Module for Certificate in Education Programme

2nd Semester
April, 2023

IoE/MoF/TUC/GHANA CARES TRAINING AND RETRAINING PROGRAMME FOR PRIVATE SCHOOL TEACHERS

Ministry of Finance

Trade Union Congress

Institute of Education, UCC

EIN 056: GENERAL SCIENCE

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UNIT 1: CLASSIFICATION AND NAMING OF ORGANISMS

There are millions of living organisms in the world. Some of these organisms are related and others are not. Again, these organisms may be called differently by different people. There ought to be a system that will ensure that related organisms are grouped together and also produce a unified identification system so scientist everywhere can have a common name for organisms. This unit introduces participants to scientific classification of organisms. The unit will expose learners to the concept of classification, organization plan of classification, the binomial system of nomenclature and the characteristics/ Life processes of living things.

Learning outcome(s)

By the end of the unit, the participant will be able to:

- demonstrate understanding of the concept of classifying organisms outline the use of a hierarchical system for grouping organisms explain the binomial system of naming organisms.
- describe life processes of living things.

Session 1: Concept of biological classification

In this session, we will focus on the concept of classifying living things. The principle behind classification and the importance of classification will be discussed.

Learning outcomes

By the end of the session, the participant will be able to:

1. define classification of living things.
2. enumerate some importance of classifying living things.

In everyday life, we classify different items into groups on the basis of some shared features they have in common. This act is also done in the biological world by scientists. Biological classification can be defined as grouping living things according to their structural or physical similarities. Biological classification is also seen as the scientific procedure of arranging organisms into a hierarchical series of groups and sub-groups on the basis of their similarities.

A group of organisms is similar enough to be classified together by certain characteristics. Characteristics are the appearance/form and behaviour/function of something. These characteristics decide which organisms will be placed in a group. For example, a dog has limbs, but a snake does not. A dog and a snake can move, but plants cannot. These are the characteristics of different organisms. These features help scientist to classify them into different groups.

Importance of classification

Classifying organisms comes with lots of benefits. Some of the importance associated with classification of organisms are listed below:

- Classification helps us to make sense out of the overwhelming number different kinds of organisms.

- It helps scientists to identify new organisms by enabling them find what group an organism belongs to.
- It makes study of organisms easy
- Classifying organisms helps to understand the relationship, similarities, and differences between different organisms.
- Classification simplifies the understanding of the characteristics of organisms.

Session 1: Organization plan of classification

We have seen that scientists classify organisms based on the features expressed by the organisms. However, there may be organisms that may share some specific features while other organisms may share broad features. For instance, both cat and bird are animals but they differ extremely. To further ensure that more similar organisms are grouped together, scientists use a system like an organizational plan to identify organisms. In this session, we will discuss the organizational plan of biological classification.

Learning outcome(s)

By the end of the unit, the participant will be able to:

 demonstrate understanding of the hierarchical system of biological classification. outline the various taxonomic ranks

From the historical point, Aristotle classified different animals based on the habitat, characteristics, etc. This was an attempt to group organisms. Later, a Swedish botanist Carolus Linnaeus introduced a system where organisms can be ranked and put into groups. This created a sort of organogram for classifying organisms. This organizational plan for classifying organisms is known as the taxonomic hierarchy Categories. Thus, the hierarchical system of biological classification was born. This system of classification is followed globally till date.

Taxonomic hierarchy refers to the sequence of categories in increasing or decreasing order. In other words, taxonomic hierarchy is the process of arranging various organisms into successive levels of the biological classification either in a decreasing or an increasing order from kingdom to species and vice versa. This means that organisms are grouped based on broad features to the narrowest of features or vice versa.
Each of this level of the hierarchy is called the taxonomic category or rank. The word "Taxonomy" is derived from a Greek word – "taxis", meaning arrangement or division, and "nomos", meaning method. Taxonomy is a branch of Biology that refers to the process of classifying different living species. A taxon is referred to as a group of organisms classified as a unit. The taxonomic ranks into which organisms are classified are the kingdom, phylum, class, order, family, genus and species.

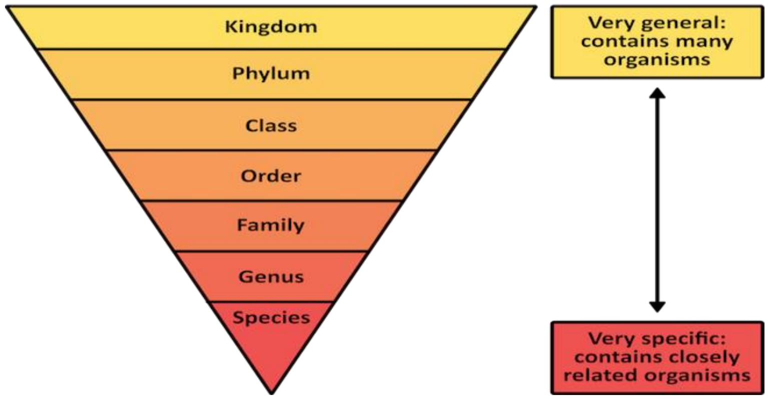


Figure 1: Hierarchical taxonomic arrangement

Kingdom

The kingdom is the highest level of classification, which is divided into subgroups at various levels. There are 5 kingdoms in which the living organisms are classified, namely, Animalia, Plantae, Fungi, Protista, and Monera (Prokaryotae) Organisms at the kingdom level will share very broad characteristics which may not be so similar. For instance, elephants and snakes belong to kingdom Animalia.

Phylum (plural, phyla)

This is the next level of classification and it is more specific than the kingdom. This means that organisms that belong to the same phylum will share more peculiar features than those that belong to different phylum. In the kingdoms Fungi and Plantae the equivalent term for Phylum is Division.

Class

The class ranks below the phylum. Members of a class share more characteristics with each other than they do with other organisms in the same phylum. Amphibians and reptiles both belong to the phylum chordata, but each belongs to a different class. Members of the class amphibia (chiefly frogs, toads, and salamanders) have moist, smooth skin and reproduce by laying large quantities of jellylike eggs in water. Members of the class reptilia (snakes, lizards, turtles, and tortoises) have dry scaly skin and reproduce by laying small clutches of leathery eggs on land.

ORDER

The order ranks below the class in the taxonomic hierarchy. The groups in an order have more in common with each other than they do with other members of the same class. This means that organisms in the same order resemble each other more than those within the same class. For example, bats and mice belong to the class (Class Mammalia) but bats belong to the Order Chiroptera and the mice the Order Rodentia.

FAMILY

In taxonomy, the family ranks below the order. Members of the same taxonomic family are more closely related to each other than they are to other members of the same order. For example, foxes, coyotes, lions, and cats, all belong to the Order Carnivora. However, foxes and coyotes belong to the family Canidae. Lions and cats belong to the family Felidae.

GENUS

The genus (plural, genera) is the taxonomic rank between family and species. The groups of organisms in a genus share many structural similarities and are very closely related. Members of a genus are more closely related to each other than they are to other genera in the same family. The cat family, Felidae, includes lions, tigers, domestic cats, and lynx. However, lions and tigers belong to the genus *Panthera*, and domestic cats are part of the genus *Felis*, and lynx are in the genus *Lynx*.

SPECIES

The species is the most fundamental unit in taxonomy and ranks at the base of the biological classification hierarchy. Members of the same species share the same evolutionary history and are more closely related to each other than they are to any other organisms, including other members of the same genus. Organisms are grouped into a species based on physical and genetic similarities. They have several common characteristics and resemble each other closely. All members of a species have the same number of chromosomes. A species is the group of organisms that share similar characteristic features and capable of breeding to produce fertile offspring. The most important factor in species classification is the ability of members to successfully interbreed—that is, to mate and produce viable offspring (those that can in turn breed and produce more offspring). Individuals of the same species can successfully interbreed with one another but almost never with members of other species. Different species within a genus have been known to produce hybrid offspring, but the offspring are almost always sterile. An example of this is the mating of a horse and a donkey, which produces a mule. Because mules are sterile, the interbreeding is not considered successful.

Session 3: The binomial system of nomenclature

Organisms can be found in different locations of the world. Each location may have their different language and dialects. For instance, in Ghana, different tribes have different names for dog. Multiple local names make it extremely difficult to identify an organism globally and keep a track of the number of species. Thus, it creates a lot of confusion. To get rid of this confusion, a standard protocol came up. According to it, each and every organism would have one scientific name which would be used by everyone to identify an organism. This process of standardized naming is called the Binomial Nomenclature. In this session, we are going to discuss the binomial system of nomenclature.

Learning outcome(s)

By the end of the unit, the participant will be able to:

- describe the binomial system of nomenclature.
- demonstrate understanding of how to write scientific name for organisms.

Binomial nomenclature is the biological system of naming organisms through the use of two names where, the first part indicates the genus and the second part indicates the species of the organism**.** The binomial nomenclature was proposed by Carolus Linnaeus (1707-1778). The binomial nomenclature is used to come up with a scientific name for a species . In this system each organism has two names which could be Latin (most often) or Greek. The two names are composed of a **generic name** (coming from the genus of the organism) beginning with a capital letter and the second which is the **species name** (coming from the species of the organism) beginning with a lower case. The system can commonly be likened to a general name and a specific name or family name/surname and first name of a person. When handwritten the two names are underlined separately e.g. Anopheles gambiae. If typewritten, they are put in italics (*Anopheles gambiae*) but not underlined.

Session 4: Characteristics/ Life processes of living things

The universe is made up of lots of different materials. There are microscopic particles that cannot be seen with the naked eye. Of those materials that can be seen, some do not have life while others are living. How can we distinguish between things that are living and those that are not? This session will take a critical look at processes expected to be seen in organisms that are living.

Learning outcome(s)

By the end of the unit, the participant will be able to:

outline the life processes of living things

- describe the life processes of living things
- distinguish between living and non-living things.

Life processes are series of actions that are essential to determine if an organism is alive. These processes are undertaken by all living things including plants and animals. They are necessary and essential for the survival of the organisms. Among many organisms, the inability to perform some of these life processes could be detrimental to the existence of the organism. These life processes are movement, respiration, sensitivity, growth, reproduction, excretion and nutrition. Let's discuss each of these processes.

Movement

All living things including plants move. Animals move to look for food and shelter, and to escape from danger. They have bodies that support the ability to move. Most animals can move their whole body from one place to another. This is known as locomotion. The movement in plants is mostly seen as bending, turning, twisting or elongation of parts of the plant. Plants movements are mostly towards sunlight, or roots growing into the soil.

Reproduction

Reproduction is a biological process by which organisms bring forth offspring that are biologically similar to the parent organism. Reproduction enables and ensures the continuity of species, generation after generation. It is the main feature of life on earth. Some organisms reproduce by giving birth to young ones, others lay eggs while in others parts of their bodies are used to produce young ones. Thus, reproduction can be sexual or asexual. Asexual reproduction refers to the type of reproduction in which only a single organism gives rise to a new individual while sexual reproduction involves the production of an offspring by the fusion of male and female gametes.

Sensitivity

All living things can respond to changes in their surroundings. Thus, they notice and react/respond to changes around them. Animals use their senses to see, hear, taste, touch and smell the world around them. Plants move towards sunlight and water and they also respond to touch.

Figure 2: Seedling moving towards light. Figure 3: Mimosa plant folding up due to touch

Growth

All living things grow. Thus, they become bigger, taller and heavier over time.
Animals grow from babies to adults and seeds grow into plants. Animals including human beings grow at a fairly steady pace until they reach adulthood. Every day as they get older their bodies are changing. Their skeleton grows with them, each bone getting bigger over time. Other animals such as insects, spiders, crabs and other animals with external skeletons – grow by shedding their skeleton and grow a new one! Plants also grow by increasing in height and width. Some plants grow from seeds (germination) to adult plants.

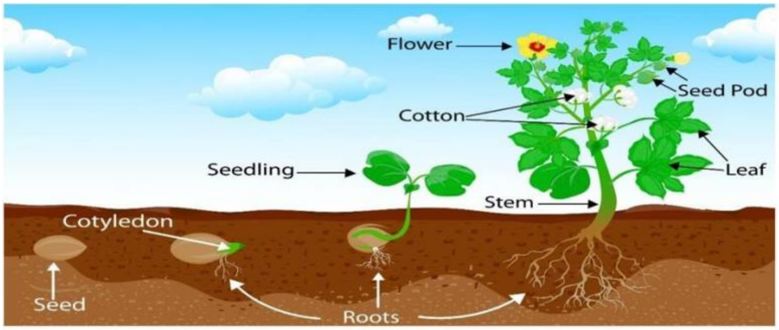


Figure 4: Process of plant growth

Respiration

All living things use oxygen in the air for survival. The oxygen helps the organism to break down nutrient to get energy. This process is described as respiration. Respiration is the process in which organisms exchange gases between their body cells and the environment to convert glucose to energy. Respiration is a chemical reaction and occurs in every cell in living things.

Excretion

All living things get rid of waste – like when humans sweat or urinate. Excretion is the process by which metabolic waste materials produced by the body are removed. In animals, excretion gets rid of carbon dioxide, water and other harmful substances from your body. Plants get rid of water, and wastes such as resins, saps, latex and tannins.

Nutrition

All living things require energy in order to survive. The energy is derived from nutrients, or food. This allows living things to grow and heal. Green plants, algae, and some bacteria can make their own food from water and carbon dioxide via a chemical reaction called photosynthesis. Photosynthesis relies on a chemical called chlorophyll, which helps to capture the light energy needed to convert water and carbon dioxide into glucose, a basic sugar that the organism can then use for respiration.

However, animals need to get their nutrients from external sources: either by eating plants, or other animals. Different types of animal have evolved to have very different diets, but there are three main groups:

Carnivores - exclusively eat meat

Herbivores - exclusively eat plants

Omnivores - eat both meat and plants

All living things undergo all these processes in order to survive. Thus, we are able to distinguish between living and non-living things based on the life processes. On your own, identify some differences between living and non-living things?

Key ideas

- Biological classification ensures that related organisms are grouped together and also produces a unified identification system so scientist everywhere can have a common name for organisms.
- Organisms have been grouped based on broad features to the narrowest.
- All living things are named by two names emanating from their genus and species.
- Living things have processes they all undergo in order to survive.

Reflection

- How do you organisms get their taxonomic names?
- How do life processes of organisms affect their habitat?

Discussion

- How will you distinguish living things from non-living things?
- Discuss the consequence of an organism will suffer if it fails to undergo a named life process.

UNIT 2: CELL

Complex structures are always made up of small parts that come together to make a complete whole. For instance, buildings are made up of blocks that come together make the whole edifice. This is how living things have been structured. This unit will discuss the organizational structure of living things starting from the cell, the cell theory and classification of cells, cell structure and organelles, functions of the organelles of a cell, differences that exist between plant and animal cells and cells in relation to tissues, organs, systems and organism. **Learning outcome(s)**

By the end of the unit, the participant will be able to:

- demonstrate understanding of the cell as basic unit of life.
- outline the cell theory.
- classify different types of cells.
- describe the structure of a cell.
- identify the functions of organelles of the cell.
- different between plant and animal cells.

The cell is a membrane-bound unit that contains the fundamental molecules of life and of which all living things are composed. In other words, cells are the basic building blocks of all living things. The human body is composed of trillions of cells. Cells provide structure for the body, take in nutrients from food, convert those nutrients into energy, and carry out specialized functions.

Session 1: The cell theory

Early prediction and speculation about the nature of the cell were generally unsuccessful. The decisive event that allowed the observation of cells was the invention of the microscope in the 16th century, after which interest in the "invisible" world was stimulated. Cell theory was not formulated for nearly 200 years after the introduction of microscopy. Explanations for this delay range from the poor quality of the microscopes to the persistence of ancient ideas concerning the definition of a fundamental living unit. Many observations of cells were made, but apparently none of the observers was able to assert forcefully that cells are the units of biological structure and function. Three critical discoveries made during the 1830s, when improved microscopes with suitable lenses, higher powers of magnification without aberration, and more satisfactory illumination became available, were decisive events in the early development of cell theory. In this session, we will briefly discuss the cell theory.

Learning outcomes

By the end of the session, the participant will be able to:

- outline the tenets of the cell theory.

The cell theory is a scientific theory that describes the properties of cells. In 1839 German physiologist Theodor Schwann and German botanist Matthias Schleiden promulgated that cells are the “elementary particles of organisms” in both plants and animals and recognized that some organisms are unicellular and others multicellular. This theory marked a great conceptual advance in biology and resulted in renewed attention to the living processes that go on in cells.
Essentially, the cell theory is the first three statements below but have been expanded to include some modern ones:

a. All living things are made up of cells and the products of cells such as scales
b. The cell is the structural and functional unit of all living things
c. All cells come from pre-existing cells by division-spontaneous generation does not occur
d. Cells contain hereditary material (DNA) which is passed from cell of the next generation during cell division
e. All cells are basically the same in chemical composition
f. All energy flow (metabolism and biochemistry) of life occurs within cells
g. The activity of an organism depends on the total activity of independent cells.

The cell theory holds true for all living things; no matter how big or small or how simple or complex.

Session 2: Types of cells

There are variety of organisms on earth. These organisms compose of cells. In this session, we will take a look at the types of cells.

Learning outcomes

By the end of the session, the participant will be able to:

- demonstrate understanding of the types of cell outline the characteristics of prokaryotic cells.
- enumerate the characteristics of eukaryotic cells
- identify differences between prokaryotic and eukaryotic cells.

Cells fall into one of two broad categories: prokaryotic and eukaryotic. The single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes (pro = before; karyon– = nucleus). Animal cells, plant cells, fungi, and protists are eukaryotes (eu = true). All cells share four common components:

1. plasma membrane-an outer covering that separates the cell’s interior from its surrounding environment
2. cytoplasm – consisting of a jelly-like cytosol within the cell in which there are other cellular components
3. DNA – the cell’s genetic material and
4. Ribosomes – which synthesize proteins.

However, prokaryotes differ from eukaryotic cells in several ways. Let’s discuss the two types of cells.

Prokaryotic cells

A prokaryotic cell is a simple, single-celled (unicellular) organism that lacks a nucleus, or any other membrane-bound organelle. Example of prokaryotic cell is bacteria. Organisms with prokaryotic cells are called **prokaryotes**. They were the first type of organisms to evolve and are still the most common organisms today. The cell size ranges from 0.1 to 0.5 µm in diameter. Prokaryotic DNA is found in the central part of the cell in a darkened region called the nucleoid.

Prokaryotes have a cell wall made of peptidoglycan, comprised of sugars and amino acids, and many have a polysaccharide capsule. The cell wall acts as an extra layer of protection, helps the cell maintain its shape, and prevents dehydration. The capsule enables the cell to attach to surfaces in its environment. Some prokaryotes have flagella, pili, or fimbriae. Flagella are used for locomotion, while most pili are used to exchange genetic material during a type of reproduction called conjugation. Conjugation is a process by which one bacterium transfers genetic material to another through direct contact. Bacteria use fimbriae to attach to a host cell.

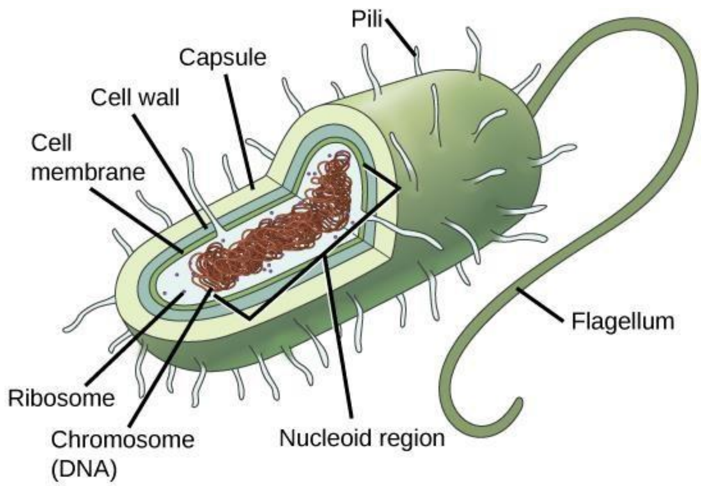


Figure 5: A generalized structure of a prokaryotic cell.

Eukaryotic cells

Eukaryotic cells can be found in animals, plants, protists, and fungi. Eukaryotes are organisms composed of eukaryotic cells. Eukaryotic cells are usually larger than prokaryotic cells, and they are found mainly in multicellular organisms.

Eukaryotic cells have a membrane-bound nucleus where their DNA is stored. Eukaryotic cells also contain other organelles besides the nucleus. An **organelle** is a structure within the cytoplasm that performs a specific or specialized job in the cell. Since organelles are membrane bound, each function occurs in a different compartment within the cell. The word eukaryotic means “true kernel” or “true nucleus,” alluding to the presence of the membrane-bound nucleus in these cells. The word “organelle” means “little organ”.

Session 3: Cell structure and organelles

Cells have many parts, each with a different function. As seen in the earlier session, organelles are structures within the cytoplasm that perform specialized tasks within the cell. In this section, we will discuss the various organelles found within a eukaryotic cell.

Learning outcomes

By the end of the session, the participant will be able to:

- describe the organelles of the cell
- enumerate functions of the organelles

Cell Structure

The cell structure comprises individual components with specific functions essential to carry out life's processes. These components include- cell membrane, cytoplasm, nucleus, and cell organelles.

Cell membrane

The cell membrane, or plasma membrane, is a selective permeable biological membrane that surrounds the cytoplasm of a cell. It is a selective membrane because it allows some materials to pass through while blocking or refusing to let other materials from entering through. In other words, its selects materials that can enter the cell.

This is mainly because of the sizes and polarity of molecules.

In animals, the plasma membrane is the outer boundary of the cell, while in plants and prokaryotes it is usually covered by a cell wall. This membrane serves to separate and protect a cell from its surrounding environment. The cell membrane supports and protects the cell. It controls the movement of substances in and out of the cells. It separates the cell from the external environment. The cell membrane is present in all the cells. The cell membrane is the outer covering of a cell within which all other organelles as well as the cytoplasm and nucleus are enclosed.

Cytoplasm

The organelles of a cell sit in a matrix called **cytoplasm**. The part of the cell referred to as cytoplasm is slightly different in eukaryotes and prokaryotes. In eukaryotic cells, which have a nucleus, the cytoplasm is everything between the plasma membrane and the nuclear envelope. In prokaryotes, which lack a nucleus, cytoplasm simply means everything found inside the plasma membrane.

One major component of the cytoplasm in both prokaryotes and eukaryotes is the gel-like **cytosol**. In eukaryotes, the cytoplasm contains the membrane-bound organelles, which are suspended in the cytosol. The cytoskeleton, a network of fibers that supports the cell and gives it shape, is also part of the cytoplasm and helps to organize cellular components.

Nucleus

The nucleus contains the hereditary material of the cell, the DNA. It sends signals to the cells to grow, mature, divide and die. The nuclear envelope is a double-membrane structure that constitutes the outermost portion of the nucleus. The nuclear envelope is punctuated with pores that control the passage of ions, molecules, and RNA between the nucleoplasm and cytoplasm. The nucleoplasm is the semi-solid fluid inside the nucleus, where we find the chromatin and the nucleolus. The nucleolus appears as a rounded darkly stained structure inside the nucleus

Cell organelles and their functions

Ribosomes

Ribosomes are the cellular structures responsible for protein synthesis. They are tiny organelles (20 nm in diameter) that are found in large numbers throughout the cytoplasm. Ribosomes are found in practically every cell because of their function of processing proteins. This makes them particularly abundant in cells that synthesize large amounts of protein. Ribosomes can be found either floating freely or bound to a membrane.

Endoplasmic reticulum

The endoplasmic reticulum (ER) is a series of interconnected membranous sacs and tubules. The ER is involved in the transportation of substances throughout the cell. The ER comes in two forms: the rough ER and the smooth ER.

The rough ER has ribosomes on its surface. The smooth ER on the other hand lacks ribosomes. Rough ER is concerned with the transport of proteins which are made by ribosomes on its surface. The smooth ER is involved in lipid synthesis.

Golgi apparatus/complex

The golgi apparatus consists of a stack of flattened, membrane-bound sacs called cisternae. There is a system of associated vesicles (small sacs) called Golgi vesicles. The function of the Golgi complex is to transport and chemically modify the materials contained within it. It is particularly important in secretory cells.

Mitochondria

Mitochondria (singular = mitochondrion) are often called the “powerhouses” or “energy factories” of a cell because they are site for production of energy. Cells with high energy requirements possess great number of mitochondria. Each mitochondrion is bounded by two membranes; the outer one being separated from the inner by a narrow space called the intermembranal space. The inner membrane is folded inwards into several shelf-like cristae. The cristae increase the surface, providing space for the components of the respiratory chain.

The Centrosome

The centrosome is a microtubule-organizing center found near the nuclei of animal cells. It contains a pair of centrioles, two structures that lie perpendicular to each other. Each centriole is a cylinder of nine triplets of microtubules. The centrosome (the organelle where all microtubules originate) replicates itself before a cell divides, and the centrioles appear to have some role in pulling the duplicated chromosomes to opposite ends of the dividing cell.

Lysosomes

Lysosomes protect the cell by engulfing the foreign bodies entering the cell and help in cell renewal. Therefore, they are known as the cell’s suicide bags.

Chloroplasts

Chloroplasts are plant cell organelles that carry out photosynthesis. Photosynthesis is the series of reactions that use carbon dioxide, water, and light energy to make glucose and oxygen. Chloroplasts have outer and inner membranes, but within the space enclosed by a chloroplast’s inner membrane is a set of interconnected and stacked fluid-filled membrane sacs called thylakoids. The chloroplasts contain a green pigment called chlorophyll, which captures the light energy that drives the reactions of photosynthesis

Vacuoles

Vacuoles are membrane-bound sacs that function in storage and transport. The membrane of a vacuole does not fuse with the membranes of other cellular components. Additionally, some agents such as enzymes within plant vacuoles break down macromolecules. Plant cells each have a large central vacuole that occupies most of the area of the cell

Session 4: Differences between plant and animals

In the previous session, we discussed the various organelles that can be found in a cell. During the discussion, it could be seen that specific mentions were made as to whether such organelles are found in animal or plant cell. In this session, we are going to briefly different between plant and animal cells**.**

Learning outcomes
By the end of the session, the participant will be able to:

- differentiate between plant and animal cells

Although both plant and animal cells are eukaryotic cells, there are some differences in terms of the organelles that are present or absent in them.

Animal cell	Plant cell
It does not have a cell wall. Has a cell wall composed of cellulose. Vacuoles are usually small and sometimes they Presence of a large vacuole are absent.	
Cilia is present in most animal cells	Cilia is absent
Absence of plastids.	Presence of plastids.
Presence of lysosomes.	Lysosomes are very rare
Animal cells have centrosomes.	Centrosomes are absent in plant cells

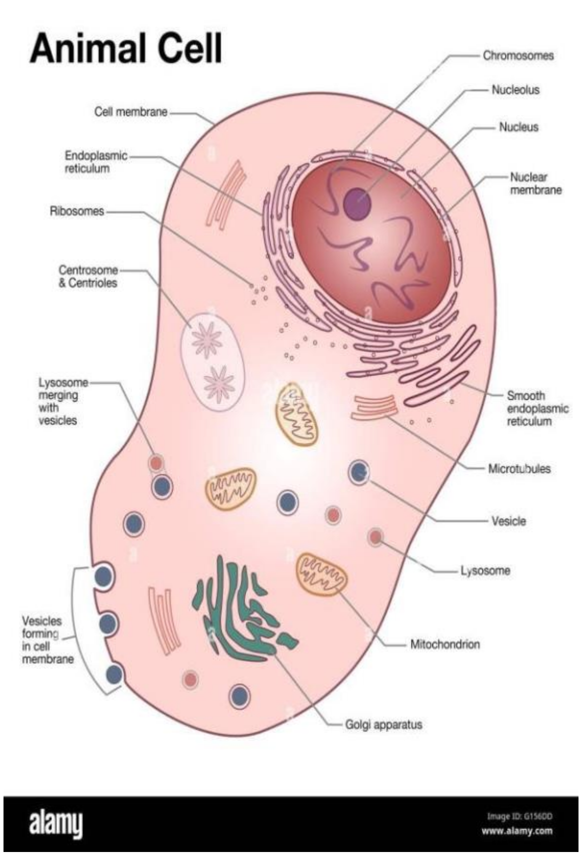


Figure 6: A generalized animal cell

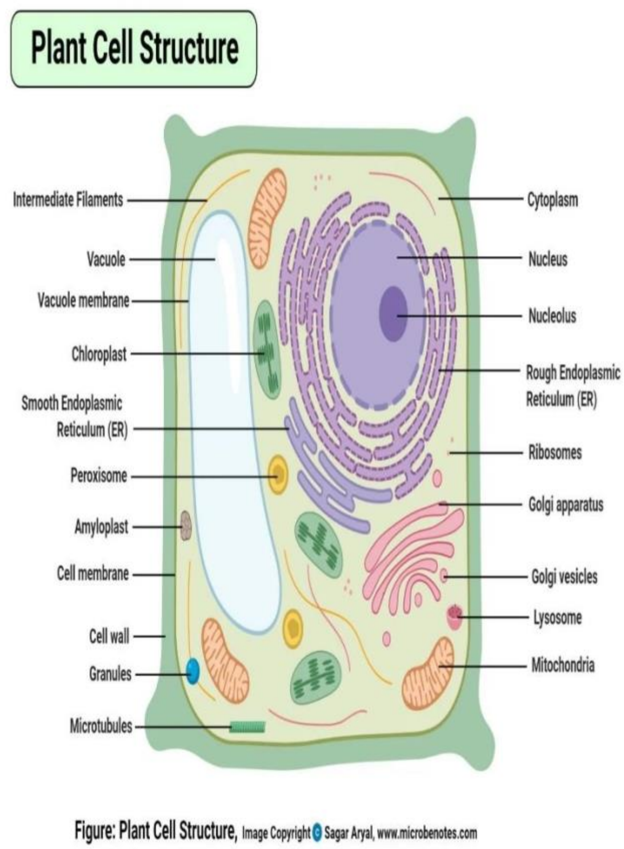


Figure 7: A generalized plant cell

Session 5: Levels of Organization

Living things are highly organized and structured. Following a hierarchy that we can examine from one level to the other or on a scale from small to large. The **atom** is the smallest and most fundamental unit of matter. Atoms come together to form **molecules.** In the same light, the cell being the basic block forms part of a complex structure. In this session, we will describe the complex structure of living things in relation to cells.

Learning outcomes

By the end of the session, the participant will be able to:

- describe the organizational structure of living things.

Cells have been seen to be the basic building block of all living things. Cells are made up of unit aggregates of macromolecules surrounded by membranes and these are what we know as organelles. In complex organisms such as plants and animals, cells form tissues, organs, and organ systems. Tissues are groups of cells that have similar structures and functions. For example, connective tissues, one of the four types of animal tissue, are found between organs. Organs are groups of tissues that carry out a specific function or set of functions and may be comprised of either similar or different tissue types. The heart, for example, is found in most animals and pumps blood throughout the body to provide other organs with oxygen and nutrients as well as remove waste products. Finally, groups of organs make up organ systems that work together to carry out vital processes. For example, the animal's cardiovascular system is comprised of the heart, vessels, and blood. In plants, a diverse set of tissues create the root and shoot system that provides different functions. Ultimately, the organ systems come together to make the organism.

- Cells are the basic building blocks of all living things.
- All cells arise from pre-existing cells.
- Organisms can either be eukaryotic or prokaryotic
- Eukaryotic cells have organelles that perform specific function to help sustain the cell and ultimately the organism.
- Plants and animals differ in terms of the components of their cells.
- There is biological organizational structure that sustains life.

Figure 8: Biological levels of organization

Key Ideas

Reflections

- How does the presence of organelles affect the sustenance of life of organisms?
- How does the difference between plant and animal cells affect plant and animal life?

Discussion

 Discuss the fate of a cell that has a malfunctioning mitochondrion.
Justify why animal cells do not need a chloroplast.

UNIT 3: STRUCTURE AND FUNCTION OF FLOWERING PLANTS

Plants belong to kingdom Plantae and can produce their own food. The ability to produce their own food through a process called photosynthesis sets them apart from other organisms. Plants serve as the primary producers in the food chain which make them very critical in the survival of other organisms in the ecosystem. There are different types of plants but for this unit we are going to discuss structure and function of flowering plants. The unit will focus on discussing the structure and function of vegetative parts of flowering plants, the two groups of flowering plants (monocots and dicots), the reproductive parts of a flowering plant**,** pollination, agents that facilitate pollination and finally fertilization.

Learning outcomes

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

- describe the structure and function of the vegetative parts of a flowering plant
- distinguish between monocot and dicot plants
- describe the reproductive part of a flowering plant
- describe the functions of parts of the flower
- draw half and full flowers
- explain pollination and the various types
- define fertilization

SESSION 1: STRUCTURE AND FUNCTION OF VEGETATIVE PARTS OF A FLOWERING PLANT

Plants have different parts. These parts can be grouped broadly into the vegetative parts and the reproductive parts. The vegetative parts of a plant are those parts that do not participate in sexual reproduction process. All flowering plants have three main vegetative parts which the leaves, stem, and roots. These parts are grouped into two systems. The leaves and stem form the shoot system and the roots constitute the root system. This session seeks to describe the various parts of the vegetative parts of flowering plants.

Learning outcomes

After going through this session, you should be able to;

- describe the parts of the shoot system of a plant
- identify the types of roots

The two systems of the vegetative parts of the plant are the shoot and root systems.

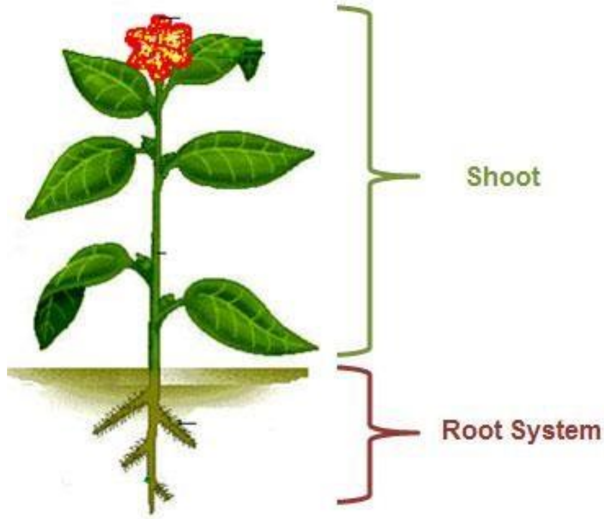


Figure 9: The two systems of flowering plants

The shoot system

The shoot system of plants grows above ground and are made up of the leaves and stem. Leaves form on the stem at places known as nodes. The gap between two nodes is called the internode.

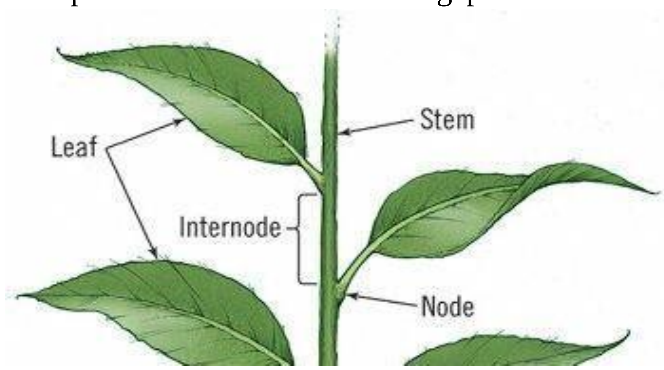


Figure 10: Stem showing nodes and internodes

Leaves

The leaves are outgrowth of the shoot apex and mostly have a flattened portion known as the blade or lamina and a stalk called petiole. A complex system of veins runs through the lamina with a main vein called midrib. The midrib arises from the leaf base and runs through the petiole and the lamina ending at the tip of the leaf. The margin of the leaf which is the edge of the lamina may be smooth or serrated. The angle between the petiole and the stem is the axil. The axils contain axillary or lateral buds which may develop into lateral shoots or flowers.

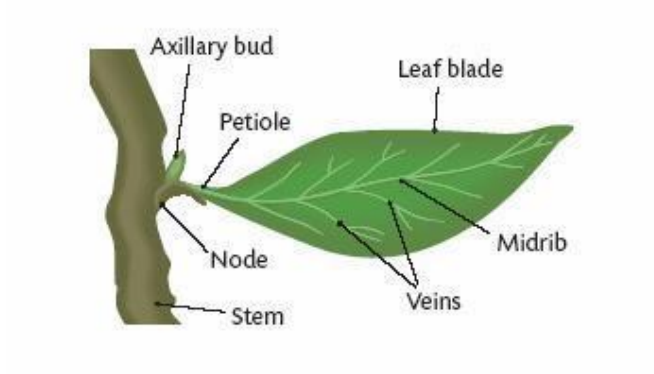


Figure 11: Stem with a leaf

In figure 12, we can see that there are veins on the leaf. The pattern of veins on a leaf is called venation. There are two common types of venation: parallel venation and net (reticulate) venation. In parallel venation, the veins run alongside each other while in net or reticulate venation the veins form a branching network.

Parallel venation

Net venation

Figure 12: Leaf venations in flowering plants

Functions of the leaves

The leaves serve numerous functions to the plant. Some of the functions are listed below. Photosynthesis- the leaves are light capturing photosynthetic organs of most plants. They help the plant to make its own food through a process called photosynthesis. Through this process plants obtain the food they need to live.

Gas exchange-Plants take in carbon dioxide and release oxygen through their leaves.

Transpiration- Plants lose water through their leaves. As a result, fresh water enters the leaves through the midrib and veins.

Food storage- some plants store their food in the leaves.

Stems

A stem is the main axis of a plant along with its lateral branches. The stem of a flowering plant terminates in tissue that allows the stem to elongate and produce leaves. The stem supports leaves in such a way that each leaf is exposed to as much sunlight as possible. As already mentioned, the leaves are attached to the stem at the nodes and the region between two nodes is the internode. The presence of nodes and internodes is used to identify stems. In some plants the nodes of horizontal stems asexually produce new plants.

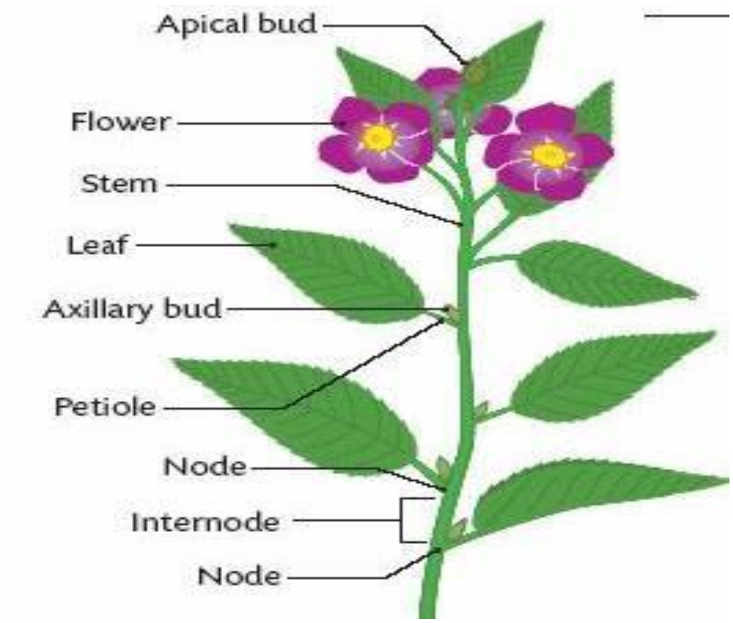


Figure 13: Structure of a stem of a flowering plant

Functions of stem

Now that we have seen the structure of the stem, let us take a look at some of the functions the stem performs for the plant.

1. Stems support leaves so that the leaves will have enough sunlight for photosynthesis.
2. Stems conduct water from the roots to all parts of the plants.
3. They also transport inorganic nutrients from the roots to all parts of the body.
4. They bring products of photosynthesis to where they needed or stored.

Roots

Roots are the parts of the plant usually found below ground or in the soil. They anchor the plant in the soil. As you may be aware, the roots of mango tree are different from that of maize. This indicates that there are different types of roots. The types of roots are taproot, adventitious roots and fibrous roots. Taproots grow deep into the soil and consist of one main vertical root that develops from the radicle of the embryo. The taproots give rise to lateral roots. The adventitious and fibrous roots grow from parts of the plant other than the radicle of the embryo. The adventitious roots develop from the lower part of the stem. The fibrous roots have no predominant root and are made up of thin roots spreading out below the soil surface. The fibrous roots are usually shallower and concentrated in the upper few centimetres of the soil.

Figure 14: Types of root

Functions of roots

1. The root is the organ that anchors the plant in the soil. It is the root that holds the plant firmly in the soil so that it can survive.
2. It absorbs water from the soil.
3. Roots also absorb minerals from the soil.
4. Some roots store organic nutrients.

SESSION 2: MONOCOTS AND DICOTS

Plants differ in various forms. As you are aware, grasses are different from mango trees. These differences manifest in various parts of the plant. This session will explore the types of flowering plants.

Learning outcomes:

By the end of this session, you will be able to;
identify a monocot plant.

- identify a dicot plant.
- distinguish between dicots and monocots.

Now read on…

Differences between monocots and dicots

Flowering plants are divided into two groups based on the number of cotyledons or seed leaves in the embryo. The cotyledons provide nutrient for the seedlings before they develop leaves capable of undergoing photosynthesis. Plants with one cotyledon are known as monocotyledonous (monocots) plants while plants with two cotyledons are called dicotyledonous (dicots) plants. In the previous session, we had discussions on the vegetative parts of the flowering plants. These parts of the plants differ between dicots and monocots. Aside these vegetative parts that differ, other parts of the plants differ based on the number of cotyledons. We are now going to look at how monocots and dicots differ.

From our earlier discussion, we noted that monocots and dicots differ based on their cotyledons. Dicots have two cotyledons while monocots have one cotyledon. The leaves of monocots have parallel venation but that of dicots exhibit net venation. In the stems, the vascular tissue (these are the tissues that help the stem to transport of substances) of monocots are scattered but that of the dicots are usually arranged in ring. Monocots usually have fibrous root with dicots having taproot. In most monocots, the floral parts are usually in multiples of three but that of dicots are in multiples of four or five.

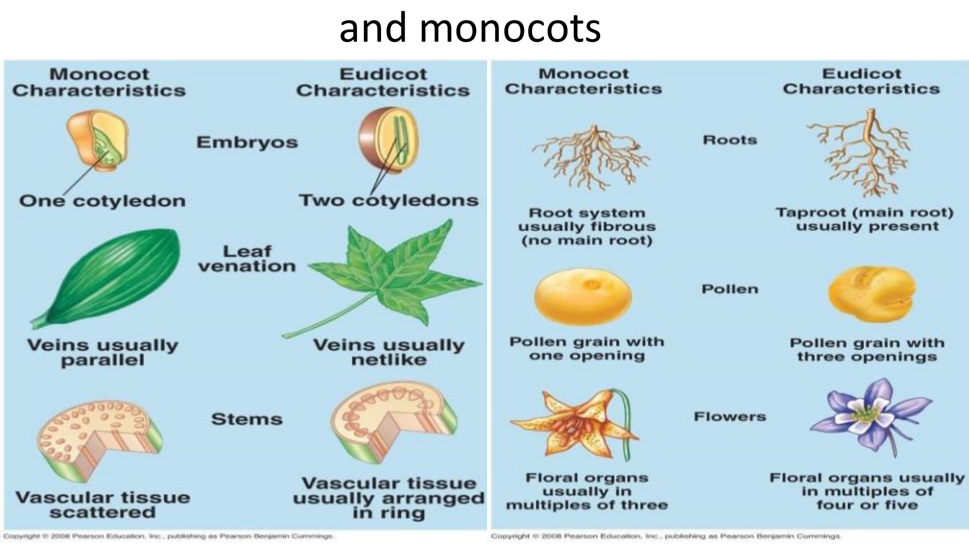


Figure 15: Differences between monocots and dicots.

SESSION 3: REPRODUCTIVE PARTS OF A FLOWERING PLANT

One of the characteristics of living organisms is their ability to reproduce. There are organs that facilitate the process of reproduction in living organisms. This session seeks to discuss the reproductive parts of flowering plants.

Learning outcomes:
After studying this session, you should be able to;

- identify the reproductive part of the flowering plant.
- describe the parts of a flower
- identify the functions of the various parts of the flower.

Flower Structure

The flower is the part of the plant which produces gametes. It is the reproductive part necessary for sexual reproduction in plants. A flower may be solitary (single) or in clusters. A cluster of flowers is called an inflorescence and have a stalk called peduncle. The stalk of each flower is known as pedicel. However, if the flower has no stalk it is described as sessile. The flower is a specialized shoot that can have up to four rings of modified leaves or whorls which are attached to a receptacle. These whorls are sepals, petals, stamen, and carpels. The sepals are usually green which start at the base of the flower and enclose the flower before it opens. The sepals may be free or fused(united). Sepals that are free are known as polysepalous and those that are fused or united are called gamosepalous. The sepals protect the flower at the bud stage and support~~s~~ inner whorls. The sepals are collectively called calyx.

The petals are found above the sepals. Most petals are brightly coloured to aid in attracting pollinators. Petals of flowers that are pollinated by wind generally are not brightly coloured. The petals could also be free or fused. What was the name for fused or free sepals? The petals also have similar names. Thus, petals that are fused are known as gamopetalous and those that are free are called polysepalous. The petals are collectively called corolla. If the petals and sepals are similar making distinguishing between them difficult, then they are collectively called the perianth. The sepals and petals are the sterile floral parts meaning that they are not directly involved in reproduction.

The stamens are considered as the male part of the flower because it holds the part that produces the male gamete. A stamen consists of a stalk called the filament and a terminal sac called the anther. The anther produces pollen grains. The stamens are collectively called the androecium. Carpels (pistils) are the female reproductive parts of the flower. A carpel is made up of a swollen base called the ovary, a stalk that is called the style and a sticky or hairy stigma which receives the pollen. The ovary contains the ovules which contains the female gametes. When the ovary is attached above the other floral parts then such ovary is described as a superior ovary (hypogynous flower) and when the ovary is attached below the other floral parts then is known as an inferior ovary (epigynous flower). Some plants have their flowers possessing both the male and female parts of the flower while others may have one of them. When both male and female parts are present in the same flower, such flower is described as bisexual or hermaphrodite. Unisexual flowers have only the male or the female parts. Flowers differ in shape, colour, scent and size. When it comes to shape, flowers can be described as actinomorphic or zygomorphic. Actinomorphic flowers are radially symmetrical indicating that they can be divided into two equal halves by any radial plane which passes through their centre. Zygomorphic flowers on the other hand can be divided into two equal halves by only one radial plane which passes through their centre. Flowers can also be termed as complete or incomplete. Complete flowers are those that have all the floral parts while incomplete flowers lack one or more of the floral parts.

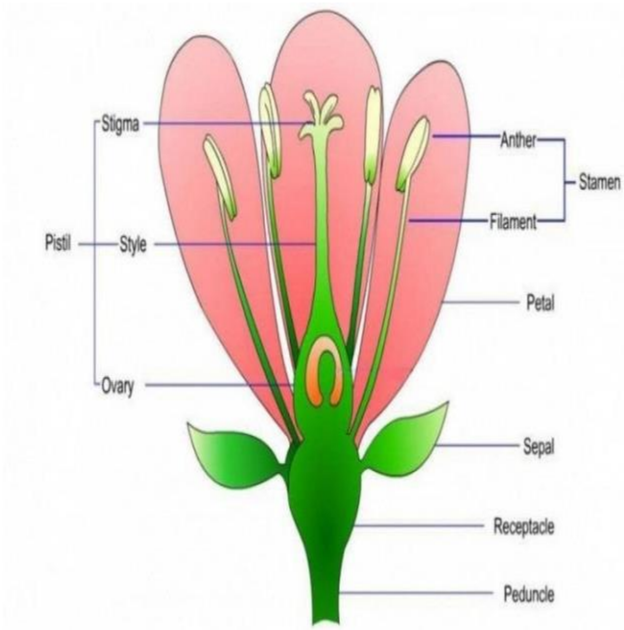


Figure 16: Parts of a flower

SESSION 4: POLLINATION

Plants need to propagate and multiply. There are two forms of reproduction in plants. These are sexual reproduction and asexual (vegetative) reproduction. For sexual reproduction to occur, there should be the mating of male and female gametes. This session will explore the process that facilitates sexual reproduction in flowering plants.

Learning outcomes:

By the end of this session, you will be able to;

- define pollination.
- identify the types of pollination

Pollination is the transfer of pollen grains from the anther of a flower to the stigma. Pollination is an essential stage in sexual reproduction of flowering plants, whereby pollen is transferred from its site of production (the anthers) to the stigma.

Types of Pollination

There are two types of pollination. Self-pollination is the transfer of pollen grains from the anther of a flower to the stigma of the same flower or another flower on the same plant. **Crosspollination** is the transfer of pollen grains from the anther of a flower to the stigma of a flower on another plant of the same species.

Self-pollination

Adaptation of flowers that make self-pollination likely include the following:

- The flower is bisexual (hermaphrodite), e.g. wild marigold.
- The plants are **monoecious**, i.e. separate male and female flowers occur on the same plant, e.g. maize, coconut.
- The flower is **homogamous**, i.e. the anthers and stigmas mature at the same time, e.g. tomato.
- The flower is **cleistogamous**, i.e. the flower does not open until self-pollination has taken place.
- The flower is buried in the ground

Cross-pollination

Adaptations that make cross-pollination likely include:

- The plants are **dioecious**, i.e. male and female, i.e. male and female flowers occur on separate plants, e.g. pawpaw.
- Each flower is bisexual, but male and female parts mature at different times. The flower is **protandrous** (e.g. cowpea) when the androecium matures first or **protogynous** when the gynaecium matures first.
- Each flower exhibits self-sterility, i.e. the pollen grains cannot germinate on the stigma of the same flower and even if they do, fertilisation cannot occur, e.g. passion flower.
- Each flower is **herkogamous**, i.e. there is a physical barrier between androecium and gynaecium so that the pollen grains cannot reach the stigma. It may be a space, e.g. maize.
- The flowers show **heterostyly**, i.e. male and female parts are of different lengths in flowers of the same species. For example, long style and short stamen and vice versa. This prevents pollen grains reaching the stigma of the same flower.
- The flowers are **chasmogamous**, i.e. they are conspicuously large and adapted to crosspollination y insects, birds and wind.
- The flowers are **dichogamous**, i.e. male and female parts of the flower mature at different times, ensuring that self-pollination does not occur.

  Cross-pollination is more common than self-pollination. It guarantees variation. Which can help survival of a species.

SESSION 5: AGENTS OF POLLINATION

Plants cannot move from one place to another to ensure that the pollen has been transferred to the stigma. How then does pollination occur in plants? This session will discuss the means through which the pollen can be transferred to the stigma.

Learning outcomes:

After going through this session, you will be able to;

- identify the agents of pollination.
- describe the characteristics of flowers pollinated by insects.

The factors responsible for the transfer of pollen grains to the stigma are referred to as **agents of pollination**. The two most common agents are wind and insects. Water, birds and bats are also known to carry out pollination.

Adaptations of wind Pollinated flowers

Flowers that are wind pollinated are termed as **anemophilous**. Such flowers do not usually have sepals and petals. Even if they are present, these structures are small and inconspicuous. Wind pollinated flowers include Guinea grass, sugar cane and maize.

In wind pollinated flowers, the male inflorescence is found at the top end of the plant. It is made up of long slender branches bearing male flowers only. These occur in pairs, each pair having three stamens. When mature, the anthers hang out of the flowers on long thin filaments. The anthers swing freely in the wind. Wind pollinated flowers produce large quantity of smooth pollen grains. The female inflorescences occur in the axils of leaves lower down the stem. The stigma is feathery, and so provides a large surface area on which pollen grains can be trapped. The flowers are usually not scented.

Adaptations of insect Pollinated Flowers

Insect pollinated flowers are termed as **entomophilous**. They normally have large flowers with bright petals and a sweet scent. The flower also has a nectary which produces nectar. Insects such as bees and butterflies are attracted to the flowers by these features. The stigma is sticky and compact and usually enclosed in the flower. The pollen grains are large and rough which are normally produced in few quantities as compared to wind pollinated flowers. The stamen in insect pollinated flowers are short with stout filaments. Their anthers are usually enclosed in the flower.

SESSION 6: FERTILIZATION

The pollen has been transferred to the stigma during pollination. How does the flower get a young one after this process? This session will discuss the next stage of sexual reproduction in flowering plants.

Learning outcomes:

After going through this session, you will be able to;

- define fertilization.
- explain double fertilization.

Fertilization in plants

After pollination, the next stage of the sexual reproduction process in flowering plants is fertilization. Fertilization is the fusion of the nuclei of the male and female gametes. Fertilization takes place in the ovule in flowering plants. The pollen grain after falling on the stigma will swell up after absorbing water and nutrients. The nucleus of the pollen grain divides into two forming a tube nucleus and generative nucleus. The nucleus of the pollen moves through the stigma through the help of pollen tube. The pollen tube will grow through the style towards the ovary. In the ovary, there are the ovules.

The ovule is made up of an embryo sac and two protective layers called integuments. The embryo sac contains the egg nucleus and two polar nuclei. There is a tiny pore at the end of the embryo sac through which the pollen tube enters the embryo sac. Flowering plants undergo a process called double fertilization. This is where one male nucleus fuses with the egg to form a zygote and the other male nucleus fuses with the polar nuclei to form primary endosperm nucleus. The zygote undergoes cell division to form the embryo. The ovule develops into the seed and the ovary becomes the fruit.

The zygote undergoes cell division to form the embryo. The embryo has the plumule, the radicle and cotyledon. The micropyle remains as a small hole in the seed coat through which water is absorbed during germination.

- Plants have both vegetative and reproductive parts.
- Flowering plants have different structural differences.
- The flower is an integral organ of reproduction in flowering plants.
- Different parts of the flower are suited for different functions
- Plants are adapted differently to ensure pollination

Key ideas

Reflection

- How do flowers adapt themselves to suit a particular form of pollination?
- Plants differ in form and structure to survive

Discussion

- Identify differences between a grass and mango leaf.
- Discuss the probable agent of pollination a flower with sweet scent and nectar.

UNIT 4: MEASUREMENT

This unit introduces you to the SI system of units. The unit highlights the fundamental and derived quantities of measurement including the length, mass, weight, time, volume, volume, and temperature. Finally, the unit looks at the density and relative density and also talked about Archimedes' principles and flotation.

Learning outcome(s)

By the end of the unit, the students will be able to:

- Explain what is meant by SI units;
- Explain what is meant by fundamental and derived quantities and guide learners to identify these quantities and their SI units;
- Distinction between mass and weight;
- Demonstrate the use of lever balance and chemical/beam balance to measure mass and spring balance to measure weight;
- Demonstrate the use of a clock to measure time with a heartbeat, pendulum, and stopwatch/clock;
- Demonstrate the use of a thermometer to measure temperature in degrees Celsius and Kelvin;
- Explain the Inter-conversion of Kelvin to degree Celsius and vice-versa, Celsius to Fahrenheit, and vice-versa with examples;
- Distinction between density and relative density;
- Experimental determination of density of regular and irregular objects;
- Explain the rationality behind Archimedes' principle to the measurement of relative density and;
- Explain floatation by the use of the principle of density e.g. Hydrometer, balloon.

SESSION 1: SI UNITS

Learning outcomes

By the end of the session, the participant will be able to:

1. Describe what measurement is;
2. Explain what units are in measurement;
3. Explain the SI system.

What is measurement?

Measurement is the process of estimating the magnitude of some attribute of an object, such as its length, weight, or depth relative to some standard unit of measurement, such as a metre or a kilogram. The term is also used to indicate the number that results from that process. The act of measuring usually involves using a measuring instrument, such as a ruler, weighing scale, thermometer, speedometer, or voltmeter which is calibrated to compare the measured attribute to a measurement unit. Any kind of attribute can be measured, including physical quantities such as distance, velocity, energy, temperature, or time.

Measurement is fundamental in science; it is one of the things that distinguish science from pseudoscience. It is easy to come up with a theory about nature but hard to come up with a scientific theory that predicts measurements with great accuracy. Measurement is also essential in industry, commerce, engineering, construction, manufacturing, pharmaceutical production, and electronics.

Unit

To measure a quantity, we always compare it with some reference standard. To say that a rope is 10 metres long is to say that it is 10 times as long as an object whose length is defined as 1 metre. Such a standard is called a unit of quantity. Therefore, **a *unit of a physical quantity is defined as the established or accepted standard used for comparison of the given physical quantity.*** The units in which the fundamental quantities are measured are called fundamental units and the units used to measure derived quantities are called derived units.

System International de Units (SI system of units)

In the earlier days, many systems of units were followed to measure physical quantities. The British system of the foot, pound, and second (or fps) system, the Gaussian system of centimetre - gram - second (or cgs) system, and the metre-kilogram second (or mks) system were the three systems commonly followed. To bring uniformity, the General Conference on Weights and Measures in the year 1960, accepted the SI system of units. This system is essentially a modification over the mks system and is therefore rationalized **mks** (metre, kilogram, second ampere) system. This rationalisation was essential to obtain the units of all the physical quantities in physics. In the SI system of units, there are seven fundamental quantities and two supplementary quantities. They are presented in Table 1.

SI System

The SI system (*International System of Units*) is the modern metric system of measurement and the dominant system of international commerce and trade. SI units are gradually replacing Imperial and USCS units. The SI is maintained by the International Bureau of Weights and Measures (BIPM, that is the Bureau International des Poids et Mesures) in Paris. The SI system is founded on the

- SI base units
- SI-derived units described in terms of acceptable SI unit
- SI-derived units with names of symbols acceptable in SI
- SI Prefixes

Key Ideas

- Measurement is the process of estimating the magnitude of some attribute of an object, such as its length, weight, or depth relative to some standard unit of measurement, such as a metre or a kilogram.
- Measurement is fundamental in science
- Measurement is important in industry, commerce, engineering, construction, manufacturing, pharmaceutical production, and electronics.
- Unit is always to measure a quantity
- The unit of a physical quantity is defined as the established or accepted standard used for comparison of the given physical quantity
- The SI system (International System of Units) is the modern metric system of measurement and the dominant system of international commerce and trade
- The SI is maintained by the International Bureau of Weights and Measures (BIPM, that is the Bureau International des Poids et Mesures) in Paris.

Reflection

- What are some of the experiences you had about measurement (length, weight, and kilogram)? And how does this experience impact to your daily life.
- How does the study of the SI unit influence you in this session?

Discussion

- Briefly explain what measurements are and their uses in our daily life experiences.
- Locate the various measurement to their units.
- In your own words, how do you describe the SI system?

SESSION 2: FUNDAMENTAL AND DERIVED QUANTITIES

Learning outcomes

By the end of the session, the participant will be able to:

1. Explain what fundamental and derived quantities;
2. Identify the various quantities and units of the fundamental and derived quantities.

Fundamental Quantities

Base units are fundamental units from which all derived units can be obtained. ***Fundamental quantities are quantities that cannot be expressed in terms of any other physical quantity***. For example, quantities like length, mass, time, and temperature are fundamental quantities. The seven fundamental quantities and their units are shown in Table 4.1.

Table 4.1: Fundamental Quantities and their units

Quantity	**SI unit**	**Symbol of SI unit**
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Derived Quantities

Other quantities, called derived quantities, are defined in terms of the seven base quantities via a system of quantity equations. ***Quantities that can be expressed in terms of two or more combinations of the fundamental quantities are called derived quantities***. Area, volume, and density are examples of derived quantities. The SI-derived units for these derived quantities are obtained from these equations and the seven SI base units. Examples of such SI-derived units are given in Table 4.2.

Table 4.2: Derived Quantities and their units

Quantity	Description	Symbol	Expression in terms of SI base units
Acceleration	metre per second	m/s^2	$m\ s^{-2}$
Area	metre squared	m^2	m^2
Concentration (of the amount of substance)	mole per cubic metre	mol/m^3	$mol\ m^{-3}$
Density	kilogram per cubic metre	kg/m^3	$kg\ m^{-3}$
Force	Newton	N or J/m	$m\ kg\ s^{-2}$
Heat capacity	joule per kelvin	J/K	m2 kg s-2 K-1
Luminance	candela per square metre	cd/m^2	$cd\ m^{-2}$
Magnetic field strength	ampere per metre	A/m	$A\ m^{-1}$
Molar energy	joule per mole	J/mole	m-2 kg s-2 mol-1
Moment of inertia	kilogram metre squared	$kg\ m^2$	$kg\ m^2$
Momentum	kilogram metre per second	kg m/s	$kg\ m\ s^{-1}$
Permeability	henry per metre	H/m	$m\ kg\ s^{-2}\ A^{-2}$
Permittivity	farad per metre	F/m	m-3 kg-1 s4 A2
Power	Watt	W	$kg\ m^2\ s^{-3}$
Pressure (often used symbol *P* or *p*)	Pascal	Pa	kg m-1 s-2
Specific energy	joule per kilogram	J/kg	m2 s-2
Specific heat capacity (often used symbol c_p, c_v or *s*)	joule per kilogram per kelvin	J/(kg K)	m2 s-2 K-1
Surface tension	newton per meter	N/m	$kg\ s^{-2}$
Thermal conductivity (often used symbol *k*)	watt per meter Kelvin	W/(m K)	$m\ kg\ s^{-3}\ K^{-1}$
Torque	newton metre	N m	$m^2\ kg\ s^{-2}$
Velocity (or speed)	metre per second	m/s	$m\ s^{-1}$
Volume	cubic metre	m^3	m^3
Wave number	1 per metre	1/m	m-1
Work	joule	J or N m	$kg\ m^2\ s^{-2}$

Rules governing the use of SI units

- Units should be written out in full using internationally agreed symbols.
- The letter 's' is not used to show a plural form. We write 6 kg or 7 cm and not 6 kgs or 7 cm because **s** is the symbol for time in seconds.
- Capital letters are used in symbols only for certain units named after famous scientists, such as newton (N), watt (W), or joule (J).
- When symbols are combined as a quotient, e.g. joules per second, they are written as J/s or Js^{-1}. Similarly, acceleration, which has units of metre per second per second, can be recorded as m/s^2 or ms^{-2}.

Numbers in SI units are often written to a power of 10 for convenience. Certain powers of 10 are indicated by prefixes, which can be used with all of the SI units and derived units. Examples are shown in Table 4.3.

Table 4.3: Prefixes and their Multiplication Factor

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^1	deca	da	10-1	deci	d
10^2	hecto	h	10-2	centi	c
10^3	kilo	k	10-3	milli	m
10^6	mega	M	10-6	micro	µ
10^9	giga	G	10-9	nano	n
10^{12}	tera	T	10-12	pico	p
10^{15}	peta	P	10-15	femto	f
10^{18}	exa	E	10-18	atto	a
10^{21}	zetta	Z	10-21	zepto	z
10^{24}	yotta	Y	10-24	yocto	y

Note: Do not interpret the symbols as units

Table 4.4 illustrates the summary of the quantities with the instruments used to measure them.

Table 4.4: Quantities and measuring instrument

Quantity	**Measuring Instrument**
Mass	Balances e.g. top pan balance, beam balance, lever arm balance, electronic balance, dial spring balance, top loading balance.
Length	Metre rule, vernier calipers, surveyors' tape, measuring tape, micrometer screw gauge, pair of calipers
Volume	Graduated beaker, volumetric flask, measuring cylinder, burette, and pipette. **NB:** They are for measuring specific volumes of liquids.
Time	Stop watch, stop clock, electronic watch, and electronic clock.
Temperature	Thermometers e.g. absolute thermometer, clinical thermometer, celsius thermometer
Atmospheric pressure	Barometers e.g. Fortins barometer, Aneroid barometer
Electric potential	Voltmeter
Electric current	Ammeter
Luminous intensity	Photometer

Key Ideas

- Fundamental quantities are quantities that cannot be expressed in terms of any other physical quantity.
- Quantities like length, mass, time, and temperature are fundamental quantities.
- Quantities that can be expressed in terms of two or more combinations of the fundamental quantities are called derived quantities.
- Area, volume, and density are examples of derived quantities.
- Numbers in SI units are often written to a power of 10 for convenience.

Reflection

- What are some of the fundamental and derived quantities and their units?
- How do you understand the rules that govern the use of SI units in this study?
- How does the study reflect on the understanding of fundamental and derived quantities?

Discussion

- Briefly discuss the fundamental and derived quantities. Locate the various units to their corresponding fundamental and derived units.
- Briefly explain the rules that govern the use of SI units.

SESSION 3: MEASUREMENTS OF VARIOUS QUANTITIES IN SCIENCE (LENGTH, MASS, TIME, VOLUME, AREA, WEIGHT, AND TEMPERATURE)

Learning Objectives

By the end of the session, the participant will be able to;

1. Differentiate between the mass and the weight
2. Demonstrate the use of lever balance and chemical/beam balance to measure mass and spring balance to measure weight.
3. Demonstrate the use of a clock to measure time with a heartbeat, pendulum, and stopwatch/clock.
4. Demonstrate the use of a thermometer to measure temperature in degrees Celsius and Kelvin.
5. Explain the Inter-conversion of Kelvin to degree Celsius and vice-versa, Celsius to Fahrenheit, and vice-versa with examples.

MASS AND WEIGHT

The mass of an object is the amount of matter it contains. Weight, on the other hand, refers to the downward force produced when an object is in a gravitational field. Weight can also be seen as the gravitational force between the earth and an object. It is the force a body exerts on its support. In free fall, objects lack weight but retain their mass. The kilogram is the SI unit of mass. The mass of an object or body and its weight are related by $W = mg$, where **W** is the weight, ***m*** is the mass, and ***g is*** the acceleration due to gravity. This implies that when the mass of the body is known, the weight can be calculated since g = 9.8 m/s^2 or approximated to 10 m/s^2.

An instrument for measuring weight or mass in the laboratory is called a weighing scale or, often, simply a scale. A spring scale measures force but not mass, a balance compares masses but requires a gravitational field to operate. The most accurate instrument for measuring weight or mass is the digital scale, but it also requires a gravitational field, and would not work in free fall.

Difference between Mass and Weight

Mass	**Weight**
The mass of an object is a fundamental property of the object; a measure of its inertia; the amount of matter in a body	The weight of an object is the force of gravity on the object
The SI unit of mass is a kilogram	The SI unit of weight is newton
Is measured using a beam balance.	Is measured using a spring balance.
Is always a constant at any place and time	Depends on gravity at the place.
It is a scalar quantity.	It is a vector quantity.

Effect of gravity on a body

- Bodies experience constant acceleration as they fall on the surface of the earth.
- The weight of a body varies from place to place on the earth.
- Gravity enables us to walk on the earth.
- Gravity keeps the atmosphere round the earth because of the attraction between the particles of the air and the earth.
- The gravitational attraction between the moon and the ocean causes tides.

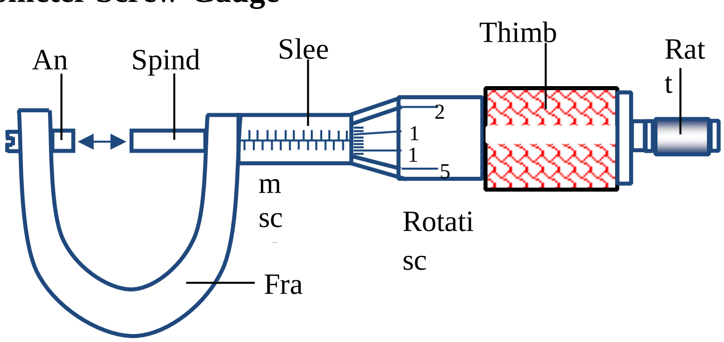
MEASUREMENT OF LENGTH

Straight edges and distances are measured with a rule or surveyors' tape. The ruler is the instrument used to **rule** straight lines and the calibrated instrument used for determining length is called a measure. However common usage calls both instruments rulers and the special name straightedge is used for an unmarked rule. The use of the word measure, in the sense of a measuring instrument, only survives in the phrase tape measure, an instrument that can be used to measure but cannot be used to draw straight lines.

In using the metre rule to measure, the rule is placed against the object to be measured, and the zero mark of the rule is made to coincide with the one end of the object. The length of the object being measured is the mark on the metre rule that coincides with the other end of the object.

The units used for the measurement of length are metres (m), centimetres (cm), and millimetres (mm). Other instruments that can be used to measure length are the vernier caliper for measuring both internal and external diameters of objects and the micrometer screw gauge used to measure small, or tiny, lengths such as the diameter of a wire.

Micrometer Screw-Gauge



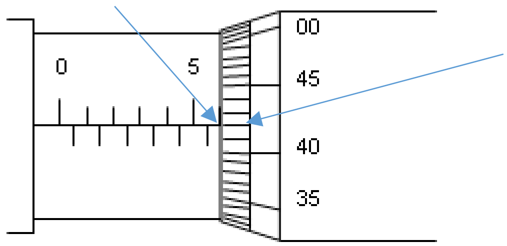
Using a Micrometer Screw-Gauge

- Place the wire between the anvil and spindle end as indicated in the diagram.
- Rotate the thimble until the wire is firmly held between the anvil and the spindle.
- The ratchet is provided to avoid excessive pressure on the wire. It prevents the spindle from further movement – squeezing the wire.

To take a reading:

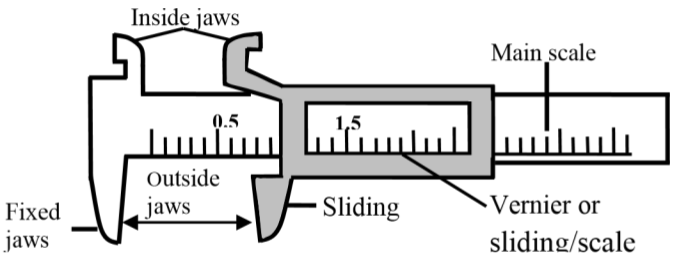
- First look at the main scale on the sleeve. This has a linear scale reading on it. The long lines are in millimetre and the shorter ones denote half a millimetre.
- On the diagram below this reading is 6.0 mm
- Now, look at the rotating scale, read and record the reading from the rotating scale at the point the where the main scale and rotating scale coincide. On the diagram below this reading is 47 divisions. Each division is 0.01 mm so we have 0.47 mm from this scale.
- The diameter of the wire is the sum of these readings:

  6.0 + 0.47 = **6.97 mm**

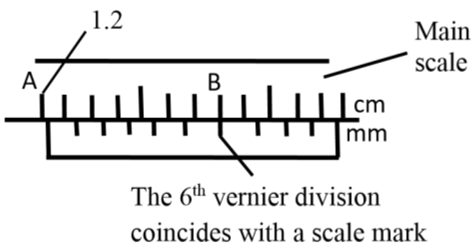


The Vernier Calipers

The vernier caliper is used for measuring both the internal and external diameters of objects. It consists of a main scale in centimetres and a small vernier scale in millimetres and it is precise up to 2 decimal places (e.g. 1.46 cm). the vernier caliper has a fixed jaw and a movable jaw. The object to be measured is placed between the jaws of the calipers, the reading is taken first from the main scale. The reading to the second decimal place is obtained by finding the vernier mark which is exactly opposite a mark on the main scale. Each division on the vernier equals **0.1 mm or 0.01 cm** as shown in the diagram below.



To take a reading:



The reading A on the main scale is 1.2 cm. The reading B on the main scale coincides with the 6th division mark on the vernier scale. Therefore, the vernier reading equals 0.6 mm or 0.06 cm.

Total reading = 1.2 +0.06 = 1. 26 cm

MEASUREMENT OF TIME

The S I unit of time is the second (s) which is part of the time the earth takes to perform one revolution on its axis. The other commonly used units are the minute, hour, day, week, month, and year. In the laboratory, time is normally measured using a stop-clock or stop-watch. In some cases, where more accuracy is required, for example, when measuring the acceleration of a trolley moving on a ramp, a millisecond timer clock can also be used.

MEASUREMENT OF TEMPERATURE

Temperature and heat are related but they are not the same and should not be confused with each other. Temperature is the degree of hotness (or coldness) of a body or substance. It is measured in degree Celsius (^oC) or kelvin (K) which corresponds to the Celsius and the absolute scale respectively. There are two fixed points on the Celsius scale. These are;

- The lower fixed point is the temperature of pure melting ice.
- The upper fixed point is the temperature of pure boiling water at normal atmospheric pressure.

The absolute scale of temperature is based on the kinetic theory of matter. This theory assumes that there exist temperatures at which the particles of a substance stop moving completely. This temperature is called absolute zero and it corresponds to -273^oC or 0K. The symbol of absolute temperature is T.

Conversion of Temperature Scales

The relation between the kelvin and degree Celsius scales is

$$\mathbf{T = 273 + \theta}, \text{ or } \mathbf{\theta = T - 273}$$

where θ is the temperature in degrees Celsius and T is the temperature in kelvin.

Worked Examples

1. Convert 57 ^oC to a temperature on Kelvin scale.

   Solution

   $T = 273 + \theta\ ^oC$

   $T = 273 + 57$

   $T = 330$ K

2. What is the equivalent of – 112 ^oC on the Kelvin scale?

   Solution $T = 273 + \theta\ ^oC$

   $T = 273 + (-112)$

   $T = 273 – 112$

   $T = 161$ K

Find the equivalent of 90 K on the Celsius scale.

ANSWER: -183 ^oC

Fahrenheit and Celsius

The Fahrenheit temperature scale is named after the German physicist Daniel Gabriel Fahrenheit is used primarily in the United States. The Celsius temperature scale – originally *centigrade* and later renamed after the Swedish astronomer Anders Celsius – is used almost everywhere else in the world.

The temperature *T* in degrees Fahrenheit (°F) is equal to the temperature *T* in degrees Celsius (°C) times 9/5 plus 32. That is $T_{(°F)} = [T_{(°C)} \times 9/5] + 32$

To convert temperatures in degrees Fahrenheit to Celsius, subtract 32 and multiply by 5/9. That is

$$T_{(°C)} = [T_{(°F)} - 32] \times (5/9)$$ **Example**

1. Convert 20 degrees Celsius to degrees Fahrenheit.

   Solution

   $T_{(°F)} = (20 \times 9/5) + 32 = 68\ °F$

2. Convert 50 degrees Fahrenheit to degrees Celsius

   Solution

   $T_{(°C)} = (50 - 32) \times (5/9) = 10°C$

THERMAL EQUILIBRIUM

Heat is the transfer of energy due to temperature differences. If two objects are in contact with each other and no heat is transferred, we can say that the two objects are in thermal equilibrium. Two objects in thermal equilibrium with each other will have the same temperature.

THERMOMETERS

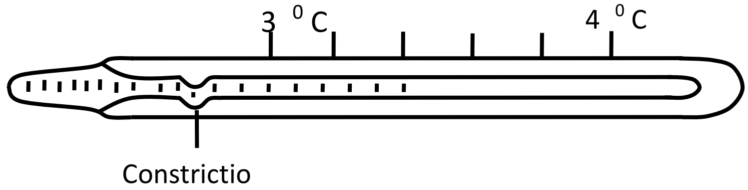
A thermometer is an instrument used for measuring the temperature of a body or a place.

Kinds of Thermometers

The kinds of Thermometers include;

- liquid - in - glass thermometers, for example mercury-in-glass, clinical thermometers, etc.
- gas thermometers
- bimetallic thermometers
- thermocouples

Clinical thermometer



- pyrometers

Thermocouple is a very common electrical thermometer used widely in industry. Often, two different metals, copper and constantan are used.

The advantages of a thermocouple are;

- since it is electrical, it can be read from a remote site.
- a thermocouple can be made very small. Hence, it can respond to changes in temperature very fast.

A thermocouple works because when two different metals are in contact, they will generate a tiny electromotive force, which can be read by a sensitive voltmeter. To measure this voltage, the wire need to form a closed circuit, forming two junctions. No voltage is produced when the two junctions are placed at the same temperature. However, if one junction is placed at the lower fixed point and the other junction is placed at the temperature to be measured, then the generated e.m.f. can be read as the temperature.

Characteristics of a Thermometer

All thermometers have limitations. Nevertheless, in general, there are four characteristics concerning a thermometer. These are:

Sensitivity

Sensitivity refers to the ability to give a large response to a small change in temperature. A sensitive thermometer is able to detect small changes in temperature. It can also give a rapid response to temperature change. To make a liquid-in glass thermometer sensitive, a large bulb is used. A large bulb will cause a big change in volume of the mercury, which will appear as a change in the length of mercury up the capillary tube. Making the capillary tube small also increases the sensitivity of the thermometer because volume change results in a big change in the length of liquid up the tube. Lastly, a liquid-in-glass thermometer may increase its sensitivity by choosing a liquid that expands more readily. Alcohol expands more than mercury, and would make a thermometer more sensitive than a mercury-in-glass thermometer.

Linearity

A temperature scale is calibrated using two fixed points. Between these two fixed points, 100 equal divisions are marked to represent temperature change of 100 °C. To obtain the temperature, one reads off the scale using the interpolated divisions. This assumes that the thermometric property changes linearly between the two fixed points. In reality, this is not exactly true. Different materials change their thermometric properties differently at different temperatures. Hence, a good thermometer should have thermometric property that changes linearly in between the two fixed points such that the thermometric property at a particular temperature corresponds to the reading on the interpolated scale.

Responsiveness

A thermometer with a larger bulb or thicker glass round the bulb will be less responsive because it takes a longer time for the thermometric liquid to detect temperature changes.

Range

Range refers to the operating temperature at which the thermometer can be used. A laboratory thermometer can measure from -10 °C to110 °C, beyond which the scale will not be able to register any readings. The expanding liquid column may even break the thermometer if the expansion is restrained beyond the maximum 110 °C. A thermocouple that uses two metal junctions can have a large range from -200 °C to over 1000 °C. This makes the thermocouple a very versatile thermometer and is suitable in many situations.

Key Ideas

- The mass of an object is the amount of matter it contains.
- Weight refers to the downward force produced when an object is in a gravitational field.
- Weight can also be seen as the gravitational force between the earth and an object.
- The ruler is the instrument used to rule straight lines and the calibrated instrument used for determining length is called a measure.
- The units used for the measurement of length are metres (m), centimetres (cm) and millimetres (mm).
- The Vernier caliper is used for measuring both the internal and external diameters of objects.
- The S I unit of time is the second (s) which is part of the time the earth takes to perform one revolution on its axis.
- Temperature is the degree of hotness (or coldness) of a body or substance.
- If two objects are in contact with each other and no heat is transferred, we can say that the two objects are in thermal equilibrium.
- A thermometer is an instrument used for measuring the temperature of a body or a place.
- Range refers to the operating temperature at which the thermometer can be used.

Reflection

- What are the differences between mass and weight?
- What happens when there is an effect of gravity on the body?
- What were your experiences when using the following?
  - Micrometer Screw-Gauge
  - Vernier Calipers
- How do you understand the measurement of time and temperature?
- Have you ever been checked by the use of a thermometer when you visited the hospital? How were your experiences?

Discussion

- Briefly discuss the differences between mass and weight.
- Briefly explain how to use the following tools.
  - Micrometer Screw-Gauge
  - Vernier Calipers
- Describe the use of the thermometer at the hospital.

SESSION 4: DENSITY AND RELATIVE DENSITY

Learning objectives

By the end of the session, the participant will be able to;

1. Distinction between density and relative density
2. Explain the experimental determination of the density of regular and irregular objects.

DENSITY OF MATTER

Matter is made up of particles of different sizes (atoms, molecules, ions). The degree of packing of particles in matter describes its density. Matter in which the particles are large and closely packed together is described to be dense and vice versa.

Density of a substance is defined as the mass of the substance that occupies a unit volume, i.e.

$$density = \frac{mass}{volume}$$

$$\rho = \frac{m}{v}$$

The SI unit of density is kilogram per cubic metre (kg/m^3 or kgm^{-3}). A smaller unit of density is g/cm^3.

Mass

The mass of a body is measured with an appropriate scale or balance.

Volume

The volume of a body or an object is the amount of space occupied by the body or the object. Volume is measured in cubic metres (m^3). The volume may be measured directly (from the geometry of the object) or by the displacement of the body in a fluid. A very common instrument for the direct measurement of the density of a liquid is the hydrometer, which measures the volume displaced by an object of known mass. In physics, the measuring cylinder is most commonly used for volume measurements of liquids. When reading off the volume of a liquid, it is important to look at the bottom of the curved liquid surface (meniscus). To find volume of an object (in a liquid) there are two displacement methods. You can drop the object directly into a graduated cylinder partially filled with water and calculate what the displacement or change in volume is (Fig 2.1), or use of an overflow can (Fig 2.2) to measure the volume of the displaced liquid.

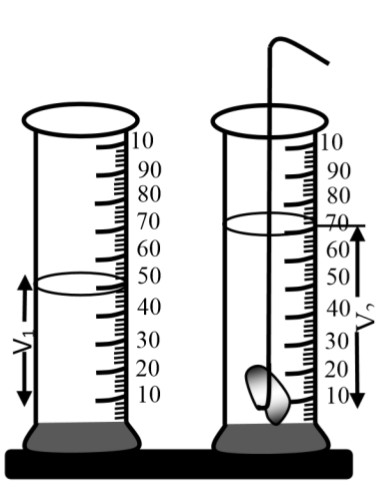


Figure 2.1: Measuring

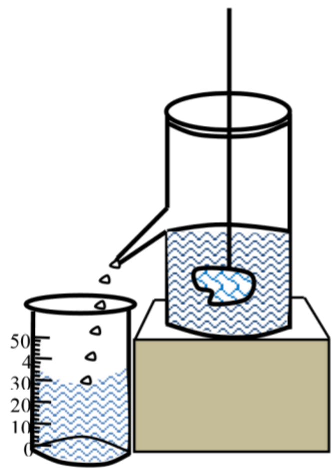


Figure 2.2: Using the Overflow

The volume of some objects can be found from the formulae below: a) Volume of cube = (side) ^{3} or l^3

b) Volume of rectangular solid = length × width × height

c) Volume of right pyramid = $\frac{1}{3}$ ×Area of base × height

d) Volume of cylinder = $\pi r^2 \times h$

e) Volume of a sphere = $(4/3) \times \pi r^3$

RELATIVE DENSITY

The relative density (RD) of a substance is defined as *the ratio of the density of a substance to the density of water*. This gives the relation:

$$\text{Relative density of a substance} = \frac{\text{density of substance}}{\text{density of water}}$$

The unit volumes are equal and cancel out:

$$\text{Relative density} = \frac{\text{mass of substance}}{\text{mass of equal volume of water}}$$

From a table of relative densities of substances (Table 4.5), one may determine whether an object will sink or float in water. Since the relative density of water is 1, any object of relative density greater than 1 will sink in water while any object of relative density less than 1 will float in water.

Table 4.5: Densities and Relative Densities some common Substances

Substance	Density (kgm^{-3})	Relative Density
Air	1.3	0.0013
Ethanol	940	0.94
Methanol	790	0.79
Ice	930	0.93
Fresh water	1000	1.00
Sea water	1030	1.03
Aluminium	2650	2.65
Lead	11300	11.30
Gold	19300	19.30
Wood	750	0.75
Iron	7870	7.87
Brass	8900	8.90
Mercury	13600	13.60
Glass	3700	3.70
Petrol	700	0.70
Rubber	950	0.95

If the same body is immersed in different liquids, the body will sink more in the liquid with lower density. From the table above, since sea water has relative density of 1.03, whereas fresh water has a relative density of 1.00, a boat or ship will sink deeper in fresh water than in sea water. Also, since water has a higher density than that of ethanol, a person with a container of fresh water with the same volume as that of ethanol will feel the fresh water being heavier than that of ethanol.

Difference between Density and Relative Density

Density	Relative Density
Density has unit	Relative density has no unit
It is a measured quantity	It is a comparison between measured quantities
It is the mass per unit volume of a substance	It is the ratio of the mass of any volume of a substance to the mass of an equal volume of water
There may be errors in volume measurement	There is a high degree of accuracy in all measurements

Experimental Determination of Density of Regular and Irregular Objects

Regular Solid

The mass of the solid is found by weighing it on a scale or chemical balance as discussed. The volume of the regularly-shaped body is obtained by length measurements using a ruler, vernier calipers or a micrometer screw gauge, depending on the accuracy required. This method applies to cuboids, spheres, cylinders and cones amongst other regular shapes. The formulae discussed under the volume section can be used to calculate for such shapes. The volume of the regular shape is then calculated from the formula;

$$density = \frac{\text{mass}}{\text{volume}}$$

An Irregular Solid

The mass (M_1) of an irregularly-shaped body or solid is found in the same way as the regular one. To find the volume, it is necessary to partly fill a measuring cylinder with water. The initial reading (V_1) on the cylinder is taken. The solid is then tied to a thin length of a thread and lowered gently into the cylinder with water until it is completely immersed. The new reading (V_2) is taken. The difference between the two readings ($V_2 - V_1$) gives the volume of the irregular solid. The density of the irregular solid is given by;

$$density = \frac{M_1}{V_2 - V_1}$$

A Liquid

A measuring cylinder is first weighed empty to find its mass say M_1 using, for example, a top-pan balance. Some of the liquid is poured into the cylinder and re-weighed together with the liquid to find the new mass say M_2. The difference between the two readings ($M_2 – M_1$) gives the mass of the liquid. The density of the liquid is calculated from:

$$density = \frac{M_2 - M_1}{V_2 - V_1}$$

Worked Examples

Question 1: A piece of silicon metal has a mass of 144 g and a volume of 24cm^3. Find the density of the silicon metal.

Solution

mass = 144 g and volume = 24 cm^3

$$density = \frac{mass}{volume}$$

$$density = \frac{144\ g}{24\ cm^3} = 6.0gcm^{-3}$$

Question 2: If 25 cm^3 of a quantity of wood ash has a mass of 45g, calculate the density of the wood ash in kgm^{-3}.

Solution

Mass of wood ash = 45 g = 45 x 10^{-3} kg

Volume of wood ash = 25 cm^3 = 25 x 10^{-6} m^3. Therefore, the density of wood ash is given as,

$$\rho = \frac{45 \times 10^{-3}}{25 \times 10^{-6}} = 1.8 \times 10^3 kgm^{-3}$$

Question 3: A gold metal which is to be used to make a necklace weighs 90g on a scale balance. When it is immersed in a measuring cylinder containing water, the water level rises from the 55cm^3 mark to the 95cm^3 mark. What is the density of the piece of gold?

Solution

Mass of gold metal, M_1 = 90 g

Initial volume of water, V_1 = 55 cm^3

Final volume of water, V_2 = 95 cm^3

Volume of gold metal, V = V_2 – V_1 = (95 – 55) cm^3 = 40 cm^3

$$density = \frac{M_1}{V_2 - V_1} = \frac{90}{95-55} = \frac{90}{40} = 2.25gcm^{-3}$$

Experiment to Determine the Relative Density of a Liquid (e.g. ethanol)

1. Find the mass (M_1) of an empty relative density bottle.
2. Fill the bottle with water, wipe off any excess water on the bottle, and weigh again to obtain the mass of the water, say M_2.
3. Empty and dry the relative density bottle.
4. Fill the bottle with the liquid (ethanol), cork it and reweigh it to find the mass of the liquid, say M_3.
5. The relative density of the liquid (ethanol) can be calculated as follows;
   Mass of empty bottle = M_1
   Mass of bottle filled with water = M_2
   Mass of bottle filled with liquid (ethanol) = M_3
   Mass of water alone = (M_2 - M_1)
   Mass of liquid (ethanol) alone = (M_3 - M_1)

$$Relative\ Density = \frac{mass\ of\ liquid}{mass\ of\ equal\ volume\ of\ water}$$

$$Relative\ Density = \frac{M_3 - M_1}{M_2 - M_1}$$

Worked Examples on Relative Density

Question 1

An empty relative density bottle weighs 25 kg. It weighs 65 kg when filled with ethanol and 75 kg when it is filled with water. Find the relative density of the ethanol and hence its density.

Solution

Let M_1 be the mass of the empty relative density bottle = 25 kg
M_2 be the mass of water and the relative density bottle = 75 kg M_3 be the mass of ethanol and the relative density bottle = 65 kg

$$Relative\ Density = \frac{M_3 - M_1}{M_2 - M_1} = \frac{65-25}{75-25} = \frac{40}{50} = 0.8$$

Therefore, The density of ethanol = Relative density of Ethanol x Density of water
= 0.8 x 1000 kg/m^3
= 800 kg/m^3

Note: Density of water is 1000 kg/m^3

Question 2

The relative density of an alloy is 6.5

a) Find the mass of a solid alloy cube of side 20 cm
b) What volume of the alloy has a mass of 13 kg? (Density of water = 1g/cm^3)

Solution

(a) Density of alloy = relative density of alloy × density of water
= 6.5 × 1 g/cm^3
=6.5 g/cm^3

Volume of alloy = l×b×h = 20×20×20 = 8000 cm^3
Mass = Density × volume = 6.5 × 8000 = 52,000 g

(b) Density of alloy = 6.5 g/cm^3
Mass of alloy = 13 kg = 13000 g

$$density = \frac{mass}{volume}$$

$$volume = \frac{mass}{density} \qquad = \frac{13000}{2000} \qquad = 6.5cm^3$$

UPTHRUST ON OBJECTS IN FLUIDS

When an object is placed in a fluid, it displaces some amount of fluid and the fluid exerts an upward force on the object. The upward force exerted on an object placed in a fluid is called upthrust. Due to the upthrust on an object in a fluid, the net weight of the object in a fluid is less than its weight in air. Suppose an object of weight W_a in air is placed in a fluid that exerts an upthrust U on the object, then:

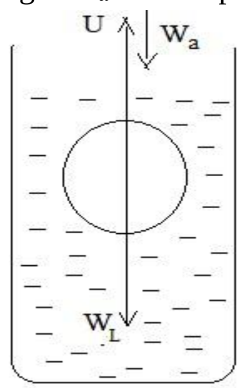


Figure 2.1: Upthrust on objects in fluids

(i) If $> U$, the object will sink to the bottom of the fluid as a stone does in water. The net or apparent weight of the object in the fluid is $W_L = W_a - U$.
The difference between the weight in air and that in the fluid or loss in weight, $W_a - W_L = U$ is the Upthrust

(ii) If $> W_a$, the object will levitate (rise) in the fluid as a hydrogen balloon does in air.

(iii) If $W_a = U$, the object will remain stationary or float in the fluid as a cork does in water (law of floatation).

Also, the solid displaces a volume of fluid equal to the part of the volume of the solid submerged. If the solid is fully immersed, then the volume of the solid equals the volume of the fluid displaced. This is the bases of the method of difference that is used to obtain the volume of a solid by immersion in a liquid.

Key Ideas

- The matter is made up of particles of different sizes (atoms, molecules, ions).
- The density of a substance is defined as the mass of the substance that occupies a unit volume.
- The mass of a body is measured with an appropriate scale or balance.
- The volume of a body or an object is the amount of space occupied by the body or the object.

- The relative density (RD) of a substance is defined as the ratio of the density of a substance to the density of water.
- Any object of relative density greater than 1 will sink in water while any object of relative density less than 1 will float in water.

Reflection

- What are the differences between mass and volume?
- What happens when an object sink or floats on the water? Share your view on it.
- What are the differences between density and relative density?
- How do you understand the measurement of time and temperature?
- Have you ever been checked by the use of a thermometer when you visited the hospital? How were your experiences?

Discussion

- Explain what the density of matter is.
- Briefly discuss whether an object will sink or float in the water with an experiment.
- Explain the differences between density and relative density.

SESSION 5: ARCHIMEDES' PRINCIPLE

Learning Objectives

By the end of the study, a participant will be able to;

1. Explain the rationality behind Archimedes' principle to the measurement of relative density;
2. Describe the application of Archimedes' principle to determine the relative density of a liquid.

ARCHIMEDES' PRINCIPLE

Archimedes' principle states that when an object is totally or partially immersed in a fluid, it experiences an upthrust, which is equal to the weight of the fluid displaced.

Experiment to verify Archimedes' Principle

i. Attach a solid to a spring balance, read and record its weight in air, W_a. See Figure 2.2.
ii. Fill an overflow can with water to the spout and place an empty beaker at the spout. iii. Immerse the solid fully in the overflow can while attached to the spring balance.
iv. Read and record the weight of the solid in water.

v. Calculate the loss in weight or Upthrust: $W_a - W_W = U$.
vi. Determine the weight of the displaced liquid in the beaker by difference, W_d.

It will be observed that the Upthrust or loss in weight of the solid is equal to the weight of water displaced. Thus:

$$W_a - W_W = U = W_d$$

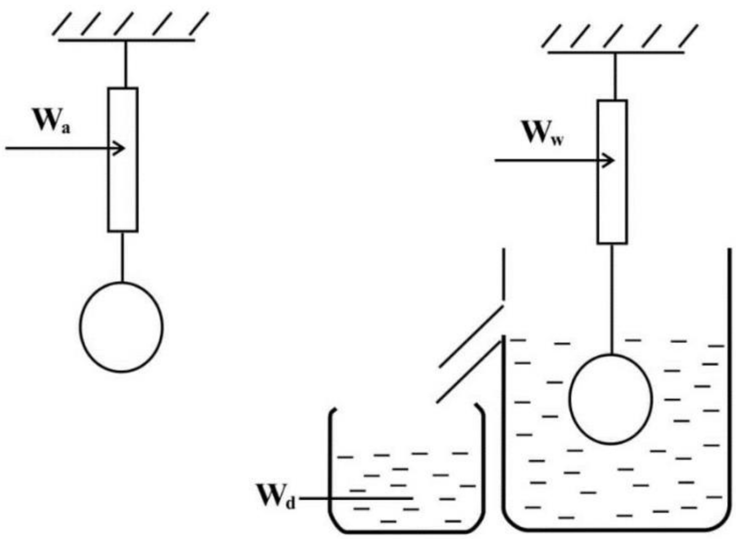


Figure 2.2: Verification of Archimedes' Principle

Application of Archimedes Principle to Determine the Relative Density of a Liquid

The same solid is used to displace equal volumes of the liquid and water by fully immersing the solid in the liquid and water in turn. Since the weights of the displaced liquid and the water represent the upthrust on the solid in both cases, the relative density of the liquid may be calculated by application of Archimedes' Principle as follows:

$$\text{Relative density of the liquid} = \frac{\text{weight of liquid displaced by solid}}{\text{weight of water displaced by solid}}$$

$$= \frac{\text{upthrust on solid by the liquid}}{\text{upthrust on solid by water}}$$

$$= \frac{W_a - W_l}{W_a - W_w}$$

Where W_a is the weight of the solid in air
W_l is the weight of the solid in the liquid and
W_W is the weight of the solid in water

Example:

In an experiment to determine the relative density of liquid using Archimedes' Principle, the following recordings were made:

Weight of a solid in air = 10.2N
Weight of the solid in the liquid = 5.9N
Weight of the solid in water = 8.6N.

Use the information above to determine the relative density of the liquid.

Solution:

Upthrust of liquid on solid = 4.3N
Upthrust of water on the solid =1.6N

Relative density of liquid = $\frac{4.3}{1.6} = 2.69$

Key Ideas

- Archimedes' principle states that when an object is totally or partially immersed in a fluid, it experiences an upthrust, which is equal to the weight of the fluid displaced.

Reflection

- What is the law of Archimedes' principle?
- What are the experiments to verify the Archimedes' principle?
- What the application of Archimedes' principle to determine the relative density of a liquid?

Discussion

- Explain what Archimedes' principle is?
- Briefly discuss the experiment to proof or verify the Archimedes' prnciple.
- Explain the application of Archimedes' principle to determine the relative density of a liquid.

SESSION 6: FLOATATION

Learning objectives

By the end of the study, a participant will be able to;

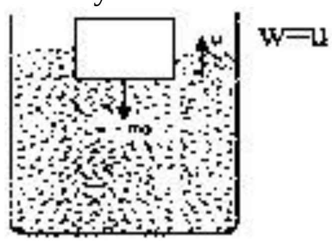
1. Explain the law of floatation;
2. Explain floatation by the use of the principle of density e.g. Hydrometer, balloon.

Floatation

A body floats in liquid when the upthrust balances the weight of the body (i.e. *mg = u).* Also, the weight of the fluid displaced equals upthrust and therefore a body will float when the weight of the fluid displaced is equal to the weight of the body. i.e.

$$mg = \rho_1 V_d g$$

$$\therefore m = \rho_1 V_d$$



where

ρ_1 = density of liquid

V_d = volume of liquid displaced

Law of Flotation

The law of flotation states that a floating body displaces its weight of the fluid in which it floats. The weight displaced is equal to the upthrust and the body is in equilibrium.

APPLICATIONS OF FLOTATION

Hydrometer: This is an instrument used to measure the density of liquids. It sinks lower in liquids of low density and floats higher in liquids of high density. Its action is based on the law of floatation. It is made to float in the liquid whose density is to be measured and the density read off from a scale attached to the side.

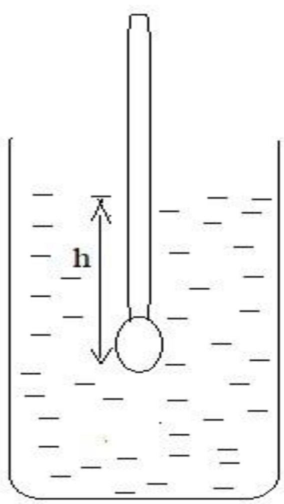


Figure 2.3: Hydrometer

Suppose a hydrometer of weight W_H and cross-sectional area A_H floats in a liquid of density ρ_l. Then from the law of floatation, the weight of the hydrometer equals the weight of fluid displaced:

$W_H = m_l g = \rho_l V_l g = \rho_l A_H h g$ where h is the depth of the hydrometer below the surface of the liquid.

Then $\rho_l = \frac{W_H}{A_H h g}$ or $\rho_l \propto \frac{1}{h}$.

This means the hydrometer sinks deeper in a liquid of lower density and vice versa.

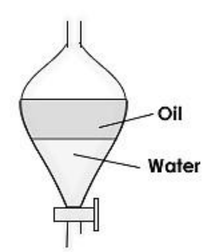
Balloon: A balloon filled with hydrogen gas will rise and float in the air. The density of air is much greater than that of hydrogen; it is about 14 times greater. The average density of the balloon containing hydrogen is less than the density of the air. The weight of air, which will be displaced by the balloon with hydrogen, is greater than that of the balloon. Per Archimedes' principle, the balloon is acted upon by a resultant upward force equal to the difference between the weight of the balloon and the weight of air displaced. The resultant upward force provides the lifting power of the balloon.

Boats and ships: Boats and ships are designed to have a hollow cavity. This hollow cavity contains air. This makes the mean density of a boat to be less than that of water. The hollow cavity reduces the weight of the boat or ship for the volume of water it can displace. The weight of the volume of water displaced balances with the weight of the boat or ship and hence the ship or boat floats on water.

Sinking ships: In the past, some European ships sank when they entered the tropics for the first time. All was well when the cargo was put aboard in cold, salty waters, but then the ship sank when it reached warmer, less salty seas. When the ship was first loaded it floated because cold, salty water has a relatively high density. This meant that less water had to be displaced to equal the mass of the ship. The problem was that Archimedes' principle had not been taken into account when the ship was first developed. This meant that less water had to be displaced to equal the mass of the ship. As the ship steamed to warmer, less salty waters, more water had to be displaced to maintain equilibrium. The ship dropped lower in the water, sometimes dropping below the waterline, and sinking. This was overcome by Samuel Plimsoll who marked his ships with what became known as the **Plimsoll Line.**

Submarines: Submarines can move under water and can rise to the surface of water and float like a ship. The buoyancy of a submarine depends on the amount of water in its ballast tanks. The ballast tanks are two tanks on the sides of the submarines, which are filled with water. When the tanks are filled with water, the mean density of the submarine becomes greater than that of the sea water and this makes the submarine dive in the water. For the submarine to move on the surface of sea water, water is ejected from the tanks through compressed air.

Use of Separating Funnel: A separating funnel is employed in the separating of mixtures of immiscible liquids, for example water and kerosene. The less-dense liquid settles at the top after they have been well shaken and left to stand after a few minutes. The two liquids can then be separated by opening the tap of the separating funnel to allow the denser liquid to drain. The diagram above shows a Separating funnel demonstrating the separation of oil and water.



Worked Examples

1. A metal block weighs 1.8 N in air and 1.5 N in water. What will be its weight in a liquid of relative density 0.6?

Solution

Weight in air Wa = 1.8 N,
Weight in water W_w= 1.5 N
Relative density = 0.6

$$RD = \frac{W_a - W_l}{W_a - W_w}$$

$$0.6 = \frac{1.8 - W_l}{1.8 - 1.5}$$

$$0.6 = \frac{1.8 - W_l}{0.3}$$

$$W_l = 1.8 - (0.6 \times 0.3) = 1.62\text{N}$$

2. A simple hydrometer of mass 50 g floats in a liquid of relative density 1.4. Calculate the volume of liquid displaced by the hydrometer. (Density of water = 1 gcm^{-3})

Solution

$$RD = \frac{Density\ of\ liquid}{Density\ of\ water}$$

$$1.4 = \frac{Density\ of\ liquid}{1\ gcm^{-3}}$$

Density of liquid = l.4 x 1 = l.4 gcm $^{-3}$

$$\text{density of liquid}, \rho_l = \frac{\text{mass of liquid displaced, m}_\text{l}}{\text{volume of liquid displaced, V}_\text{l}}$$

$$\text{volume of liquid displaced, V}_\text{l} = \frac{\text{mass of liquid displaced, m}_\text{l}}{\text{density of liquid}, \rho_l}$$

$$\text{volume of liquid displaced, V}_\text{l} = \frac{50}{1.4} = 35.71\text{cm}^3$$

3. A ship of mass 1200 tonnes floats in sea-water.
   a. What volume of sea-water will it displace if the ship enters fresh water?
   b. What mass of cargo must be unloaded so that the same volume of water is displaced as before?

(Density of fresh water = 1000 kgm-^{3}, Relative density of sea-water = 1.03, 1 tonne = 1000 kg)

Solution

a. The ship displaces a weight of sea-water equal to its own weight and therefore mass of sea-water displaced is equal to mass of ship.

Mass of sea-water displaced = 1200 tonnes
= 1200 x 1000 kg
= 1200000 kg

$$RD = \frac{\text{density of sea water}}{\text{density of fresh water}}$$

$$1.03 = \frac{\text{density of sea water}}{1000}$$

$Density\ of\ sea\ water = 1.03 \times 1000 = 1030\ kgm^{-3}$

$$Volume\ of\ sea\ water\ displaced = \frac{1200000}{1030} = 1165m^3$$

The same volume of fresh water will be displaced

⇒Volume of fresh water displaced = 1165 rn^3 and

Mass of fresh water displaced = 1165 m^3 x 1000 kgm^{-3}

Mass of fresh water displaced = 1165000 kg

Mass of cargo to be unloaded = 1200000 - 1165000 = 35000 kg
= 35 tonnes

Key Ideas

- The law of flotation states that a floating body displaces its weight from the fluid in which it floats.
- Hydrometer is an instrument used to measure the density of liquids.
- Boats and ships are designed to have a hollow cavity.
- Submarines can move underwater and can rise to the surface of the water and float like a ship.
- A separating funnel is employed in separating of mixtures of immiscible liquids, for example, water and kerosene.

Reflection

- What is the law of floatation?
- What are the applications of the following to the law of floatation?
  - Hydrometer
  - Balloon
  - Boats and ships
  - Sinking ships
  - Submarines
  - Using separation funnel

Discussion

- Briefly describe the law of floatation.
- Describe the following;
  - Hydrometer
  - Balloon
  - Boats and ships
  - Sinking ships
  - Submarines
  - Using separation funnel

UNIT 5: ENERGY, WORK AND POWER

This unit introduces you to energy, work, and power. The unit also highlights the sources of energy and further explain the law of conservation of energy. Finally, the differentiation of the work and energy will be elaborated in this unit.

Learning outcome(s)

By the end of the unit, the students will be able to:

1. Discuss forms of energy and their transformations.
2. Perform simple calculations on work, power and energy
3. Explain the relation between work, power and energy

SESSION 1: SOURCES OF ENERGY

Learning Objectives:

By the end of the session, participant will be able to:

1. Describe what energy is;
2. Identify the sources of energy;
3. Identify the differences between the renewable and non-renewable sources of energy;
4. Identify the general sources of energy.

ENERGY

You have heard of the word “energy” all your life. You need to eat vegetables to grow strong and have “energy”. You need to go to bed early so you will have “energy” in the morning to go to school. Energy is the ability to do work. Energy is everywhere in nature; sunlight, wind, water, plants, and animals. We use energy every day.

Sources of Energy

Energy sources can be classified as a renewable source of energy and non-renewable source of energy.

Renewable Source

Renewable Source is that energy which is inexhaustible (which can never be used up), always available and never runs out. Examples are:

1. The sun (solar energy) wave
2. Nuclear fusion.
3. Wind
4. Geothermal
5. Tides
6. Hydropower

Non-Renewable Sources

Non-Renewable Source is that energy, which is exhaustible (which can be used up), they are not always available and they can run out.

Examples are,

- Coal and oil
- Nuclear fission
- Wood, charcoal

Difference between Renewable and Non-renewable Sources of Energy

Renewable	**Non-renewable**
The resources that can be renewed once they are consumed are called renewable sources of energy.	The resources that cannot be renewed once they are consumed are called non-renewable sources of energy.
These resources do not cause any environmental pollution.	These resources cause environmental pollution..
Renewable resources are inexhaustible.	Non- Renewable resources are exhaustible.
Renewable resources are not affected by human activities.	Non- Renewable resources are affected by human activities.
Examples of Renewable resources- Air, water and solar energy.	Examples of Non-renewable resources- natural gas, coal and nuclear energy.

General Sources of Energy

- Foods
- Electricity
- Fuel
- Light
- Sound
- Sun
- Chemicals
- Heat

Key Ideas

- Energy is the ability to do work.
- Energy sources can be classified as a renewable sources of energy and non-renewable source of energy.
- Non-Renewable Source is that energy, which is exhaustible (which can be used up), they are not always available and they can run out.

Reflection

• What is energy? And identify the sources of energy. • How is your experiences and ideas about the sources of energy?
Discussion • Briefly describe energy. • Explain the differences between the rewable and non-renewable sources of energy. • Identify the various sources of energy and their examples.

SESSION 2: FORMS OF ENERGY

Learning objectives

By the end of this session, participant will be able to;

1. Identify the various forms of energy
2. Describe the uses of the various forms of energy identified.

Forms of Energy

Energy is found in different forms, such as light, heat, sound and motion. Different forms of energy are

a. Light
b. Chemical
c. Mechanical
d. Heat
e. Sound
f. Nuclear
g. Electric

Electrical Energy is associated with the movement of electrical charges. Matter is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrical charges moving through a wire is called electricity. Lightning is another example of electrical energy.

Chemical Energy is the energy stored in the bonds of atoms and molecules. It is the energy that holds these particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

Mechanical Energy is the energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy. Mechanical energy is the sum of both Potential and Kinetic energy.

Mechanical Energy (ME) = Potential Energy (PE) + Kinetic Energy (KE)

A frog sitting on a lily pad is an example of potential energy. The frog leaping is an example of kinetic energy.

Thermal Energy, or internal energy is the energy contained in a substance that is responsible for its temperature. It arises from the vibrations and movements of atoms and molecules within that substance. Geothermal energy is an example of thermal energy.

Heat Energy is thermal energy that flows from one substance to another when there is a temperature difference between the substances. Heat energy is thermal energy in transit.

Nuclear Energy is the energy stored in the nucleus of an atom — the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms in a process called **fusion**. Scientists are working on creating fusion energy on earth, so that someday, in the future, there might be fusion power plants.

Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate — the energy is transferred through the substance in a wave.

Gravitational Energy is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

Radiant Energy is the electromagnetic energy that travels as transverse waves in matter or space. Radiant energy includes gamma rays, x-rays, ultra-violet rays, visible light, infra-red rays, microwaves and radio waves.

Key Ideas

- Electrical Energy is associated with the movement of electrical charges
- Chemical Energy is the energy stored in the bonds of atoms and molecules.
- Mechanical Energy is the energy stored in objects by the application of a force.
- Thermal Energy, or internal energy is the energy contained in a substance that is responsible for its temperature
- Heat Energy is thermal energy that flows from one substance to another when there is a temperature difference between the substances.
- Nuclear Energy is the energy stored in the nucleus of an atom — the energy that holds the nucleus together.
- Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.
- Gravitational Energy is the energy of position or place.
- Radiant Energy is the electromagnetic energy that travels as transverse waves in matter or space.

Reflection

• What are the various forms of energy to you have studied in this session? • How is your experiences on some of the forms of energy?
Discussion • Briefly describe all the various forms of energy you have studied in this session. • Identify the uses of the various forms of energy.

SESSION 3: CONSERVATION OF ENERGY

Learning Objectives:

By end of this session, a participant will be able to:

1. Identify the law of conservation of energy;
2. Identify the ways of conserving energy;
3. Identify the energy transformation;
4. Analyze the efficiency of energy change.

Law of Conservation of Energy

The law states that energy can neither (cannot) be created nor destroyed but may be converted from one form to another. Energy is always changing from one kind to another. The total energy of an object never changes.

Potential energy + Kinetic energy = Total energy,

Total energy – Kinetic energy = Potential energy and

Total energy – Potential energy = Kinetic energy

Ways of Conserving Energy

a. By using energy saving lamps
b. By switching off electrical appliances when they are not in use.
c. By closing doors and windows when using an air conditioner.
d. Not leaving fridges and deep freezers open for a long time.

Energy Transformation (Interconversion of Energy)

Energy can be transformed from one form to another and is detected when it is always stored or hidden. Devices are used to carry out energy transformation. Examples of such transformations are;

a. Candle changes chemical energy into heat and light energy. The energy chain will be;
   Chemical energy ⟶ heat energy ⟶ light energy.
b. A spring compressed by the fingers and then released.
   Chemical energy ⟶ kinetic energy ⟶ potential energy ⟶ kinetic energy
c. When a stone is falling from a height

Potential energy $\longrightarrow$ kinetic energy $\longrightarrow$ sound energy $\longrightarrow$ heat energy

d. When a pendulum is swinging
   Potential energy $\longrightarrow$ kinetic energy $\longrightarrow$ potential energy

e. Rubbing the palms together to fell warm
   Chemical energy $\longrightarrow$ kinetic energy $\longrightarrow$ heat energy

f. Using a dry cell to light a lamp
   Chemical energy $\longrightarrow$ electrical energy $\longrightarrow$ light energy + heat energy

g. Carpenter hitting a nail with a hammer
   Chemical energy $\longrightarrow$ potential energy $\longrightarrow$ kinetic energy $\longrightarrow$ sound + heat

h. Using electric fan
   Electrical energy $\longrightarrow$ kinetic energy + heat energy

i. Telephone receiver
   Electrical energy $\longrightarrow$ sound energy

j. Electric iron/oven/heaters
   Electrical energy $\longrightarrow$ heat energy

k. Television set
   Electrical energy $\longrightarrow$ light energy + sound energy + heat energy

Efficiency of Energy Change

The conversion of one form of energy to another is not 100% efficient because some of the energy is lost in the process. The efficiency (***E***) of energy transformed is given as

Efficiency = useful energy obtained total/energy transformed × 100%

Efficiency = energy output/energy input × 100%

$$\text{Efficiency} = \frac{work\ output}{work\ input} \times 100\%$$

$$\text{Efficiency} = \frac{\text{Eo}}{\text{E1}} \times 100\% = \frac{\text{Wo}}{\text{W1}} \times 100\%$$

Worked Examples

1. A 120J of useful work is done by a machine when 150J of energy is supplied to it. What is the efficiency of the machine?

Solution

E_o = 120 J, E_1 = 150 J But

$$E = \frac{\text{Eo}}{\text{E1}} \times 100\% = \frac{120\text{J}}{150\text{J}} \times 100\% = 80\%$$

2. A machine has 75% as its efficiency when a 40,000J of energy is supplied to it. What useful work does it produce?

Solution

E = 75%, E_1 = 40,000J

From

$$E = \frac{Eo}{E1} \times 100\%$$

we have

$$E_o = \frac{E \times E1}{100} \quad \frac{75 \times 40000}{100} = 30000J$$

3. In the conversion of 1000 J electrical energy into heat, 250 J of energy got lost. What is the output energy and hence its efficiency?

   Solution

   E_1 = 100 J

   Energy Output, E_o = Input Energy – Wasted Energy = 1000 J – 250 J = 750 J

$$E = \frac{Eo}{E1} \times 100\% = \frac{750}{1000} \times 100\% = 75\%$$

4. A crane at Bans Timbers uses a fuel which when burnt produces energy of $7.5x10^5$ J. If the efficiency of the crane is 80%, calculate the workdone by the crane in lifting logs.

   Solution

   From

$$\text{E} = \frac{\text{energy output}}{energy\ input} \times 100\%$$

$$Energy\ output = \frac{Efficiency}{100\%} \times energy\ input$$

$$= \frac{80}{100} \times 7.5 \times 10^5 = 6 \times 10^5 J$$

Key Ideas

- The law of conservation of energy states that energy can neither (cannot) be created nor destroyed but may be converted from one form to another.
- The total energy of an object never changes
- Energy can be transformed from one form to another and is detected when it is always stored or hidden.
- The conversion of one form of energy to another is not 100% efficient because some of the energy is lost in the process
- Radiant Energy is the electromagnetic energy that travels as transverse waves in matter or space.

Reflection

• What is the law of conservation of energy? • What is your experiences on the ways of conserving energy? • How does energy transform from one form to another? And make a reflection of some examples of transformation of energy. • What are the efficiency of energy?
Discussion • Explain the law of conversation of energy. • Identify the ways of conserving energy. • Briefly explain the energy transformation. • Identify the examples of transformation of energy. • Describe efficiency of energy.

SESSION 4: WORK

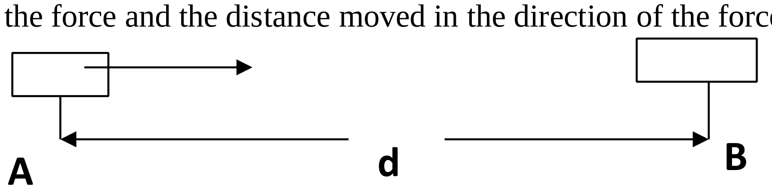
Learning Objectives

By the end of this session, participant will be able to;

1. Define what work is;
2. Practically give an examples of work;
3. Identify the positive, negative, and zero work;
4. Differentiate between the work and energy;
5. Solver mathematical problems of and energy.

WORK

In everyday life, the word "work" is applied to any form of activity that requires the exertion of muscular or mental effort. Work is defined as the dissipating or expenditure of energy and said to be done, when the point of application of a force moves in the direction of the force. And it is the product of the force and the distance moved in the direction of the force.



The point of application of the force F, moves through a distance AB = d.

Mathematically,

$$\text{Work (W)} = \text{Force} \times \text{Distance}$$
$$= F \times d = Fd$$

but F = ma, therefore **W = mad**

Work is a scalar quantity. The only circumstance in which a force does work is when the force moves through a distance in the direction of the force. The S.I. unit of work is Joule or (J).

$1 \text{ J} = 1 \text{ Nm} \quad = 1 \text{ kgm}^2\text{s}^2$

Worked Examples

1. What work is done when a body of weight 10 N is lifted through a vertical height of 2 m?

Solution

$$W = F \times d \quad = 10 \times 2 \quad = 20 \text{ J}.$$

2. A body is moved horizontally by a force of 20 N applied horizontally through a distance of 10 m. Calculate the work done.

Solution

$$W = F \times d = 20 \times 10 = 200 \text{ J}$$

Positive, Negative and Zero Work

Positive Work: If the component of the force is in the same direction as the displacement, the work done is positive. Examples are:

a. A boy running up a flight of steps.
b. Work done when a force is applied to a body to lift it upwards in the same direction.
c. Work done when a force is applied to a spring to stretch it in the direction of the applied force.

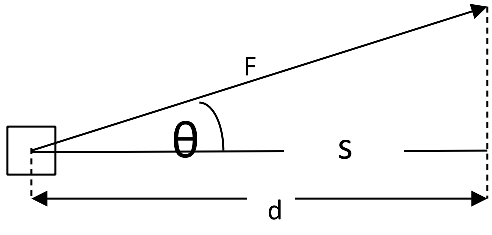
***Negative Work*:** If the component of the force is in opposite direction to the displacement, the work done is negative. Examples are:

a. Work done by friction on a moving body.
b. Work done by gravitational force on a body being lifted.

***Zero Work*:** If the component of the force is perpendicular to the displacement, the work done is Zero. Also if the point of application of the force makes no displacement, no work is done. Examples are:

a. A man walking on a level floor carrying a heavy load does no work.
b. Work done by the normal reaction on a body by the surface on which the body is placed.

Work done by an Inclined Plane



In the above diagram, a constant force F acts at an angle θ with the direction of motion. If the force undergoes a displacement d, the work done is the product of the magnitude of the displacement and the horizontal component of the force F.

Work done = horizontal component of F × displacement

Horizontal Component = F Cos θ

$$\mathbf{W = F \cos\theta \times d}$$
$$\mathbf{= F \cos\theta . d}$$

Worked Example

A piece of wood is pulled along an inclined plane by a 2500 N by attaching a rope, which makes an angle of 60^o with the horizontal. Calculate the work done if the wood is moved a distance of 100 m?

Solution

Let the horizontal component of the force

$W = F \cos\theta \times d$

$= 2500 \times \cos 60 \times 100 \qquad = 125,000$ J

Work and Energy

The terms work and energy are quite familiar to us and we use them in various contexts. In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, *work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force.* If no displacement takes place, no work is said to be done. Therefore, for work to be done, two essential conditions should be satisfied:

a) a force must be exerted
b) the force must cause a motion or displacement

Key Ideas

- Work is defined as the dissipating or expenditure of energy and said to be done, when the point of application of a force moves in the direction of the force.
- Work is a scalar quantity.
- The S.I. unit of work is Joule or (J).
- If the component of the force is in the same direction as the displacement, the work done is positive.
- If the component of the force is in opposite direction to the displacement, the work done is negative.
- If the component of the force is perpendicular to the displacement, the work done is Zero.
- Work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force.

Reflection

• What are some of the practical examples of force and distance moved in one direction of the force? • With practical examples, briefly record and discuss the positive, negative, and zero type of work. • How does work done practically with the inclined plane?

Discussion
• Briefly describe what work is.
• What is the SI unit of work?
• Explain the following types of work.
  ○ Positive
  ○ Negative
  ○ Zero
• Briefly explain the work done by constant force and variable force.

SESSION 5: POWER

Learning Outcome (s)

By the end of the session, participant will be able to:

1. Define what power is;
2. Work with an examples of power.

Power

It is the rate of doing work or the rate of expenditure of energy. It is a scalar quantity. The unit of power is the watt (W). Watt = 1 joule/seconds (one joule per one second).

Mathematically,

$$Power = \frac{work\ done}{time\ taken} \qquad = \qquad \frac{w}{t}$$

1 kilowatt (lkW) = 1000 watts = 1000J/s

The kilowatt-hour (kWh) is a unit of work. It is the work done in one hour at the rate of lkW.

1 kW = 1000J/S x 1 hour = 1000J/s x 60 x 60 =1000J/s x 3600 = 3.6 x 10^6 J = 3.6 MJ.

Worked Examples

1. A pump raises water to a height of 20 m. If it delivers 400 kg of water in 19.6 s, what is the power of the pump? (Take g = 9. 8 m/s^2)

Solution

Work done = F x d = 400 x 9. 8 x 20 =78400 Nm

$$Power = \frac{work\ done}{time} = \frac{78400}{19.6} = 4000\ W$$

2. A loaded cable of an elevator has a mass of 3.0 x 10^3 kg and moves 210 m up the shaft in 23 s at a constant speed. At what average rate does the cable do work on the cab? (g = 9. 8 m/s^2).

Solution

$$Power = \frac{work\ done}{time} = \frac{mgh}{t} = \frac{3 \times 30^3 \times 9.8 \times 210}{23} = 268.4\ KW$$

Key Ideas

- It is the rate of doing work or the rate of expenditure of energy.
- The unit of power is the watt (W).
- The kilowatt-hour (kWh) is a unit of work.

Reflection

- What is power and give practical examples?

Discussion

- Briefly define power.
- Discuss with an example how power works in our daily life.

UNIT 6: OPTICS

This unit introduces you to optics. The unit highlights the reflection of light, laws of reflection and types of reflections. The unit further describe the formation of image and the reflection of light. Finally, the unit looks at the refraction of light and total internal reflection of light.

Learning outcome(s)

By the end of the unit, the students will be able to:

- Demonstrate adequate understanding reflection of light.
- Demonstrate adequate knowledge of refraction
- Explain Snell's law and solve mathematical problems on it.
- Explain the use of convex and concave mirror in the security and automobile industries.
- Describe the mirror formula and perform simple calculations on it

SESSION 1: REFLECTION OF LIGHT

Learning Outcome (s)

By the end of this session, a student will be able to:

1. Describe what optics mean;
2. Explain what reflection of light is;
3. Explain the laws of reflection;
4. Identify the types of reflection;
5. Identify the differences between regular and irregular reflection;

OPTICS

Optics is the study of visible light, which forms a small part of the electromagnetic spectrum. Light is a form of energy, with a short wavelength and visible to the eye. When light falls on an object, part of the light may be reflected, part absorbed and the remaining transmitted. The amount of light reflected, transmitted or absorbed depends on the nature of the surface of incidence.

REFLECTION OF LIGHT

Reflection is the phenomenon that occurs when light bounces off an object. Generally, all surfaces reflect some light but good reflectors of light are smooth, shiny, white, or well-polished surfaces such as mirrors, polished metal, white smooth walls, the moon etc.

Ray Diagram Terminology

The following terms are essential when describing the laws of reflection:

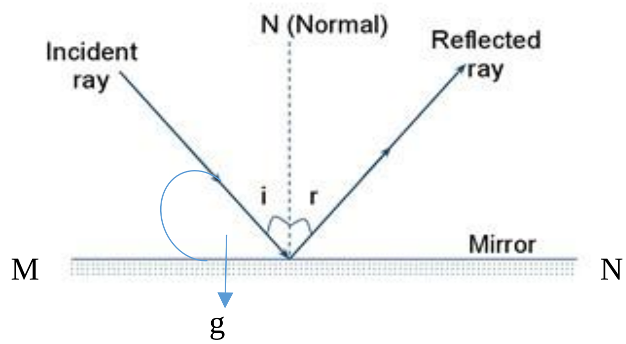


Figure 6.1: A diagram showing the reflection of light at a plane surface

MN is a reflecting surface e.g. a plane mirror.

Incident Ray - is the ray that falls on or hits the surface

Reflected ray - the ray that travels away from the surface of incidence.

Normal - the line perpendicular to the surface and passing through the point of incidence.

Angle of Incidence (i) - the angle between the incident ray and the normal.

Angle of Reflection(r) - the angle between the reflected ray and the normal

Glancing Angle (g) - the angle between the incident ray and the surface of the mirror

The laws of reflection state that;

1. The incident ray, the reflected ray and the normal to the surface at the point of incidence, all lie in the same plane.
2. The angle of incidence (i) is equal to the angle of reflection (r). That is $i = r$

Types of Reflection

When reflection occurs at a surface, the reflected light may produce a clear image or may not produce any image. Hence there are two types of reflection. For example, a mirror reflects light and produce a clear image however, a white sheet of paper also reflects light but does not produce any image.

(a) Regular (specular) reflection
(b) Diffused or Irregular, or scattered reflection

Regular (specular) reflection**:** Regular reflection is the type of reflection that occurs when the surface of reflection is smooth or highly polished. In regular reflection, all parallel rays incident on the smooth surface are reflected parallel. Since the surface is smooth, all rays fall on the surface at the same angle of incidence resulting in the same angle of reflection for all reflected rays. Surfaces that can produce regular reflection include mirrors; surface of water, shiny cooking utensils, and polished furniture.

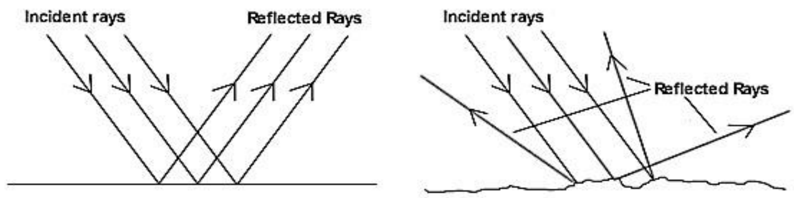


Figure 6.2: (a) Regular reflection (b) Irregular reflection

Irregular reflection: Irregular (scattered) reflection is the type of reflection caused by rough or unpolished surfaces. When parallels rays of light are incident on a rough surface, the reflected rays are not parallel but are scattered outwards in different directions. Since the surface is rough, each ray falls on the surface at a different angle of incidence resulting in different angles of reflection for each ray, and so the reflected light is scattered. Surfaces that produce irregular reflection are the sea, ponds, white sheet of paper, white walls etc.

Differences between Regular and Irregular Reflection
Table 6.1 shows the differences between Regular and Irregular reflection.

Table 6.1: Differences between Regular and Irregular reflection

Regular	**Irregular**
Parallel rays are reflected in the same directions.	Parallel rays are reflected in different directions.
Occurs on highly polished surfaces.	Occurs on rough, unpolished surfaces.
All rays strike at the same angle of incidence.	Individual rays strike at different angles of incidence.
Images formed here are clear and well defined.	Images formed by this type of reflection are not clear and not defined.

Key Ideas

- Optics is the study of visible light, which forms a small part of the electromagnetic spectrum.
- Reflection is the phenomenon that occurs when light bounces off an object.
- The laws of reflection state that the incident ray, the reflected ray, and the normal to the surface at the point of incidence, all lie in the same plane.
- Also, the angle of incidence (i) is equal to the angle of reflection (r). That is i = the conversion of one form of energy to another is not 100% efficient because some of the energy is lost in the process

- Regular reflection is the type of reflection that occurs when the surface of the reflection is smooth or highly polished.
- Irregular (scattered) reflection is the type of reflection caused by rough or unpolished surfaces.

Reflection

• What is the study of optics mean to you? • What is the laws of reflection talks about the light?
Discussion • Briefly describe the laws of reflection. • Explain the differences between the regular and irregular reflection

SESSION 2: FORMATION OF IMAGES IN A PLANE MIRROR

Learning Outcome (s)

By the end of this session, the participant will be able to;

1. Describe the formation of images in a plane mirror;
2. Describe the types of images formed by plane mirror;
3. Identify the characteristics of images formed by plane a mirror.

THE FORMATION OF IMAGES

An image is formed where two or more rays, reflected or refracted from a surface can be traced to a common point of intersection (or an apparent intersection point).

Types of images

1. *Real Images:* They are images that are formed by the actual intersection of reflected or refracted light rays. These images can be produced on a screen. Examples are images formed by photographic film, and by the television screen. They are also formed by convex lenses and concave mirrors.

2. *Virtual Images:* They are images that appear to be formed by an apparent intersection of reflected or refracted rays. Virtual images cannot be received on a screen. Plane and convex mirrors form virtual images.

Image Formation in a Plane Mirror

A plane mirror is a piece of glass silvered at the back. Because of its shiny and polished surface, it produces regular reflection. An image formed by a plane mirror has the following characteristics:

- The image is of the same size as the object
- The image is virtual
- The image is laterally inverted e.g. if you look at yourself in a mirror you will notice that your left ear appears as your right ear is.
- The image distance behind the mirror is the same as the object distance in front of the mirror
- It is upright.

Uses of a Plane Mirror

1. As dressing mirror
2. Plane mirrors are also used in constructing periscope which is used in submarines.
3. Used in sextant.
4. Plane mirrors are used as looking glass.
5. Plane mirrors are used in solar cookers
6. Used in mirror galvanometer
7. Used in kaleidoscope.

Application of Reflection in Plane Mirrors

a. Periscope - used by submarines, drivers of double Decker buses
b. Many plane mirrors are used to reflect the sun's beam onto metals in solar furnaces to produce very high temperature to boil substances or to assess the properties of certain materials.

SESSION 3: REFLECTION OF LIGHT AT CURVED MIRRORS (SPHERICAL MIRRORS)

Learning Outcome (s)

By the end of this session, the participant will be able to;

1. Identify the tyepes of curved mirrors;
2. Describe the formation of images in curved mirrors;
3. Identify the characteristics of images formed by curved mirrors;
4. State the uses of concave and convex mirrors.
5. Use the mirror formular to solve mathematical problems.

Types of Curved Mirrors

A curved mirror is a part of a hollow sphere with one side polished and the other, painted. There are two types of curved mirrors – convex and concave mirrors. The type of curved mirror depends on the part of the sphere which is painted.

Convex (Diverging) Mirrors: It is a curved mirror with the inside surface painted and the outside, polished. It is also called a diverging mirror because when a beam of parallel light incident on a convex mirror, the reflected rays diverge in different directions but appear to come from a point behind the mirror.

Properties of Images Formed by Convex Mirrors Convex mirror produces only one type of image.

a. Image always smaller than object (diminished).
b. Image always behind the mirror
c. Virtual
d. Lie between Focus and Pole.

Uses of Convex Mirrors

1. Used as driving mirrors to give wide field of view and erect image
2. Used in shops to give view behind shelves or racks of goods and also to detect shoplifting.

Concave (converging) Mirror: It is a curved mirror with the inside surface polished and the outside, painted. It is also known as converging mirror, because when a beam of parallel light incident on a concave mirror, the reflected rays converge to a common point in front of the mirror.

Uses of Concave Mirrors

1. As reflectors in car head light
2. Shaving mirrors/make up mirrors
3. Dentists mirrors.
4. As reflectors in touches/search lights
5. Used in telescope
6. Used to concentrate sun's rays for solar furnaces,
7. Used to reflect light on slide in microscope.

The nature of the image formed by a Concave mirror depends on the distance of the object from the mirror.

Features of a Curved Mirror

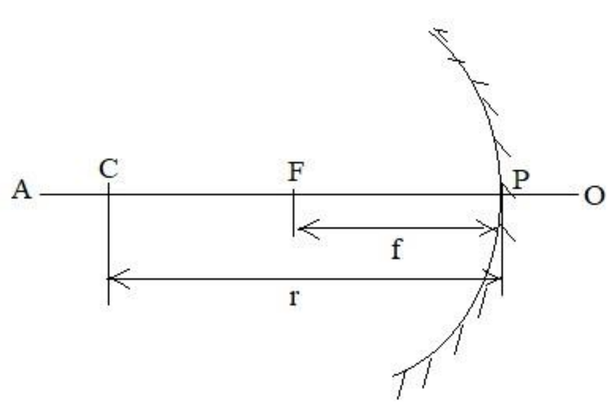


Figure 6.3: Parts of a concave mirror

- **Aperture:** Aperture is the reflecting surface of a curved mirror. The wider the aperture, the more the light can incident on the mirror.
- **Pole (P):** The pole is the geometric centre of a curved mirror. It is also known as the vertex.
- **Centre of Curvature (C):** It is the center of sphere from which the mirror was sliced or the center of the sphere of which the mirror forms a part. For a convex, C is behind the mirror, while for concave mirror it is in front of the mirror.
- **Principle axis** is the imaginary line through the pole and the centre of curvature.
- **Radius of Curvature (r):** Is the distance between the centre of curvature and the pole of the mirror.
- **Principal Focus (F):** Is a point on the principal axis to which all rays close and parallel to the principle axis converge (concave mirrors) or from which they diverge (convex mirror) after reflection.
- **Focal Length (f):** It is the distance between the pole and principal focus.

$$f = \frac{1}{2}r$$

Thus, r = 2f.

Finding the Position of Images by Ray Diagrams for Curved Mirrors

The following steps are used when finding the position of images by ray diagrams

1. A ray parallel to the principal axis is reflected so that it passes through the focus.
2. A ray passing through the principal focus is reflected, parallel to the principal axis
3. A ray through the Centre is reflected back along the same path.

The nature of the image formed by a concave mirror depends on the distance (position) of the object from the mirror. Table 6.2 shows the relationship between the object and the image formed by a concave mirror.

Table 6.2: Relationship between Object and Image formed by a Concave Mirror

Position of object	**Type of Image**	**Orientatio n of image**	**Position of image**	**Size of Image**
Between F & P	Virtual	Upright	Behind the mirror	Magnified
At F	Real	Inverted	Infinity	Magnified
Between F & C	Real	Inverted	Beyond C	Magnified
At C	Real	Inverted	At C	Same size as object
Beyond C	Real	Inverted	Between F & C	Diminished
At infinity	Real	Inverted	At F	Diminished

MIRROR FORMULA

The mirror formula is given as:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Note: r = 2f and

$$M = \frac{v}{u}$$

where
u – Object distance (distance of object from the pole of a mirror)
v – Image distance (distance of image from the pole of a mirror)
f – Focal length
r – Radius of Curvature
M – Magnification, the factor by which the size of the image is bigger or smaller than the size of the object.

Conventions: In the application of these formulae, two conventions are used namely;

1. The real is positive convention (RPC).
2. New Cartesian Conventions (NCC).

Real is Positive Conversion (RPC) Rules

a. All distances are measured from the mirror (origin)
b. Distances of real objects and images are positive
c. Distance of virtual objects and images are negative
d. Focal length (f) of a concave mirror is real hence it is positive
e. Focal length (f) of a convex mirror is negative because it is virtual

Worked Examples

1. An object is placed 20 cm from a concave mirror of focal length l2cm. Calculate the position of the image. What is its nature?

Solution
u = +20, f = +l2cm

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}, \qquad v = \frac{fu}{f-u} = \frac{20 \times 12}{20 - 12} = 30cm$$

The image distance is + 30cm. Therefore, it is real and 30cm in front of the mirror.

2. An object is placed 8cm in front of a concave mirror of focal length 12cm. Determine image distance.

Solution

u = + 8cm, f = + 12cm

$$v = \frac{fu}{f-u} = \frac{8 \times 12}{8-12} = -24cm$$

3. An object is placed 10cm in front of a Concave mirror of focal length 15cm. Find the image position and the magnification.

Solution

u = +10cm, f = + 15cm,

$$v = \frac{fu}{f-u} = \frac{10 \times 15}{10-15} = -30cm$$

$$m = \frac{v}{u} = \frac{30}{10} = 3cm$$

The image is 3 times as large as the object and is 30cm from the mirror. Since *v* is negative, the image is virtual.

4. An image is produced 3cm behind a convex mirror of focal length 6cm. Find the position of the object.

Solution

v = 3cm, f = -6

$$u = \frac{vf}{v-f} = \frac{-3(-6)}{-3-(-6)} = \frac{18}{-3+6} = \frac{18}{3} = +6cm$$

The object is 6cm in front of the mirror.

5. A concave mirror produces a real image 2cm tall of a 3.4 cm item tall placed 6cm from the mirror. Find the position of the image and the focal length of the mirror.

Solution

a. Height of Image, h_i = 2cm

Height of Object, h_o = 3.4cm

Image Distance, u = 6cm

$$Magnification = \frac{image\ distance}{object\ distance} = \frac{image\ height}{object\ distance}$$

$$m = \frac{v}{u} = \frac{h_i}{h_o}$$

$$v = \frac{u \times h_i}{h_o} = \frac{2 \times 6}{3.4} = \frac{12}{3.4} = 3.529cm$$

b.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{6} + \frac{1}{3.529} = \frac{3.529 + 6}{21.1764} = \frac{9.529}{21.1764}$$

$$\therefore f = \frac{21.1764}{9.529} = 2.22cm$$

Key Ideas

- An image is formed where two or more rays, reflected or refracted from a surface can be traced to a common point of intersection (or an apparent intersection point).
- Real Images are images that are formed by the actual intersection of reflected or refracted light rays.
- Virtual Images are images that appear to be formed by an apparent intersection of reflected or refracted rays.
- A plane mirror is a piece of glass silvered at the back.
- Periscope - used by submarines, drivers of double Decker buses.

Reflection

- Share your ideas on the real and virtual images.
- How does the image formation on the plane mirror occurs?
- Share your opinion on the position of images by ray diagrams.

Discussion

- Explain the formation of the image.
- Describe the various types of images.
- Briefly describe the formation of an image on the plane mirror.
- Identify the uses of the plane mirror.
- Identify the reflection of light on curved mirrors
- Identify the curved mirrors.

SESSION 4: REFRACTION OF LIGHT

Learning Outcome (s)

By the end of the session, participant will be able to;

1. Describe what refraction of light is;
2. Identify the effect of refracton of light;
3. State and apply the laws of refraction;
4. Describe the formation of total internal reflection;

REFRACTION OF LIGHT

Refraction is the change in speed and direction (bending) of light when it travels from one medium to another medium of different optical density.

Consider an object *O* in a bowl half full of water. The interface *AA* is the boundary between the air above and the water below. In order to view the object from air, light rays must travel from the object through the water (one medium) to another, air. On reaching the boundary, the rays bend away from the normal and enter the eye.

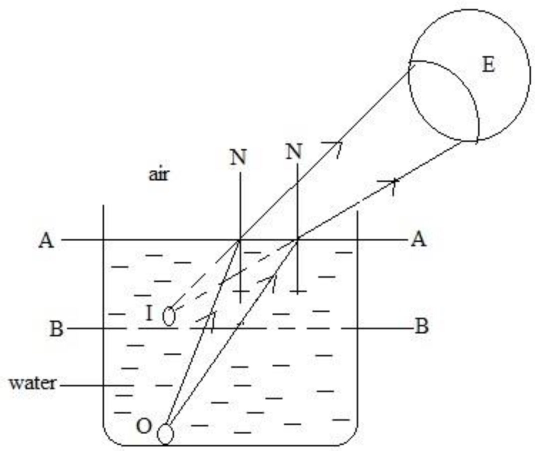


Figure 6.4: Refraction of light at water- air interface

The eye *E*, looking along a straight line, observes the image to be at a location *I*, which is displaced upwards. *I* is therefore a virtual image of *O*. The image *I* is formed due to the bending away of light from the normal at the interface between the water and air.

Note that for a ray of light to be refracted,

1. Two media of different optical densities must be in contact,
2. The light ray must pass obliquely through the medium.
3. In refraction, when a ray moves from a denser medium (water) to a less dense (air), the ray bends away from the normal and vice versa.

Effects of Refraction

The following are observed due to refraction of light:

1. The bottom of a pond or a swimming pool appears to be shallower than it actually is.
2. A straight stick e.g. a ruler, appears bent when partly immersed in water.
3. A thick glass block placed on an ink mark makes the mark appear displaced upwards.
4. Mirage (a “pool of water” on a plane field far ahead on a hot day (sunny day).
5. A coin in a cup of water appears to be nearer to the surface than it actually is.
6. Early sun rise and delayed sunset.

LAWS OF REFRACTION

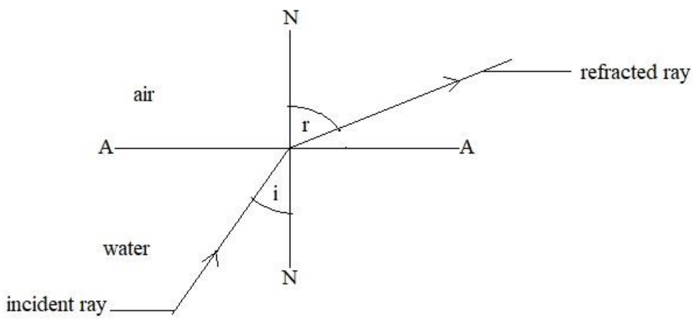


Figure 6.5: Refraction of light at a plane interface

The laws state that, when a ray of light moves from one medium to another medium:

1. The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

This second law is also known as Snell's law. The constant is the same as the relative refractive index ŋ between the two media.

Real and Apparent Depth

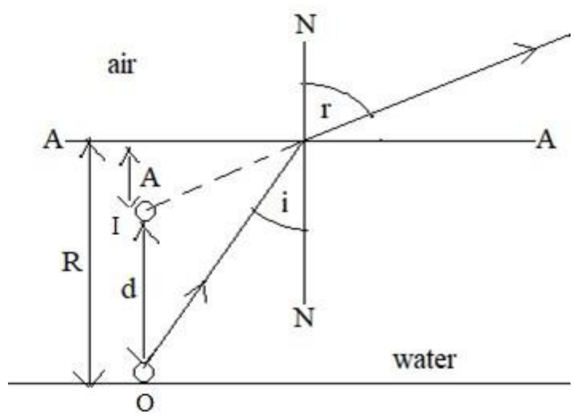


Figure 6.6: Real and apparent depths due to refraction of light

The relative refractive index between any two media may also be obtained from measurement and calculations of real depth and apparent depth when an object located at the bottom of a pond for example is viewed from the air above.

$$ŋ = \frac{\text{Real Depth(R)}}{\text{Apparent Depth(A)}} = \frac{R}{A}$$

Worked Examples

1. A coin is placed in a bucket of water at the depth of 15 cm from the level of the water. An observer looking through the water sees the coin at a depth of 8 cm from the water level. Calculate
   a. the refractive index of the water
   b. the displacement of the coin.

Solution

Real depth = 15 cm, Apparent depth = 8 cm

a. $ŋ = \frac{Real\ depth}{apparent\ depth} = \frac{15}{8} =$ 1.875 apparent depth

b. Displacement (d) = Real depth – apparent depth
   d = 15 – 8 = 7 cm.

2. An object pin is placed inside a beaker containing water to a depth of 6.0 cm. Calculate the displacement of pin if the refractive index of the water is 5/4.

Solution

R=6.0cm,

$$ŋ = \frac{5}{4} = 1.25$$

$$d = R(1 - \frac{1}{ŋ}) = 6\left(1 - \frac{1}{1.25}\right) = 1.2cm$$

3. A ray of light is incident in water at an angle of 30° on water - airplane surface. Find the angle of refraction in the air (refractive index (ŋ) for water = 4/3).

Solution

$$ŋ = \frac{4}{3} = 1.333, \mathrm{i} = 30^0$$

$$\text{but } ŋ = \frac{\sin \mathrm{i}}{\sin \mathrm{r}}$$

$$\rightarrow \sin \mathrm{r} = \frac{\sin \mathrm{i}}{ŋ} = \frac{\sin 30}{1.333} = 0.67$$

$$\therefore r = sin^{-1}(0.67) = 41.8^0$$

4. What is meant by the statement "the refractive index of glass is 1.5?

Solution

It means for a ray of light passing from air to glass the ratio of the speed of light in air to speed of light in glass equals 1.5.

5. If sin i = 0.4 for a ray of light traveling from a vacuum into a block of glass of refractive index 1.6, the value of sin r is?

Solution

$$\eta = \frac{\sin i}{\sin r} = \frac{0.4}{\sin r}, \sin r = \frac{0.4}{\eta} = \frac{04}{1.6} = 0.25,$$

Critical Angle (C)

It is the angle of incidence in the denser medium for which the angle of refraction in the less dense medium is 90°. Also, it is the minimum angle beyond which total internal reflection occurs.

Note: $$\eta = \frac{1}{\sin C}$$

where C is the critical angle. If the critical angle is greater than one (1) then;

- there is no refracted ray
- all the light is reflected back into the denser medium

TOTAL INTERNAL REFLECTION

It is the phenomenon whereby light rays traveling from an optically denser medium to a less dense medium are completely reflected inside the denser medium.

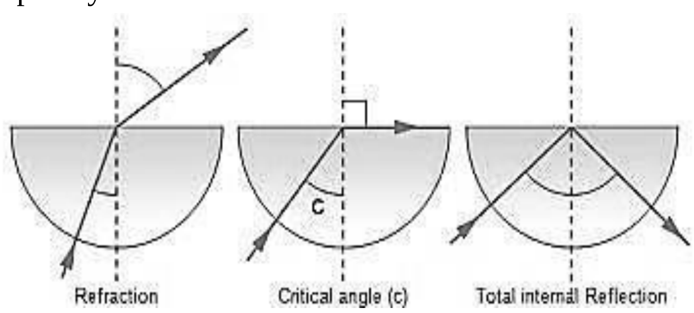


Figure 6.7: Demonstrating total internal reflection

Conditions for Total Internal Reflection to Occur

- Two different media of different optical density must be in contact.
- Light ray must be passing from a denser into a less dense medium.
- The angle of incidence in the denser medium must be greater than the critical angle.

Application of Total Internal Reflection

1. Prism periscope
2. Fish eye-view
3. Mirage
4. Multiple images in thick mirror e. Prism Binoculars
5. Inversion correction
6. Optical fiber (light tube)

Key Ideas

- Refraction is the change in speed and direction (bending) of light when it travels from one medium to another medium of different optical density.
- Light travels at different velocities in different media.
- The laws state that, when a ray of light moves from one medium to another medium:
  - The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.
  - The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.
- This second law is also known as Snell's law. The constant is the same as the relative refractive index ŋ between the two media.
- Total internal reflection is the phenomenon whereby light rays traveling from an optically denser medium to a less dense medium are completely reflected inside the denser medium.

Reflection

- What is refraction of light?
- Law of refraction states that…..?

Discussion

- Brifly discuss what refraction of light mean.
- Identify the laws of refraction.
- Identify the three condition for total internal reflection to occurs.

UNIT 7: BASIC UNDERSTANDING IN CHEMISTRY

Learning outcome(s)
By the end of the unit, the participant will be able to:

- Demonstrate understanding of matter

Session 1: Understanding Matter

Learning outcome(s)
By the end of the session, the participant will be able to:
- Define matter
- Describe the states of matter

What is Matter

There are millions of things around us. We know they are around us because we can use our senses of sight, smell, touch, taste and hearing to identify them. We give names to most of them. We put some together and give them specific names based on their similar features. For example, we put things into living and non- living. These things are classified as matter in science. Scientists say that anything that can occupy space and has mass is a matter.

Supposing you sit on a chair, can any other body sit where your body is touching? Unless you are displaced (removed) from where you are sitting no other body can occupy your space. Have you ever considered why balloons inflate when we blow air into them?

The air particles (blown air) try to occupy their own spaces and because the walls of the balloon are elastic (can stretch), the air particles push the walls of the balloon to expand to create more spaces for the air particles. What do you think happens when the walls of the balloon are not able to expand quickly to create spaces for the rushing air?

Consider the following everyday experiences: The gas in our cooking gas cylinders is not seen when the gas is leaking. The filled gas cylinder is heavier than the empty one. What do these everyday experiences tell you about the nature of matter?

Classification of Matter

Scientists classify matter based on similar features. Let consider the following six everyday things: ***Chair, water, cup, kerosine, smoke, air***. Put them into three groups based on any common feature(s) you know about them.

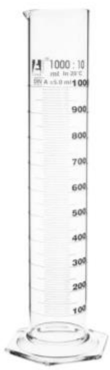
Another way of looking at the matter listed above are that:
1. Chair and cup remain fixed at specific position and their shapes do not change when you put them down.
2. Water and kerosine will not remain at fixed position when pour from their containers. They will spread and their shapes on the floor are different from the shape you observed when they

were in their containers. However, the extent of their spread depends on their amount available.
3. Smoke and air will spread irrespective of their amount into the entire room when they are released from their containers.

Based on these and other observations, chair and cup are classified among other matters as solids, water and kerosine are liquids whereas smoke and air are grouped as gases.

<u>Activity 1</u>

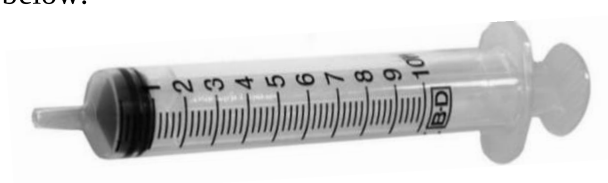
Fill the 500ml measuring cylinder (**B**) with water to the 500ml mark. Pour the water into **A**, the 1000ml measuring cylinder and read the mark of the water level in **A**. Fill **B** again and pour into **C** and read the mark of water level in **C**. Repeat the activity using granular sugar.

A

B

C


What do you observe about solids and liquids?

Activity 2:
Get 3 syringes like the one below.



a) Pull the plunger of the first syringe to about 8ml mark and push it back. You realize that as you push air rushes out of the syringe. Now pull up to the 10ml and seal the syringe by heating the tip of the syringe. Push the plunger. What do you observe?

b) Draw water into the second syringe by inserting the tip into water and pulling the plunger up to the 10ml mark. Seal the tip with heat. Try to push the plunger. What do you observe?

c) Pull the plunger from the syringe and fill with granular sugar, push the plunger in again, try to push beyond the 10ml mark and write your observation.

Observed Properties of Matter

The three states of matter can be distinguished from one another based on four properties:

Density

Density which is the ratio of the mass and volume of a substance is a characteristic property of pure substances. Solids and liquids are much more dense than gases. The solid and liquid states of a particular pure substance have very similar densities. The solid is usually slightly more dense than the liquid. Water is an exception, which is why ice floats on water.

Shape

Solids have well defined shapes and require no container to hold them. Liquids flow and take on the shape of their container. The volume of a container that is occupied by a liquid depends on the amount of liquid placed in the container. Gases , like liquids, flow and take on the shape of their container. Unlike liquids, gases expand to occupy the total volume of a container, regardless of the quantity of gas placed in the container.

Compressibility

Compressibility is the ability to reduce the volume of a substance by applying pressure. Gases are highly compressible. Liquids and solids are not compressible.

Thermal expansion

Thermal expansion is the increase in volume that occurs when a substance is heated. Gases display moderately high thermal expansion. Liquids and Solids expand very little when heated.

Key ideas

- Matter is anything that occupies space and has mass
- Matter, seen or unseen occupies space and has mass (weight).
- Solids and liquids have definite volumes but gases have indefinite volumes.
- Gases can be compressed but solids and liquids cannot be compressed

Session 2: Nature of Matter

Learning outcome(s)
By the end of the session, the participant will be able to:

- Differentiate between physical and chemical properties of matter
- Differentiate between physical and chemical changes
- Describe the nature of matter

Kinetic Theory of Matter

The kinetic theory of matter is the theory used to explain the different states of matter. Different aspects of the theory have been developed over 2400 years ago. The generalizations from the theory include:

- Matter is composed of tiny particles. These particles may be **atoms molecules or ions**.
- The particles possess **kinetic energy** because they are in constant motion. The kinetic energy is the source of disruptive forces that tend to pull the particles apart.
- The particles possess **potential energy** because they are attracted and repelled by each other. The potential energy tends to provide cohesive forces that hold the particles together
- The average speed of a particle (kinetic energy) increases with **temperature**.
- The particles transfer energy from one to another during collisions in which no net energy is lost.
- The total energy of a sample of matter is equal to the sum of its kinetic and potential energies

Models for the States of Matter

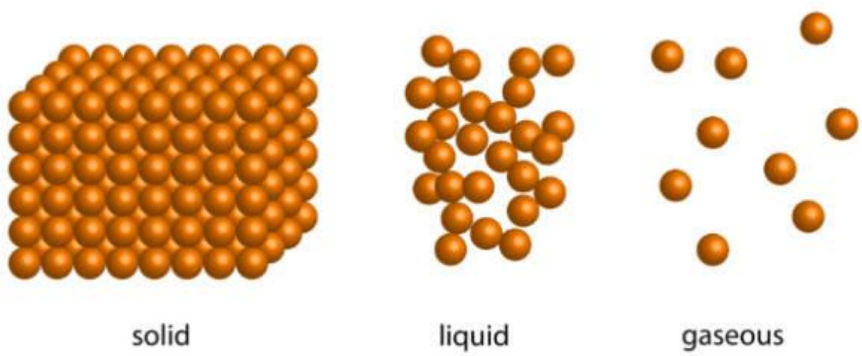


Figure 7.1: The three states of matter

Solids

In solids the cohesive forces are much greater than the disruptive forces. In a crystalline solid, each molecule is held at a fixed location within a crystal lattice. The disruptive forces cause the molecules to vibrate at their fixed location, but does not allow the molecules to move past one another. The kinetic-molecular model of matter can explain the characteristic properties displayed by solids.

High density

Because the cohesive forces are dominant, the molecules in a solid are very close together, which results in a greater number of molecules in a given volume.

Definite shape
Because the molecules in a solid cannot move past one another, they maintain a defined shape.

Low compressibility

Because the molecules in a solid are very close together, increasing the pressure is unable to move them much closer together.

Small thermal expansion
Though heating causes the molecules in a solid to vibrate faster about their fixed positions, the cohesive force still predominates, holding them very close together.

Liquids

In the liquid state the cohesive forces still predominate, holding the molecules almost as close together as but not as close like that in the solid state. The disruptive forces are strong enough causing the the molecules not to have fixed locations. Instead, the molecules are able to move about, slipping past one another. The kinetic-molecular model of matter can explain the characteristic properties of liquids. Because the cohesive forces are able to still hold the molecules close together in liquids, their densities, compressibilities and thermal expansions are similar but slightly lower to their corresponding solids. Unlike solids, liquids do not have defined shapes because, their molecules are capable of moving past one another but like solids, liquids have definite volumes.

Gases

In the gas state, the disruptive forces predominate. The cohesive forces are no longer able to hold the molecules together. The molecules move about independently of one another but come in contact with one another only when they collide. The molecules collide briefly and move in different direction along a straight line at constant velocity. The kinetic-molecular model of matter can explain the characteristic properties displayed by gases.

Low density

In gases the disruptive forces are dominant. The molecules are spread out and as far apart from one another as possible. This give gases very low densities, and therefore little mass in a giving volume

Indefinite shape

Like liquids, the molecules can easily move past one another. They take on the shape of their container.

Large compressibility

In gases the molecules are spread out with lots of space between them. When pressure is applied they can easily be pressed closer together.

Moderate thermal expansion

As a gas is heated the individual molecules acquire more velocity, move further apart and also strike the walls of the container with a greater force.

Change of State

When heat is applied to a solid the particles vibrate faster as result of increased temperature. At a specific temperature, particles start to moves like liquid particles. For example, when ice gain heat it changes to liquid water at 0^oC. Alternatively, when heat is removed, particles tend to come together. When water is put in a freezer, the temperature is reduced and liquid water become solid ice. The diagram below shows different processes whereby matter changes from one state to another.

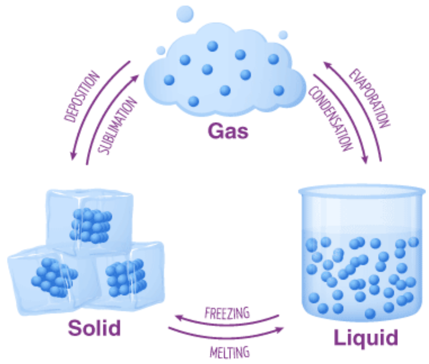
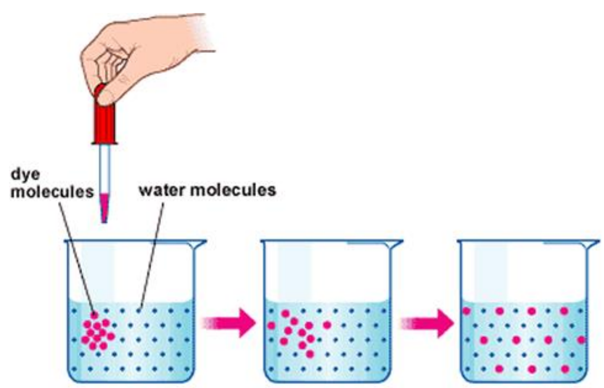


Figure 7.2: Change of State

Define the six processes shown above:

Some evidence of particular nature of matter

Several everyday events prove that substances consist of particles. Solid chalk is broken into smaller powdered particles. Perfumes are smelled from distance.



One of the figures shows what happens when dye is put in water and left for some time. The other is a model that tend to explain using particular nature of matter. Describe and explain the phenomena using particular nature of matter.

Physical and chemical properties

A physical property is a characteristic of a substance that can be observed or measured without changing the identity of the substance. Physical properties include color, density, hardness, and melting and boiling points. A chemical property describes the ability of a substance to undergo a specific chemical change.

Physical and chemical changes

Interaction of substances lead to a change. A change may either be physical or chemical change. The figure below shows mixing of iron filling with sulphur in two different samples. One sample form a mixture and the other form a compound.

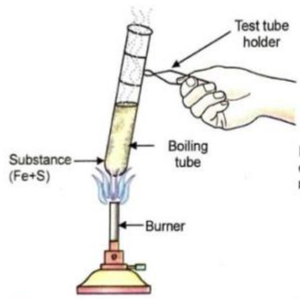


Fig Heating a mixture of iron fillings and sulphur in a test tube.

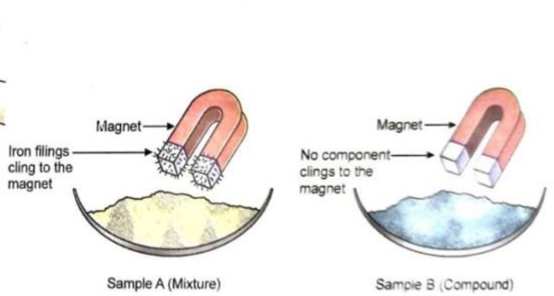


Fig : Effect of magnet on a mixture (Fe + S) and compound (FeS).

Which of the samples is heated in the boiling tube and which is not heated?
What is the evidence that the two samples are different?

Table 7.1: Some differences between physical and chemical changes

Physical Change	Chemical Change
1. No new matter is formed.	New matter is formed.
2. The physical property of the matter changes.	The chemical property of the matter changes.
3. The change is generally reversible.	The Change is not reversible.

Session 3: Scientific Method

Learning outcome(s)
By the end of the session, the participant will be able to:

- Explain the steps/procedures involved in the scientific method
- Use the scientific method to solved a hypothetical problem

Scientific method involves making *observations and gathering data*. For example, since it was observed that the sun rises in the east and sets in the west, the observation has never seemed to vary.

The observation of the rise and set of the sun has been the same from history. We can say that scientific observations are ***reproducible***. As scientists observe, they tend to make a guess that tries to explain the observation. This explanation is called **hypothesis**. The first plausible explanation to the rise and set of the sun was advanced by Claudius Ptolemy, a Greek philosopher, in A.D. 150. He suggested that the sun, as well as the rest of the universe, revolves around the Earth from east to west. However, Ptolemy's hypothesis did not explain other observations known at the time, which included the movement of the planets across the sky and the phases of the moon.

In 1543, a new hypothesis was proposed. Nicolaus Copernicus explained all of the observations about the sun, moon, and planets by suggesting that Earth and the other planets orbit around the sun instead of vice versa. This shows that scientific knowledge may change in view of new evidence. That is to say scientific knowledge is ***tentative***.

In 1609, a Venetian scientist by the name of Galileo Galilei built a telescope to view the sky. Galileo eventually produced evidence to support the hypothesis of Copernicus. Since the hypothesis of Copernicus withstood the test of experimental challenge, the hypothesis was considered to be a theory.

In 1684, an English scientist named Sir Isaac Newton stated a law that governs the motion of planets around the sun. Newton's law of universal gravitation states that planets are held by gravity in stationary orbits around the sun.

From the discussion above, briefly describe the steps that led to the Newton's law of nature:

Using scientific method to solve problem

Tetrapleura tetraptera is a species of flowering plant in the family Fabaceae native to Western Africa and Central Africa. The plant is called prekese in the Twi language of Ghana. It is also called uhio in the Igbo language of Nigeria. The tree has many uses. When consumed regularly, it has been said to help with diabetes and glucose levels, reducing hypertension, lowering blood pressure, providing essential postpartum nutrients that restore blood loss and produce milk, relieving fevers and showing wound-healing effects.

Outline scientific steps that may be taken to develop a potent drug to cure any of the diseases stated above using prekese.

Key Ideas

- A **hypothesis** *is a tentative explanation of observations*.
- A **theory** *is a well-established hypothesis*. Theory should predict the results of future experiments or observations.
- A **law** *is a concise scientific statement of fact to which no exceptions are known*.

UNIT 8: CHEMICAL FORMULAE AND EQUATIONS

By the end of the unit, the participant will be able to

- Differentiate between chemical formulae and chemical equations

Session 1: Chemical formulae
Learning outcome(s)
By the end of the session, the participant will be able to:

- Describe chemical symbols and formulae
- Explain the following:

(a) Cations

(b) Anions

(c) Radicals

(d) Valency

- Write the chemical formulae of binary and ternary compounds
- Describe the types of chemical formulae

Elements and their symbols

There are millions of matters around us. However, scientists have discovered that these millions of matters come from different combinations of just abut 92 naturally occurring kind of matters called elements. These elements cannot be broken down into simpler substances. The basic unit of elements are atoms. An element has the same kind of atoms. Elements are identified with unique symbols which are arrange in a certain periodic table according to their increasing atomic numbers. The table below shows the names and symbols of the first 20 elements.

Table 8.1: Names and symbols of the first 20 elements

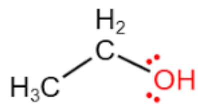
Atomic Number	Element	Symbol	Atomic Number	Element	Symbol
1	Hydrogen	H	11	Sodium	Na
2	Helium	He	12	Magnesiu m	Mg
3	Lithium	Li	13	Aluminiu m	Al
4	Beryllium	Be	14	Silicon	Si
5	Boron	B	15	Phosphoru s	P
6	Carbon	C	16	Sulphur	S
7	Nitrogen	N	17	Chlorine	Cl
8	Oxygen	O	18	Argon	Ar
9	Fluorine	F	19	Potassium	K
10	Neon	Ne	20	Calcium	Ca

Molecules, Molecular Compounds, and Covalent Bonds

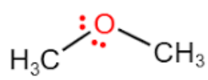
A **compound** is a unique substance that is composed of two or more elements that are chemically combined. For example, water is a compound which comprises hydrogens chemically combine with oxygen. Just as the basic particles of elements are atoms, the basic particles of a particular type of compound are known as molecules. A **molecule** is formed by the chemical combination of two or more atoms. Molecules composed of different atoms are the basic particles of **molecular compounds**. The atoms in a molecule are joined and held together by a force called the **covalent bond**. Each molecule of water for example, is composed of two atoms of hydrogens joined by covalent bonds to one atom of oxygen.

The Formulae of Molecular Compounds

A compound is represented by the symbols of the elements of which it is composed. This is called the **formula** of the compound. The formula for water is therefore H_2O. A chemical compound has a unique formula or arrangement of atoms in its molecules. For example, there is another compound composed of just hydrogen and oxygen, but it has the formula H_2O_2. Its name is hydrogen peroxide, and its properties are distinctly different from those of water (H_2O). Two or more compounds may have the same molecular formula but the way their atoms are arranged in their molecules (structural formulae) are different. For example, ethanol and dimethyl ether are two different compounds with different chemical and physical properties. The two compounds have the molecular formula C_2H_6O but different structural formulae.



ethanol



dimethyl ether

Structural formula shows how the atoms in the molecule are arranged or bonded to each other while the molecular formula shows the number of the constituent atoms in the molecule.

The molecular formulae of other well-known compounds include $C_{12}H_{22}O_{11}$ (sucrose, which we know as table sugar), $C_9H_8O_4$ (aspirin), NH_3 (ammonia), and CH_4 (methane). When chemists are investigating the constituents of compounds, they are able to identify the individual atoms and their proportion in compounds. Different compounds may have the same constituent atoms but the proportion of each atom in the compounds may differ. The formulae that show the simplest ratio of the constituent atoms in the compound is called the empirical formulae.

Cations and Anions

Atoms consist of protons and electrons. Electrons are negatively charge and protons are positively charge. Atoms are neutral because they have the same number of electrons as protons. Atoms may gain or loss electrons during interaction of matter and become ions. *Positively charged ions are known as* **cations**, *and negatively charged ions are called* **anions**.

Radical and valency

Generally, atoms or groups of atoms are stable only if they have fully paired electrons in their outer electronic shells. Atoms or group of atoms with unpaired electrons are said to be radicals or free radicals. A radical can be an atom, molecule or an ion. The presence of an unpaired electron(s) in radicals makes them unstable. Radicals are therefore, very reactive chemical species with very short lifetime. The number of unpaired electrons are known as valence electrons. Most elements (exception, noble gases) have valence electrons and become stable either by combining with other element(s) or by losing or gaining electrons. The ability of an element to combine with other elements is refer to as Valency. Valency is measured by the number of hydrogen atoms an element can displace or combine with. It is a chemical concept that measures the reactivity of a chemical element.

Ionic Compounds

Ordinary table salt is a compound named sodium chloride. In sodium chloride, the sodium exists as a cation with a single positive charge and the chlorine exists as an anion with a single negative charge. The structure of sodium chloride consists of several positive cations and negative anions to form a huge structure like the figure below.

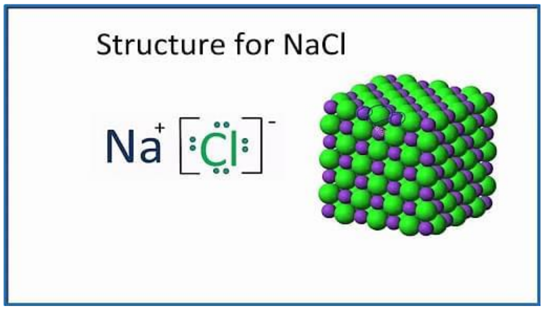


Figure 8.1: Structure of sodium chloride

The positive cations neutralize negative anions. In this case, the unit for the sodium chloride is NaCl. Ionic compounds consist of cations and anions as their formula units. The table shows some ionic compounds and their formula units.

Table 8.2: Formula units of ionic compounds

Name of ionic Compound	Cation	Anion	Formula unit
Potassium chloride	K^{+}	Cl^{-}	KCl
Calcium Chloride	Ca^{2+}	Cl^{-}	$CaCl_2$
Sodium oxide	Na^{+}	O^{2-}	Na_2O
Aluminum oxide	Al^{3+}	O^{2-}	Al_2O_3
Sodium nitrate	Na^{+}	NO_3^{-}	$NaNO_3$
Sodium carbonate	Na^{+}	CO_3^{2-}	Na_2CO_3
Calcium carbonate	Ca^{2+}	CO_3^{2-}	$CaCO_3$
Aluminum nitrate	Al^{3+}	NO_3^{-}	$Al(NO_3)_3$
Aluminum carbonate	Al^{3+}	CO_3^{2-}	$Al_2(CO_3)_3$

Chemical formulae of binary and ternary compounds

Binary compounds contain two elements. One of the elements is a metal and the other one being nonmetal. Ternary compounds however, contain three elements comprising at least one metal and one nonmetal. Check the formula units and indicate which of them are binary or ternary compounds. The valency or the type of ions elements form can easily be identified from the periodic table of elements.

Table 8.2: Cations and anions in the Periodic Table

IA	IIA	IIIA	IVA	VA	VIA	VIIA
Hydride H^-						
Lithium Li^+	Beryllium Be^{2+}		Carbide C^{4-}	Nitride N^{3-}	Oxide O^{2-}	Fluoride F^-
Sodium Na^+	Magnesium Mg^{2+}	Aluminum Al^{3+}		Phosphide P^{3-}	Sulfide S^{2-}	Chloride Cl^-
Patassium K^+	Calcium Ca^{2+}				Selenide Se^{2-}	Bromide Br^-
Rubidium Rb^+	Strontium Sr^{2+}				Telluride Te^{2-}	Iodide I^-
Cesium Cs^+	Barium Ba^{2+}					

The Table 8.2 shows positions of some cations and anions on the periodic table. Ionic compounds are neutral. This means that to form compound the formula unit should be such that the charges of the cations and anions cancel out. For example, the formula unit for barium chloride should be $BaCl_2$. Barium ion has +2 but chloride ion has -1 [+2 + 2(-)] = [+2 -2] =0.

Find the formulae of the following compounds.

a) Calcium selenide
b) Potassium telluride
c) Sodium sulfide
d) Magnesium nitride

Name the following binary compounds

a) $SrCl_2$
b) AlP
c) Al_2S_3
d) $L1_4C$

Use the table of polyatomic ions to help you name the following compounds.

a) NH_4CN
b) $NaMnO_4$
c) $Ca(ClO_4)$
d) $(NH4)_2SO_4$

Table 8.3: Polyatomic ion

Ion	Name	Ion	Name
NH4^{+}	Ammonium	CN^{-}	Cyanide
OH^{-}	Hydroxide	ClO^{-}	Hypochlorite
CO_3^{2-}	Carbonate	ClO_4^{-}	perchlorate
NO_2^{-}	Nitrite	MnO_4^{-}	permanganate
NO_3^{-}	Nitrate	PO_4^{3-}	Phoshate
ClO_2^{-}	Chlorite	SO_4^{2-}	Sulphate
ClO_3^{-}	Chlorate	SO_3^{-}	Sulphite
HCO_3^{-}	Bicarbonate		

Write the formulae of the following compounds

a) Ammonium hypochlorite
b) Ammonium phosphate
c) Sodium sulphite
d) Potassium carbonate

Session 2: Chemical Equation

Learning outcome(s)
By the end of the session, the participant will be able to:

- Write both word equations and chemical equations
- Balance chemical equations
- Describe the types of chemical reactions

You may remember, when testing the presence of hydrogen gas during integrated science lesson, the source of hydrogen gas was brought close to a glowing splint. The pop sound that was heard is actually a result of explosive reaction between hydrogen gas and oxygen in the air. The heat from the glowing splint provided the energy needed for the reaction to happen. Aside, the sound you hear from the reaction, water vapour is also produced from such reaction. We summary the reaction as:

Hydrogen + oxygen → water   word equation

$H_2 + O_2 \rightarrow H_2O$ Symbol equation

The reaction can either be represented by word equation or symbol equation. Symbol equations have many advantages so symbol equation is use mostly.

A **chemical equation** is therefore the representation of a chemical reaction using the symbols of elements and the formulas of compounds.

In a chemical equation, the original reacting species are shown to the left of the arrow and are called the **reactants**. The species formed as a result of the reaction are to the right of the arrow and are called the **products**. In this format, note that the phrase combines with (or reacts with) is represented by a plus sign (+). When there is more than one reactant or product, the symbols or formulas on each side of the equation are separated by a (+) sign. The word produces (or yields) may be represented by an arrow (→).

A balanced equation

An important duty of a chemical equation is to demonstrate faithfully the law of conservation of mass, which states that *mass can be neither created nor destroyed*. In Dalton's atomic theory, this law was explained for chemical reactions. He suggested that reactions are simply rearrangements of the same number of atoms. A close look at the equation above shows that there are two oxygen atoms on the left but only one on the right.

$$H_2 + O_2 \rightarrow H_2O$$

To conform to the law of conservation of mass, an equation must be balanced. *A* **balanced equation** *has the same number and type of atoms on both sides of the equation. An equation is balanced by introducing* **coefficients**. Coefficients are whole numbers in front of the symbols or formulas. The equation in question is balanced in two steps. If we introduce a 2 in front of the H_2O, we have equal numbers of oxygen atoms, but the number of hydrogen atoms is now unbalanced.

$$H_2 + O_2 \rightarrow 2H_2O$$

This problem can be solved rather easily. Simply return to the left and place a coefficient of 2 in front of the H_2. The equation is now completely balanced.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Note that equations cannot be balanced by changing or adjusting the subscripts of the elements or compounds. For example, the original equation could seem to be balanced in one step if the H_2O were changed to H_2O_2. However, H_2O_2 is a compound known as hydrogen peroxide. This is a popular anti-septic but not the same as water.

Finally, the physical states of the reactants and products under the reaction conditions are sometimes added in parentheses after the formula for each substance. Hydrogen and oxygen are gases. (g) is used to denote gas. Water is a liquid with (l) but you remember that the water produced during the test for hydrogen was in the form of gas (water vapour) therefore (g) is maintain for the water instead of (l).

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O(g)$$

Table 8.4: Some State Symbols in Chemical Equations

Symbol	Use
+	Between the symbols and/or formulas of reactants or products
$\rightarrow$	To mean "yields" or "produces"; separates reactants from products
=	Same as arrow
$\rightleftharpoons$	For reversible reactions in place of a single arrow
(g)	For a gaseous reactant or product
$\uparrow$	Sometimes to indicate a gaseous product
(s)	As a solid reactant or product
$\downarrow$	Sometimes to indicate a solid product
(g)	For a liquid reactant or product
(aq)	For the reactant or product in aqueous solution (dissolved in water)
$\xrightarrow{\Delta}$	Heat to speed up reaction
$\xrightarrow{cat}$	Catalyst to speed up reaction (could be an element/compound)

Rules for Balancing Equations

Properly balanced equations are a necessity when we consider the quantitative aspects of reactants and products. Before we consider some guidelines in balancing equations, there are three points to keep in mind concerning balanced equations.

1. The subscripts of a compound are fixed; they cannot be changed to balance an equation.
2. The coefficients used should be the smallest whole numbers possible.
3. The coefficient multiplies all of the number of atoms in the formula. For example, $2K_2SO_3$ indicates the presence of four atoms of K, two atoms of S, and six atoms of O.

The following rules are helpful in balancing simple equations by inspection.

1. In general, it is easiest to consider balancing elements other than hydrogen or oxygen first. Look to the compound on either side of the equation that contains the greatest number of atoms of an element other than oxygen or hydrogen. Balance the element in question on the other side of the equation.
2. If polyatomic ions appear unchanged on both sides of the equation, consider them as single units.
3. Balance all other elements except hydrogen and oxygen, except those that appear as free elements (not as part of a compound).
4. Balance hydrogen or oxygen next. Choose the one that is present in the fewer number of compounds first. (Usually, that is hydrogen.)
5. Finally, balance any element that is by itself.
6. Check to see that the atoms of all elements are balanced. The final balanced equation should have the smallest whole-number ratio of coefficients.

During baking of bread, baking powder in the form of sodium bicarbonate is used. The heat from the oven breaks down the sodium bicarbonate to release sodium carbonate, water and carbon dioxide. The rising of the carbon dioxide gas causes the bread to become soft.

a) Write word equation to represent the chemical process
b) Use symbol equation to write a balanced equation for the process including all state symbols.

Session 3: Types of Chemical Reactions

Learning outcome(s)

By the end of the session, the participant will be able to:

- Describe the types of chemical reactions

Different types of reaction are identified and characterized in chemistry. We will look at three basic types of reactions in this section. These are combustion, combination and decomposition reactions.

Combustion reactions

Combustion is a common everyday reaction. Combustion reaction, also known as burning produces a lot of heat which is accompany by flame. Human beings depend on combustion in many ways. Respiration is another example of combustion. Combustion is reaction of elements or compounds with elemental oxygen. Oxide of element are produced when oxygen react with elements.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

When oxygen reacts with compounds containing carbon and hydrogen, carbon and water are produced. For example, the gas we use in cooking is mainly hydrocarbon gas called methane (CH_4).

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

When the amount of oxygen is limited combustion reactions may produce carbon monoxide or carbon.

$$2C_5H_{12}(l) + 11O_2(g) \rightarrow 10CO(g) + 12H_2O(l)$$

A lot of carbon monoxide is produced by petrol cars when the engines are allowed to stay on in a garage.

$$C_{12}H_{26}(l) + 10O_2(g) \rightarrow 7CO(g) + 5C(s) + 13H_2O(l)$$

Black carbon (soot) may form in kerosine lanterns.

The metabolism of glucose ($C_6H_{12}O_6$, blood sugar) occurs in our bodies to produce the energy to sustain our life. It is also a combustion reaction that occurs at a steady, controlled rate.

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Combination reactions

Consider the two combustion reactions involving magnesium and sulphur, you realize that both have only one product.

$$2Mg(s) + O_2 (g) \rightarrow 2MgO(s)$$

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

These two reactions also belong to a type of reaction known as a combination reaction. Combination reaction concerns the formation of one compound from two or more elements and/or simpler compounds. The combination reaction is also referred to as synthesis. Other examples include:

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$

Decomposition

When a reactant breaks down into simpler substances the reaction is considered decomposition. For example, in carbonated beverages carbonic acid fizzes in a decomposition reaction.

$$H_2CO_3 (l) \rightarrow H_2O (l) + CO_2 (g)$$

Other decomposition reactions include:

$$2HgO (s) \rightarrow 2Hg (g) + O_2 (g)$$

$$CaCO_3(s) \rightarrow CaO (s) + CO_2 (g)$$

$$2KCLO_3 (s) \rightarrow 2KCl (s) + 3O_2 (g)$$

Name the type of chemical reaction in the following processes:

a) In the heat of the oven, baking powder breaks down releasing carbon dioxide and other products
b) In the cells of living organisms, inhaled oxygen reacts with sugar to release carbon dioxide, water and energy.
c) Some metals burn in air to form metallic oxides.
d) When carbon dioxide (CO_2) is pass over lime water (calcium hydroxide), calcium carbonate ($CaCO_3$) is formed.

UNIT 9: THE MOLE CONCEPT

By the end of the unit, the participant will be able to

- Demonstrate understanding of the mole concept

Session 1: Calculation of Molecular and Formula masses
Learning outcome(s)
By the end of the session, the participant will be able to:

- Distinguish between molecular mass and formula mass

Molecular mass

Mass of each atom is known. These masses are extremely small compare to gram. The unit is called atomic mass unit (amu). For example, hydrogen atom has mass of 1amu, carbon has 12 amu, oxygen has 16 amu and nitrogen having 14 amu. We know from the preceding discussion that a molecule consists of two or more atoms. The mass of any molecule is the sum of the masses of each of the atoms in the molecule. For example, what is the molecular mass of water. Water has two hydrogen atoms and one oxygen atom.

The formula of water is H_2O.

Molecular mass = (2 x 1 amu) + (1 x 16 amu)
= 2 amu + 16 amu
= 18 amu

Find the molecular masses of the following molecules

a) CH_4
b) C_2H_5OH
c) H_2O_2

(Remember H = 1amu, C = 12 amu and O = 16 amu)

Formula mass

Ionic compounds are not made of molecules but consist of ions which form huge structures. For example, sodium chloride is made of several units of cations and anions. However, a unit of the huge structure comprises one sodium cation and one chlorine anion together as NaCl. Each unit of ionic compounds represent the formula of the compound. The formula mass therefore is the masses of all the atoms in the cations and anions found in the formula of the ionic compound.

The formula mass of NaCl = (1 x 23) + (1 x 35.5)
= 23 + 35.5
= 58.5 amu

Find the formula masses of the following compounds.

a) Na_2CO_3
b) $MgCl_2$
c) $Ca(OH)_2$

Session 2: Understanding Mole Concept

Learning outcome(s)
By the end of the session, the participant will be able to:

- Explain the mole

Avogadro Constant

Atomic mass unit is extremely small mass compare to a gram. In order to weigh just a gram of hydrogen atoms, you need about 600, 000, 000, 000, 000, 000, 000, 000 atoms. That is to say 6.0×10^{23} atoms/particles of hydrogen weigh just 1 gram. The same number of particles of carbon and oxygen weigh 12g and 16g respectively. Just as we know a length of a distance called a meter or mass of an object as a gram or kilogram, scientist describe a unit of particle/matter as **mole**. One mole of any substance contains 6.0×10^{23} particles. This number of particles is called Avogadro constant.

Molar mass

The mass of a mole of any substance is called molar mass. Molar mass has the unit g/mol. In ordinary conditions of temperature and pressure, hydrogen gas exist as di-atomic molecular, H_2.

The molecular mass of hydrogen gas = (1 x 2 amu)
= 2 amu

However, the mass of one mole of hydrogen gas (6.0×10^{23} molecules of hydrogen gas)
= 2g

The molar mass of hydrogen gas = 2g/mol

The Number of Mole (n)

The molar mass of any substance is mass of the substance per one mole. Supposing you have two moles of the substance, the new mass of the substance then will be 2 x the molar mass. We can say that the mass of any substance, m is given as:

m = Molar mass (M) x number of moles (n)

That is m = M x n

Thus: Number of moles, n = mass/molar mass

Find the number of the mole in following substance:

a) 5g of CH_4
b) 10g of $CaCO_3$
c) 20g of $Na2CO_3$
d) 40g of NaOH

Session 3: Concentration

Learning outcome(s)
By the end of the session, the participant will be able to:

- Use molar mass to calculate molarity of solutions, concentration in g/mol, and molality.

Supposing you put a spoonful of sugar in a cup of water and three spoonsful of sugar in a similar cup. Will the two cups of sugar solution taste the same? The amount of substance in a given volume of solution is known as concentration. The concept of concentration is important because different concentrations of the same mixture may have different effect on the body.

Concentration, C is defined as

$$C = \frac{\text{Amount of substance}}{\text{Volume of solvent}}$$

For example, concentration of 4g of NaOH in 200ml of water $= \frac{40g}{200ml}$

$$= 0.2g/ml$$

However, amount of substance can also be in moles so that the concentration becomes mol/ml. In this case the 40g of NaOH must be converted to moles.

Remember moles, n is given as: $n = \frac{\text{mass}}{\text{Molar mass}}$

Molar mass of NaOH $= (23 + 16 + 1)$

$= 40g/mol$

Therefore $n = \frac{40g}{40g/mol}$

The number of moles of 40g of NaOH is 1 mole

Therefore, the concentration, C = 1mol/200ml

= 0.005mol/ml

Chemist preferred standard concentration which is amount in mols in 1dm^3 (1 liter) of solution. This standard concentration is known as Molarity. To get the molarity of the 40g of NaOH in 200ml, we need to convert the 200ml into dm^3 by dividing the ml by a factor of 1000. When it is done right, we get 0.2 dm^3.

$$\text{Molarity, } M = \frac{\text{Amount in moles}}{\text{Volume in dm}^3}$$

$$M = \frac{\text{I mol}}{0.2\ dm^3}$$

$$= 5\ mol/dm^3$$

Molarity, M = 5M

When small amounts of substances are introduced into other substances, the melting and boiling points of the mixture become different from the pure substance. The change in boiling or melting points of the mixture from the pure substance can help to identify the nature of an unknown solute which is dissolved in a known solvent. The amount of solute in mole per a kilogram of solvent is known as molality.

Find the molality of the solution when 1g of NaCl is dissolve in 200ml of water taking the density of water as 1g/ml.

$$\text{Molality} = \frac{\text{mole of solute}}{\text{Mass of solvent in kg}}$$

The mass of solute = 1g; molar mass of solute = (Na + Cl) = 23 =35.5) = 58.5g/mol

The number of moles of solute is given as = mass/molar mass

= 1/58.5

= 0.017 mol

The mass of the solvent is given = The density of solvent x the volume of solvent

= 200ml x 1g/ml

= 200g

$$= \frac{200g \times 1kg}{1000g}$$

= 0.2kg

$$\text{The molality of the solution is therefore} = \frac{0.017mol}{0.2kg}$$

= 0.085mol/kg

1. Find the molarity of the following solutions in mol/dm^3
   a) 5g of NaOH in 200ml of solution
   b) 40g of Na_2CO_3 in 500ml of solution
   c) 4g of $Ca(OH)_2$ in 100ml of solution

2. 5g of table salt was dissolved in 100ml of water.
   a) Find the concentration of the salt solution in g/ml
   b) Find the molarity of the salt solution
   c) Find the molality of the salt solution

[Na = 23; O = 16; Ca = 40; C = 12; H = 1; density of water = 1g/ml]

UNIT 10: FARMING SYSTEMS

This unit introduces participants to the various farming practices available. Farming systems refers to the various methods by which farming activities are carried out to produce crops and animals. They are also referred to as agricultural systems. This unit will discuss some common farming systems in Ghana such as mixed farming, mixed cropping, pastoral farming, crop rotation, monoculture, mono-cropping and ecological farming.

Learning outcome(s)

By the end of the unit, the participant will be able to:

- explain farming systems in Ghana.
- demonstrate understanding of the various farming systems in Ghana.
- enumerate the strengths and weaknesses associated with the various farming systems.

Mixed farming

Mixed farming is a method of farming in which the farmer cultivates crops and raise farm animals on the same piece of land at the same time. Large area of land is used for this system.

Advantages /merits

1. Crop residues such as husks, peels, straws are used as fodder to feed the farm animals.
2. Farm yard manure can be used to improve soil fertility
3. There is efficient use of land.
4. Regular supply of food and meat to feed the farmer and his family.
5. Animals such as the bulls can provide farm power for ploughing, carting, planting, harrowing and transportation.

Disadvantages/demerits

1. It is labour intensive
2. It is capital intensive
3. When the animals are not confined, they can destroy the crops.
4. Special skills are needed to manage the animals and the crops

Mixed cropping

Mixed cropping is a system of farming whereby a farmer cultivates two or more crops on the same piece of land at the same time.

Merits

1. It guards against total crop failure since different crops are grown
2. Effective disease control due to different life cycle of the different crops
3. Soil nutrients are fully utilized due to different depths of crop roots
4. Farmers get regular supply of food throughout the year because he harvests the crops at different times.

Demerits

1. Improper spacing may lead shading of crop
2. There is competition for resources by the crops
3. Nutrients and water in the soil may be used up faster
4. Mechanization of crops is impossible

Mono-cropping

This is where the farmer cultivates one type of annual crop on a same piece of land and changes it after harvest.

Merits

1. It leads to specialization of crops
2. Easy control of pests and diseases
3. Reduced cost of production and higher produce
4. It enables the demand for a particular crop to be met
5. Mechanization is possible

Demerits

1. Fall in market price may lead to serious loss of profits
2. Invasion of pests and diseases may lead to total crop loss
3. Farmers are exposed to dangers as a results of adverse weather conditions

Monoculture

This is where the farmer cultivates one type of annual or perennial crop on the same piece of land from year to year.

Merits

1. Farm mechanization is easily
2. Cultural practices are easily carried out
3. The farmer specializes in the cultivation of the crops
4. Farmers can easily produce crops on a large scale

Demerits

1. Pests easily attack crops
2. Disease spread easily
3. There is crop failure in terms of bad weather
4. Loss of soil fertility due the same type of nutrients being utilized year after year.

Pastoral Farming

Pastoral farming is a system of farming whereby the farmer keeps or raise farm animals such as cattle, sheep, and goats and move them from place to place in search of food and water.

Merits

- Animals get the chance to feed on variety of feeds
- Animals exercise their bodies as they are normally not confined
- Droppings from animals are used to fertilize the grassland on which the animals feed

Demerits

- Destruction to crops on farms
- Animals can get entangled in the bush

- Overgrazing can occur if the area is not paddocked
- Overgrazing may lead to soil erosion

Ecological farming

This is the type of farming system in which the environment or the vegetation is protected. Machinery and chemical usage are not used in ecological farming.

Advantages

- Farm produce are free from chemicals
- Soil erosion can be avoided since the soil is not disturbed
- Environmental pollution is greatly reduced
- Incidence of pests is reduced by biological control

Demerits

- It is labour intensive
- Cannot be practiced on a large-scale

Crop rotation

This is a system of farming where different types of crops are grown on the same piece of land in a definite order or cycle or sequence from season to season. A practice by which a farmer cultivates different crops in succession on the same plots of land over a period of years.

Demerits

- Inclusion of leguminous crops in the plan add nitrogen to enhance soil fertility
- Controls soil erosion due to inclusion of cover crops
- Manuring and farrowing maintain soil fertility
- Controls weeds, pests and diseases due to rotation.
- Plant nutrients are uniformly utilized due to different plant roots

Principles of crop rotation

- ✓ Deep rooted crops must be followed by shallow rooted crops
- ✓ Inclusion of leguminous crops in the system add nitrogen to the soil
- ✓ Crops belonging to the same family such as rice and maize should not follow each other
- ✓ Fallow period should be included in the crop rotation plan

Year/season	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**
1st year	cassava	cowpea	tomato	maize
2nd year	cowpea	tomato	maize	cassava
3rd year	tomato	maize	cassava	cowpea
4th year	maize	cassava	cowpea	tomato

- There are variety of farming systems farmers can employ
- Each farming system comes with its pros and cons.
- Farmers should look at the benefits they want to derive before selecting to practice a system

- How can farmers ensure sustainable use of the land through the practice of farming systems?

Discussion

- Justify why you will choose a particular farming system for a farmer.