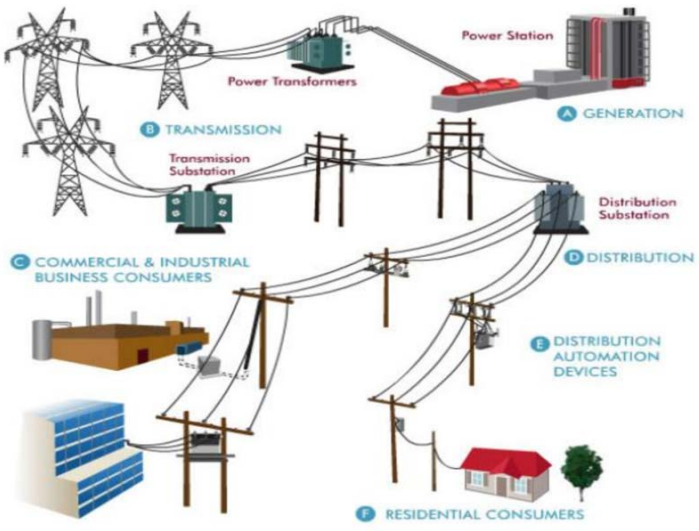


Fig 2.4.11: Medium Distribution Network

3. **Low-voltage Distribution (Low-voltage):**

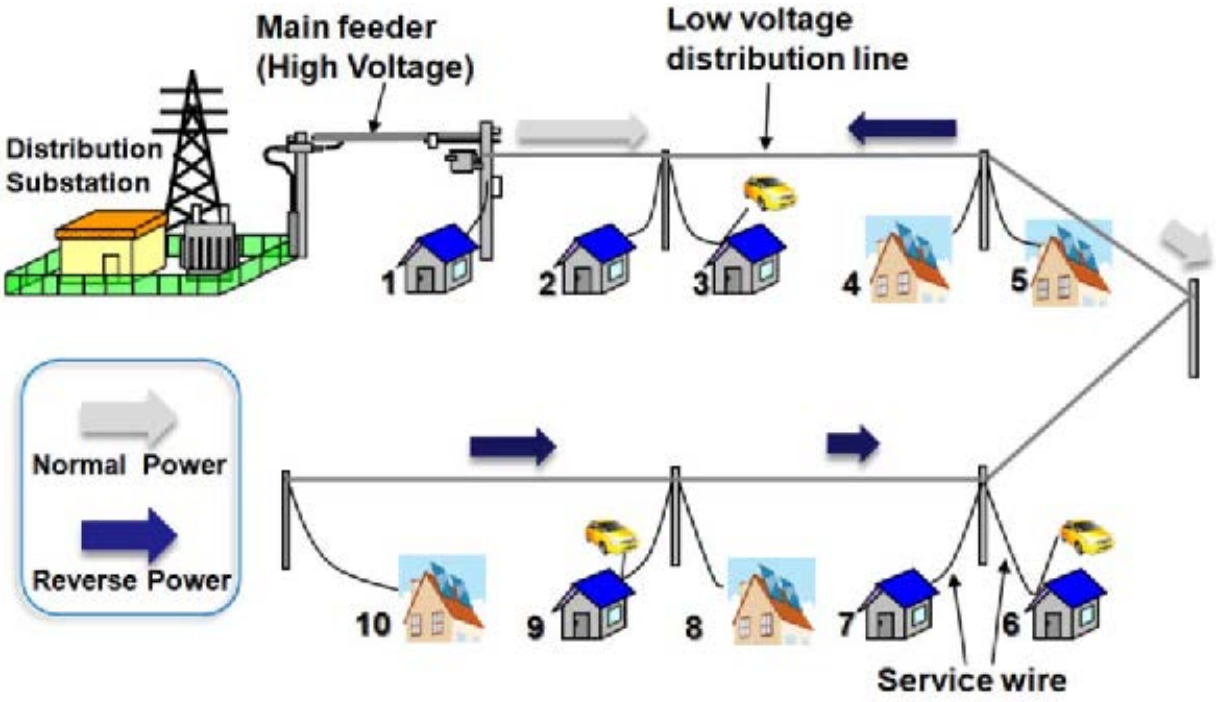


Fig 2.4.12: Low-voltage Distribution Network

The low-voltage level in Ghana is typically defined as a voltage of 415/240V in a three-phase system and 240V in a single-phase system. This level is commonly used for supplying power to residential buildings, small commercial establishments, and small-scale industrial units. The low-voltage level is suitable for powering lighting, household appliances, and other low-power devices.

NOTE: specific voltage levels may vary depending on the region, the capacity of the distribution infrastructure, and the type of consumer being served.

4. **The Distribution Sub-station:**

A sub-station is a collection of electric equipment intended to transform and distribute electric power. A power sub-station is an assembly of electric equipment that transform / step-down and distribute electric power. The system consists of an extensive inter-connected network of power stations, sub-stations and transmission networks supplying electric power to the whole country.

The sub-stations serve to:

a. receive the high voltage electric power generated by power stations,
b. step-down or step-up power received from the generating station,
c. transmit electric power from one area to another,
d. distribute electricity at the various voltage ratings required to
e. industrial, commercial and domestic consumers.

5. **Incoming Power lines:**

Substations receive power from transmission lines, which carry high voltage electricity from the power generation plants or other transmission substations.

Fig 2.4.13: Power lines to a Substation

6. **Circuit Breakers and Disconnect Switches:** Circuit breakers are protective devices with a making and breaking capacity. They have superior isolating properties and indication of switch position. Circuit breakers can interrupt the flow of electricity, when necessary, disconnect switches provide a means to isolate specific sections of the substation for maintenance or repairs.

Fig 2.4.14: Circuit Breakers and Disconnect Switches

7. **Power Transformers:** The power transformer steps-up or steps-down voltage to the required level needed to be supplied to consumers. They are typically oil-filled and use electromagnetic induction to transfer power from one voltage to another.

Fig 2.4.15: Power Transformer

8. Busbars: Busbars are conductive bars or pipes that carry electric current within the substation. They act as the main distribution point for power within the substation, allowing for the interconnection of various components such as transformers, circuit breakers, and other devices.

Fig 2.4.16: Busbars in a Substation

9. **Switchgear:** An important component of a sub-station includes the switchgear. A switchgear unit includes circuit breakers, disconnecting or isolating switches, high voltage fuse. It controls and isolates the electric equipment within the substation.

Fig 2.4.17: Switchgear in a Substation

10. **Distribution Feeders:** These are outgoing power lines that distribute electricity from the substation to consumers. Distribution feeders typically operate at lower-voltages and branch out to various neighbourhoods or areas, connecting to distribution transformers located closer to the end consumers.

Fig 2.4.18: Distribution Feeder in a Substation

11. **Distribution Transformers:** These transformers are located near the consumers and further step down the voltage to levels suitable for domestic or commercial use. They are responsible for supplying electricity to individual buildings or groups of consumers.

Fig 2.4.19: Distribution Transformers on a H pole

12. **Instrument transformers:** Instrument transformers are used to drop the voltage and current by known ratios so that standard instruments can be used for the measurement of voltage and current. This reduces the shock hazard, to instrument operators. The two kinds of instrument transformers are the potential (voltage) and current transformers.

13. **Monitoring and Control Systems:**

Power distribution substations are equipped with various monitoring and control systems to ensure safe and efficient operation. These systems include protection relays, meters, remote terminal units (RTUs), and supervisory control and data acquisition (SCADA) systems. They provide real-time monitoring, data collection, and remote control capabilities for the substation operators.

Fig 2.4.20: Monitoring and Control of a Power Distribution Substation

Activity 2.4.1

1. Alternating current is used in transmitting electric power over long distances. Clarify why alternating current is preferred to direct current in power transmission.
2. Visit the internet and search for answers to the following
   a. typical transmission voltages in Ghana
   b. distribution voltages and the application of each voltage rating.
   c. advantages and disadvantages of high –voltage transmission.

Hints for activity

1. identify at least two methods of power generation that produce
   a. direct current (d.c)
   b. alternating current (a.c)
2. What type of current electricity is used to operate electronic portable devices such as mobile phones and laptops. Which type of current electricity is used to operate household devices such as blender, refrigerator and pressing iron?
3. The laptop and the mobile phone are connected to the power source through a charger, what is the function of the charger connected to the laptop?
4. Which type of electricity is fed to the mobile phone from the charger? Why is the voltage low?
5. Why is the voltage supplied to the pressing iron and refrigerator high?
6. Draw a conclusion on the levels of voltage supplied to the mobile phone and the refrigerator.

7. Comparing the transmitting voltage to the voltage supplied to the refrigerator, which one is higher?

3. The high transmitting voltage was changed to a low voltage and supplied to the refrigerator by a process referred to as stepping down.
   a. Explain why; generation of alternating current is simpler
   b. alternating current simplifies stepping up or stepping down of voltage to suit a particular requirement
   c. it is easier to convert alternating current to direct current and cater for a wide application of direct current (d.c)

Distribution of electric power from service line to the local area

The final stage of the supply of electricity to the local / domestic consumer is referred to as distribution. A power sub-station is an assembly of electric equipment that transforms / step-down and distribute electric power. The system consists of an extensive interconnected network of power step down, sub-stations and transmission networks supplying electric power to the whole country. At this point, the local sub-stations reduce the incoming voltage (for example, from 11 KV to 415/240 V, for small-scale industrial, commercial and domestic consumers) to the rating required for supply to the local consumers. Concrete and seasoned wooden service poles are used to support the distribution power lines. The methods by which electric power is distributed to homes is by:

1. **Single-phase two wire:** Single-Phase 240 V alternating current generally, will suffice for lamps, heating devices, refrigerators, blenders, fans, etc.

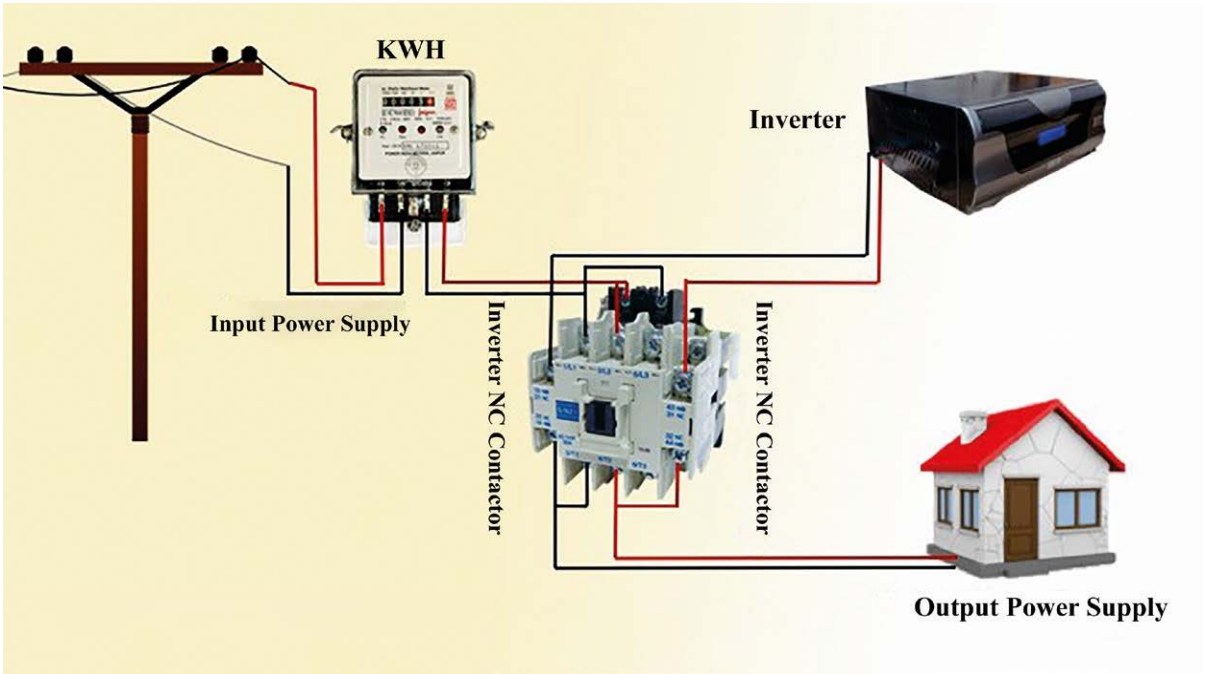


Fig 2.4.21: Single-phase distribution line

2. **Three- phase four wire (3-phase,4-wire):** For small-scale industrial and commercial consumers however, where large quantity of electric power is consumed, 3-phase,415 V arrangement is implemented.

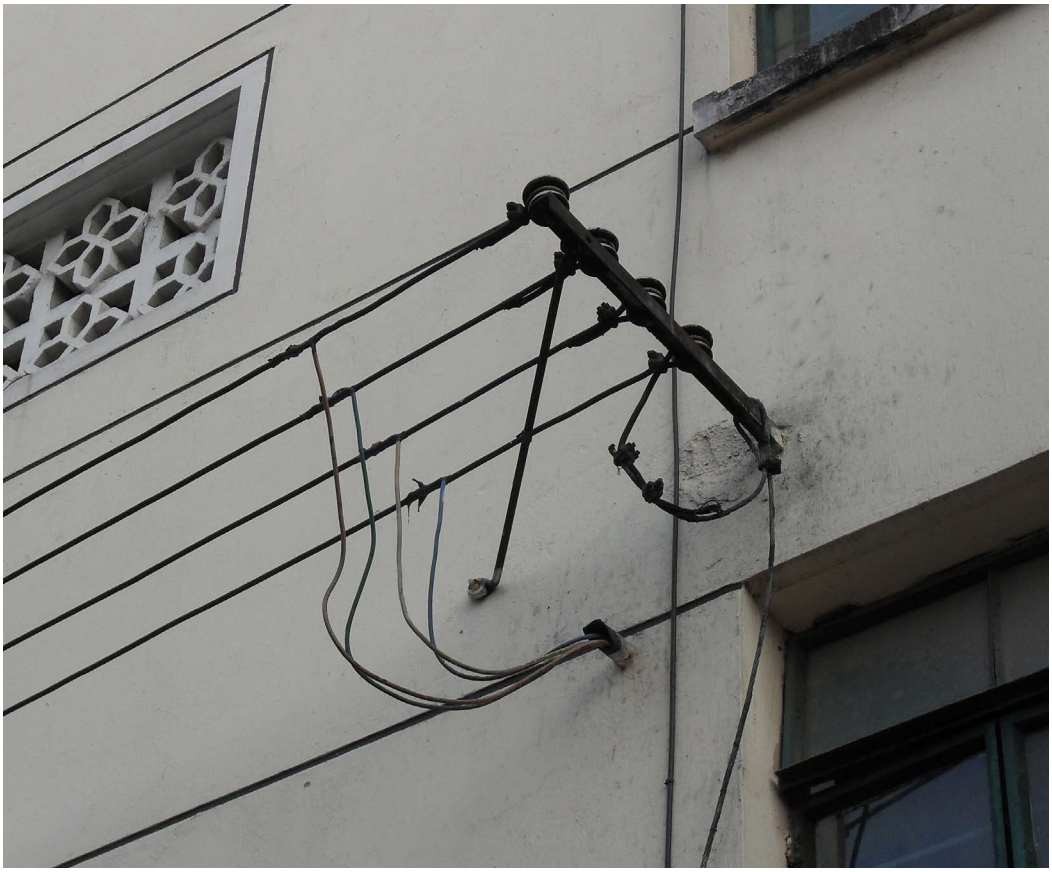


Fig 2.4.22: Three-phase distribution line

The Fig 2.4.13 below is a characteristic distribution sub-station showing various components.

Fig 2.4.23: Electric power flow through Distribution Substation

Activity 2.4.2

1. Describe the process of power distribution from sub-stations to industrial and domestic consumers.

Hint

a. Where is the electric power terminated from the transmission line?

b. State three functions of an electric power sub-station.

c. Which function of the sub-station is being implemented in this context?

d. Between industrial and domestic consumers, which of the two needs a high power supply?

Identify the method of distribution used to supply

a. industrial consumers

b. domestic consumers

c. commercial consumers

2. Embark on a field trip to ECG or NEDCo sub-station. Observe, question and present a report on the following;

a. the layout of the sub-station

b. Sub-station equipment, including switchgear, isolator, main switch and instrument transformers busbars and feeders.

c. Distribution system, 3-phase,3-wire, 3-phase -4-wire 415 / 240 V, single-phase arrangements.

d. the monitoring and control system

Review Questions Section 2 Unit 4

1. State the companies responsible for power transmission and distribution in Ghana.
2. What are the differences and similarities between power transmission and distribution sub-stations?
3. Describe the major challenges faced during the transmission of electric power over long distances.
4. Justify the preference of high voltage, low current method in power transmission.
5. Electricity is generated from conventional or mainstream sources.
   a. Identify at least two methods of generating electric power in Ghana.
   b. Outline how the thermal power plant works and list the key components in the thermal power plant.

      Consider the following in answering question 5b:

      i. List the fuels used in the thermal plant.
      ii. How are the fuels processed to produce heat energy.
      iii. What is the driving force used in turning the turbine.
      iv. How is the steam produced?
      v. Describe how the steam turbine is used to drive the generator to produce electricity.
      vi. State the principle on which the generator operates.
      vii. What type of current electricity is produced by the generator?
      viii. Identify the energy change that occurs in the generator.
      ix. List the key components of the thermal power plant.

References

Evans C. Sraha (2016), Applied Electricity & Electronics for SHTS

B. L Theraja, A. K Theraja (2002) Electrical Technology, Basic Electrical Engineering Vol. I, New Delhi: S. Chand &company Ltd. https://d10lpgp6xz60nq.cloudfront.net/physics_images/NVT_SCI_TECH_DIG_X_P2_C05_E12_013_S01.png

https://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/media/Coal_fired_power_plant_diagram.png?width=500

https://www.eia.gov/energyexplained/biomass/images/wastetoenergy.png

https://www.nationalgrid.com/sites/default/files/styles/content_embedded_image/public/images/EnergyExplained_WhatIsSubstation_640x360_0.jpg?itok=enSbReTI

https://www.osha.gov/sites/default/files/inline-images/substation_energy_flow.jpg

UNIT 5

METAL TECHNOLOGY

Engineering Materials, Tools and Machines

INTRODUCTION

When the earth was formed, the molten mass contained the many different metals which today we extract and use in huge quantities. The materials generally used in metal workshop include ferrous, non-ferrous metals and plastics. The most important metals are those of the ferrous group: that is, those that contain iron and non-metallic materials (plastics). Their selection and uses depend largely on their properties.

This unit covers the properties and uses of ferrous and non-ferrous metals as well as non-metallic materials (plastics). Research has shown that about 98% of packages used in our industries, homes and schools are made of plastics.

This unit highlights some examples of ferrous metals such as cast iron, wrought iron, low carbon steel, mild steel, medium carbon steel, high carbon steel and stainless steel. It further discusses non-ferrous metals such as aluminium, copper, lead, tin and non-ferrous alloys such as soft solder, brass, and bronze. Attention has also been given to the properties and uses of non-metallic materials (plastics), mainly thermoplastics and thermosetting plastics.

At the end of this unit, you should be able to:

- Explain ferrous and non-ferrous metals with engineering applications and state the uses of non-metallic materials

Key Ideas

- The properties or characteristics of metals are quoted by manufacturers to assist designers and engineers to select appropriate metals for use.
- Anyone involved in designing and making needs to know what materials are available, how these materials behave, and how to use them.
- When selecting a material for a particular product, the first question you need to ask is what materials are available for the product? It is essential to choose a material with the appropriate properties.
- To do this you need to study the properties or characteristics and uses of metals to be able to make a suitable selection of metals for designing and making of artefacts.

Keywords: Ferrous metals, non-ferrous metals, cast iron, wrought iron, copper, aluminium, tin, zinc, ductility, brittleness, colour, conductivity, malleability, fusibility, toughness, elasticity, tenacity, magnetism, thermosetting plastics, Phenol formaldehyde, Bakelite, Urea formaldehyde, Melamine resin, Polypropylene, Polyvinyl chloride, nylon.

FERROUS METALS

What are ferrous metals?

Ferrous metals refer to any metal that contains iron. The presence of iron causes the metals to rust. They have many uses in engineering and construction. They are used in shipping containers, industrial piping, cars, railroad tracks, domestic tools, etc.

Table 2.5.1: Showing some specific ferrous metals, their properties, their uses and pictures of some products.

S/N	Ferrous metal	Carbon content (%)	Properties	Uses	Pictures of Some Products
1	Mild steel	0.25-0.3	Machines readily. It can be cast, forged and welded. It corrodes in the atmosphere. Melting point is between 1371-1450 degrees Celsius.	Agricultural tools, ironmongery (door hinges, tower bolts), screws, hinges, bolts and nuts, nails, washers, bicycle frame, builders scaffolding, wheelbarrow, car bodies, oil drum, storage unit, food cans.	 Agricultural tools  Wheel barrow  Bolts and nuts  Hinges
2	Wrought iron	Less than 0.10%	It is the purest of all ferrous metals, containing almost 99.9 percent iron. It is strong, tough and easy to machine. It resists corrosion and can withstand shock. Meling point is 1482 degrees Celsius.	Anvils, swage block, crane hooks and chains, rails and railway couplings, haulage gear, and shackles	 Anvil  Shackles  Swage block
3	Cast iron (types: grey cast iron, white cast iron and Malleable cast iron)	2.4-4.0	It is the hardest and more brittle than steel and these qualities making it difficult to bend or forge. Melting point is 1204 degrees Celsius.	Centre lathe bed, engineers vice. Anchor for ships, engine blocks, casting machines, bodies of horticultural and agricultural implements.	  Engineers' vice Anchor

NON-FERROUS METALS

What are non-ferrous metals:

Non-ferrous metals refer to any metal that does not contain iron. They, therefore, do not rust.

Table 2.5.2: Showing some non-ferrous metals, their properties and uses

S/N	Non-ferrous metal	Properties	Uses	Picture of product
1	Copper	Reddish-brown in colour, malleable, and ductile. It is a good conductor of heat and electricity. Melting point is 1085 degrees Celsius.	Electrical cables, soldering bits or soldering iron, alloying with other metals (copper and tin – bronze, copper and zinc – brass), refrigerator pipes linings.	 Soldering iron  Electrical cable
2	Aluminium	Light in weight, a good conductor of heat and electricity. Malleable and ductile but hardens as it is worked. Melting point is 660 degrees Celsius	Manufacture of aeroplane bodies, cooking utensils, electric cables, refrigerators, window frames.	 Cooking utensils  Window fame  Electric wires
3	Zinc	Brittle, ductile, malleable when heated, lustrous bluish-white appearance, low melting point at 419.5 degrees Celsius	Used to galvanise other metals such as iron to prevent rusting. It is used for car bodies, street light post, safety barriers and suspension bridges.	 Galvanised sheet
4	Tin	Tin is a soft, pliable, silvery-white metal. It is not easily oxidized and resists corrosion because it is protected by an oxide film. It melts at 232 degrees Celsius.	It takes a high polish and is used to coat other metals to prevent corrosion, such as in tin cans which are made of tin-coated steel. It is used for making soft solder.	 Tin containers for measuring food ingredients

PROPERTIES/CHARACTERISTICS OF MATERIALS (METALS)

Different materials behave in different ways when they are in use and being worked. The features of any material make it different from the others and it is these characteristics or properties which make the material more suitable for a particular use than another. Characteristics, then, are the specific features of any material that could be used to describe it.

Table 2.5.3: Showing characteristics or properties of materials (metals) grouped under physical and mechanical

Physical	Mechanical
Colour	Brittleness
Conductivity	Ductility
Elasticity	Fusibility
Tenacity	Malleability
Magnetism	Toughness
	Hardness

Table 2.5.4: Showing the explanations of characteristics or properties of materials (metals)

S/N	Property	Description
1	Hardness	The ability of the metal to resist scratching and wear. e.g. cast iron.
2	Ductility	The ability of a metal to be stretched cold without breaking. It is an essential property for wire and tube drawing. e.g. copper and aluminium.
3	Brittleness	This is the ability of the metal to break easily without bending. e.g. cast iron.
4	Colour	This is the appearance of a metal which helps in identifying it. The colour enhances the appearance when polished. It is useful in decorative work such as beaten metalwork and jewellery. e.g. copper: - brownish pink in colour, gold: - yellow.
5	Conductivity	The ability of the metal to allow heat and electricity to flow through it. This makes the metal a good conductor. e.g. copper and aluminium.
6	Malleability	The ability of a metal to be hammered, rolled or bent without breaking. e.g. Forging a hoe using mild steel or wrought iron.
7	Fusibility	The property of a metal becoming liquid when heated and combine with other metals to form alloys. It is important when considering metals for casting. e.g. lead and tin melt at temperature as low as 160oF (70oC) making them useful in various safety devices.

S/N	Property	Description
8	Toughness	This is the ability of a metal to withstand shock without breaking. e.g. an anvil.
9	Elasticity	The ability of the metal to return to its original shape or size after being stretched, compressed or deformed. e.g. stainless steel for making springs.
10	Tenacity	The ability of a metal to resist a direct pull without rupturing. This describes the tensile strength of metals. e.g. mild steel, wrought iron are some examples of tenacious metals.
11	Magnetism	The ability of a metal to be attracted by magnets. e.g. iron, cobalt, nickel, steel.

TYPES OF PLASTIC (NON-METALLIC MATERIALS)

What are plastic materials?

Plastic materials are materials consisting of a wide range of synthetic or semi-synthetic organic components that are malleable and therefore, can be moulded into solid objects. Plasticity is the general property of all materials that involves permanent deformation without breaking.

Thermosetting plastics are plastics that when heated and moulded cannot be reheated and remoulded back to their original shape.

Table 2.5.5: Showing examples of thermosetting plastics and their properties and uses.

S/N	Examples of thermosetting plastics	Properties	Uses	Pictures of products
1	Phenol formaldehyde (Bakelite)	Hard and brittle, natural dark, glossy colour, resist heat without softening, good thermal insulator, good electrical insulator.	Switches, sockets, soldering iron handle, saucepan handle, toilet seat, cistern, cooker knob.	 Toilet seat  Socket and plug  Switch

S/N	Examples of thermosetting plastics	Properties	Uses	Pictures of products
2	Urea formaldehyde	Colourless, harder than Bakelite, no taste, no odour, good thermal and electrical insulator, can be coloured.	Adhesive for particle board, fibre-glass mats, electric iron handles, electrical fittings, drawer handle, bottle top, door handle.	 Bottle tops  plastic drawer handle  Electric iron handle
3	Melamine resin (formaldehyde)	Heat resistant, harder than bakelite, can be coloured.	Used as additives in the manufacture of paints, papers and flame-resistant textiles, unbreakable tableware, handles, laminating kitchen worktops and cheese pieces.	 Kitchen worktop  textiles

Thermoplastics are plastics that can be reheated and reshaped in various ways.

Table 2.5.6: Showing examples of thermoplastics, their properties and uses

S/N	Example of thermoplastic	Properties	Uses	Pictures of products
1	Polypropylene	Tougher and more rigid than high density polythene, greater resistance to heat, lowest density but of high impact strength, softens at around 150°C.	Used for packaging trash, grocery bags, wire and cable insulation, squeeze bottle, toys and houseware, cotton reel, chair, cutlery, helmet, baby walker.	 Squeeze bottle  Helmets
2	Polyvinyl chloride (PVC)	Stiff and hardwearing, soft and pliable	Water service pipes, cable and wire insulation, automotive interiors and seat coverings, suitcase, garden hose pipe, waterproof jacket, electrical cable insulation.	 Garden hose pipe  PVC pipes  Suit cases

S/N	Example of thermoplastic	Properties	Uses	Pictures of products
3.	Nylon	Fairly hard material, good resistance to wear, high resistance to chemical attack, high melting point.	Used for screws, bolts, washers, nuts and circuit boards, clothing, carpet, brushes. Solid nylon for engineering purposes e.g. Gears and bearings, comb and brush, toothbrush bristles, gearwheel.	 Comb  Carpet  Toothbrush bristles

Conclusions

This unit covered ferrous metals and non-ferrous metals with their engineering applications and uses of non-metallic materials. They are essential for you to learn the engineering materials in metal work to create detailed and intricate metalwork projects. The lesson has equipped you with the knowledge and types of ferrous and non-ferrous metals along with their engineering applications and uses of non-metallic materials (plastics). Examples are given for you to recognise and identify. A given workshop project is undertaken to appreciate and practice the use of the various engineering materials.

Activity 2.5.1

1. You have been assigned in groups to prepare a Chart for learning the topic 'Properties and Uses of Ferrous and non-ferrous metals.'

   a. Using the table below as a guide, prepare the chart by copying and completing the table below:

S/N	Metal	Three Properties of each metal	Two Uses of each metal	Pictures/sketches of the products
1	Mild steel			
2	Wrought iron			
3	Cast iron			
4	Copper			
5	Aluminium			
6	Tin			
7	Zinc			

   b. Display your chart for appraisal in class in groups.

   c. Write an appraisal report in groups by stating the strengths, weaknesses and modifications of the chart and discuss in class.

Activity 2.5.2

1. It is essential to understand the properties of metals as the selection of metals for production largely depends on the properties.

   a. Using ICT tools, find out more about engineering applications of ferrous metals, non-ferrous metals and non-metallic materials (plastic).

   b. Use the table below as a guide to arrange your findings in it.

S/N	Material	Five of each of Engineering Applications
1	Ferrous metals	1. 2. 3. 4. 5.
2	Non-ferrous metals	1. 2. 3. 4. 5.
3	Plastics	1. 2. 3. 4. 5.

   c. Display your work for appraisal in class in groups.

   d. Prepare an appraisal report by stating the strengths, weaknesses and recommendations to improve your work.

Activity 2.5.3

1. Using ICT tools, find out more about advantages and disadvantages of ferrous metals, non-ferrous metals and non-metallic materials (plastics)
2. Type your information gathered on the computer/tablet in groups.
3. Display your work for appraisal in groups.
4. Write an appraisal report stating the strengths, weaknesses and recommendations.
5. Identify and list all the websites you visited to gather your information.

Activity 2.5.4

1. Using your tablet or laptop, prepare a chart for learning the topic 'difference between ferrous and non-ferrous metals.
2. List all the websites you visited for your information.
3. Display your chart for appraisal in class in groups.
4. Prepare your appraisal report indicating strengths, weaknesses and recommendations.

Activity 2.5.5

The selection of metals for designing and making of artefacts depends largely on their properties. You therefore expected to have adequate knowledge in the properties and uses of metals.

1. Using ICT tools find out more about the uses of aluminium, wrought iron and mild steel.
2. Search for reasons why properties of metals make them suitable for making artefacts
3. List all the websites visited for gathering the information for (ai and aii) above.

Activity 2.5.6

Group Project Work to Last for Three Weeks

1. Gather as many as non-functional empty containers or products made from metals and non-metallic materials (plastics).
2. Classify the products into ferrous metals, non-ferrous metals and non-metallic materials (plastics).
3. Label the ferrous products as mild steel, wrought iron and cast iron.
4. Label the non-ferrous products as copper, aluminium, zinc and tin.
5. Label the thermoplastic products as polypropylene, polyvinyl chloride and nylon.
6. Label the thermosetting plastic products as phenol formaldehyde (Bakelite), Urea formaldehyde and melamine resin (formaldehyde).
7. Present your work for appraisal in class in groups.
8. Write a group report indicating the strengths, weaknesses and recommendation for improvement of the project.

Review Questions Section 2, Unit 5

1. Most of the materials used for making engineering artefacts are of ferrous and nonferrous in nature.
   a. Outline the main difference between ferrous and non-ferrous metals.
   b. List two examples of each of ferrous and non-ferrous metals
   c. Sketch two products of each of ferrous and non-ferrous metals
2. Metals are used for making different products based on their properties.
   a. Write two uses of each of the following metals:
      i. Aluminium
      ii. Wrought iron
      iii. Mild steel
   b. Clarify two reasons why each of the properties of the materials in (q2ai, ii, and iii) made it suitable for use.
3. Different engineering materials behave in different ways when they are in use and being worked. The features of any material make it different from the others and it is these characteristics or properties which make the material more suitable for a particular use than another. Describe five engineering applications for each of the following metals:
   a. ferrous metals
   b. non-ferrous metals
   c. non-metallic materials (plastics)

References

Addo, J etal (2008). Basic Design and Technology for Junior High School, Unimax/Macmillan Ltd, Accra-North, Ghana.

Aidoo F, etal (2007). Innovative Basic Design and Technology for Junior High Schools. Sedco Publishing Ltd, Accra, Ghana.

Amoakohene, S. K., & Sackey, J. K. N. (2007). Metalwork Technology (Motivate series). Macmillan Education.

Fowler, P. & Hershey, M. (1998). Craft, Design and Technology. Glasgow, Harper Collins.

Garatt, J. (1994). Design & Technology. Oxford, Cambridge University Press.

Love, G. (1980). The Theory & Practice of Metalwork: London & Edinburgh, Longman.

Timings, R. L. (1991). Mechanical Engineering Craft Theory & Related Subjects: Vol 1&2, Singapore, Longman-Singapore.

Acknowledgements

Ghana Education Service (GES)

List of Contributors

Name	Institution
Philip Kwesi Incoom	Metro Education Office, Cape Coast
Micheal Kobla Tsorgali	AAMUSTED, Kumasi
Tetteh Bruce	Koforidua SHTS
Frank Fabiaa Aidoo	Ga North M.E.O, Ofankor
Evans Charles Sraha	Ghana National College, Cape Coast