SCIENCE

Grade 11

Part - I

Educational Publications Department

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The National Anthem of Sri Lanka

Sri Lanka Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Sundara siri barinee, surendi athi sobamana Lanka
Dhanya dhanaya neka mal palaturu piri jaya bhoomiya ramya
Apa hata sepa siri setha sadana jeewanaye matha
Piliganu mena apa bhakthi pooja Namo Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha
Oba we apa vidya
Obamaya apa sathya
Oba we apa shakthi
Apa hada thula bhakthi
Oba apa aloke
Apage anuprane
Oba apa jeevana we
Apa mukthiya oba we
Nava jeevana demine, nithina apa pubudukaran matha
Gnana veerya vadawamina regena yanu mana jaya bhoomi kara
Eka mavakage daru kela bevina
Yamu yamu vee nopama
Prema vada sema bheda durerada
Namo, Namo Matha
Apa Sri Lanka Namo Namo Namo Namo Matha

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ஆனந்த சமரக்கோன்
கவிதையின் பெயர்ப்பு.

Being innovative, changing with right knowledge
Be a light to the country as well as to the world.

Message from the Hon. Minister of Education

The past two decades have been significant in the world history due to changes that took place in technology. The present students face a lot of new challenges along with the rapid development of Information Technology, communication and other related fields. The manner of career opportunities are liable to change specifically in the near future. In such an environment, with a new technological and intellectual society, thousands of innovative career opportunities would be created. To win those challenges, it is the responsibility of the Sri Lankan Government and myself, as the Minister of Education, to empower you all.

This book is a product of free education. Your aim must be to use this book properly and acquire the necessary knowledge out of it. The government in turn is able to provide free textbooks to you, as a result of the commitment and labour of your parents and elders.

Since we have understood that the education is crucial in deciding the future of a country, the government has taken steps to change curriculum to suit the rapid changes of the technological world. Hence, you have to dedicate yourselves to become productive citizens. I believe that the knowledge this book provides will suffice your aim.

It is your duty to give a proper value to the money spent by the government on your education. Also you should understand that education determines your future. Make sure that you reach the optimum social stratum through education.

I congratulate you to enjoy the benefits of free education and bloom as an honoured citizen who takes the name of Sri Lanka to the world.

Akila Viraj Kariyawasam
Minister of Education

Foreword

The educational objectives of the contemporary world are becoming more complex along with the economic, social, cultural and technological development. The learning and teaching process too is changing in relation to human experiences, technological differences, research and new indices.Therefore, it is required to produce the textbook by including subject related information according to the objectives in the syllabus in order to maintain the teaching process by organizing learning experiences that suit to the learner needs. The textbook is not merely a learning tool for the learner. It is a blessing that contributes to obtain a higher education along with a development of conduct and attitudes, to develop values and to obtain learning experiences.

The government in its realization of the concept of free education has offered you all the textbooks from grades 1-11. I would like to remind you that you should make the maximum use of these textbooks and protect them well. I sincerely hope that this textbook would assist you to obtain the expertise to become a virtuous citizen with a complete personality who would be a valuable asset to the country.

I would like to bestow my sincere thanks on the members of the editorial and writer boards as well as on the staff of the Educational Publications Department who have strived to offer this textbook to you.

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Biology

01 Living tissues

You have studied about tissues as one of the organizational levels of multicellular organisms in grade 10. You will learn more about tissues in this chapter.

1.1 Plant tissues

Let's do the activity 1.1 to study about plant tissues.

Activity 1.1

Materials required :- Thin peel of lower epidermis of betel leaf, thin section of a potato tuber, thin cross section of a stem of a plant like *Balsam.*

Method :-
- Prepare temporary slides using above plant materials.
- Observe them under microscope.
- Try to identify tissues formed by cells with the help of your teacher.

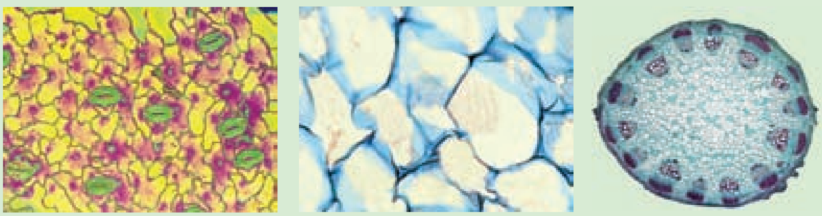


Figure. 1.1 - View of different plant tissues under optical microscope

You may have observed that plant tissues are of different forms. Animal tissues are also of different forms. It is observable that different cell types are present in living beings and similar cells are arranged together.

A group of cells with a common origin that has been modified to perform particular functions in the body is known as a tissue.

Classification of plant tissues

Let's do the activity 1.2 to study further about how tissues are oraganized in plant organs.

Activity - 1.2

Materials required :- Prop root of Banion/ Stilt root of Pandanus/ Stilt root of Rampe.

Method :-

- Observe the external view of the growing tips of above roots.
- Use a hand lens to observe them.

Figure 1.2 - External view of a root

We can identify the nature of a growing root from the above observation. Growing part is soft and light coloured. Mature part is rough and dark coloured. This is because of the nature of tissues.

Figure 1.3 shows the microscopic view of longitudinal section of such a root.

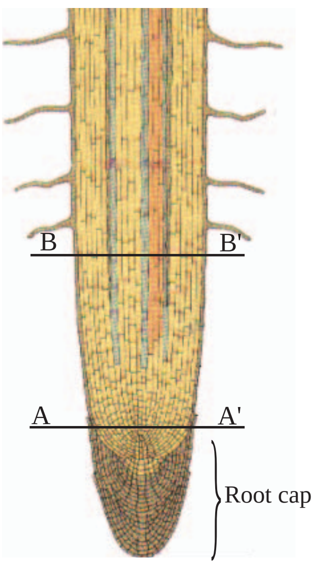


Figure 1.3 - Microscopic view of longitudinal section of root apex

It is observed that region A-A' has cells with the ability of cell division. Region B-B' contain different cell types that are different in nature from cells in region A-A'.

Plant tissues can be categorised using different criteria. Plant tissues can be divided into two groups according to the ability of cell division.

- Meristematic tissues
- Permanent tissues

Permanent tissues can be found in region B-B' and Meristematic tissues in region A-A' as shown in figure 1.3.

1.1.1 Meristematic tissues

The tissues with cells that divide actively by mitosis to produce new cells are called **meristematic tissues.** These cells are not differentiated. The growth of plants takes place due to activity of meristematic tissues.

Features of meristematic tissues

- This tissue consists of small sized living cells
- No intercellular spaces or intercellular spaces are not prominent
- There is a distinct nucleus in each cell
- Absence of large central vacuole but small vacuoles may be present
- Absence of chloroplasts
- Large number of mitochondria are present

Meristematic tissues are present in specific locations of the plant. They are of three types.

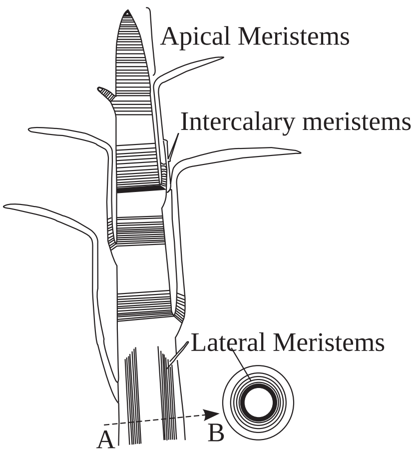


Figure 1.4 - Locations of meristematic tissues

Apical meristems

Apical meristems are found in shoot apex, root apex and axillary buds. Plant increases its height due to the activity of this tissue.

Intercalary meristems

Intercalary meristems are found at nodes. The length of internode increases due to the activity of the above tissue. They are found in plants of grass family.

Lateral meristems

Lateral meristems are present laterally in the stem and roots of plant. They are found parallel to the longitudinal axis of plant. The diameter of the plant increases due to the activity of this tissue. Cambium tissue found in dicots is a lateral meristematic tissue.

1.1.2 Permanent tissues

Do the activity 1.3 to identify different types of tissues of plant stem.

Activity - 1.3

Materials required :- Pumpkin / Tridex plant stem, A glass slide, A microscope

Method :-

- Observe the cross section of above plant stem using a microscope
- Identify the different tissue types present in them

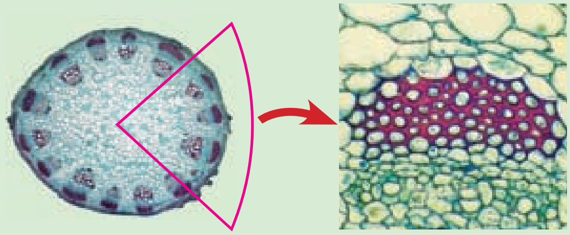


Figure 1.5 - Microscopic view of cross section of dicot stem

A tissue that lost its ability to divide and specialized to perform a particular function is known as a permanent tissue.

According to the nature of the permanent tissues, it can be grouped into two.

- Simple Permanent tissues - One type of cells collected together
- Complex Permanent tissues - Different types of cells collected together

• Simple permanent tissues

The tissue is composed of similar cells. According to the shape of cell and the nature of cell wall, three types of simple permanent tissues as parenchyma, collenchyma and sclerenchyma can be identified in plants (Figure 1.6).

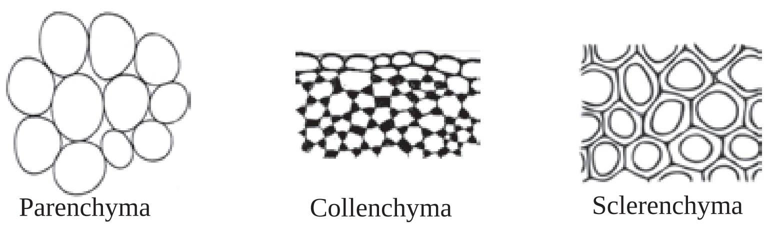
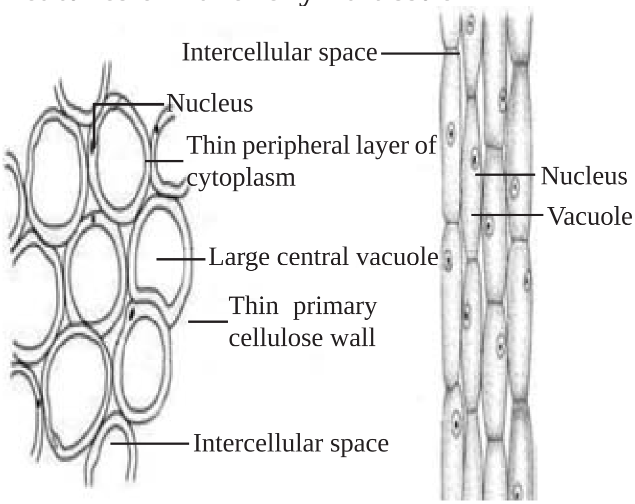


Figure 1.6 - Simple permanent tissue types

Parenchyma

The tissue that forms the soft parts of the plant body is the parenchyma tissue. This is the most abundant tissue found in the plant.

Features of Parenchyma tissue



Cross section of parenchyma **Longitudinal section of parenchyma**

Figure 1.7 - Parenchyma tissues

- Parenchyma tissue consists of living cells.
- Cells are isodiametric (spherical) with a large central vacuole.
- Nucleus is present peripherally in the cytoplasm.
- The cell wall is thin and made up of cellulose.
- Intercellular spaces are present.

Locations of parenchyma tissues

- Cortex and pith of plant stem
- Pith and cortex of roots
- Fleshy parts of fruits
- Seeds (endosperm)
- Leaves (mesophylls)

Functions of parenchyma

- Photosynthesis - Palisade and spongy mesophylls in plant leaves contain chlorophyll within chloroplasts. Photosynthesis takes place within these chloroplasts.
- Food storage - Food is stored in some parenchyma tissues and they are called as storage tissues.

  E.g. : Potato tuber, Carrot and Sweet potato roots, Papaw and Banana fruits.
- Storage of water - Specially xerophytic plants store water in Parenchyma tissue.

  E.g. : *Aloe* leaves, *Bryophyllum* leaves, *Cactus* cladode
- Providing support - Herbaceous plants like *Balsam* absorb water into vacuoles of the parenchyma cells. Thereby cells become turgid and provide mechanical support to the plant.

Collenchyma

Collenchyma tissue provides mechanical strength and support to the plant body. They are modified parenchyma cells.

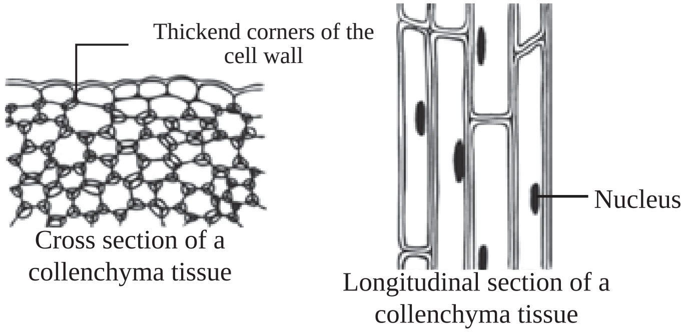


Figure 1.8 - Collenchyma tissue

Features of collenchyma tissue

- Collenchyma tissue consists of living cells.
- Cells possess a cytoplasm, nucleus and central vacuole.
- Generally cells are elongated and polygonal in cross section.
- The corners of the cell walls are thickened.
- Intercellular spaces may present or may not present.

Locations of collenchyma

The collenchyma forms a cylindrical tissue inner to the epidermis of herbaceous stems. They are found in the veins of dicot leaves.

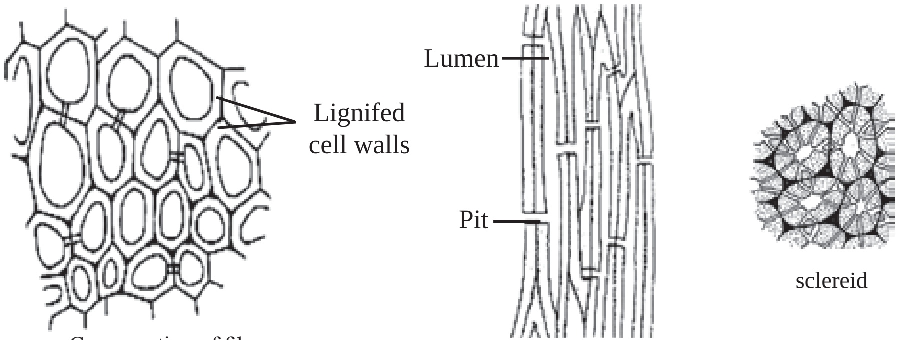
Functions of collenchyma

1. Support - Collenchyma provides mechanical support to dicot plant stem, before the formation of wood. (Provides mechanical support to herbs)

   This tissue provides support to the plant leaves by the collenchyma in veins.

2. Photosynthesis - Chloroplasts are found in the collenchyma of immature dicot stems. Photosynthesis is carried out by those cells.

Sclerenchyma



Cross section of fibers

Longitudinal section of sclerenchyma tissue

Figure 1.9 - Sclerenchyma tissue

Sclerenchyma tissue helps in providing mechanical strength and support to the plant body. This tissue has two types of cells as sclereids and sclerenchyma fibres.

Features of sclerenchyma tissue

- Sclerenchyma tissue consists of dead cells.
- Lignin is deposited on the cellulose cell wall.
- Cells are tightly packed. Therefore, no intercellular spaces.
- Cell wall is evenly thickened and forms a central lumen.

Locations of sclerenchyma tissue

Fibres present in xylem are called as xylem fibres and in phloem as phloem fibres. Other than above, coconut fibres, agave fibres and cotton wool are made up of fibres (sclerenchyma)

Selereids are found in endocarp of coconut, Kaduru and mango fruits, the pericarp of guava fruit and in pear fruit and seed coat of coffee and dates.

Functions of sclerenchyma

- Provide support to the plant body

• Complex permanent tissues

Different types of cells together form a complex permanent tissue. Two complex permanent tissues as xylem and phloem can be identified in plants (Figure 1.10).

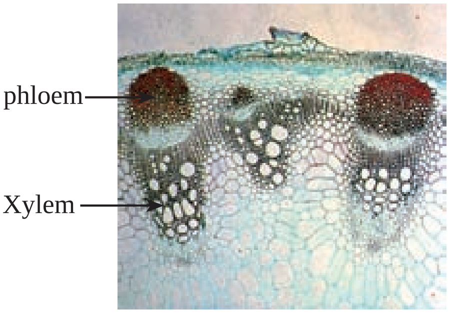


Figure. 1.10 - Complex permanent tissue

Xylem and phloem are found in vascular systems of root, stem and leaves of the plant.

Xylem tissue

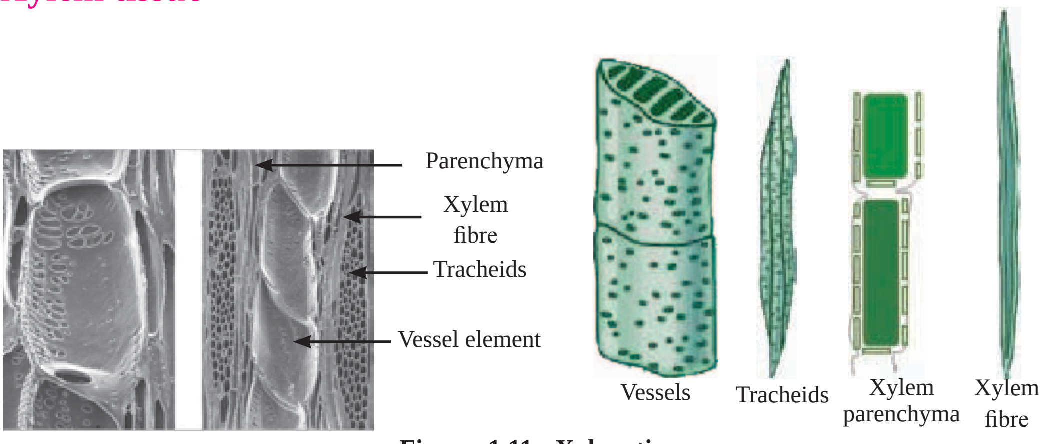


Figure 1.11 - Xylem tissue

This tissue is composed of four different types of cells.

- Xylem vessel element
- Tracheids
- Fibres
- Parenchyma cells

Xylem vessel elements are cylindrical elongated cells. Xylem vessel element stack on top of the others and the cross walls are dissolved to form a continuous xylem vessel. This tubular structure helps in transportation of water in plants. Tracheids are elongated, spindle shaped cells. They also help in transportation of water. Xylem fibers are narrower and shorter than tracheids. Xylem vessels, tracheids and xylem fibers become dead due to lignification of cell walls. They provide support to the xylem tissue. Xylem parenchyma are living cells with a thin cell wall. They involve in food storage.

Functions of xylem

- Transportation of water and minerals to the plant body which are absorbed by plant roots.
- Providing of mechanical support to plant body.

Phloem tissue

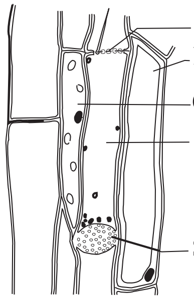


Figure. 1.12 - Longitudinal section of the phloem tissue

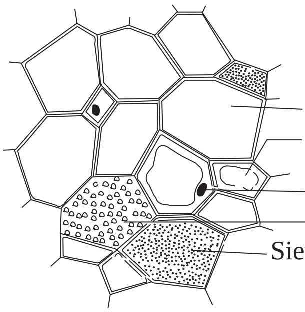


Figure. 1.13 - Cross section of the phloem tissue

Phloem tissue is composed of four different types of cells.

- Sieve tube elements
- Companion cells
- Phloem fibres
- Phloem parenchyma

The sieve tube elements fuse end to end and the cross walls are incompletely dissolved to form a sieve tube. The cross walls in these sieve tubes are called sieve plates. Sieve tubes transport food (mainly sucrose) throughout the plant, as a solution.

Companion cells are elongated cells associated with sieve tube elements. The nucleus of the companion cell controls the activities of the sieve tube elements (sieve tube elements lack a nucleus). Sieve tube elements, companion cells and phloem parenchyma are living cells whereas phloem fibres are dead and found scattered in phloem tissue.

Functions of phloem tissue

The food synthesized in the leaves are transported throughout the plant body by this tissue (Translocation).

Assignment 1.1

Compare structural and functional characteristics of phloem and xylem. Include them in a table.

1.2 Animal tissues

The animal body is also made up of different types of cells.

Example :- The human body is made up of about 210 different types of cells.

There are groups of cells with common origin to perform a particular function in the multicellular animal body. Main types of animal tissues are given below.

- Epithelial tissue
- Connective tissue
- Muscle tissue
- Nervous tissue

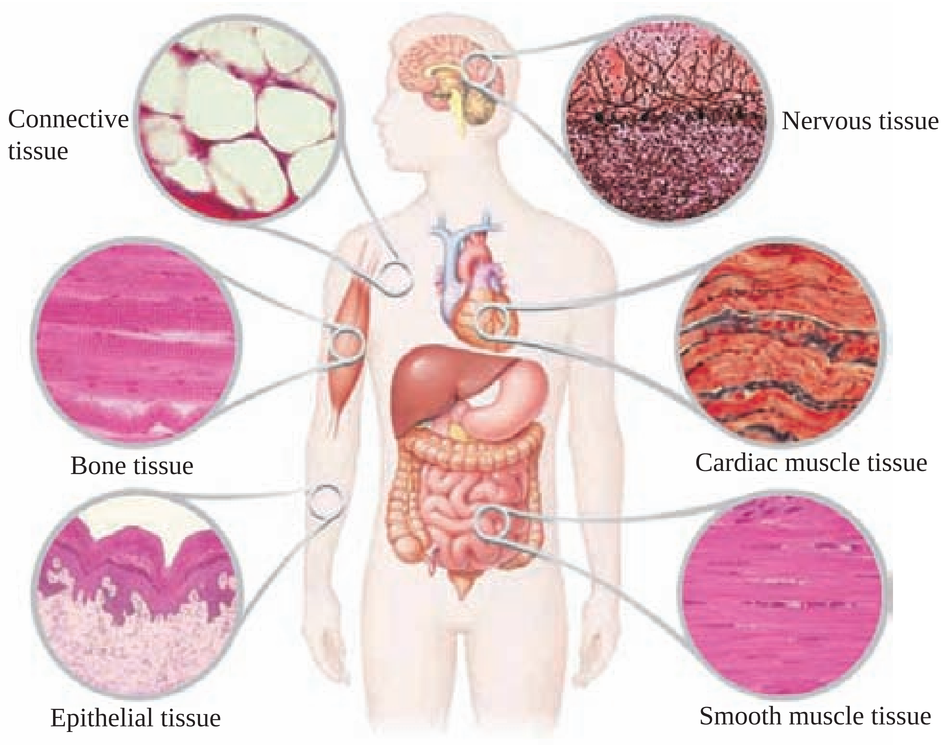


Figure 1.14 - Different tissues in human body

1.2.1 Epithelial tissue

This is the tissue that lines up the free surfaces (internal and external) of the vertebrate body. Some of them are composed of single layer of cells and the others are with several cell layers.

Features of epithelial tissues

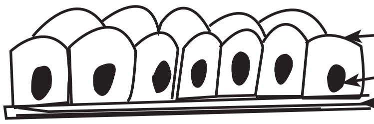


Figure 1.15 - Epithelial tissue

- The cells are placed on a basement membrane
- The cells are tightly packed
- A nerve supply is present within the tissue but there is no blood supply

The epithelial tissue is classified according to the shape of the cell and the number of cell layers.

Examples for several locations of epithelial tissues are given below.

- Wall of blood capillaries
- Thyroid gland
- Lining of nasal cavity
- Wall of urinary bladder
- Skin (Epidermis)

Functions of epithelial tissue

- Lining up of free surfaces and protection - Protects the internal organs from pressure, friction and microbes
- Absorptive function - The epithelium of digestive tract absorbs digestive end products
- Perception of stimuli - The epithelium of tongue and nose, detect taste and smell senses
- Secretory function - Secretion of mucous by the lining epithelium of respiratory tract
- Filtering function - Epithelium of Bowman's capsule in nephrons, filters blood

1.2.2 Connective tissue

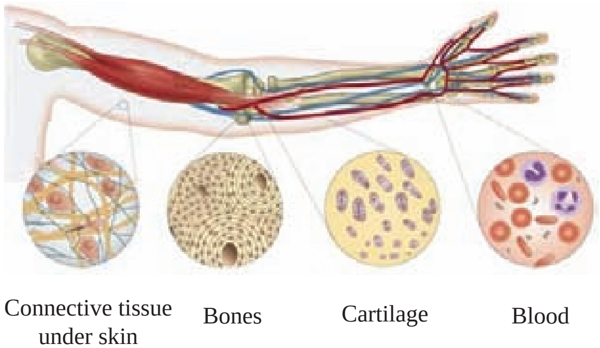


Figure 1.16 - Different Connective tissue present in human arm

Connective tissue is composed of different types of cells and fibres. These cells and fibres are embedded in a large matrix.

Most connective tissues possess nerve and blood supply.

The connective tissues provide connection between tissues and organs and provide support too.
E.g. :- Blood tissue, Bone tissue

Blood tissue

Blood is a special connective tissue. The speciality is that the matrix (plasma) is not secreted by the blood cells. Blood tissue helps in maintaining proper connection between organs and tissue of the human body.

Features of blood tissue

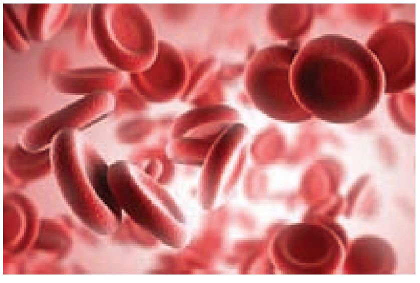


Figure 1.17 - Blood tissue

- Blood is composed of a fluid matrix. Matrix is called plasma
- The matrix contains cells called red blood cells (erythrocytes) and white blood cells (leucocytes) and cellular fragments called platelets
- Fibres are not found always but during blood clotting they appear

Functions of blood tissue

- Transportation of materials - Respiratory gases, nutrients, excretory materials and hormones are transported to the relevant organs
- Protection - White blood cells destroy foreign bodies (Microbes) by phagocytosis and by producing antibodies
- Maintenance of homeostasis

1.2.3 Muscle tissue

Muscle tissue is one of the main tissues that makes up the human body. Muscle tissue is made up of muscle cells or muscle fibres. These muscle fibres possess contraction and relaxation ability. Not like epithelial tissue, the muscle tissue possesses a good blood supply. Therefore muscle tissue receives oxygen and nutrients at a high rate. Muscle tissue acts as one of the effectors in responding in coordination.

Muscle tissue is of three types,

- Smooth muscle tissue
- Skeletal muscle tissue
- Cardiac muscle tissue

Assignment 1.2

Compare the characteristics of different muscle tissues.

Smooth muscle tissue

Smooth muscle tissue is made up of smooth muscle cells. This tissue is found in the walls of organs with cavities.

Example :- Walls of digestive tract, uterus, blood vessels and bladder

Features of smooth muscle cell

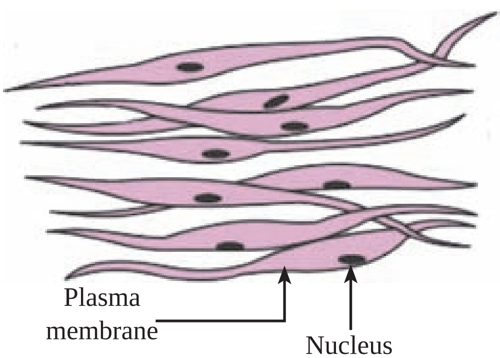


Figure 1.18 - smooth muscle tissue

- These cells are spindle shaped. The cells are unbranched
- These cells have one nucleus at the centre. No striations
- These cells do not become fatigue quickly. They are controlled involuntarily

Skeletal muscle tissue

Skeletal muscle tissue is made up of skeletal muscle fibres. These are mostly associated with skeletal system. The skeletal muscles help in locomotion and movements of chordates.

Features of skeletal muscle fibres

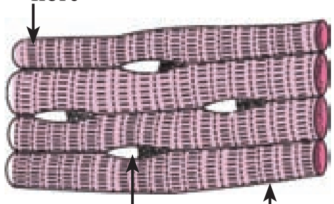


Figure 1.19 - Skeletal muscular tissue

- Skeletal muscle fibres are long, cylindrical, unbranched cells.
- They are multinucleate cells with striations. The nuclei present peripherally, and many mitochondria are present.
- These cells are voluntarily controlled and become fatigue easily.

E.g. :- Bicep muscle, Tricep muscle, Muscles in leg, Facial muscles

Cardiac muscle tissue

Cardiac muscle tissue is made up of cardiac muscle cells. It is exclusively found in the vertebrate heart.

Features of cardiac muscle fibres

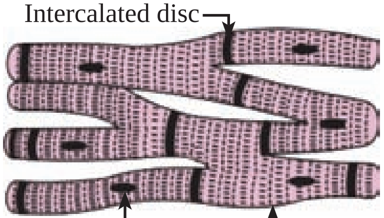


Figure 1.20 - Cardiac muscle tissue

- Cardiac muscle cells are uninucleate, striated and short cells
- Intercalated discs are present among cells
- They never become fatigue. They contract rhythmically
- They are involuntarily controlled

1.2.4 Nervous tissue

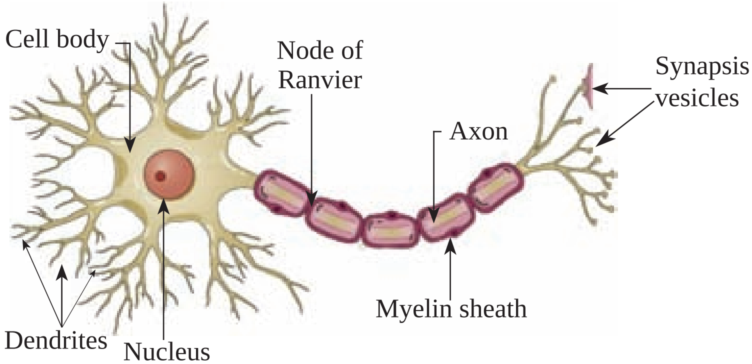


Figure 1.21- Structure of a typical neuron

It is an important tissue found in chordates body. The structural unit of nervous tissue is nerve cell or neuron. Neurons are specialised to transmit impulses.

Features of neuron

- Neuron is composed of two parts. They are **cell body** and **nerve fibres.**
- Nucleus, mitochondria, golgi body and endoplasmic reticulum are found in the cell body.
- Axon arises from the cell body as a single process. The axon transmits impulses away from the cell body.
- Slender process called dendrites receive stimuli and transmit impulses to the cell body.
- Most of the axons in chordates are myelinated. Myelin sheath is not continuous and the interrupted places are known as nodes of Ranvier. The myelin sheath increases the speed of transmission of impulses.

Functions of neurons

The function of the neuron is to receive the information from the receptors (eye, ear, nose, tongue, skin) or another neuron and to transmit them to the effector (muscles) or to another neuron.

According to the function of the neuron, they can be divided into three types as follows (Figure 1.22).

- Sensory neuron
- Inter neuron
- Motor neuron

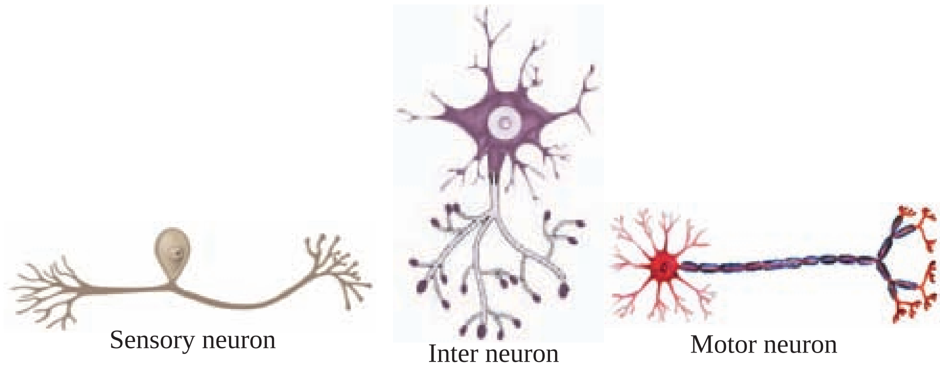


Figure 1.22 - Types of neurons

Extra knowledge

Sensory neuron

The cell body of the sensory neuron is present at the middle of the nerve fibers. The cell bodies are present inside ganglion. The dendrites are present at the sensory organs and the axon is present in the central nervous system. Ganglion is a structure formed by the collection of cell bodies. They transmit impulses from sensory organs to the central nervous system.

Motor neuron

A motor neuron possesses a star shaped cell body with many fibres. One of them is the axon and it is long. Sometimes it is greater than 1m in length. The other fibres and cell body are found within the central nervous system.

The function of the motor neuron is to transmit impulses from central nervous system to effector (muscles).

Inter neuron

The whole neuron is present within the central nervous system. The axons are short. Many dendrites are present.

The inter neuron connects the sensory neuron with motor neuron.

Summary

- Plant tissue
  - Meristematic tissue
    - Apical meristem
    - Lateral meristem
    - Intercalary meristem
  - Permanent tissue
    - Simple permanent (one type of cell)
      - Parenchyma
      - Collenchyma
      - Sclerenchyma
    - Complex permanent (More than two types of cells)
      - Xylem
      - Phloem

- A group of cells with a common origin adapted to perform particular functions in living body is known as a tissue.

- Chordate body is composed of four main tissues such as epithelial tissue, connective tissue, muscle tissue and nervous tissue.

- Epithelial tissue lines up the free surfaces of chordates and performs absorption, secretion, filteration, perception of senses and protection.

- The connective tissue is made up of different types of cells, fibres and a large matrix. It connects the organs and tissues together and provides support to them.

- Smooth muscles, skeletal muscles and cardiac muscles are present in the human body. The contraction and relaxation of those help in different movements in the body.

- Transmission of impulses is carried out by the nervous system. There are three types of neurons. They are sensory neurons, motor neurons and inter neurons.

Exercise

(1) Underline the correct answer

I. Out of the cells and tissues given below which type is of dead cells?
1. Fibres 2. Parenchyma
3. Collenchyma 4. Sieve tube element

II. Which of the following is a complex tissue?
1. Parenchyma 2. Xylem 3. Sclerenchyma 4. Collenchyma

III. Features mentioned below could be observed in a plant tissue under a microscope. Identify the tissue.
- Isodiametric cells
- Large vacuoles
- Living cells

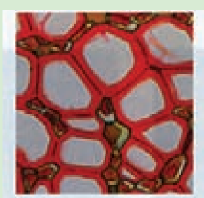
1. Sclerenchyma 2. Collenchyma 3. Xylem 4. Parenchyma

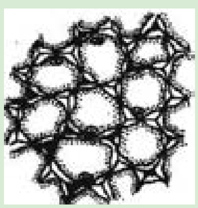
iv. A characteristic of skeletal muscle fibre is,
1. Spindle shaped 2. Cross striations
3. Uninucleate 4. Never becomes fatigue

v. When a student observes an animal tissue under the microscope, he observed the cells present on a basement membrane. The tissue is,
1. Epithelial tissue 2. Posseses connective tissue
3. Muscle tissue 4. Nervous tissue

vi. Which is correct about cardiac muscle fibres?
1. Non striated 2. Posseses intercalated discs
3. Multinucleate 4. Long, cylindrical cells

(2) State two differences between meristematic and permanent tissues.
(3) Name the tissue types given below


(a)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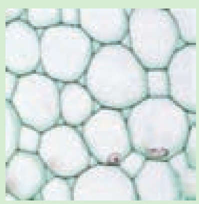
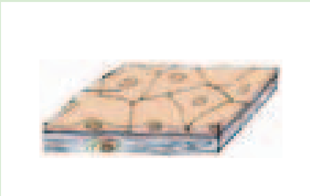
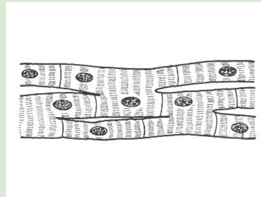

(c)

(4) State two structural differences between a cardiac muscle fibre and a skeletal muscle fibre.

(5.) Name the animal tissues given below in diagrams.


(a)


(b)


(c)

Technical terms

Meristematic tissues	විභාජක පටක	பிரியிழையம்
Apical meristems	අග්‍රස්ථ විභාජක	உச்சிப் பிரியிழையம்
Lateral meristems	පාර්ශ්වික විභාජක	இடைப் புகுந்த பிரியிழையம்
Intercalary meristems	අන්තරස්ථ විභාජක	பக்கப் பிரியிழையம்
Parenchyma tissue	මෘදුස්තර පටකය	புடைக் கலவிழையம்
Collenchyma tissue	ස්ථූලකෝණාස්තර පටක	ஒட்டுக் கலவிழையம்
Sclerenchyma tissue	දෘඪස්තර පටකය	வல்லருகுக் கலவிழையம்
Xylem tissue	ශෛලම පටකය	காழ்
Phloem tissue	ප්ලෝයම පටකය	உரியம்
Fibres	තන්තු	நார்கள்
Sclereids	උපල	வல்லுருக்கள்
Animal tissues	සත්ත්ව පටක	விலங்கிழையம்
Epithelial tissues	අපිච්ඡද පටක	விலங்கிழையம்
Muscle tissues	පේශි පටක	தசையிழையம்
Connective tissues	සම්බන්ධක පටක	தொடுப்பிழையம்
Nervous tissues	ස්නායු පටක	நரம்பிழையம்

Biology

02

Photosynthesis

Food is essential for the survival of all organisms. Food is obtained by many ways. Using the knowledge about modes of nutrition of living beings, try to do the assignment 2.1.

Assignment - 2.1

Figure. 2.1

- Identify the organisms in the picture
- State their modes of nutrition

As you know the food of cow and stork, you can state easily how the cow and the stork obtain their food. They depend on other organisms for their food. It is known as heterotrophic mode of nutrition.

How do green plants obtain their nutrition? These plants produce their food within them. Therefore, it is called autotrophic mode of nutrition. Living organisms depend on that food directly or indirectly for their existence.

Figure 2.2 shows a diagramatic representation of the process of photosynthesis. Try to understand the phenomenon of photosynthesis by studying it.

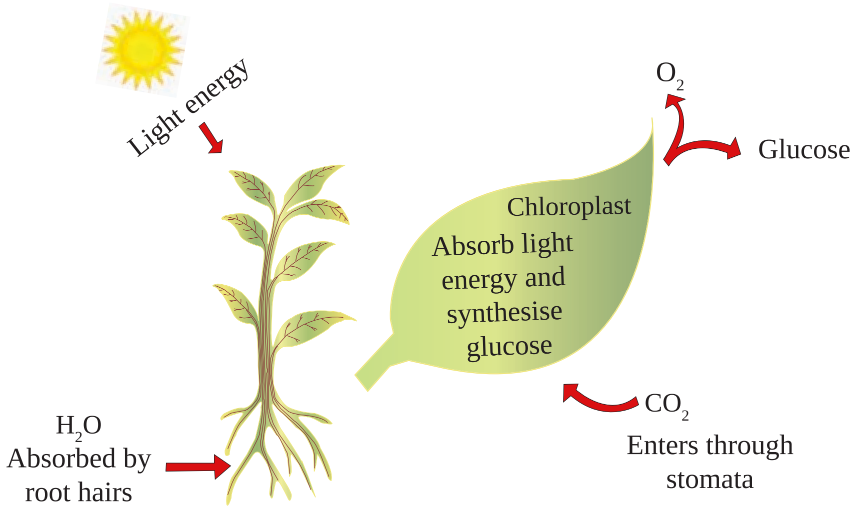


Figure. 2.2 - Factors necessary for photosynthesis and its products

Utilizing the light energy the cells containing chlorophyll in green plants synthesize food using carbondioxide and water as raw materials. This process is called photosynthesis.

2.1 Factors that affect photosynthesis

Let us study how green plants obtain water and carbondioxide for photosynthesis. Terrestrial plants obtain water from soil for photosynthesis. Water in the soil is absorbed through root hairs by osmosis. The absorbed water then travels into root xylem through cortex and endodermis. From there water is transported into mesophyll cells of leaves via the xylem of stem and the veins of leaves. The network of veins in the leaves distributes water throughout the leaf.

CO_2 is obtained from the atmosphere for photosynthesis. CO_2 diffuses into leaf through stomata. Then it reaches the mesophyll cells via inter cellular spaces.

Figure. 2.3 - Electron microscopic view of a chloroplast

The special green pigment called chlorophyll found in the chloroplasts in plant cells, absorb energy from sunlight.

Accordingly, the factors that affect photosynthesis are,

- Chlorophyll
- Light energy
- Water
- Carbon dioxide

Activity - 2.1

Materials required :- *Hydrilla* or *vallisneria leaves*, A glass slide, A microscope
Method :-
- Observe a small section of a *Hydrilla* or *Vallisneria* plant leaf under the microscope.
- Observe the way that chloroplast with chlorophyll move towards the direction of sunlight for photosynthesis.

2.2 Products of photosynthesis

The glucose ($C_6H_{12}O_6$) produced during photosynthesis will be temporarily stored in leaves as starch. Later, part of that starch is converted into sucrose ($C_{12}H_{22}O_{11}$) and transport into other tissues, via phloem. The sucrose that is transported to storing organs are again stored as starch.

E.g :- Fruits, Vegetables, Yams, Leaves, Roots

The byproduct of photosynthesis is O_2 and it is diffused into the atmosphere through stomata.

Assignment - 2.2

Prepare a report on adaptations shown by plants to absorb light energy from sunlight efficiently for photosynthesis.

Photosynthesis can be expressed by a word equation as given below.

$$\text{Carbon dioxide} + \text{Water} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \text{Glucose} + \text{Oxygen}$$

The balanced chemical equation for photosynthesis is,

$$6CO_{2\,(g)} + 6H_2O_{(l)} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_{6\,(s)} + 6O_{2\,(g)}$$

Extra knowledge

Plants absorb red and blue light of sunlight during photosynthesis.

Glucose produced during photosynthesis is stored temporarily in leaves as starch. Therefore it could be tested whether the photosynthesis has taken place or not by doing a test for starch.

Carry out the activity 2.2 to identify starch produced during photosynthesis.

Activity - 2.2

Materials required :- Beaker, Test tube, Tripod, Bunsen burner, Water, Alcohol, Plant leaf

Method :-
- Pluck a leaf from a plant which was in sunlight and boil it in water.
- Place that leaf in the boiling tube with alcohol and boil the tube in a water bath for few minutes.
- Next wash the leaf and put few drops of iodine solution onto it and observe the colour change.

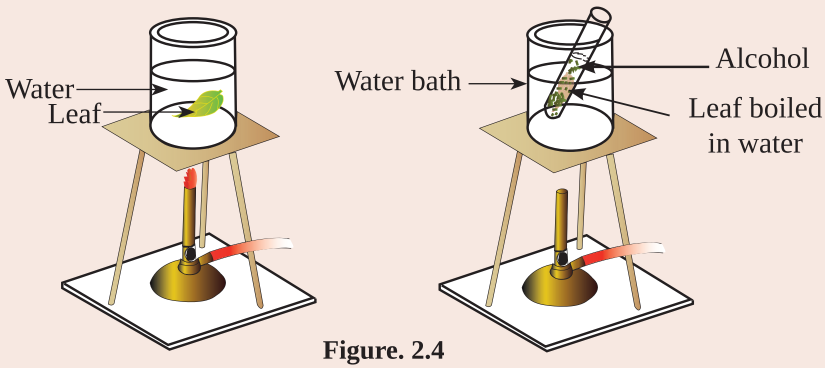


Figure. 2.4

As chlorophyll dissolve in alcohol, the leaf is boiled in an alcohol solution. Then the solution becomes green in colour and leaf turns to pale colour. As alcohol is highly inflammable, it is boiled in a water bath.

If the leaf turns to blue or dark purple, once iodine is added, we can conclude that starch is present in the leaf.

Testing of factors required for photosynthesis

The plant should be kept in dark for 48 hours before the experiment to show that light energy and carbon dioxide is needed for photosynthesis. When the plant is in the dark the stored starch completely removes from the leaves.

We will conduct the activity 2.3 to show that light energy is required for photosynthesis.

Activity - 2.3

Experiment to show that light energy is required for photosynthesis

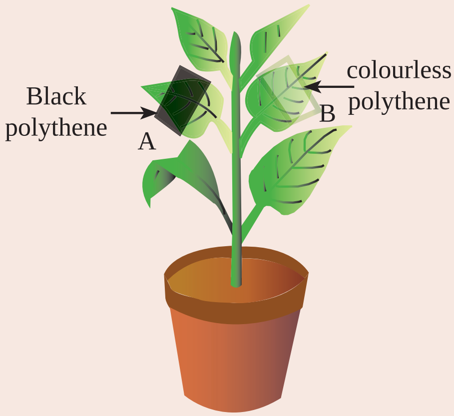


Figure. 2.5

Materials required :- Potted plant kept in dark for 48 hrs, materials needed for starch test, black and colourless polythene strips

Method :-

- Select two leaves almost similar to each other (A and B leaves) of the plant kept in dark for 48hrs
- Cover a part of leaf A with black polythene and part of leaf B with colourless polythene
- Keep it under sunlight for 3-5 hours
- Prepare the leaves for starch test as in activity 2.2

There is no colour change in the covered area of the leaf A but the covered area of leaf B turns to purple or blue.

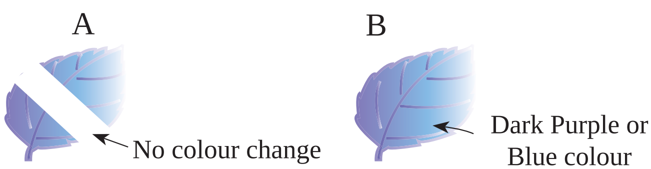


Figure. 2.6

The covered area of leaf **A** has not received light energy. Therefore photosynthesis has not taken place. Hence, there was no colour change with iodine solution. The covered area of leaf **B** with colourless polythene has received light energy. Therefore photosynthesis has taken place and showed a colour change to dark purple or blue indicating starch has been produced.

Accordingly, we can conclude that light energy is necessary for photosynthesis.

Let's conduct the activity 2.4 to show that CO_2 is required for photosynthesis.

Activity - 2.4

Experiment to show CO_2 is required for photosynthesis

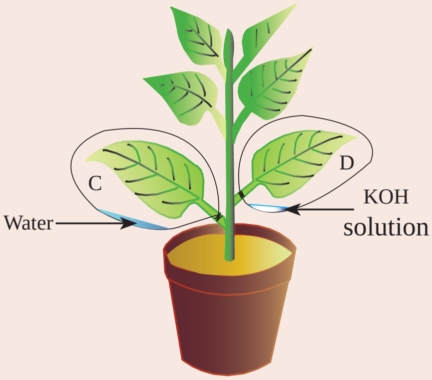


Figure. 2.7

Materials required :- Potted plant, materials required for starch test, two polythene bags of same size, KOH solution, water

Method:-

- Select two similar leaves of the above plant. C and D
- Add potassium hydroxide (KOH) and water to transparent polythene bags separately. Then insert leaf **D** into the polythene bag with KOH and leaf **C** into the bag with water and make them air tight.
- Place the plant in sunlight for 3-5 hrs.
- Then detach leaves C and D and carry out starch test separately

You can observe that there is no colour change in leaf **D** and there is a colour change in leaf **C** after adding iodine solution.

Figure. 2.8

KOH present in bag D absorbs CO_2. Therefore leaf D does not do photosynthesis as it does not receive CO_2. Therefore there is no colour change.

Leaf C receives CO_2, so it photosynthesises. Therefore a colour change can be observed. Leaf D has not produced starch but leaf C has produced starch.

Accordingly it can be concluded that CO_2 is necessary for photosynthesis.

Let's do the activity 2.5 to show that chlorophyll is required for photosynthesis.

Activity - 2.5

Experiment to show chlorophyll is required for photosynthesis

Materials required :- Mosaic plant leaf (Hibiscus/ Croton), white paper, materials required for starch test

Method :- Pluck a mosaic leaf. Draw a sketch of it with its pattern. Carry out starch test for it.

There is no color change in the white regions but a colour change can be observed in green colour regions.

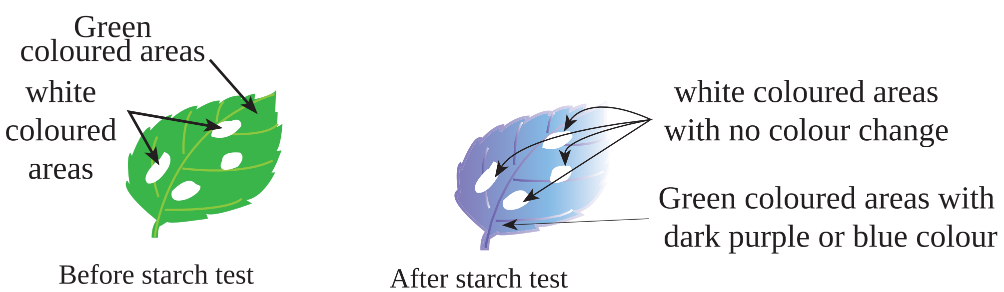


Figure. 2.9

The white colour regions lack chlorophyll, so photosynthesis has not taken place. Therefore starch has not been produced. So it can be concluded that chlorophyll is essential for photosynthesis.

An experiment cannot be designed in the laboratory to test the need of water for photosynthesis, because without water, the plant in the control experiment will die. Scientists have shown the need of water for photosynthesis using water with $^{18}_{8}O$ isotope. The oxygen end product contains $^{18}_{8}O$ isotope. It confirms that water is needed for photosynthesis.

Let's conduct the experiment below (Activity 2.6) to show that O_2 is produced as a product of photosynthesis.

Activity - 2.6

Experiment to show O_2 is produced during photosynthesis

Materials required :- Trough, boiling tube, glass funnel, aquatic plant (*Hydrilla*, *Vallisneria*), water

Method :- Add water into the trough. Then place *Hydrilla* or *Vallisneria* inside the funnel. Fill a boiling tube inside water trough and place it inverted on the funnel as in the diagram. Place the setup in sunlight.

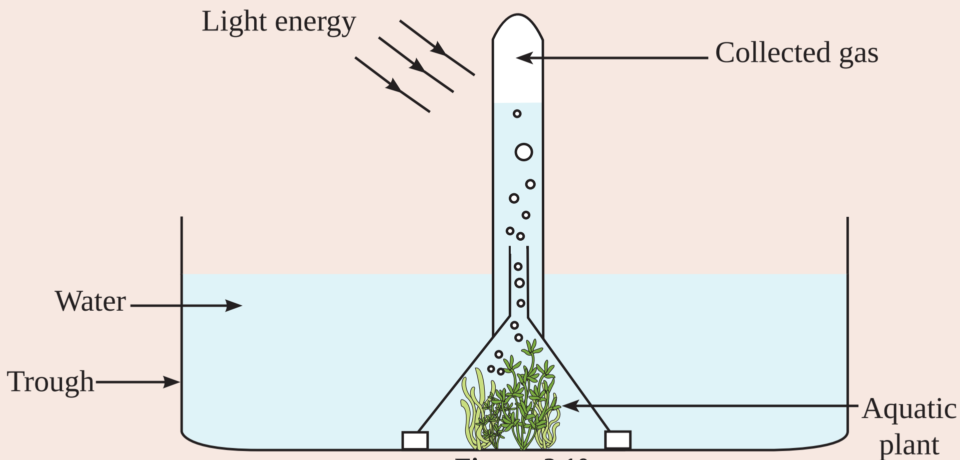


Figure. 2.10

Gas bubbles release from the aquatic plant and that gas gets collected at the top of the boiling tube. After the accumulation of gas about $3/4^{th}$ of its volume, the tube will be taken out and a glowing splinter is inserted to test whether the gas is oxygen.

The splinter will burn with a bright flame. So we can conclude that the gas given out in photosynthesis is oxygen.

Extra knowledge

Lavoisier is the first scientist who showed that oxygen diffuse from green plants in the presence of sunlight.

2.3 Importance of photosynthesis

- Light energy is converted to chemical energy during photosynthesis. Plants produce food and all organisms live on earth depend directly or indirectly on that food. Photosynthesis cannot be done artificially. Therefore this process carried out by green plants is essential for the maintenance of life on earth
- The oxygen gas which is required for the survival of aerobic organisms and combustion of materials is released mainly by photosynthesis
- Carbondioxide that is accumulated due to respiration and combustion is removed from the environment by photosynthesis. Thereby it helps to maintain O_2 and CO_2 balance in the atmosphere
- Photosynthesis helps to maintain the carbon cycle

Summary

- Light energy is converted into chemical energy by green plants during photosynthesis.
- Light energy, water, CO_2 and chlorophyll are required for photosynthesis.
- The main product of photosynthesis is glucose and oxygen is produced as a byproduct.
- Photosynthesis can be expressed by a balanced equation as below.

$$6CO_{2\,(g)} + 6H_2O_{(l)} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_{6\,(s)} + 6O_{2\,(g)}$$

- The global importance of photosynthesis is provision of food to all organisms directly or indirectly, Maintenance of $O_2 : CO_2$ balance in the atmosphere and maintaining the carbon cycle.

Exercise

1. Underline the correct answer.
   i. What is the main product of photosynthesis?
      1. Glucose 2. Starch 3. Sucrose 4. Oxygen

   ii. What is the tissue involved in transporting products in photosynthesis to storing organs?
      1. Xylem 2. Phloem 3. Parenchyma 4. Collenchyma

   iii. What is the food type that translocates to storing organs?
      1. Sucrose 2. Glucose 3. Starch 4. Cellulose

   iv. What is the gas emitted during photosynthesis?
      1. Carbondioxide 2. Nitrogen 3. Oxygen
      4. Carbonmonoxide

   v. Into which energy that solar energy is converted to, during photosynthesis?
      1. Heat energy 2. Light energy
      3. Chemical energy 4. Potential energy

2. Put "✓" or "×" for the given statements.
   i. Colour change with the starch test can be seen in a leaf after keeping it in dark for 48 hours. ( )
   ii. Leaf should be boiled in water to dissolve chlorophyll for the starch test . ( )
   iii. Photosynthesis takes place in leaves only. ( )
   iv. When leaves are boiled in water the permeability of them increases. ( )
   v. Photosynthesis takes place only in green plants. ( )

3. "When grass is covered for three days with a black coloured polythene, it becomes yellow in colour. Design an experiment to prove this phenomenon. State observations and conclusions.

Technical terms

Photosynthesis	ප්‍රභාසංශ්ලේෂණය	ஒளித்தொகுப்பு
Chloroplasts	හරිතලව	பச்சையவுருமணி
Chlorophyll	හරිතප්‍රද	பச்சையம்
Aquatic plants	ජලරූහ ශාක	நீர்வாழ் தாவரங்கள்

Mixtures

Chemistry 03

3.1 Types of mixtures

Let us pay our attention to the composition of the air around us. Air is composed of gases like nitrogen, oxygen, argon, carbon dioxide, water vapour, and very small particles such as dust. So, you may understand that air is a mixture of several substances.

Therefore, if some matter contains two or more substances, such matter is referred to as mixtures. You have already learnt that elements and compounds are pure substances. But, mixtures are not pure substances. Natural environment mostly contains mixtures, not pure substances. Air, soil, sea water, river water and rocks around us are examples. The things that we drink such as cool drinks, fruit drinks, tea, coffee and food items such as ice cream, yoghurt and fruit salad are also mixtures. Let us do the following activity to study more about the components of a mixture.

Activity 3.1.1

Materials required: - Hydrated copper sulphate, naphthalene (moth balls), mortar and pestle

Method: - Take some copper sulphate and naphthalene (moth balls) into a mortar, grind them together with the pestle into a powder and mix well. Transfer the powder onto a piece of paper and observe.

At a glance, you may not be able to see two substances, copper sulphate and naphthalene but, you have a mixture of the two. A blend of two or more pure substances is called a mixture and individual substances that form the mixture are known as components.

Activity 3.1.2

Materials required :- Two beakers, a glass rod, a funnel, a filter paper, hand lens.

Method :- Transfer the mixture made in activity 3.1.1 above into a small 100 ml beaker, add about 50 ml of water to it and stir well. Then, place a filter paper in a glass funnel and filter this solution into another beaker. Allow the residue on the filter paper to dry and observe with a hand lens. Observe the filtrate as well.

From this activity, you would have understood that the residue on the filter paper is naphthalene powder. Since the solution is blue in colour, the substance that dissolved in water is copper sulphate.

The above activity clarifies another feature of a mixture. That is, even when the components are in a state of being mixed, their chemical nature remains unchanged. In other words, the identity of the components constituting a mixture does not change even in the mixture. Moreover, the above activity shows that the components in a mixture can be separated by physical methods.

How the components in a mixture can be separated by physical methods will be discussed under the sub unit 3.3.

Thus mixtures can be defined as follows: **Mixtures are matter consisting of two or more components which are not chemically combined, and can be separated by physical methods.**

Table 3.1.1 shows the components of some commonly known mixtures.

Table 3.1.1

Mixture	Components
Cement mortar	Sand, cement, water
Cake	Sugar, flour, water, colouring, butter
Well water	Water, dissolved oxygen, dissolved carbondioxide and various salts.
Sea water	Water dissolved oxygen and salts such as sodium chloride, magnesium chloride, magnesium sulphate, calcium sulphate

When considering mixtures, it is very important that how well the components are mixed. Understand this thoroughly with the help of the following examples.

Ex:- 1. When making colours by mixing paints, application of the paint will not give a uniform colour unless they are mixed well.

2. If the components used to make cake are not mixed well, different parts of the cake taste differently. Also, the rising will be different in different parts.

3. The medicinal property of tablets, capsules or liquid mixtures is not even in all the parts if the components are not mixed well when producing medicines.

Investigate into more instances like the above examples.

Let us do activities 3.1.3 and 3.1.4 to study how the components are distributed in a mixture.

Activity 3.1.3

Materials required :- A beaker, clay, water, a piece of cloth

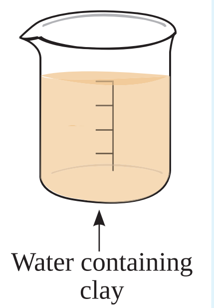


Figure 3.1.1

Method :-

(i) Take about 500 ml of water into a beaker. Add about 10g of clayey soil to it, stir well and allow to stand still for about one minute. Then filter the muddy coloured water into another beaker using a piece of cloth. Allow to stand still for about an hour and see whether the muddy colour is uniformly distributed throughout the solution. See if the clearness of the solution is similar from top to bottom.

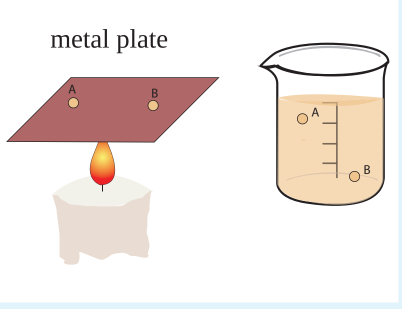


Figure 3.1.2

(ii) Take a piece of a metal sheet with a lustrous surface. As shown in figure 3.1.2, take two identical drops of the solution from two places A and B with a pipette or glass rod, place them on the spots marked as A and B respectively, on the piece of metal and let them vaporize. Check to see which water sample contains more residual matter. See, water obtained from which place contains more residual matter.

The above activity leads to the following conclusions. In the mixture formed by dissolving clay in water,

- The colour/transparency is different from place to place.
- The amount of clay particles in a unit volume is different from place to place.

Activity 3.1.4

Materials required :- A beaker, water, common salt, a piece of cloth

Method :- Take about 250 ml of water into a beaker. Add about 10 g of pure salt into it, stir till the salt dissolves and filter the solution with a piece of cloth. Allow to stand still for about one hour and see whether the clearness of the solution is equal from top to bottom. Repeat what you did in activity 3.1.2 for this solution as well.

Following conclusions can be drawn from the above activity. In the mixture formed by dissolving salt in water,

- The transparency is equal throughout the solution.
- The amount of salt particles in a unit volume of the solution is equal throughout the solution.

Pay your attention again to the mixtures you studied in activities 3.1.3 and 3.1.4. According to the nature of the distribution of components, mixtures can be divided into two categories.

- Mixtures in which the composition of the components is uniform throughout the mixture.

Ex: mixture prepared by dissolving common salt in water.

- Mixtures in which the composition of the components is not uniform throughout the mixture.

Ex: mixture prepared by dissolving clay in water

The mixtures in which the components are separated from one another are called heterogeneous mixtures. The mixtures whose composition of the components are uniformly distributed throughout are known as homogenous mixtures.

Homogeneous mixtures

The mixtures in which the components cannot be observed separately from one another and the properties and composition are similar throughout are termed **homogenous mixtures.** In a homogeneous mixture, the physical properties such as colour, transparency and density are identical everywhere. Homogenous mixtures are also known as solutions.

Examples: salt solution, sugar solution

Heterogeneous mixtures

The mixtures in which the components can be distinguished from one another and they are known as **heterogeneous mixtures.** The physical properties of the mixture such as colour, transparency and density are different from place to place, in a heterogeneous solution.

Examples: Water in which clay is dissolved, water in which laundry blue (the powder used for whitening of clothes) is dissolved, cement mortar, sherbet drinks, fruit salad.

Activity 3.1.5

Dissolve the following substances in water and record the observations.

Common salt, washing powder, laundry blue (added to clothes), copper sulphate, potassium permanganate, wheat flour, ethyl alcohol

Classify the various mixtures you prepared as homogeneous and heterogeneous

Heterogeneous and homogeneous mixtures can be classified further depending on the physical state of the components. Study and understand the facts given in table 3.1.2 describing mixtures of two components.

Table 3.1.2

First component	Second component	Nature of the mixture	How the mixture is termed
Wheat flour(Solid)	water(liquid)	heterogeneous	solid-liquid heterogeneous
Salt (solid)	Water (liquid)	homogeneous	solid-liquid homogeneous
coconut oil (liquid)	Water (liquid)	heterogeneous	liquid-liquid heterogeneous
Ethyl alcohol (liquid)	Water (liquid)	homogeneous	liquid-liquid homogeneous
Sugar (solid)	Salt (solid)	heterogeneous	solid-solid heterogeneous
Copper (solid)	Zinc (solid)	homogeneous	solid-solid homogeneous *
Carbon dioxide (gas)	Hot water (liquid)	heterogeneous	gas-liquid heterogeneous
Carbon dioxide (gas)	Cold water (liquid)	homogeneous	gas-liquid homogeneous

* Brass is an alloy composed of 65% of copper and 35% of zinc. This is a solid-solid homogeneous mixture.

Assignment 3.1.1

Prepare a list of mixtures used in various occasions in the laboratory and day-to-day life. State the components in those mixtures. Differentiate them as homogeneous and heterogeneous. Indicate how those mixtures can be named according to the state in which the components exist.

Solute and solvent of a solution

It was mentioned that a homogenous mixture is also called a solution. A solution is composed of a solvent and one or more solutes. Of the components mixed to form the solution, the component present in excess is the solvent. The rest of the components are solutes.

Hence, it can be represented as,

Solute + Solvent = Solution

This can be further understood by paying attention to the solutions used in day-to-day life.

Ex: Salt + Water = Salt solution

Copper sulphate + Water = Copper sulphate solution

Sugar + Water = Sugar solution

• Solubility of a solute

What will happen if a small amount of a given solute is added to a solvent? It will dissolve and disappear.

What quantity of a solute can be dissolved like this in a given volume of the solvent? Do the following activity to find it out.

Activity 3.1.6

Materials required :- A beaker, salt, a glass rod

Method :- Measure 100 ml of water into a clean beaker. Weigh 100 g of pure salt (NaCl). Add salt, little at a time into the beaker of water and stir with the glass rod to dissolve it. Do not add more salt until the salt added before dissolves completely. When no more salt dissolves, stop adding more salt and weigh the remaining amount of salt. Approximately, what is the maximum mass of salt that can be dissolved in 100 ml of water?

Is the amount of other components that dissolve in the same volume of water, the same? To investigate this, conduct the following activity.

Activity 3.1.7

Materials required :- A beaker, calcium hydroxide, a glass rod

Method :- Weigh 10 g of calcium hydroxide at the laboratory. Take 100 ml of water to a beaker and dissolve calcium hydroxide in it, by adding a very small amount at a time while stirring. Stop the addition of solid when no more calcium hydroxide dissolves in the solution and weigh the remaining solid. Approximately what is the maximum mass of calcium hydroxide that can be dissolved in 100 ml of water?

Compare the results of the activity 3.1.7 with those of 3.1.6

The above activities show that the quantity dissolved is more for some substances, while it is less for some other substances in the same volume of water.

Repeat activities 3.1.6 and 3.1.7 using 100 ml of hot water of about 80 ^{0}C instead of water at room temperature. See whether the dissolved mass of the solute changes. It would be observed that a greater amount of the solute dissolves at a higher temperature than it does in an equal volume of water at room temperature.

In order to compare the dissolution of various solutes in a given solvent, the amount of solutes dissolved in the same volume of the same solvent at the same temperature should be compared. Therefore solubility is defined as follows.

The solubility of a solute at a given temperature can be defined as the mass of that solute which dissolves in 100 g of the solvent at a certain temperature.

Ex:- at 25 ^{0}C, the solubility of magnesium chloride in water is 53.0 g.

At the same temperature, solubility of potassium sulphate in water is 12.0 g.

Factors affecting solubility

You have already identified temperature as a factor affecting the solubility of a solute in a given solvent. Try the following activities to investigate the other factors affecting solubility.

Activity 3.1.8

Materials required :- Two small beakers, common salt, sugar

Method :- Take 50 ml of water at the same temperature into each of two small beakers. Accurately weigh 50 g each of salt and sugar. Adding a little at a time, dissolve salt in one beaker and sugar in the other. When it comes to the point beyond which no more solid dissolves, stop adding the substance and weigh the remaining solid. See whether the amounts left are equal.

You will be able to see that at the same temperature, different solutes dissolve in different amounts in equal volumes of the same solvent. Hence, it can be said that the nature of the solute affects the solubility.

Activity 3.1.9

Materials required :- Two small beakers, kerosene, sugar

Method :- Take 50 ml each of the solvents water and kerosene at the same temperature into two small beakers. Add 5 g of sugar into each of them and stir. In which solvent does sugar dissolve?

You will be able to see that the sugar completely dissolves in water but sugar added to kerosene remains almost undissolved.

This shows that the solubility of the same solute is different in equal volumes of different solvents at the same temperature.

Therefore, it can be said that the nature of the solvent affects solubility.

According to the observations of the above activities, it is confirmed that the following factors affect solubility.

1. Temperature
2. Nature of the solute
3. Nature of the solvent

Of the above factors, except temperature, the nature of the solute or the solvent are properties of matter. The characteristic properties of matter are imparted by the particles that make the matter. The nature of molecules which constitute the solute and solvent is a factor that determines the solubility. In grade 10, you have learnt about the polarity of a chemical bond. Based on the polarity chemical compounds can be classified into two categories; polar and non polar. At the same time, chemical compounds can also be classified into two types organic and inorganic - according to the constituent elements of the compound.

Hence, solutes and solvents can be classified under four classes.

1. Polar organic solutes/solvents
2. Non - polar organic solutes/ solvents
3. Polar inorganic solutes/solvents
4. Non - polar inorganic solutes/solvents

From the following schematic diagram, you can identify the examples relevant to those four classes.

Solutes / Solvents

- Organic
  - Polar
    - Alcohol
    - Formalin
    - Acetone
  - Non-polar
    - Hexane
    - Benzene
    - Carbon tetrachloride
- Inorganic
  - Polar
    - Water
    - Ammonia
    - Hydrogen chloride
  - Non-polar
    - Carbon disulphide liquid
    - Carbon dioxide

Based on the above classification, a general concept on solubility such as the one below can be composed.

Polar solutes are soluble in polar solvents

Ex 1 :- Ethanol is a polar compound. Water is a polar compound. Therefore, ethanol is soluble in water.

Ex 2 :- Ammonia is a polar compound. Water is a polar compound. Therefore, ammonia dissolves in water.

Non-Polar solutes are soluble in non-Polar solvents

Ex 1:- Grease is a non-polar solute. Kerosene is a non-polar solvent. Therefore, grease dissolves in kerosene.

Ex 2:- Jak glue (koholle) is a non-polar solute. Kerosene is a non-polar solvent. Therefore, jak glue is soluble in kerosene.

On that account, it can be concluded that solutes and solvents of similar polarity properties dissolve in each other (like dissolves like).

• Solubility of a gas

Do gases really dissolve in water? Recall the following experiences to answer this.

- As soon as a bottle of soda water or a fizzy drink is opened, gas bubbles evolve from the solution.
- When a beaker of water is heated, gas bubbles can be seen on the walls of the beaker.

In both of these instances, it is the gases that were dissolved in water that got liberated. During the production of soda water, carbon dioxide gas is mixed with water under the special conditions of high pressure using machinery. Because of this more gas dissolves in water. However, atmospheric gases are always in contact with natural water. Then gases like carbon dioxide and oxygen dissolve only in small quantities.

When water is heated, the dissolved gases are evolved. Therefore, the amount of gases remaining dissolved in hot water is very small. Accordingly, temperature can be taken as a factor affecting the solubility of a gas.

Generally, the solubility of a solid substance in a solvent can be increased by increasing the temperature. But the solubility of a gas in a given solvent decreases with the rise in temperature. Are there any more factors affecting the solubility of a gas in water? See what conclusion could be drawn from the observations of the following activity.

Activity 3.1.10

Materials required :- An unopened bottle of soda water (plastic), an empty bottle of the same type.

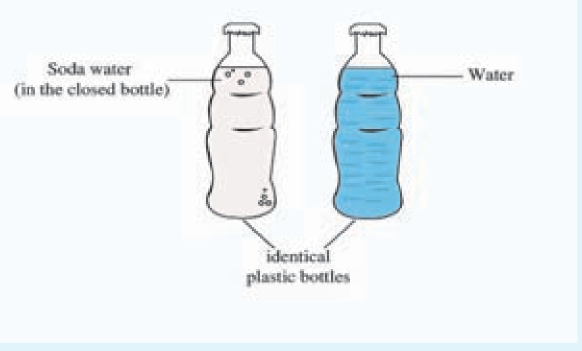


Figure 3.1.3

Method :- Take an un opened bottle of soda water available in the market. To an identical empty bottle, add water equal in quantity to that of soda water and close the cap tightly. Now squeeze both bottles with hand and select the harder bottle.

You may feel that the unopened soda bottle is very hard that it cannot be pressed. Think why it is so. In the bottle of soda above the liquid, there is carbon dioxide gas under high pressure. The moment the cap is opened, carbon dioxide gas escapes, and the rigidity of the bottle is lost. When the pressure of a gas in contact with water is increased, the solubility of that gas in water too increases. Thus, the solubility of a gas in water depends on two factors.

1. Temperature
2. Pressure

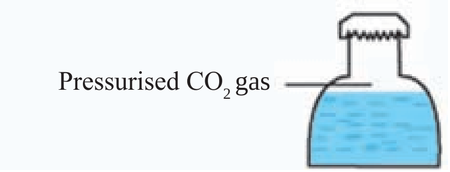


Figure 3.1.4

3.2 Composition of a mixture

Activity 3.2.1

Materials required :- Two beakers, potassium permanganate

Method :- Add 50 ml of water in each of to two beakers. Add 0.2 g and 0.4 g potassium permanganate separately to the two beakers and stir well with a glass rod. Record your observations.

You will be able to see, that the solution in the beaker with 0.2 g potassium permanganate is light purple in colour whereas the purple colour of the solution with 0.4 g potassium permanganate is relatively more intense.

When preparing the above two solutions, the volumes of water taken into the two beakers were equal. That means, the volumes of the solvent were equal. However, the masses of potassium permanganate used as the solute were different. In the solution with a more intense purple colour, a unit volume contains more solute particles. Therefore, the composition of these two solutions is different.

When preparing mixtures of weedicides and insecticides, they must be prepared in correct composition. Prescribed composition should be used when preparing solutions using pharmaceuticals. Laboratory work often involve the preparation of solutions of fixed composition. Therefore, understanding about the composition of mixtures is very important in everyday life as well as in laboratory experiments. There are several ways to express the composition of a mixture. Some of those are discussed in the following sections.

3.2.1 Composition of a mixture as a mass fraction (m/m)

Let us consider a mixture comprising of two components A and B. The mass fraction of A in that mixture can be expressed as follows.

$$\text{Mass fraction of A in the mixture} = \frac{\text{Mass of A}}{\text{Mass of A} + \text{Mass of B}}$$

Hence, the mass fraction of a given component of a mixture is the ratio of the mass of that component to the total mass of the mixture.

Worked examples :-

1) 100 g of the solution contains 5 g of a solute. Give the composition of the solute of this mixture as a mass fraction.

$$\text{Mass fraction of the solute} = \frac{\text{Mass of the solute}}{\text{Mass of the solution}}$$

$$= \frac{5\text{ g}}{100\text{ g}}$$

$$= \frac{1}{20}$$

$$= 0.05$$

2) When 250 g of a salt (NaCl) solution was weighed accurately and all the water in it was evaporated, 10 g of salt was left. Indicate the composition of salt in the solution as a mass fraction.

$$\text{Mass fraction of salt} = \frac{10\text{ g}}{250\text{ g}}$$

$$= \frac{1}{25}$$

$$= 0.04$$

3.2.2 Composition of a mixture as a volume fraction (V/V)

Volume fraction is used to indicate the composition of a mixture when both of its components exist either in the liquid state or in the gaseous state.

In a mixture containing two components A and B, the volume fraction of A can be given as follows.

$$\text{Volume fraction of A} = \frac{\text{Volume of A}}{\text{Total volume of the mixture of A and B}}$$

Accordingly, the volume fraction of a given component of a mixture is the ratio of the volume of that component to the total volume of the mixture.

Worked examples:-

1) A solution of final volume 250 cm^3 was made by adding distilled water to 25 cm^3 of ethyl alcohol (C_2H_5OH). What is the volume fraction of ethyl alcohol in this solution?

$$\text{Volume fraction of ethyl alcohol} = \frac{\text{Volume of ethyl alcohol}}{\text{Total volume of the solution}}$$

$$= \frac{25\ cm^3}{250\ cm^3}$$

$$= 1/10$$

$$= 0.1$$

2) How do you prepare 500 cm^3 of an aqueous solution of acetic acid of composition 1/25 (V/V) ?

$$\text{Volume fraction of acetic acid} = \frac{\text{Volume of acetic acid}}{\text{Final volume of the solution}}$$

$$\text{Volume of acetic acid} = \text{Volume fraction of acetic acid} \times \text{Final volume of the solution}$$

$$= \frac{1}{25} \times 500\ cm^3$$

$$= 20\ cm^3$$

Therefore, an acetic acid solution with the composition of 1/25 (V/V) is obtained by measuring 20 cm^3 of acetic acid accurately and adding water to make the final volume up to 500 cm^3.

3.2.3 The composition of a mixture as a mole fraction

The mole fraction of each component of a mixture containing only two component A and B can be expressed as follows.

$$\text{Mole fraction of A} = \frac{\text{Amount of moles of A}}{\text{Amount of moles of A + Amount of moles of B}}$$

$$\text{Mole fraction of B} = \frac{\text{Amount of moles of B}}{\text{Amount of moles of A + Amount of moles of B}}$$

Thus, the mole fraction of a component of a mixture is, the ratio of the amount of moles of that component to the total amount of moles of all the components in the mixture.

Worked examples :-

1) What is the mole fraction of sodium hydroxide (NaOH) in a solution made by dissolving 40 g of sodium hydroxide in 180 g of water?

Molar mass of water $= (1 \times 2 + 16)\ \text{g mol}^{-1}$
$= 18\ \text{g mol}^{-1}$

Amount of moles of water in the solution $= \dfrac{180\ \text{g}}{18\ \text{g mol}^{-1}}$

$= 10\ \text{mol}$

Molar mass of sodium hydroxide $= (23+16+1)\ \text{g mol}^{-1}$

$= 40\ \text{g mol}^{-1}$

Amount of moles of sodium hydroxide in the solution $= \dfrac{40\ \text{g}}{40\ \text{g mol}^{-1}}$

$= 1\ \text{mol}$

Mole fraction of sodium hydroxide in the solution $= \dfrac{\text{Amount of moles of sodium hydroxide}}{\text{Amount of moles of water + Amount of moles of sodium hydroxide}}$

$$= \frac{1}{10 + 1}$$

$$= \frac{1}{11}$$

Similarly, the mole fraction of water in the above solution can be calculated.

Mole fraction of water $= \dfrac{\text{Amount of moles of water}}{\text{Amount of moles of water} + \text{Amount of moles of sodium hydroxide}}$

$$= \frac{10}{10 + 1}$$

$$= \frac{10}{11}$$

Sum of mole fractions = Mole fraction of water + Mole fraction of sodium hydroxide

$$= \frac{10}{11} + \frac{1}{11}$$

$$= \frac{11}{11}$$

$$= 1$$

The sum of mole fractions of all the components in a mixture is one. The sum of mass fractions or volume fractions of all the components in a mixture is equal to one. There are no units for the mass fractions, volume fractions or mole fractions of a mixture.

The composition of a mixture expressed as a fraction can also be expressed as a percentage or as parts per million (ppm).

Composition as a percentage = Fraction x 100

Composition as parts per million (ppm) = fraction x 1 000 000

Worked examples:

1) 20 g of dolomite contains 12 g of magnesium carbonate. Calculate the mass fraction of magnesium carbonate and express it as a mass percentage.

Mass fraction of magnesium carbonate $= \dfrac{12\text{ g}}{20\text{ g}} = 0.6$

Magnesium carbonate composition as a percentage $= 0.6 \times 100 = 60\%$

3.2.4 Expressing composition of a mixture in terms of mass/ volume (m/v)

This expresses the mass of solute contained in a unit volume of a mixture.

1 dm^3 of Jeewani solution contains 5 g of sodium chloride. Find the composition of sodium chloride in it, in terms of m/v

$$\text{Composition of solute (m/v)} = \frac{\text{Mass of sodium chloride}}{\text{Volume of solution}}$$

$$= \frac{5\text{ g}}{1\text{dm}^3}$$

$$= 5\text{ g dm}^{-3}$$

3.2.5 Expressing composition of a mixture in terms of amount of moles / volume (n/v)

This is used to express the composition of a homogeneous mixture (solution). 'Mole' is the international unit for the amount of matter. Here, the composition is given in terms of the amount of moles of solute contained in unit volume of a solution. The composition expressed in this way is called the concentration (C). In chemistry, very often concentration of a solution is expressed in terms of the amount of moles of solute contained in a cubic decimetre of the solution.

Worked examples :-

1) 2 dm^3 of a solution contains 4 moles of sodium hydroxide (NaOH). Find the sodium hydroxide concentration of this solution.

Amount of moles of sodium hydroxide in 2 dm^3 of the solution $= 4$ mol

Amount of moles of sodium hydroxide in 1 dm^3 of the solution $= \dfrac{4\text{ mol}}{2\text{ dm}^3} \times 1\text{ dm}^3$

$= 2$ mol

Concentration of sodium hydroxide in the solution $= \frac{2 \text{ mol}}{1 \text{ dm}^3}$

$= 2 \text{ mol dm}^{-3}$

2) (i) What is the mass of glucose ($C_6H_{12}O_6$) required to prepare 1 dm^3 of a 1 mol dm^{-3} glucose solution? (C =12, H = 1, O = 16)

For this, 1 mol of glucose is required

Molar mass of glucose $= (12\text{x}6 + 1\text{x}12 + 16\text{x}6) \text{ g mol}^{-1}$

$= 180 \text{ g mol}^{-1}$

Mass of glucose required $= 180 \text{ g mol}^{-1} \text{ x } 1 \text{ mol}$

$= 180 \text{ g}$

(ii) Work out the mass of glucose that should be weighed to prepare 500 cm^3 of a 1 mol dm^{-3} glucose solution.

Mass of glucose required to prepare 1000 cm^3 of the solution $= 180 \text{ g}$

Mass of glucose required to prepare 500 cm^3 of the solution $= \frac{180 \text{ g}}{1000 \text{ cm}^3} \text{ x } 500 \text{ cm}^3$

$= 180 \text{ g}/ 2$

$= 90 \text{ g}$

Preparation of standard solutions

During chemical experiments, standard solutions are required to be prepared. A standard solution is a solution in which the concentration is very accurately known. The relationships among the following units are very important in the preparation of standard solutions.

$1dm^3 = 1 \text{ l (Litre)}$

$1dm^3 = 1000 \text{ cm}^3$

$1dm^3 = 1000 \text{ ml}$

$1cm^3 = 1 \text{ ml}$

The following laboratory equipment are required to prepare a solution of a specified concentration.

Volumetric flasks corresponding to the volume of the solution

Wash bottle

Watch glass

Funnel

Figure 3.2.1 - Laboratory equipment required to prepare a solution.

Let us study how 500 cm^3 of a 1 mol dm^{-3} sodium chloride solution is prepared. First, the mass of sodium chloride required for this should be calculated.

Molar mass of sodium chloride $= (23.0 + 35.5)\ g\ mol^{-1}$

$= 58.5\ g\ mol^{-1}$

Mass of sodium chloride in 1000 cm^3 of a 1 mol dm^{-3} solution $= 58.5\ g$

Mass of sodium chloride in 500 cm^3 of a 1 mol dm^{-3} solution $= \dfrac{58.5\ g}{1000\ cm^3} \times 500\ cm^3$

$= 29.25\ g$

- Next, weigh 29.25 g of sodium chloride very accurately onto a watch glass using a four beam balance/ chemical balance. (Get instructions from the teacher as to how weighing is done accurately using the balance).
- Select a clean 500 cm^3 volumetric flask.
- Remove its stopper and place a clean funnel as shown in the figure.
- Transfer the weighed sodium chloride on the watch glass completely through the funnel using the wash bottle. Wash the surface of the watch glass and the inner surface of the funnel and transfer the washings into the flask.
- Add about 2/3 of the required volume of water and stopper the volumetric flask.

Figure 3.2.2 - Preparation of a standard solution

- Shake the flask so that all of the sodium chloride dissolves well. (Get instructions from the teacher about how mixing should be done.)

- After all the salt is dissolved well, add water carefully, keeping the eye at the level of the volume mark of the flask. Stop adding water when the meniscus is at the position of the mark, as shown in the figure 3.2.3.
- Stopper the flask and mix again. (Get instructions from the teacher regarding how mixing should be done)

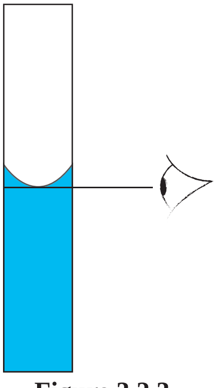


Figure 3.2.3

When preparing a solution of a specific concentration, following factors should be taken into consideration.

1. Cleanliness of all the equipment used.
2. Weighing the solute accurately.
3. Washing well and transferring the substance sticking on to the watch glass and the funnel into the flask.
4. Use the correct technique for mixing.
5. Adjusting the final volume carefully.
6. Prevention of the entry of impurities into the solution.

Activity 3.2.2

1. Divide the class into four groups and prepare the four solutions given below using the correct method.

a) 250 cm^3 of 1 mol dm^{-3} sodium chloride ($NaCl$)

b) 100 cm^3 of 1 mol dm^{-3} glucose ($C_6H_{12}O_6$)

c) 500 cm^3 of 1 mol dm^{-3} urea ($CO(NH_2)_2$)

d) 250 cm^3 of 1 mol dm^{-3} copper sulphate ($CuSO_4$)

2. In the solutions you have prepared,
   - name the solute and solvent
   - indicate the amounts of the solvents and the solutions used with their units.
   - indicate the name, concentration and the date of preparation.
3. Give examples for the instances of preparing solutions in everyday life.

Assignment 3.2.2

Make a list of instances in which solutions of very accurate composition should be prepared.
Ex: Preparation of saline solutions

Thoroughly study the following worked examples in order to get a better understanding of the composition of solutions.

Worked examples :-

1. A solution was prepared by weighing 17 g of sodium nitrate ($NaNO_3$) very accurately dissolving it in a 200 cm^3 volumetric flask and diluting with water up to a final volume of 200 cm^3. What is the concentration of this solution?

   (Na = 23, N =14, O =16)

Molar mass of sodium nitrate $= \{23+14+(16x3)\}g\ mol^{-1}$

$= 85\ g\ mol^{-1}$

Amount of moles of sodium nitrate in 17 g $= \dfrac{17\ g}{85\ g\ mol^{-1}}$

$= 0.2\ mol$

Final volume of the solution $= 200\ cm^3$

Amount of moles of sodium nitrate in 1 dm^3 (1000 cm^3) of the solution $= \dfrac{0.2\ mol}{200\ cm^3} \times 1000\ cm^3$

$= 1$

Concentration of sodium nitrate in the solution $= \dfrac{1\ mol}{1\ dm^3}$

$= 1\ mol\ dm^{-3}$

2. What is the mass of potassium carbonate (K_2CO_3) required to prepare 500 cm^3 of a 1 mol dm^{-3} potassium carbonate solution? (K = 39, C = 12, O = 16)

Molar mass of potassium carbonate $= \{(39x2)+12+(16x3)\}g\ mol^{-1}$

$= 138\ g\ mol^{-1}$

Mass of potassium carbonate in 1000 cm^3 of a 1 mol dm^{-3} solution $= 138g$

Mass of potassium carbonate in 500 cm^3 of a 1 mol dm^{-3} solution $= \dfrac{138\ g}{1000\ cm^3} \times 500\ cm^3$

$= 69\ g$

Mass of potassium carbonate required $= 69\ g$

3. A solution of 1 dm^3 is prepared by dissolving 12 g of urea $\{CO(NH_2)_2\}$ in distilled water. Find the concentration of this solution. (C = 12, O = 16, N = 14, H = 1)

Molar mass of urea $= \{12 + 16 + (14 \times 2) + (1 \times 4)\}\ g\ mol^{-1}$

$= 60\ g\ mol^{-1}$

Amount of moles of urea in 60 g $= 1\ mol$

Amount of moles of urea in 12 g $= \frac{1mol}{60\ g} \times 12\ g$

$= 0.2\ mol$

Amount of moles of urea in 1 dm^3 $= 0.2\ mol$

Concentration of urea in the solution $= \frac{0.2\ mol}{1\ dm^3}$

$= 0.2\ mol\ dm^{-3}$

4. To a 250 cm^3 volumetric flask, 18 g, of glucose ($C_6H_{12}O_6$) was transferred and distilled water was added until the total volume of the solution was 250 cm^3. What is the concentration of this solution?

Molar mass of glucose $= \{(12x6) + (1x12) + (16x6)\}\ g\ mol^{-1}$

$= 180\ g\ mol^{-1}$

Amount of moles of glucose in 180 g $= 1\ mol$

Amount of moles of glucose in 18 g $= \frac{1mol}{180\ g} \times 18\ g = 0.1\ mol$

Amount of moles of glucose in 250 cm^3 $= 0.1\ mol$

Amount of moles of glucose in 1000 cm^3 $= \frac{0.1mol}{250\ cm^3} \times 1000\ cm^3$

$= 0.4\ mol$

Concentration of the solution $= \frac{0.4\ mol}{1\ dm^3}$

$= 0.4\ mol\ dm^{-3}$

The concentration of a solution can be lowered by adding more solvent to it. Decreasing the concentration by adding more solvent is known as dilution. Most of the acids in laboratory stores are concentrated acids. Mostly the acid solutions prepared by diluting those concentrated acids are used for laboratory experiments.

For your attention

As a safety measure, when diluting concentrated solutions, always the acid should be added to water. It is because the dilution of concentrated acids is highly exothermic and may be dangerous.

When **n** moles of a solute are dissolved in a solution of volume **V**, its concentration **C** can also be found using the following equation.

$$\boxed{C = \frac{n}{V}}$$

When **n** is in moles (mol) and V is in cubic decimetres (dm^{-3}), concentration C is given in moles per cubic decimetre ($mol\ dm^{-3}$)

Using the above equation, solve the previously studied worked examples to calculate the concentration.

3.3 Separation of compounds in mixtures

Many substances essential for our daily affairs are available in the Earth's crust. Metals, mineral oils, salts, sand, clay, coal, minerals and rocks are some of them. These rarely exist in pure form in the Earth's crust. Naturally they occur mixed with other substances. Therefore, the essential components should be separated from those mixtures.

Some instances where components from mixtures should be separated, are given below.

- Removal of stones and sand from rice
- Separation of salt from sea water
- Separation of various minerals from mineral sands
- Separation of various fuels by the mineral oil refinery
- Separation of sugar from sugar cane crushes
- Separation of gases such as oxygen, nitrogen and argon from atmospheric air
- Obtaining distilled water from common well water or river water
- Preparing potable water from sea water

Many more such occasions can be given as examples. In this chapter we study about several methods of separating components in mixtures.

3.3.1 Mechanical separation

You know that rice is sifted to remove the sand mixed with it. In this, sand is removed from rice based on the difference of the densities of the components. The separation of components in a mixture using the difference of their physical properties such as density, particle size, particle shape, magnetic properties and electric properties is called mechanical separation. Study the examples given in table 3.3.1 and have a further understanding about mechanical separations.

Table 3.3.1

Mechanical method	Occasion of using	Physical property based
Winnowing	Removal of chaff from rice	Difference in densities of the components
Sieving	Removal of gravel from sand	Difference in the size of component particles
Sifting	Removal of sand from rice	Difference in densities of the components
Floating on water	Removal of dud seeds from seed paddy	Difference between the densities of components and water
Directing into a stream of water	Separating gold from ores	Difference in densities of the components
Magnetic seperation	Separating certain minerals from mineral sands	Magnetic property of the components

The methods such as winnowing, sieving, sifting, floating and subjecting to magnetism that separate components of a mixture are called mechanical methods. Methods such as these are frequently used in day today life.

Assignment 3.3.1

Prepare a list of examples for the occasions where components are separated by mechanical methods in day today life.

3.3.2 Vapourisation/Evaporation

You may have observed the extraction of salt from sea water. What happens here is that the water evaporates due to solar heat. Water gets evaporated and the dissolved salts get precipitated. **During vapourization, the unnecessary components are vaporized by supplying heat to a mixture and the essential component is isolated.**

When metals are dissolved in mercury a special solution known as an amalgam is formed.

When impure gold is dissolved in mercury, a solution of pure gold is obtained. This is known as the gold amalgam. When gold amalgam is heated, mercury is evaporated and the pure gold is remained. The evaporated mercury is cooled and used again.

3.3.3 Filtration

Have you seen adding coconut milk to some curries when they are cooked at home? How is coconut milk made? Water is added to the coconut scraped by a coconut scraper, and then crushed and squeezed by hand. Parts of the white liming remain suspended in water without going into the solution. When the stuff is put into a milk-strainer the milky solution filters off leaving the pieces of solid coconut in the strainer.

Filtration can be used to separate from a mixture, the components that remain suspended in a liquid without going into the solution. A filter is required to filter a mixture. Milk-strainer is such a device. The filter paper used in laboratories is another such filter. Water purifying plants have sand filters.

A filter has small holes. Particles smaller than the holes can pass through. But particles larger than those holes cannot pass through them. This is the concept used in filtration. In filtration, the substance left in the filter is called the residue while the solution that gets filtered is known as the filtrate.

Activity 3.3.1

Materials required :- Dry soil, salt, filter papers, a funnel, a beaker, glass rod, flask

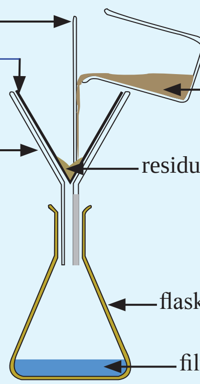


Figure 3.3.1

Method :- Mix well, about 10 g of dry soil and about 5 g of salt (NaCl). Take about 50 cm^3 of water to a beaker, add the above mixture into it and stir. Arrange the apparatus as shown in figure 3.3.1 and filter. After filtration is over, observe the filter paper. Add about 10 cm^3 of the filtrate to an evaporating dish and vaporize. See whether there is anything left in the dish.

Large clay particles in the sample of soil do not pass through the filter, and they are held back by the filter paper. Since water and salt are made up of smaller particles, they pass through the filter and get into the filtrate.

3.3.4 Crystallisation

Let us consider instances where a solid dissolves in a solvent to form a homogeneous mixture. At a certain temperature, there is a maximum concentration of a substance that stays dissolved in a solution. Such solutions are said to be saturated with that substance.

If this saturated solution is vaporized, the concentration of that substance in the solution increases further. When the concentration of the solute exceeds the maximum possible concentration in the solution, the solute separates out forming crystals.

Crystallization is thus the method of separating solid substances by concentration when a solute that can turn into a solid is present in a solution.

Manufacturing of sugar is an industry that utilities crystallization. Stems of Sugarcane are crushed and squeezed and the juice is purified. Its concentration is increased by vaporisation. Then, sugar separates out from the juicy solution as crystals.

Production of salt from sea water is another industry that adopts crystallization. During the production of salt in salterns, several salts that are dissolved in sea water get crystallized.

Assignment 3.3.2

Obtain salt by the vaporisation or evaporation of a concentrated salt solution.

3.3.5 Recrystallization

Recrystallization is used to separate pure substances from solid, crystalline substances carrying impurities. The process of dissolving a solid, crystalline substance and turning it again into crystals is called recrystallization. Crystals of high quality without impurities can be obtained by recrystallization.

In recrystallization, the impure solid is dissolved in the hot solvent till it becomes saturated. Afterwards, to separate the impurities in the impure solid, above solution is filtered while it is still hot. Pure crystals of the solid is obtained by cooling the filtrate. Here, crystallization occurs because the cold solution is saturated with the solute although the hot solution is not. The soluble components present as impurities in minor quantities are not crystallized as the solution is not saturated in them.

Activity 3.3.2

Take about 50 g of common salt available in the market. Take about 50 cm^3 of water at a temperature of about 90 ^{0}c, into a beaker and dissolve crystals of salt until the solution is saturated. Filter the solution while it is still hot, using filter paper. Take the filtrate into a beaker, place it in a container of ice and shake slowly. Observe the crystals formed.

3.3.6 Solvent extraction

You have learnt that the nature of both solute and solvent affect solubility. Some solutes are soluble in large amounts in one solvent but dissolve in very small quantities in another solvent. For example, when solid iodine is added to water, a very small amount dissolves giving a light coloured solution. But a larger amount of iodine dissolves in solvents like carbon tetrachloride and cyclohexane.

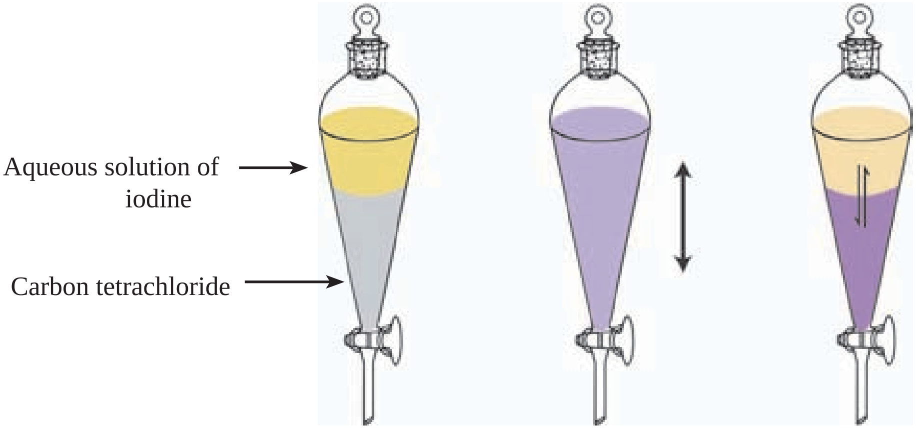


Figure 3.3.2

When carbon tetrachloride is added to an aqueous solution of iodine, they do not mix, and the layers get separated. After some time, it can be seen that the carbon tetrachloride layer turns violet while the aqueous layer becomes pale. What has happened here is the extraction of iodine from the aqueous layer into the carbon tetrachloride layer in which it is more soluble. The specialty here is the adequacy of a small volume of carbon tetrachloride to extract the iodine from a large volume of aqueous solution.

After this, iodine can be recovered by separating layers and evaporating carbon tetrachloride.

Hence, solvent extraction is the method of drawing up a substance from a solvent in which it is less soluble, into another solvent in which it is more soluble, where the two solvents are immiscible and are in contact with each other.

The medicinal components in some plants are found only in trace amounts. Medicinal solutions of higher concentration are prepared using solvent such as ethanol. Solvents extraction is used in the production of medicinal extracts and potions.

3.3.7 Simple distillation, fractional distillation and steam distillation

The separation of components by boiling a solution or a mixture and condensing the vapour is called distillation.

So, there must be a mechanism to cool the distillate or the vapour that evolves when a given mixture is heated. The Liebig condenser in the school laboratory is an apparatus designed for this. The vapour is allowed to pass through the condenser and cold water is circulated around it, in order to cool down the vapour. This condenser has an inlet and an outlet for water.

Figure 3.3.3 - The Liebig condenser

Activity 3.3.3

Collect a sample of distilled water using the Liebig condenser available in the laboratory. Discuss with your science teacher the special facts that should be taken into consideration when setting up this apparatus.

Assignment 3.3.3

Investigate into how an improvised liebig condenser can be made. Make such an apparatus, show it to the science teacher and find its merits and demerits.

- ### Simple distillation

Simple distillation is used to separate components in a mixture which contains a volatile component with other non-volatile components. Only the volatile components are vaporized during distillation. The other components are left in the solution. For example, let us assume that a sample of well water is subjected to distillation.

In addition to water, it contains various salts and some gases dissolved in it. When heated slightly, the gases escape without getting condensed. Boiling points of salts are higher than that of water. Therefore, when the sample of well water is heated and vaporized, only the water vaporizes. Salts can be seen deposited at the bottom of the container. For this kind of distillation, special control of conditions is not essential. Hence, this is known as simple distillation. For this use of simple equipment such as the liebig condenser is adequate. The figure illustrates the apartments set up to obtain distilled water from a sample of well water. Some countries use this method to obtain potable water from sea water.

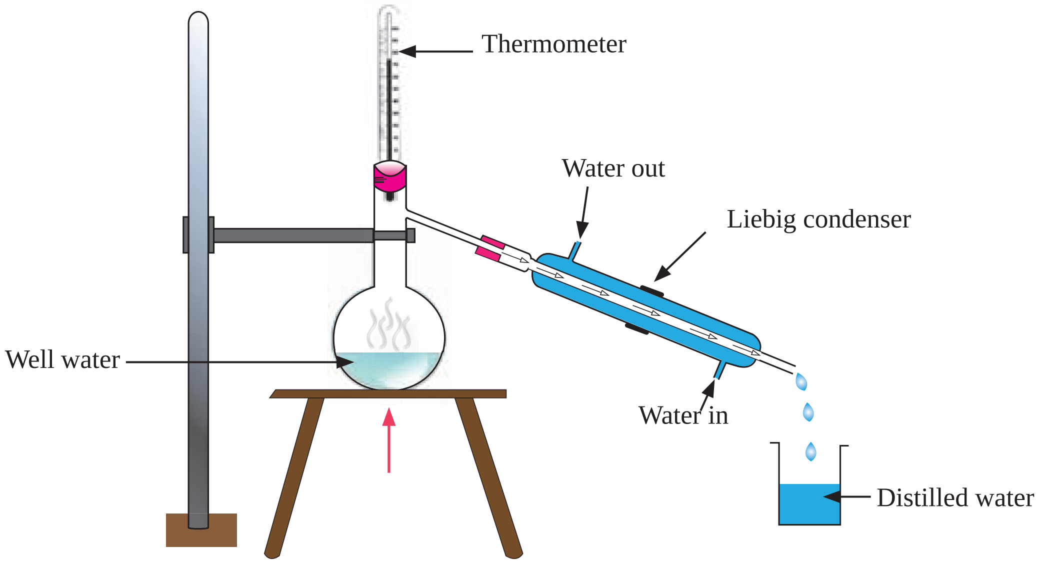


Figure 3.3.4 - Simple distillation

• Fractional distillation

If the solution or the mixture subjected to separation contains several volatile components, simple distillation or the apparatus used in simple distillation cannot be used to separate them. It has to be performed under controlled conditions and for it, a fractionating column should be used. If two liquids are to be separated by fractional distillation, there should be a considerable difference in their boiling points. That means, their volatilities need to be considerably different. Here, the vapour contains a higher percentage of the more volatile component and a lower percentage of the less volatile component.

Let us assume that the boiling point of a component A mixture is 80 ^{0}C and the boiling point of a component B is 40 ^{0}C. Upon heating, the mixture containing A and B begins to boil at a temperature slightly above 40 ^{0}C. Therefore, the vapour formed is richer in component B. When this vapour is collected and condensed at a temperature closer to 40 ^{0}C, the resulting liquid contains more B. **A** is present in smaller amount. When more of B gets removed from the mixture like this, its percentage of **A** increases. Then, the temperature at which the mixture boils also increases. This way, the components can be separated by collecting the vapours at different temperatures and condensing them. Separation of several components by distillation under controlled cooling conditions like this, is known as fractional distillation.

Crude oil is a mixture of many hydrocarbon components. When refining crude oil, a fractionating tower is used to control the cooling conditions. In this tower, the temperature is appropriately controlled at different levels and the components are separately withdrawn at the respective positions. Components with lower boiling points are separated from the upper levels of the tower. Components with high boiling points are (bitumen) deposited at the bottom of the tower. This can be further understood by studying figure 3.3.5.

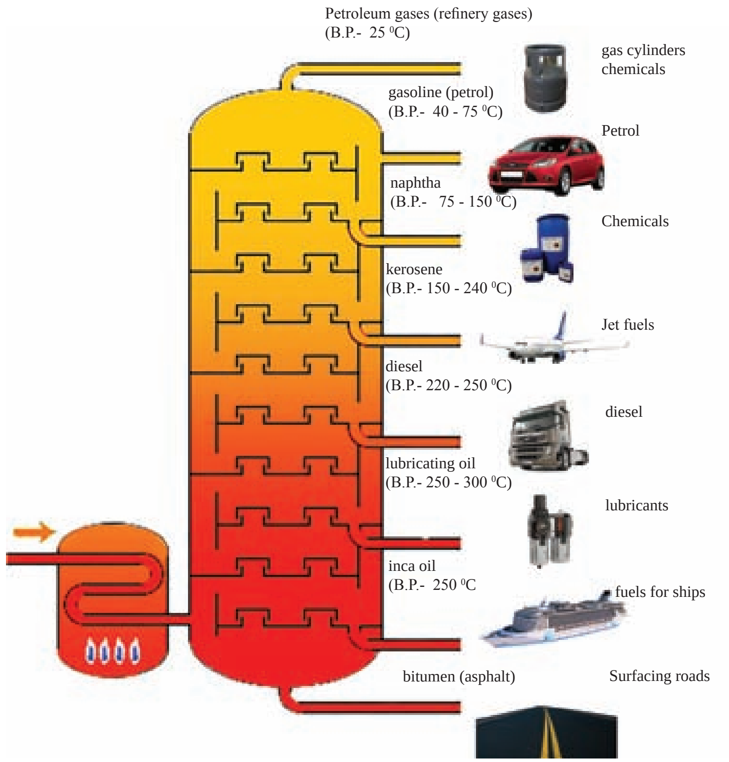


Figure 3.3.5 - Fractionating tower

Extra knowledge

Fractional distillation is also used to separate the components in atmospheric air. When air is pressurised and cooled to about - 200 ^{0}C, it liquifies. This liquid is also a mixture of several components which vaporize at their boiling points. Likewise, nitrogen boils off at - 196 ^{0}C whereas oxygen and carbon dioxide boil at - 183 ^{0}C and - 78.5 ^{0}C respectively.

• Steam distillation

We know that certain parts of plants contain volatile components. Cinnamon, clove, cymbopogon, nutmeg and cardamom are few such examples. It is difficult to increase the temperature uniformly up to the boiling point of these compounds. Moreover, at the temperatures close to the boiling point, there is a possibility of destruction of these compounds by decomposition or getting converted into other compounds. Therefore, heat is supplied to the mixture by steam.

When water soluble compounds are mixed with water, the boiling point of such mixtures are above the boiling point of water. On the other hand, when the compounds that do not mix well with water are together with water, the boiling point of the mixture drops below the boiling point of water.

Most of the essential oils are immiscible with water and their boiling points are greater than that of water. They occur in living cells, mixed with water. Extraction of essential oils can be demonstrated in the laboratory by using an apparatus such as the one given below.

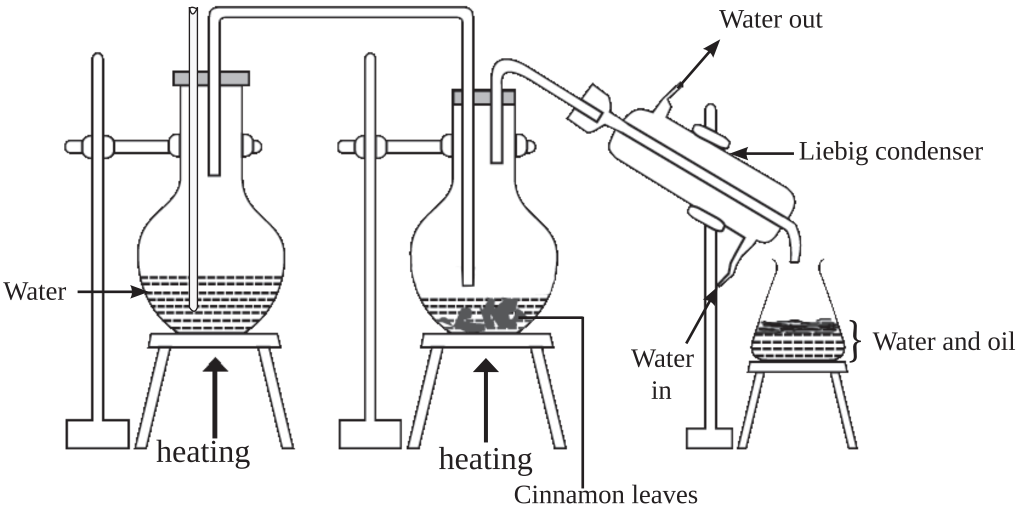


Figure 3.3.6 - Steam distillation

When heat is supplied to these mixtures by steam, both water and the essential oil get liberated as a mixture of vapors at a temperature below the boiling point of water (100 ^{0}C). When the distillate (vapour) is cooled it separates into two layers because water and the essential oil are immiscible. Therefore, they can be easily separated as pure substances.

Extra knowledge

Essential oils have many uses.

- Used as flavours and condiments in food
- Used to produce perfumes
- Used as ingredients in toothpaste
- Used to produce pharmaceuticals

Assignment 3.3.4

Prepare a list of plants used to produce essential oils in Sri Lanka. Find out which parts of these plants contain more of those essential compounds.

3.3.8 Chromatography

Chromatography is used to separate and identify the components present in a mixture (solid or liquid) containing non-volatile components. There are many different types of chromatography. The method carried out using paper (cellulose) is known as **paper chromatography.**

Add a little amount of water to a petri dish and dip one end of a dry strip of a filter paper in it. It can be observed that a stream of water particles is soaked up the strip of paper from bottom to top. Even when water is replaced by compounds such as acetone, ether and ethyl alcohol, a flow of liquid which flows up from the bottom to top can be seen. The strip of paper is called the stationary phase while the solvent that is soaked into it is called the mobile phase. When a small portion of the mixture whose components need to be separated is placed on this paper, the components in the mixture dissolve in the solvent and move up with the solvent front. This upward movement depends on the forces of attraction of the components of the mixture, to the stationary phase. For example, if one component in the mixture is strongly attracted to the stationary phase (the paper), its rate of upward movement decreases. If there is another component in the mixture that is relatively less attracted to the mixture, it moves up faster through the stationary phase. Because of this difference in the speed of movement of the components in the mixture, they get separated from one another. Let us do the following activity to separate out the components in a chlorophyll mixture using paper chromatography.

Activity 3.3.4

Materials required :- Chromatography papers or filter papers or A_4 papers, spinach leaves, mortar and pestle, a thin piece of silk cloth, a boiling tube, a rubber stopper with a hook

Method :- Crush a few spinach leaves thoroughly using mortar and the pestle available in the laboratory. Collect the chlorophyll extract onto a watch glass by placing the crushed paste on a piece of thin silk cloth and squeezing it.

- Cut a strip of chromatography/filter/A_4 paper
- Take a little bit of the chlorophyll extract to a capillary tube and place it on the strip of the paper a little above the end of it as shown in the diagram. The solvent vaporizes leaving chlorophyll on the paper. Place another drop on same spot.

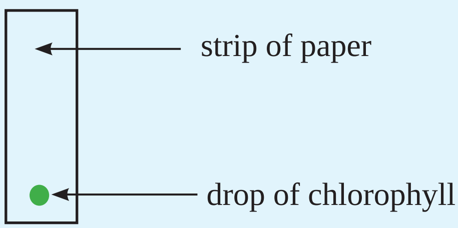


Figure 3.3.7

- Connect a piece of string to the end of the paper strip opposite to that with the chlorophyll drop.
- Add a solvent such as acetone/kerosene/petrol to the boiling tube and stopper it. Leave it to saturate. Connect a hook to the stopper as shown in the diagram and suspend the strip on the hook so that its other end dips in the solvent. Ensure that the sides of the strip do not touch the walls of the boiling tube.

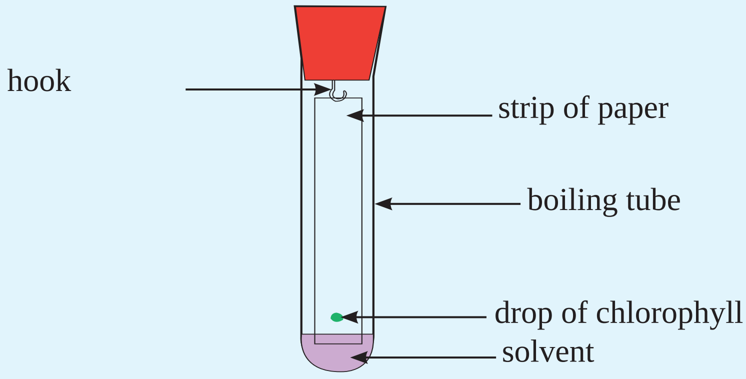


Figure 3.3.8

Leave it for some time and then take out the strip of paper and observe It can be seen that the components of different colours are separated. This leads to the conclusion that chlorophyll contains different components.

Therefore, chromatographic technique can be used to separate and identify several components when they are mixed together. Chromatography is used to find whether poisonous chemicals are mixed with water. It is also used to check whether harmful substances are associated with food items. Chromatographic technique is also useful in identifying active chemical compounds in plants.

Uses of separating techniques

Extraction of salt from sea water

In Sri Lanka salt is produced by the evaporation of sea water in salterns. The sea water collected in the salt pans are concentrated by evaporation during which salt crystallizes out finally. The separating techniques **evaporation** and **crystallization** are used in this method.

The location and structure of a saltern is very important in the production of salt. The geographical and environmental factors that should be taken into consideration when setting up a saltern are as follows.

1. A flat land situated closer to a coastal area to obtain sea water easily
2. Presence of a clayey soil with minimum percolation of water
3. Prevailence of dry and hot climate with bright sunlight and wind throughout the year
4. An area with minimum rainfall.

Regarding the structure of a saltern, three types of tanks can be identified.

- Large, shallow tanks
- Medium tanks
- Small tanks

Figure 3.3.9 A saltern

The main steps of the production of salt in a saltern are as follows.

Step 1 :- The sea water is either made to flood into the big, shallow tanks during high tide or is pumped into them and allowed to evaporate by sunlight. When the concentration is twice as double the initial concentration of sea water, calcium carbonate ($CaCO_3$) begins to crystallize and precipitate at the bottom of the first tank.

Step 2 :- This water is then transfered into the medium- sized tanks in which the water evaporates further. When the concentration of water is about four times the initial concentration, calcium sulphate ($CaSO_4$) crystallizes and settles down at the bottom.

Step 3 :- Following the precipitation of calcium sulphate, the solution is allowed to flow from the medium tanks into the smaller tanks in which water is evaporated further. When the concentration is nearly ten times the concentration of initial sea water, salt (NaCl) crystallizes and precipitates at the bottom.

While salt is precipitating, the concentration of the solution increases further. Even before the total precipitation of sodium chloride is complete, magnesium chloride ($MgCl_2$) and magnesium sulphate ($MgSO_4$) begin to precipitate. These give a bitter taste to salt. The solution left after the precipitation of salt is known as mother liquor or bittern.

Salt deposited in the third tank is taken out, heaped in prismatic piles at another place and stored for a period of six months. Pure sodium chloride is not hygroscopic. But if salt contains magnesium chloride and magnesium sulphate, it becomes bitter and hygroscopic as well as deliquescent when exposed to the atmosphere. But, as magnesium chloride and magnesium sulphate absorb moisture in the atmosphere and go into solution, with the elapse of about six months most of them get removed, salt is retained as a solid.

Extraction of essential oils

Volatile compounds obtained from plant materials are referred to as essential oils. The reason for the characteristic aroma of some plant materials are volatile compounds that they contain. Some main essential oils produced in our country are :

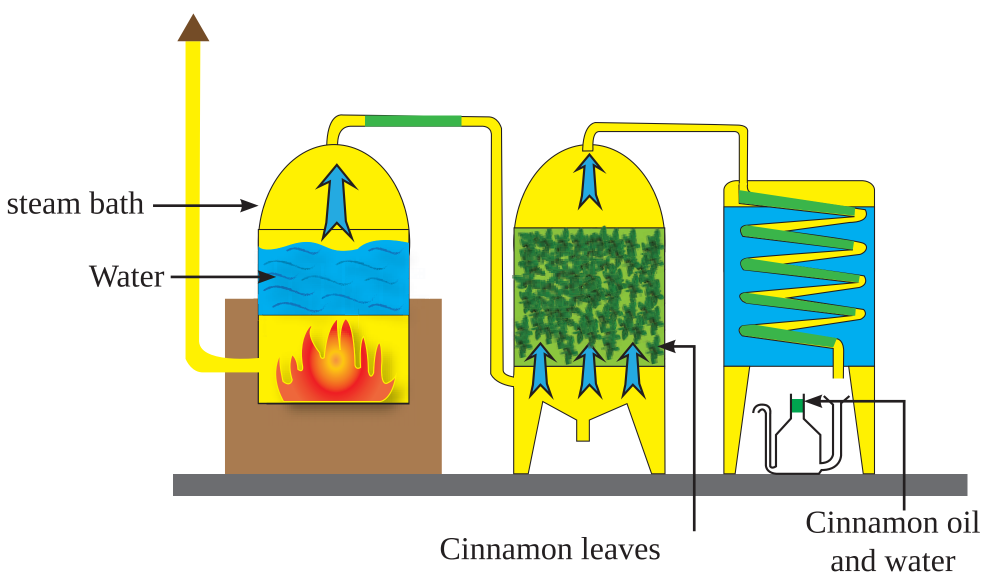
- Cinnamon leaf oil
- Cinnamon bark oil
- Citronella oil
- Pepper oil
- Cardamom oil
- Nutmeg oil
- Clove bud oil
- Eucalyptus oil

Cinnamon bark oil, pepper oil and cardamom oil promote the flavour and the scent of food. Cinnamon leaf oil, pepper oil and cardamom oil have medicinal properties as well and are frequently used in the production of medicinal ointments, toothpaste and the perfumes added to soap. Some plant parts in which essential oils are formed are given below.

Plant/Plants	Part (s) in which essential oils are formed
Veitiveria	Roots
Sandalwood	Steam
Cinnamon	Bark, Root, Leaf
Citronella	Leaf
Lemongrass	Leaf
Eucalyptus	Leaf
Clove	Floral parts
Rose, Jasmine	Flower
Lemon, Lime	Fruit
Nutmeg	Seed

The separating techniques such as steam distillation and solvent extraction are used to extract essential oils. From cinnamon leaves, oil is obtained by passing steam through them.

Extraction of essential oils by steam distillation



In this method steam generated by the steam bath is passed through the plant parts. Essential oils, being mixed with water vapour, vapourises at a temperature below 100 ^{0}C. Condensation of this mixture of vapours gives essential oil and water. As they are immiscible, they can be obtained separately.

Assignment 3.3.5

Inquire into the traditional method of cinnamon oil extraction in Sri Lanka and prepare a report.

Obtaining essential oils by solvent extraction

Solvent extraction is another method of extracting essential oils. Organic solvents such as ether, chloroform and toluene are used in this method. When plant parts are shaken with the solvent, essential oil dissolves in the solvent. The essential oil is separated by letting the solvent to vaporize.

Volatile oils in some plant parts can also be obtained by compressing them under a suitable pressure.

Summary

- Matter can be divided into two parts, pure substances and mixtures.
- In natural environment, pure substances are very rare and what is more abundant are mixtures.
- The substances formed by mixing two or more substances without any chemical changes are called mixtures. The physical and chemical properties of the components are retained even in the mixture. The components of a mixture can be separated by physical methods.
- A mixture is a homogeneous mixture when its components are uniformly distributed. If not, it is a heterogeneous mixture.
- A homogeneous mixture is also referred to as a solution. Characteristics such as concentration, colour, density and transparency of any minute part of a solution are identical. In heterogeneous mixtures these are different.
- In a solution the component present in a greater proportion is called the solvent and the component that is less in proportion is known as the solute.

- Dissolving of a solute in a solvent depends on temperature, polar characteristics related to the molecular properties of the solute and solvent as well as organic or inorganic nature.
- The solubility of a gas in water depends on the pressure of that gas over water and temperature.
- Different notations are used to indicate the composition of a mixture. Mass fraction (m/m), volume fraction (V/V), mole fraction, mass-volume ratio (m/V) and mole-volume ration (n/V) are some of them.
- Among the different notations used, mole-volume ratio (n/V) is also known as the concentration. It has the units of mol dm^{-3} (moles per cubic decimetre)
- Solutes of known composition need to be prepared for various tasks in day to day life. For this, various apparati are used in the laboratory.
- The components of mixtures are separated in everyday life as well as in industry. Various methods are used for it.
- During sifting, flatting and winnowing, components are separated by using the difference in density of the components. Sieving and filtration are carried out making use of the difference in size of the component particles.
- Components can be separated by vaporization due to the difference in their boiling points.
- The concentration of a solution is used in crystallization and recrystallization where the concentration is made to exceed the saturated concentration.
- Some substances have a higher solubility in one solvent and lower solubility in another.
- In solvent extraction, a solute dissolved in smaller quantity in one solvent is drawn into another solvent in which it is more soluble. For this, the two solvents must be immiscible.
- When separating components by distillation, the mixture is heated. The components, that vaporize at their boiling points get removed from the mixture and are collected at a different place by cooling.
- Depending on the differences of the techniques used and the properties of components, distillation can be divided into three modes-simple distillation, fractional distillation and steam distillation.
- In paper chromatography, a stream of a volatile solvent is passed through a drop of a mixture placed on a special paper. In this, components are separated from one another because of the difference of speed with which they travel through the paper which in turn is caused by the differences in the strength of attraction of the components to the paper (cellulose).

Exercises

01. Explain the meaning of the following terms.

    a. Mixture b. Homogeneous mixture

    c. Solvent d. Solute

    f. Solution g. Solubility

02. Write two properties of a homogeneous mixture or a solution

03. Explain how a solvent can be polar or non-polar

04. Explain the following observations scientifically.

    a. Jak latex (koholle) cannot be washed away with water.

    b. Styrofoam (regifoam) can be dissolved in petrol.

    c. The moment the cap of a bottle of soda water is removed, gas bubbles evolve.

05. Stones mixed with rice are removed by sifting. This is a mechanical method. Which physical property of the components rice and stones is helpful in this separation?

06. Write a similarity and a difference between vaporization and distillation used to separate components in mixtures.

07. Calculate the concentration of the solutions given in the following table.

Solute	Molar mass ($g\ mol^{-1}$)	Mass dissolved (g)	Amount of moles/ mol	Final volume	Concentration of the of the solution ($mol\ dm^{-3}$)
NaOH	40	10	$\frac{10}{40} = 0.25$	$200\ cm^3$	$\frac{0.25}{200} \times 1000 = 1.25$
$CaCl_2$	11	27.75	$\frac{27.75}{111} =$ 0.25	$500\ cm^3$	
Na_2CO_3	106	53	$\frac{53}{106} = 0.5$	$2\ dm^3$	
HCl	36.5	36.5	$\frac{36.5}{36.5} = 1.0$	$0.5\ dm^3$	

08. What is the mass of magnesium chloride ($MgCl_2$) required to prepare 500 cm^3 of a 0.5 mol dm^{-3} magnesium chloride solution.
(Mg= 24, Cl = 35.5)

09. Select mixture/ mixtures that the components can be separated by crystallization
a) Mixture of salt water b) Mixture of ethanol and water
c) Mixture of acetic acid and water d) Mixture of copper sulphate and water

10. Several salts are precipitated in the tanks during the production of salt. Arrange the precipitated salts $CaCO_3$, $CaSO_4$, NaCl and $MgCl_2$ according to the descending order of their solubility.

11. What is/are the compound/ compounds precipitated in manufacturing salt that dissolve in the atmospheric water vapour out of the following? (compounds with deliquescent quality)
$CaCO_3$, $CaSO_4$, NaCl, $MgCl_2$

12. You are given a saturated solution of salt. What could you do to dissolve some more salt in that solution?

13. Iodine is not soluble in water. Name two solvents that more iodine be dissolved?

14. Name two instances that solvent extraction is used.

15. What are the qualities of existing and the second solvents when the mixture is separated from an existing solvent into a another solvent?

16. What physical qualities of the components are used when they are separated by using distillation?

17. State one similarity and one difference between Simple and Fractional distillation

18. When setting the Liebig condenser for distillation, it is fixed with a slant and the vapour is inserted through the top end of the condenser. The water is inserted from the bottom. What is the importance of.
I. Inserting vapour from the top
II. Inserting water from the bottom

19. Name some essential oils produced by vapour distillation in Sri Lanka.

20. What is the technique you can use to find out the constituent colours of a coloured toffee in the market ?

Glossary

Mixtures	-	මිශ්‍රණ	-	கலவைகள்
Homogeneous	-	සමජාතීය	-	ஏகவினமான
Heterogeneous	-	විෂමජාතීය	-	பல்லினமான
Components	-	සංඝටක	-	பதார்த்தங்கள்
Solution	-	ද්‍රාවණය	-	கரைசல்
Solvent	-	ද්‍රාවකය	-	கரைப்பான்
Solute	-	ද්‍රාව්‍ය	-	கரையம்
Solubility	-	ද්‍රාව්‍යතාව	-	கரைதிறன்
Organic Solvents	-	කාබනික ද්‍රාවක	-	சேதன கரைப்பான்
Inorganic Solvents	-	අකාබනික ද්‍රාවක	-	அசேதன கரைப்பான்
Concentration	-	සාන්ද්‍රණය	-	செறிவு
Distillate	-	ආසුතය	-	ஆவி
Crystallization	-	ස්ඵටිකීකරණය	-	பளிங்காக்கல்
Recrystallization	-	පුනස්ඵටිකීකරණය	-	மீளப்பளிங்காக்கல்
Precipitation	-	අවක්ෂේපවීම	-	வீழ்படிவு
Solvent Extraction	-	ද්‍රාවක නිස්සාරණය	-	கரைப்பான் பிரித்தெடுப்பு
Distillation	-	සරල ආසවනය	-	காய்ச்சி வடிப்பு
Fractional Distillation	-	භාගික ආසවනය	-	பகுதிபடக் காய்ச்சி வடிப்பு
Steam Distillation	-	හුමාල ආසවනය	-	கொதி நீராவிக் காய்ச்சி வடிப்பு
Chromatographic	-	වර්ණලේඛ ශිල්පය	-	நிறப்பகுப்பியல் முறை

Physics

04

Waves and their applications

You have seen the ripples formed when you drop a pebble onto a still water surface. The disturbance caused by the pebble spreads over the water surface in the form of circles centered around the point where the pebble hit the water surface as shown in Figure 4.1.

Figure 4.1 – Formation of ripples on a water surface.

If you hold a rope horizontally as shown in Figure 4.2, and then shake the rope up and down, you will observe ripples forming in the rope. Here too the disturbance caused by the hand travels along the rope.

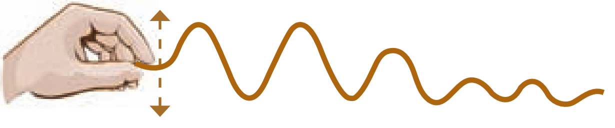


Figure 4.2 – Formation of ripples on a horizontal string

Such a disturbance propagating through a medium or space is known as a **wave**.

If you place an object like a plastic ball on the water surface and then disturb the water surface, how would the plastic ball move?

You will observe that the plastic ball moves up and down perpendicular to the water surface. In order for the ball to move up and down, energy must be transmitted to the ball. Here, energy was transmitted to the ball through the water waves.

An important property of waves is that they carry energy from one point to another. This energy transmission takes place in a manner that does not transmit the substance of the medium between the points concerned.

As an example, when a water wave travels on a water surface, although the water particles at each point move up and down, the water particles do not travel along with the water wave.

- **Wave Motion**

In the two examples given above, the waves propagate through a certain medium. The medium in the case of water waves is water. The medium in the case of waves propagating along the rope is the material of the rope. The motion of the particles in each medium transmits energy in the form of waves through the medium even though the particles themselves do not travel along with the wave. Apart from the two media mentioned above, waves propagate through many other media.

We hear various sounds through sound waves propagating through air. Sound propagates not only through air but also through liquids and solids.

In addition to waves that travel through various media, there are waves traveling without a material medium. Light is an example for a wave that travels without a medium. Although there are regions between the sun and the earth without any material medium, the earth receives light and heat from the sun. Light and heat from the sun arrive at the earth as electromagnetic waves and a material medium is not required for the propagation of electromagnetic waves.

Radio waves too are a form of electromagnetic waves. Radio programs transmitted by a radio transmission station reach the radio set in your home through air. However, air is not required for radio transmissions.

4.1 Mechanical Waves

Wave motion can be studied using a slinky. A slinky is a coil formed with a steel wire. Figure 4.3 shows a slinky.

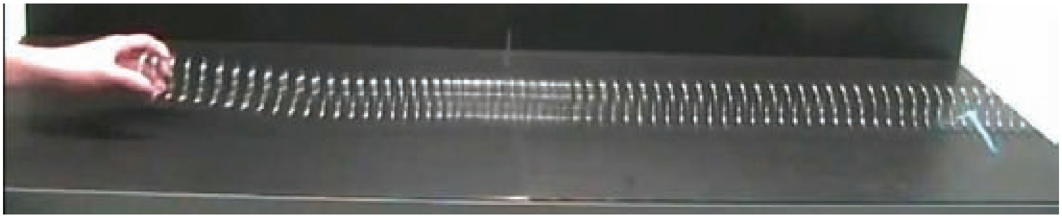


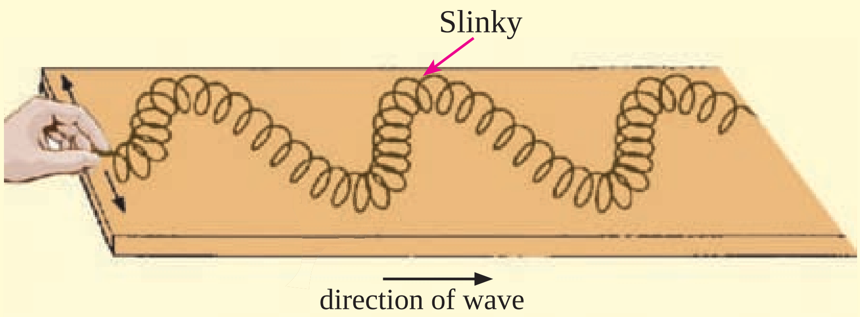
Figure 4.3 - Figure of a slinky

Let us do activity 4.1. to investigate wave motion.

Activity 4.1

Apparatus: A slinky

- Place a slinky on a table as shown in Figure 4.4
- Hold one end of the slinky and shake it to left and right on the plane of the table.



4.4 - Demonstration of the formation of waves using a slinky

You will see a wave propagating through the slinky as shown in the figure.

The wave propagating along this slinky is an example for a wave that needs a medium for propagation. Waves that need a material medium for propagation are known as **mechanical waves.** Waves formed on water surfaces, sound waves that travel in air, and waves formed on a guitar string when the string is plucked are some examples for mechanical waves.

For the propagation of mechanical waves, the participation of the particles in the medium is essential. Based on the direction of motion of the particles of the medium and the direction of propagation of the wave, mechanical waves can be divided into two categories.

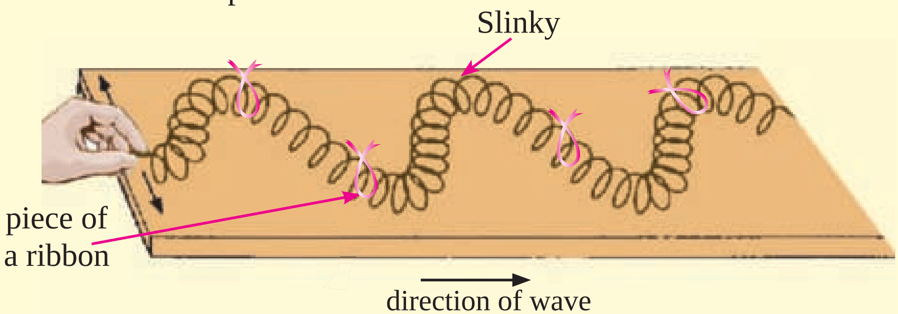
1. Transverse waves
2. Longitudinal waves

4.1.1 Transverse Waves

Activity 4.2

Apparatus: A slinky, a few pieces of ribbon.

- Tie pieces of ribbon at several places on the slinky.
- Place the slinky on the table as in activity 4.1 and shake it to left and right on the plane of the table.
- Observe how each piece of ribbon moves.



4.5 - Demonstration of the formation of transverse waves using a slinky

In this case, the wave propagates from the end held by the hand towards the fixed end. You will observe that the wave is travelling in a direction perpendicular to the direction of the ribbons are moving. Such **waves that propagate in a direction perpendicular to the direction the particles of the medium move are called transverse waves.** Therefore, this wave is a transverse wave.

The water waves generated by disturbing a still water surface by dropping an object such as a pebble, water particles of the medium move up and down within a certain range while the wave travels in a direction perpendicular to that.

We mentioned before that when we disturb a water surface after placing a floating object such as a plastic or rubber ball on the surface, the floating object moves up and down. From the up and down motion of the floating object we can understand that the force exerted on the object by the water particles is vertical. That means the water particles move up and down while the waves spread in a direction perpendicular to this. Therefore, the waves that travel on the water surface are transverse waves.

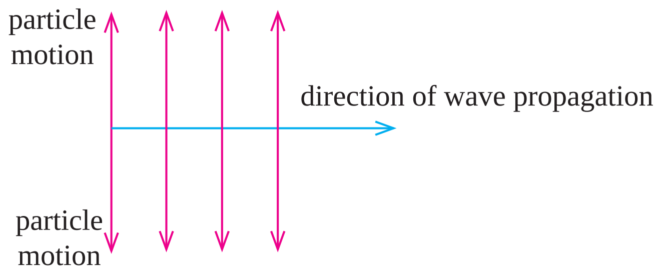


Figure 4.6 Direction of motion of the particles of the medium

As shown in Figure 4.6, in a transverse wave, the particles of the medium move in a direction perpendicular to the direction of the wave. Figure 4.7 shows how the cross section of a water wave appears at a given instance. The arrow heads indicate the direction that the water particles are moving at that instance.

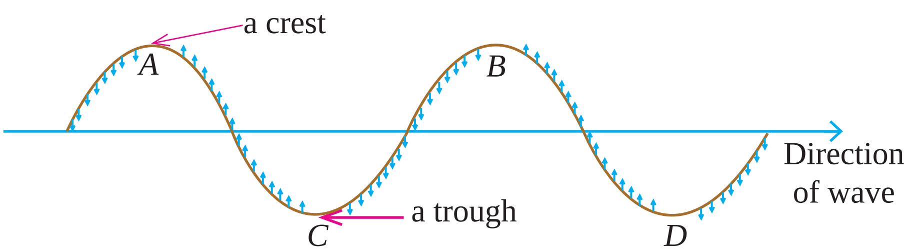


Figure 4.7 – Cross section of a water wave

The particles at points *A* and *B* have traveled the maximum distance in the upward direction. Such points in a wave are known as **crests**. The particles at *C* and *D* have traveled the maximum distance in the downward direction. Such points of a wave are known as **troughs**.

As shown in Figure 4.8, the waves formed by shaking one end of a string up and down whose other end is tied to a post also belong to the category of transverse waves.

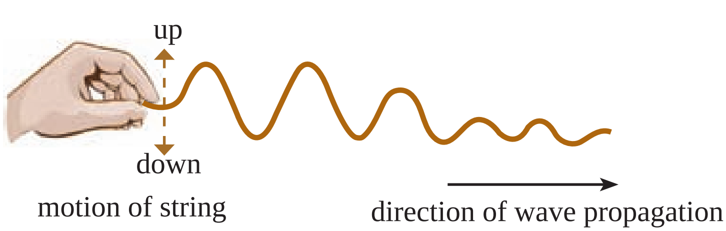


Figure 4.8 - Formation of transverse waves in a string

4.1.2 Longitudinal Waves

Activity 4.3

Apparatus: A slinky, a piece of ribbon

Place the slinky on a table and fix one end. Tie a ribbon on one coil and move the free end of the slinky forward and backward as shown in Figure 4.9. When the free end is pushed forward, the coils near that end are bunched up. This is called a compression. When the free end is pulled back, the coils will stretched-out. This is called a rarefaction.

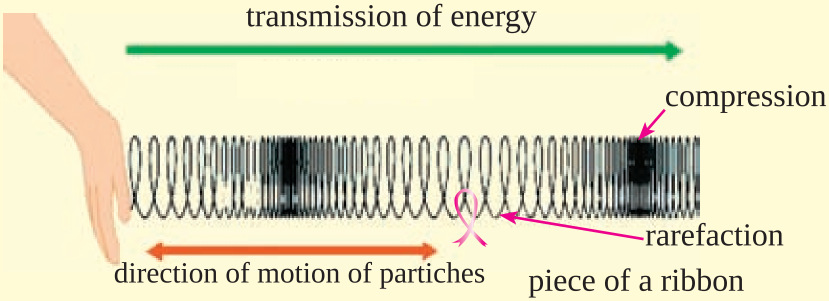


Figure 4.9. Demonstration of the formation of longitudinal waves using a slinky

Compressions are formed when the slinky is pushed forward while rarefactions are formed when the free end is moved backward. As a result of this, a wave propagates along the slinky. By observing the motion of the ribbon you can see in which direction the parts of the spring move.

If the particles of the medium oscillate parallel to the direction of wave propagation, such waves are known as longitudinal waves. You will observe that the waves formed in the slinky in this activity are longitudinal waves.

Sound a tuning fork and touch one of its two arms with your finger tip. You will sense a small vibration in your finger tip. The reason for this is the alternative contacts and removal of contact of the tuning fork arm with your finger. The back and forth motions in the arms of the tuning fork are known as **vibrations**. We can hear sounds through the waves generated by such vibrations. Such waves that cause the sensation of hearing are known as **sound waves**. Sound waves generated in air are another example for longitudinal waves.

Transverse Waves	Longitudinal Waves
Particles move perpendicular to the direction of wave propagation.	Particles move parallel to the direction of wave propagation.
Propagate along the surfaces of solids and liquids or along strings, wires etc. Eg : Water waves	Propagate through solids, liquids and gases. Eg : Sound waves

4.1.3 Physical quantities associated with wave motion

Waves are disturbances that spread from one point to another. Therefore waves have variations that depend on both time and distance. In the waves that we observe in nature, quite often these variations show complex forms. However, in this lesson we will only consider waves of a very simple form known as **sinusoidal waves**.

The graph in Figure 4.10 shows how the displacement from the central position of a particle taking part in the wave motion varies with time.

Extra Knowledge

For example, at time t_0 the displacement of that particle is zero. With time, the displacement of this particle increases and at time t_1 it takes a maximum positive value. After that the displacement starts to decrease, becomes zero at time t_2 and then increases in the negative direction. At time t_3 it takes a maximum negative value and then becomes zero again at t_4 . The motion of the particle from time t_0 to t_4 is called one oscillation. In addition to the word oscillation, the word vibration is also used to describe such motions. If this motion is slow, it is called an oscillation and if it is fast, it is called a vibration.

The graph in Figure 4.11 shows how the displacement from the central position of each particle along the travel path of the wave varies with the distance from the source to each of the particles.

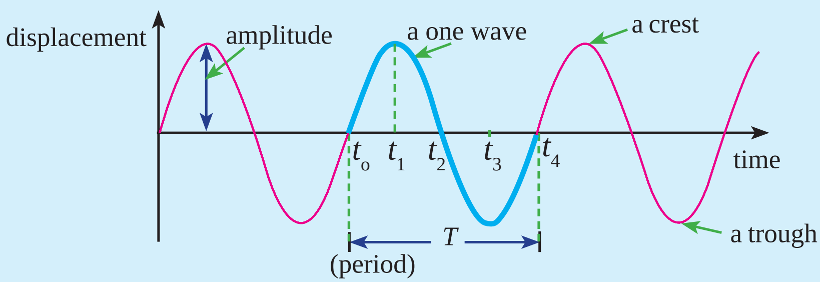


Figure 4.10 – Variation of displacement of a single particle, with time

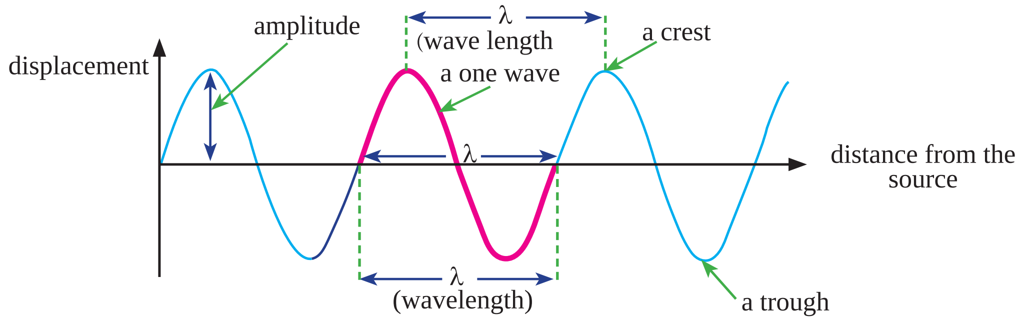


Figure 4.11 – Variation of displacement of particles with the distance from the source, at a given moment

The shape of a transverse wave that we see in a single moment, like the wave traveling along a string shown in figure 4.8, is the same as the shape of the graph of Figure 4.11 showing the variation of the displacement of the particles with the distance from the source at a given instance. Because the particle displacement in longitudinal waves takes place in the same direction as the direction of wave propagation, we can not see the form of the graph in a similar manner as for transverse waves. However, if we somehow measure and plot the variation of the displacement with distance we will obtain a graph like that shown in Figure 4.11.

With the help of these graphs we can define some physical quantities associated with waves.

• Amplitude of a Wave

The maximum displacement shown by the particles taking part in the wave motion is known as the **amplitude** of the wave.

• Wave length of a Wave

The distance between one particle and the closest next particle taking part in the wave motion having the same state of motion is known as the **wavelength** (λ) of the wave. As an example, a particle on a trough or a crest of the wave shown in Figure 4.10 has reached its maximum displacement. A particle on the next trough or crest also has the same state of motion. Therefore, the distance between these two particles, that is the distance between two consecutive troughs or crests is equal to the wavelength.

• Period

The time taken by a particle for a complete oscillation is known as the **period (*T*)**. The time taken by a wave to travel a distance equal to the wavelength is also equal to the period. (figure 4.10)

- **Frequency**

The number of oscillations carried out by a particle in a unit time is known as the **frequency (*f*)**. Frequency is equal to the reciprocal of the period. The unit used to measure the frequency is known as **Hertz (Hz)** and one Hertz is defined as one oscillation per second.

$$\boxed{f = \frac{1}{T}}$$

- **Speed**

A wave travels a distance equal to the wavelength (λ) in a time interval equal to the period (T). Therefore its speed is given by $v = \lambda / T$ or $v = f\lambda$.

Extra Knowledge

Speed (v)	=	frequency (f)	$\times$	wavelength (λ)
$m\ s^{-1}$		Hz		m

4.2 Electromagnetic Waves

The figure shown here is a photograph of a radio telescope. The antenna of this telescope receives radio waves emitted at by very distant stars. Understanding the information contained in those waves helps us to understand more about the history of the universe. Radio waves are electromagnetic waves. Now let us consider more about electromagnetic waves.

The participation of material particles of a medium is not required for the propagation of electromagnetic waves. While electromagnetic waves consist of electric fields and magnetic fields that oscillate in directions perpendicular to each other, the wave propagates in a direction perpendicular to the directions of both the electric and magnetic fields as shown in Figure 4.12. Therefore electromagnetic waves belong to the class of transverse waves.

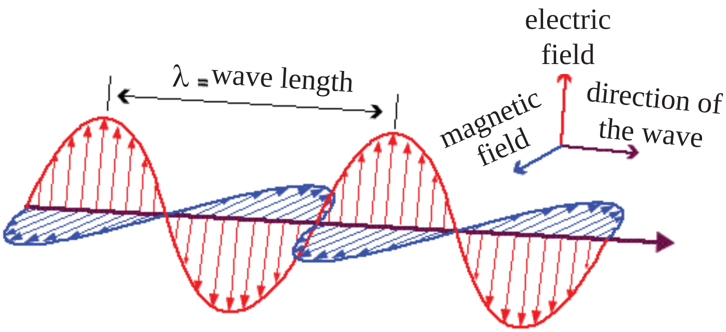


Figure 4.12 - Electric and magnetic fields of an electromagnetic wave

All electromagnetic waves propagate with the speed of 2.988×10^8 ms^{-1} in a vacuum (It is often taken as 3×10^8 m s^{-1} in calculations). Speed of electromagnetic waves in material media is less than the speed in a vacuum and accordingly the wavelength also changes. For electromagnetic waves, the speed c is given by the relationship $c = f\lambda$ where f is the frequency and λ is the wavelength.

Characteristics of electromagnetic waves

- Electromagnetic waves are not affected by external electric or magnetic fields.
- They do not require a material medium for propagation.
- They travel at a speed of 3×10^8 m s^{-1} in a vacuum.

4.2.1 Electromagnetic Spectrum

The characteristics of electromagnetic waves vary significantly in various frequency ranges. Various frequency ranges identified by such characteristics are known as the electromagnetic spectrum. Main types of electromagnetic waves belonging to the electromagnetic spectrum are listed in the table below.

Type of Waves	Frequency range (Hz)
Gamma rays	$> 3 \times 10^{19}$
X rays	3×10^{17} - 3×10^{19}
Ultra-violet rays	7.69×10^{14} - 3×10^{17}
Visible rays	4.28×10^{14} - 7.69×10^{14}
Infra-red rays	3×10^{12} - 4.28×10^{14}
Micro waves	3×10^{9} - 3×10^{12}
Radio waves	$< 3 \times 10^{9}$

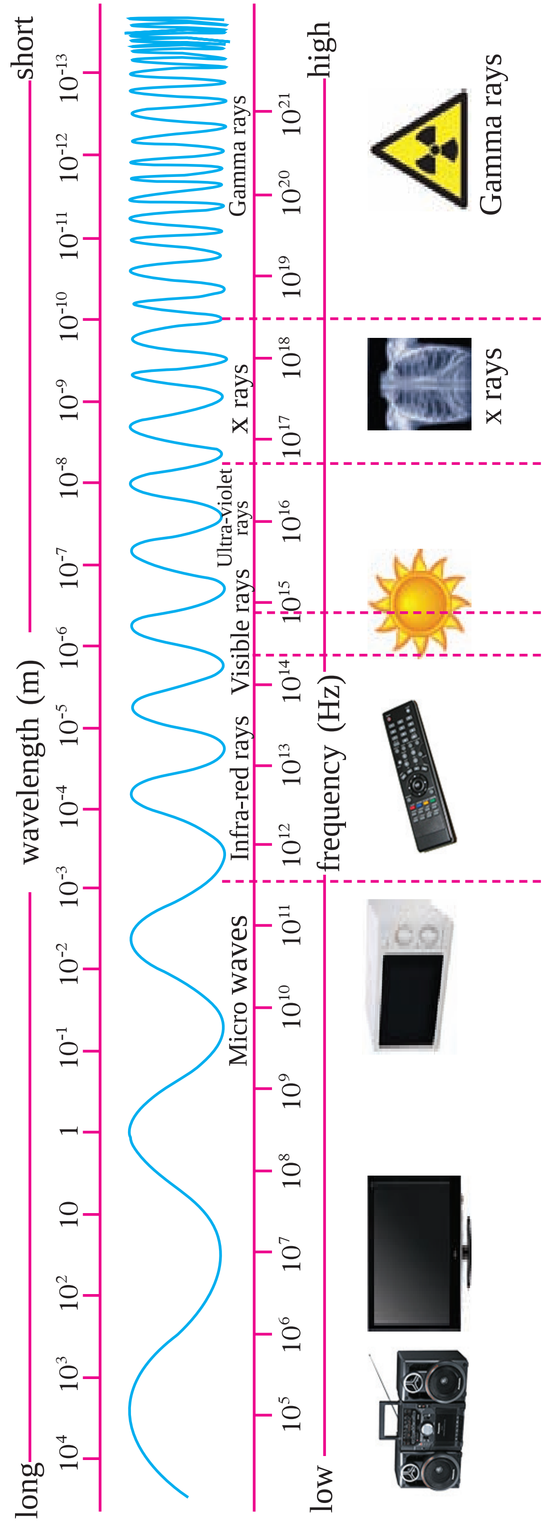


Figure 4.13 – Electromagnetic spectrum

4.2.2. Applications of Electromagnetic Waves

• Visible Light

Visible light is the range of the electromagnetic spectrum to which our eyes are sensitive. It is only a narrow band in the electromagnetic spectrum. The frequencies of the visible light range from 4.28×10^{14} Hz to 7.69×10^{14} Hz corresponding to a wavelength range from 690 nm to 400 nm. The region containing the lowest wavelength (highest frequency) in this range appears violet to the human eye. When the wavelength increases (frequency decreases) gradually the color changes to indigo, blue up to red. These are the colors that we identify as the seven colors in the rainbow.

• Gamma rays

Gamma rays are a type of waves emitted by radioactive elements. Frequencies of gamma rays are extremely high and so are the energies possessed by them. Gamma rays have the ability even to penetrate thick sheets of steel as well as concrete slabs. Since gamma rays can destroy living cells they are used to destroy cancer cells.

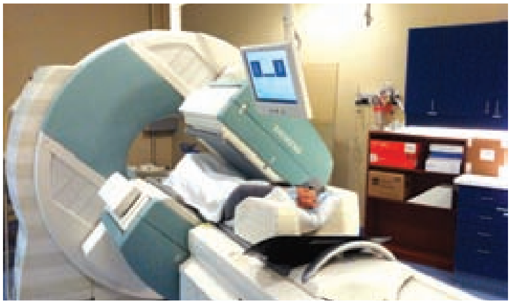


Figure 4.14 – An instance where gamma rays are used

Gamma rays are also used to sterilize utensils used for food and surgical instruments.

• X-rays

X–rays are mostly used to take photographs of internal organs of the human body. Although X-rays travel quite easily through the soft tissues in the body, their intensity decreases rapidly when traveling through the bones of the body. When the X–ray generator is turned on, X–rays propagate through the relevant part of the body of the person being photographed and thus forms an image of that part of the body. Excessive exposure to X–rays can cause cancers.

X–rays are generated by bombarding high speed electrons on metal targets. Then part of the kinetic energy of the electrons gets converted to X–rays.

X–rays are also used to examine the baggage of airline passengers and cargo inside containers transported by ships, without opening them.

Figure 4.15 – X-ray imaging

Extra knowledge

X - rays are generated by allowing a fast beam of electrons to hit a metal target. A part of the kinetic energy of the electrons is then converted to X-rays.

• Ultraviolet radiation

Ultraviolet means 'above violet'. **Violet** is the color having the highest frequency out of the seven colors that form the visible spectrum. Ultraviolet radiation is a type of rays having a frequency range above that of violet and is invisible to the human eye. Although ultraviolet rays are invisible to the human eye, it has been found that insects like bees can detect ultraviolet rays. Sunlight contains a small amount of ultraviolet rays. Ultraviolet rays are also produced in electric discharge and from mercury vapor lamps.

Since these rays produce vitamin D in the human body, it is useful to be exposed to sunlight to some extent. However, over exposure to ultraviolet rays can cause cataract in the eye and cancers in the skin.

Ultraviolet radiation is used in hospitals to kill germs. Certain chemical substances show a glitter when exposed to ultraviolet radiation. This phenomenon is used in places like banks to check hidden symbols in currency notes. Such chemicals are also added to some washing powders. Clothes washed with such washing powders show a brightness when exposed to sunlight.

Figure 4.16 – An instance of generating ultraviolet rays

• Infrared Radiation

The range of frequencies below the red color that is not visible to us is known as **infrared radiation**. Because infrared radiation is emitted by heated bodies and we feel a warm sensation when infrared radiation falls on our skin, infrared radiation is often referred to as **heat rays**.

Infrared radiation is emitted by our bodies too. Heat photographs are taken with the aid of heat rays emitted by body organs. Certain diseases can be identified using such photographs.

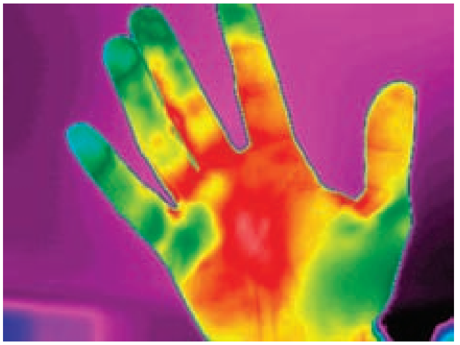


Figure 4.17 - A heat photograph

Infrared radiation is used to send signals to television sets from remote controls. Most of the cameras in mobile telephones and computers are sensitive to infrared radiation. Infrared radiation is also used for physiotherapy treatments.

(a) A remote control

(b) An infrared camera

Figure 4.18 – Instances of using infrared waves

- ## Microwaves

The range of frequencies below the infrared frequencies is known as **microwaves**. Microwaves are used in RADAR systems, mobile telephones and microwave ovens.

Extra knowledge

Water and fat in food have the ability to absorb microwaves and convert that energy into vibrational kinetic energy (heat). This is the principle behind the operation of microwave ovens.

An instrument known as the magnetron is used to produce microwaves in microwave ovens and radar systems that need high power microwaves for their operation.

Microwaves too can cause adverse effects on our bodies. Generally microwave ovens are produced so that microwaves do not leak out from the oven. However as a precautionary measure it is better not to stay too close to microwave ovens when they are in operation. It is suspected that the excessive use of mobile telephones can cause harm to the brain.

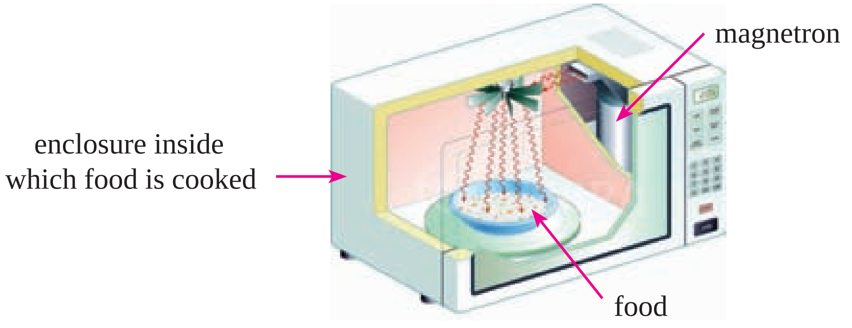


Figure 4.19 – A microwave oven

• Radio Waves

Radio waves have the longest wavelengths and the shortest frequencies of the electromagnetic spectrum. They are used in long distance communications. Radio waves are produced using radio frequency oscillators. When radio waves fall on an aerial, it received the information carried by the wave.

Antennas are used for transmitting and receiving radio waves. Information is transmitted through radio waves by modifying the amplitude or the frequency of a radio wave according to the information to be transmitted.

Figure 4.20 – Transmission and receiving of radio waves

4.3 Sound

If you listen carefully to various sounds in your surroundings early in the morning, you would hear many sounds. It is by listening that you would be able to enjoy when the musical instruments are played. The type of energy that produces the sensation of hearing in our ears is known as acoustic energy.

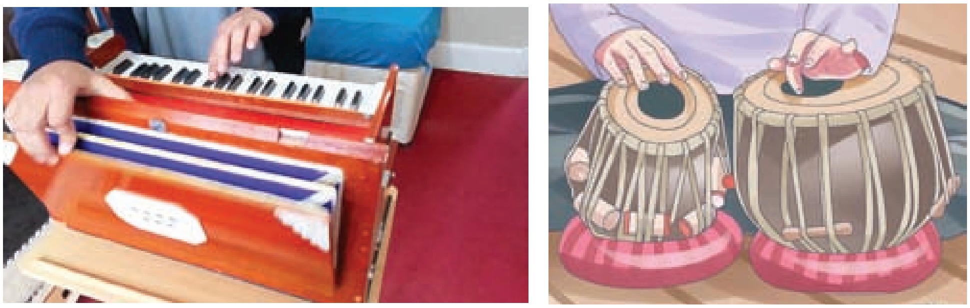


Figure 4.21 – Playing oriental music

Figure 4.22 – Hyla tree frog

The type of frogs known as Hyla tree frog shown in figure 4.22 is found in South America. They are capable of amplifying their voice using an inflatable balloon like body organ under their throat. Only the male frog can generate this sound and their voice travels about ten time further than the sounds from other varieties of frogs. This sound is generated when the air dispelled by the balloon passes through two stretched membranes at the bottom of the mouths of the frogs giving rise to vibrations in the membranes.

Many animals have the capability of producing sounds by vibrating an organ in their body. A buzzing bee makes sound waves by moving its wings to and fro repeatedly very fast.

Crickets make their sound by rubbing their wings together.

Not only animal sounds but, all sounds are generated by vibrations of objects. We hear those sounds when the resulting sound waves propagate through air and reach our ears. Our vocal cords vibrate, causing the air around them to vibrate and producing sound waves in the air.

We will investigate the propagation of acoustic or sound waves, their characteristics and applications in this lesson.

4.3.1 Propagation of Sound Waves

In order to understand how sound waves propagate in air, let us consider a sound wave generated by a loud-speaker. Sound is generated by a loud-speaker when a membrane inside the loud-speaker is set into vibrations.

Figure 4.23 (a) shows the distribution of air molecules can be seen in front of the loud speaker. when the membrane is not vibrating.

Suppose that the membrane starts vibrating by first moving to the right. When the membrane moves to the right the air molecules in front of it are pushed forward giving rise to a layer of compressed air as shown in Figure 4.23 (b).This compressed region moves forward with the kinetic energy transferred to the air molecules by the membrane.

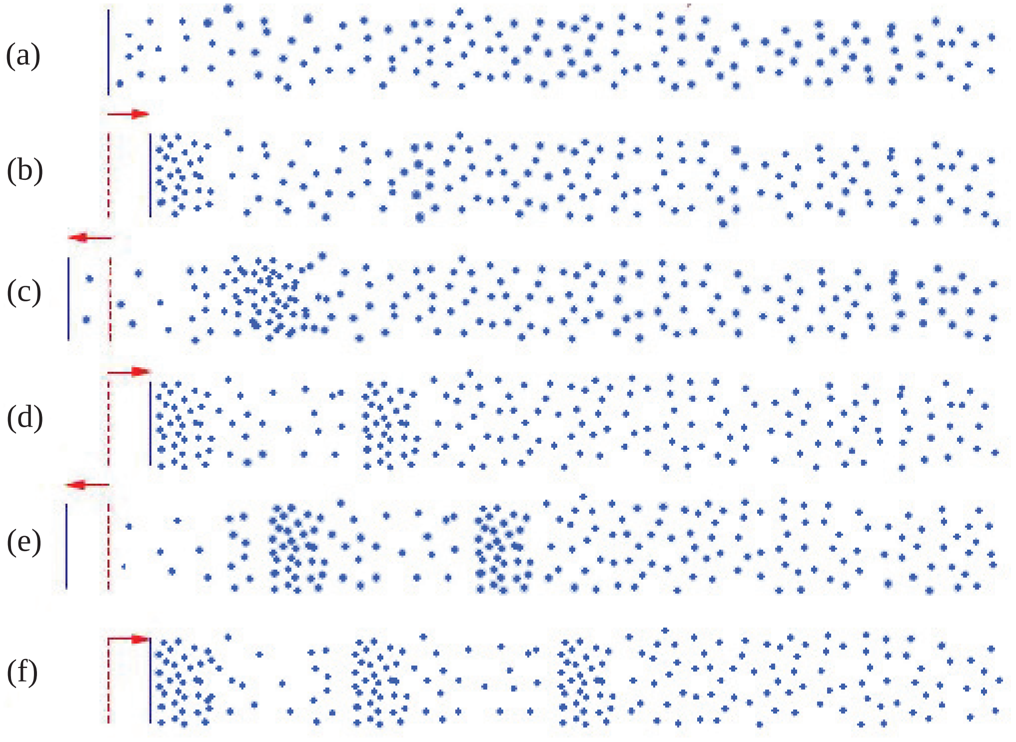


Figure 4.23 – Propagation of sound as longitudinal waves

When the membrane moves to the left, a region of rarefactions is formed in the air layer adjacent to it as shown in Figure 4.23 (c). When the membrane moves to the right again, another layer of compressed air is formed which too moves to the right as shown in Figure 4.23 (d).

The membrane alternatively generates compressions and rarefactions in the air, all of which travel forward with the same speed. These compressions and rarefactions are known as sound waves. Note that each air molecule only vibrates back and forth around a mean position although the compressions and rarefactions move forward. Sound is longitudinal waves.

Sound propagates not only through air. Sound propagates through water even faster than through air. That is why there are methods of communication through water. Whales use sound waves to communicate among themselves.

Sound waves travel through water with a speed of about 1400 ms^{-1}. Sound propagation is even better through solids.

Figure 4.24 - Communication by whales using sound waves

Speed of sound waves through steel is about 5000 $m\ s^{-1}$. That is why the sound of a train approaching from a distance can be clearly heard through the steel rails.

Snakes can detect vibrations in the ground through its lower jaw bone. These vibrations are then transmitted to it through the bones. This way, the snake hears the foot-steps of its prey.

Figure 4.25 – Perception of sound by a snake through vibrations in the ground

Unlike light, a medium is essential for sound to spread. That means sound waves are mechanical waves. Therefore they do not travel through a vacuum. The following simple experiment illustrates that sound does not travel through a vacuum.

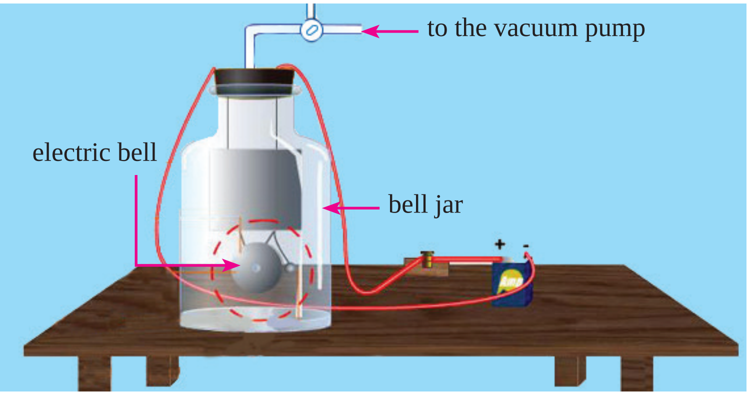


Figure 4.26 – Illustrating that sound waves needs a medium for propagation

As shown in Figure 4.26, an electric bell is fixed inside a bell jar and its connecting wires are connected to a power supply and a switch outside the jar. The bell jar is connected to a vacuum pump. The vacuum pump can pump out the air from inside the jar. After starting the ringing of the electric bell, the vacuum pump is turned on. You will observe that the sound of the electric bell becomes fainter gradually and finally no sound is heard.

The instance that the sound is no longer heard is when the interior of the bell jar becomes a vacuum. When the vacuum pump is turned on, the air inside the bell jar is gradually removed and ultimately it becomes a vacuum. This experiment illustrates that sound cannot propagate through a vacuum and that a medium is essential for sound waves to travel through.

4.3.2 Speed of Sound

We hear the sound of thunder a short while after we see the light from a lightning strike taking place at a distant point. We see the light emitted in a lightning strike when that light travels towards us and enters our eyes. Light travels at the speed of 300 000 km s^{-1} (3×10^8 m s^{-1}). Therefore it takes only a very short time for us to see the light from a lightning strike. There is a short time gap between seeing the light and hearing the thunder because it takes a longer time for the sound wave to travel to our ear than it takes for the light to travel to our eyes from the point where the lightning strike took place.


Figure 4.27 – Light is seen a short while before the sound of thunder from a lightning strike

The characteristics of waves discussed in section 4.1.3 are common to sound waves too.

- ♦ The speed of sound at 0 °C in dry air is about 330 m s^{-1}. As the temperature increases, the speed of sound waves in air also increases. The speed of sound at 30 °C in dry air is about 350 m s^{-1}.
- ♦ The speed of sound in water is about 1400 m s^{-1}. This means that the speed of sound in water is about four times as the speed of sound in air. The speed of sound through a steel rod is about 5000 m s^{-1}.

4.3.3 Characteristics of Sound

The sound of some musical instruments is of a high pitch. The sound emitted by the violin in soft. The sound of thunder caused by a lightning strike is loud. The above statements describe some characteristics of sound waves.

Properties of sound that makes it possible to distinguish different sounds are called sound characteristics. That means, sound characteristics are the sensations produced in the ear that helps us to distinguish different sounds.

There are three main characteristics of sound.

1. Pitch
2. Loudness
3. Quality of sound

• Pitch

Activity 4.4

- Clamp a hacksaw blade between two blocks of wood so that its free end juts out about 10 cm.
- Vibrate the blade and listen to the sound it generates.
- Increase the length of the blade jutting out in steps of 5 cm at time listening to the sound emitted. You will notice that the sharpness of the sound decreases gradually.
- Pitch is the quality of sound depends on by the physical quantity frequency.

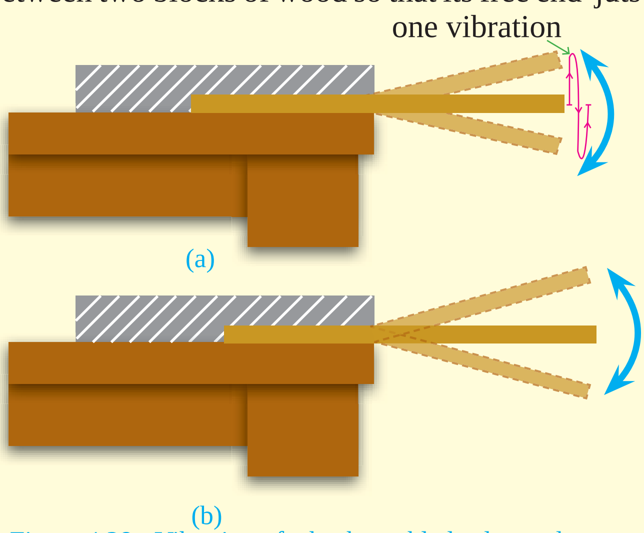


Figure 4.28 - Vibration of a hacksaw blade clamped at one end

When the length of the free end of the blade is increased, the frequency of vibrations of the blade decreases gradually. Accordingly, the pitch of the sound generated by the blade also decreases. The pitch of the sound generated by an object increases when its frequency of vibration increases while the pitch of the sound decreases when its frequency of vibration decreases. Out of the musical notes, the frequency of the note middle C is 256 Hz. The frequency of the note higher C is 512 Hz. Therefore the pitch of the higher C is twice as high as the pitch of the middle C.

The oscillation of the air molecules around their central position when a sound wave travels in air can be observed using a cathode ray oscilloscope in the form of a graph plotted against time. When a microphone is connected to an oscilloscope as shown in Figure 4.29, and strike a tuning fork on a rubber stopper to generate a sound, the oscilloscope screen displays the graph corresponding to the sound wave generated. The shape of the graph displayed on the cathode ray oscilloscope is known as the wave form of the sound wave that gave rise to the graph.

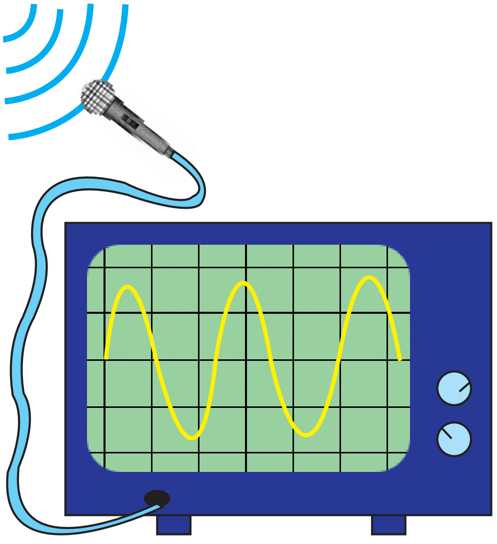


Figure 4.29 - The shape of a sound wave displayed on the screen of a cathode ray oscilloscope

Figure 4.30 shows the shapes of two sound waves generate from two tuning forks one with a high pitch or high frequency and the other with a lower pitch or lower frequency.

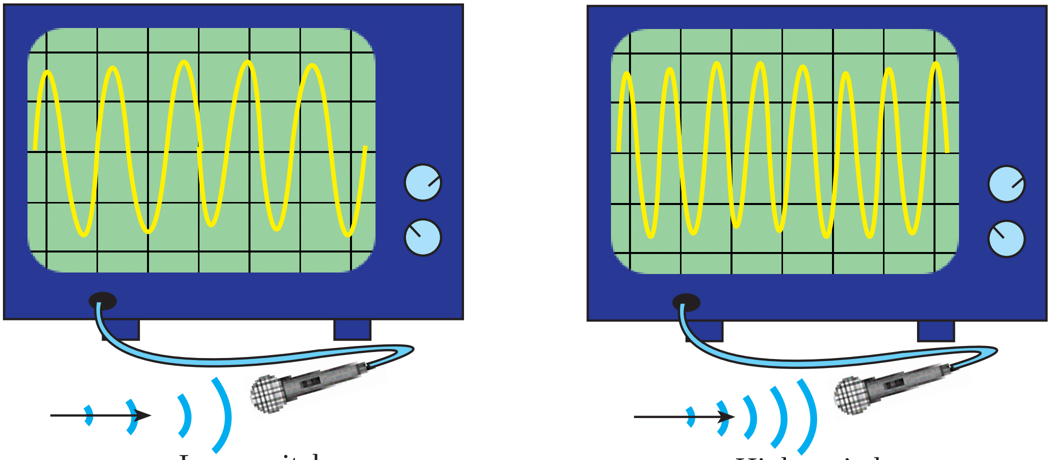
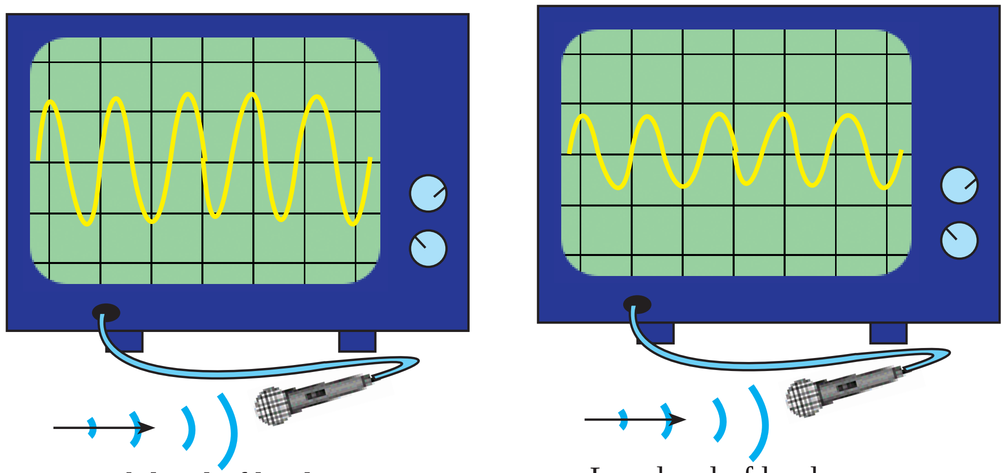


Figure 4.30 - The shapes of two sound waves of different pitch displayed on the screen of a cathode ray oscilloscope

- **Loudness**

Tap softly on a drum. Next tap the drum with a larger force. Study the difference in the sound level. The difference is the difference in the loudness. The loudness of a sound wave depends on the amount of energy it carries to the ear. Therefore, loudness is the sensation in the ear that depends on the amount of energy carried by the sound wave.

The sound generated by plucking a stretched string is louder when it is plucked harder so as to displace it further from its stationary position. In order to displace the string further, a larger amount of work has to be done on the string. Then the string imparts a larger amount of energy to the sound wave it generates. When the string is displaced further from the stationary position, the amplitude of the vibration becomes larger and the amplitude of the sound wave generated by the string also becomes large. This means that there is a relationship between the loudness of a sound and the amplitude of the corresponding sound wave. Therefore, loudness can also be considered as the characteristic of sound that varies according to the amplitude of a sound wave. Loudness increases with increasing amplitude. Loudness decreases with when the amplitude decreases. Figure 4.31 shows wave forms of two sound waves viewed using a cathode ray oscilloscope, one with a higher level of loudness and the other with a lower level of loudness.



High level of loudness
(High amplitude)

Low level of loudness
(Low amplitude)

Figure 4.31 – Waveforms of two notes with high and low levels of loudness

• Quality of Sound

When a piano and a violin are played, even if both of them play a note with the same pitch and same loudness it is still possible to identify the sound of each instrument. Such an identification is possible due to a characteristic known as the quality of sound.

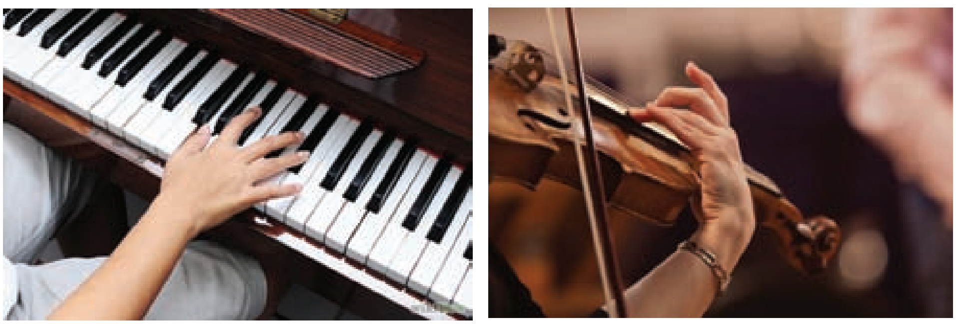


Figure 4.32 - Playing a piano and a violin

Figure 4.33 shows the wave forms of a musical note played with the same pitch using a tuning fork, a violin and a piano when viewed through a cathode ray oscilloscope.

Even though all three waves have the same frequency, it is clear from figure 4.33

that their wave forms are different. The reason for being able to identify each instrument playing the note is the difference in their wave forms. Therefore, the quality of sound is the sensation in the ear which varies according to the wave form of a given sound.

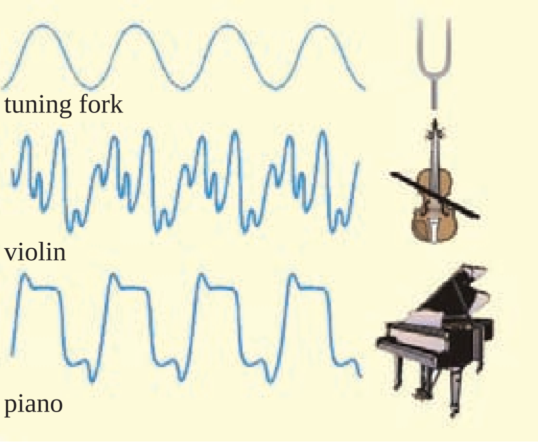


Figure 4.33 – Wave forms of the same note with the same pitch played by different instruments

4.3.4 Hearing Range

We cannot hear all the sounds in our surroundings. Certain sounds that we cannot hear are heard by other animals. While animals such as elephants that have large ears can hear sounds of very low frequencies, the ears of animals like bats and whales are sensitive to very high frequencies. It is generally considered that the frequency range that can be heard by the human ear is from 20 Hz to 20,000 Hz. This frequency range is known as hearing range of human ear. However, the high frequency limit audible to the human ear decreases gradually with age.

Sounds of frequency below 20 Hz are called **infra-sound** and sounds of frequency above 20000 Hz are called **ultrasound**. Therefore, ultrasound waves are sound waves with frequencies above the hearing range of humans.

While Rabbits, dolphins and bats can hear frequencies above 20,000 Hz (ultrasound), elephants can hear frequencies below 20 Hz (infra-sound). Dogs can hear sounds up to about 40,000 Hz.

Bats make use of ultrasound waves to fly avoiding obstacles at night. Bats emit ultrasound waves while flying. These waves are reflected back if they encounter an obstacle. When the bat receives the reflected waves it can judge the position of the obstacles and fly avoiding them.

Figure 4.34 - A bat flying by avoiding obstacles with the use of ultrasound

Dolphins use ultrasound waves to find small fish for prey and to avoid sharks that attack the dolphins. Dolphins also use ultrasound waves to communicate among themselves.

Figure 4.35 - Dolphins use ultrasound waves to communicate among themselves

• Uses of Ultrasound

Ultrasound waves are used for various important tasks. Ultrasound waves are employed to find the depth of the sea. For this, an instrument called SONAR (Sound Navigation and Ranging) fixed to the bottom of a ship emits an ultrasound pulse. The depth of the sea can be found by measuring the time taken by these ultrasound pulses to return to the original position after being reflected from the bottom of the sea.

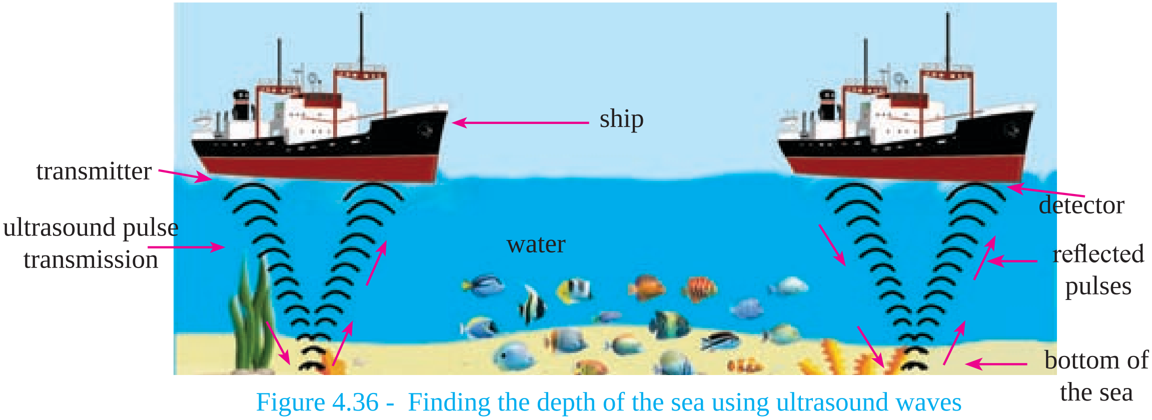


Figure 4.36 - Finding the depth of the sea using ultrasound waves

In addition to measuring the depth of the sea, ultrasound waves are used to investigate schools of fish and to detect remnants of capsized ships.

Example 1

If the time taken by ultrasound waves transmitted by a ship to reach the detector again after reflection from the sea bottom is 4 s, find the distance between the ship and the bottom of the sea. (Assume that the speed of sound in sea water is 1500 m s^{-1}).

Distance the sound travel in 4 s $= 1500 \times 4$

Distance between the ship and the bottom of the sea $= \dfrac{1500 \times 4}{2} = 3000$ m

Ultrasound waves are used in ultrasound spectacles worn by blind people.

Ultrasound waves are used to examine internal organs of the human body. This is known as ultrasound scanning. Ultrasound waves emitted by an ultrasound transmitter placed on the chest of a patient are reflected back from the internal walls of his heart. Using the reflected wave, information regarding the volume of blood sent out during a single compression of the heart, the size of the heart and pulse rate of the heart can be revealed.

Furthermore, ultrasound waves can be used to observe the womb and the condition of the fetus inside the womb of a pregnant mother.

Figure 4.37 – Examine the condition of the fetus inside the womb using ultrasound waves

Figure 4.38 – An image of a fetus inside a womb taken using ultrasound waves

An instance where ultrasound waves are used to treat diseases is the blasting of bladder stones or calcium oxalate crystals by sending ultrasound waves to places where bladder stones are found (This technology is known as lithotripsy).

Figure 4.39 – Instrument used for blasting bladder stones by using ultrasound waves

High frequency ultrasound waves do not enter air after traveling through a solid medium. If an ultrasound wave traveling in a solid comes across an air gap, the wave does not penetrate through the air gap. This principle is used to detect dangerous air gaps and fractures in solid components of air planes.

Extra knowledge

Ultrasound waves are also used to solder metals. This is done by placing the metals to be soldered in contact with one another and impinging the required place with ultrasound waves. The vibrations that result cause the two metals to rub each other generating a large amount of heat. This heat melts the metals at the contact position soldering the two metals.

4.3.5 Musical Instruments

Constantly we hear various sounds. Some sounds are pleasing to the ear while some are not. The wave forms observed on a cathode ray oscilloscope screen by playing a tuning fork, a violin and a piano were shown in Figure 4.33. Although the wave forms were different, they all show repeating patterns.

The wave form of the noise emitted by machinery in a factory, if observed through a cathode ray oscilloscope, would look like the wave shown in Figure 4.40.

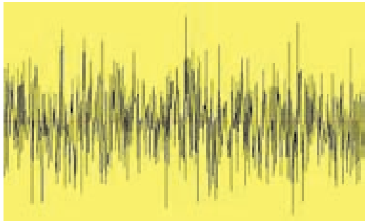


Figure 4.40 – Wave form of a noise

This wave does not show a repeating pattern. This wave is composed of irregular vibrations. The instruments that generate sound that is pleasing to the ear are known as musical instruments. Musical instruments are built in such a way that they generate periodic vibrations.

There are three main types of musical instruments.

- String instruments
- Percussion instruments
- Wind instruments

• String instruments

Musical instruments that generate sound by the vibrations of a stretched string such as the violin, Sitar, Guitar, Banjo and Cello are known as **string instruments**.

Figure 4.41 – Some string instruments

The frequency of sound generated by stringed instruments depends on the following factors.

1. Length of the vibrating string
2. Tension of the string or the extent that the string is stretched
3. Mass of a unit length of the string

• Percussion instruments

Instruments generating sound by the vibration of stretched membrane, metal rods or metal plates are known as **percussion instruments**. Such instruments have to be tapped in order to generate sound.

4.42 – Some percussion instruments

Thabla, rabana, dawula, udekki and thammattama are examples for percussion instrumens. The xylophone is an instrument with vibrating metal rods. Thalampata and the bell are instruments with vibrating metal plates.

In percussion instruments, the pitch depends on the area and the tension of the membrane or the metal plate.

• Wind Instruments

Instruments like flute, saxophone, trumpet and clarinet generate sound by the vibrations of air columns and are known as **wind instruments**.

Figure 4.43 – Some wind instruments

The pitch of wind instruments depend on the length of the air column.

Exercise 4.1

(1) Group of children studied the spreading water waves generated in a pond with still water by throwing stones onto the water surface.

(i) What happens to the energy of the waves?

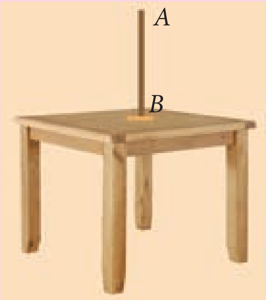
(ii) Suppose you place a paper boat on the water surface and disturb the water surface a small distance away from the boat. What change would you observe in the paper boat? What does it illustrate?

(iii) Sketch a diagram to show what happens to the water surface.

(iv) Which type of mechanical waves do water waves belong to?

(v) In what way do the above waves differ from the sound waves traveling in air?

(2) The end *B* of the metal blade *AB* shown below is clamped to a table



(i) It is made to vibrate by a force applied to the end A. Give a rough sketch to illustrate one vibration generated in the blade. (Use the letters C and D to show the maximum displacements.)

(ii) Describe what is meant by the amplitude using the points marked as *A*, *C* and *D*.

(iii) If 50 vibrations take place during 5 seconds, find the frequency of vibrations of the metal blade.

(iv) Vibrations of the metal blade gives rise to compressions and rarefactions in air.

To what physical quantity related to sound waves in air is the distance between two consecutive compressions equal to?

(v) (a) What is the sound characteristic that depends on the frequency?

(b) What is the sound characteristic that depends on the amplitude?

(c) The same musical note was played with several musical instruments, each one could be identified separately. What characteristic of sound does this depend on?

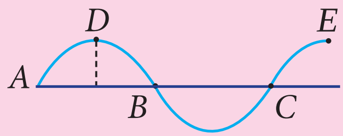
(3) Electromagnetic waves do not need a medium for propagation.

(i) Write down three characteristics of electromagnetic waves.

(ii) (a) What is the angle between the electric field and magnetic field generated together in an electromagnetic wave?

(b) What is the angle between these two fields and the direction of propagation of the electromagnetic wave?

(4) The figure below shows a segment of a string along which a transverse wave is propagating.



(a) What physical quantity of a wave is the distance between the points D and E equal to?

(b) The same distance above is shown by the distance between two other points in the figure. What are these two letters?

(5) There are many musical instruments in the music room of your school.

(i) Name

(a) Two string instruments

(b) Two percussion instruments

(c) Two wind instruments

that you expect to find in the music room.

(ii) (a) Write down two factors on which the frequency of the sound generated by a string instrument depends on.

(b) Write down two factors on which the frequency of the sound generated by a wind instrument depends on.

(c) Write down two factors on which the frequency of the sound generated by a percussion instruments depends on.

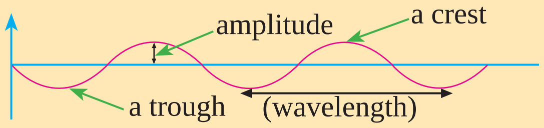
(6) Explain the following scientifically.

(i) When a ringing bell is held by hand, it stops ringing.

(ii) The pitch of a flute when played while the holes are opened one by one becomes different from the pitch when all holes are closed.

(iii) Although the lightning and thunder both happen at the same time, there is a delay between seeing the light and hearing the sound of thunder.

Summary

- A wave is a disturbance traveling in a medium or in space.
- Waves that need a material medium to travel are called mechanical waves.
- Waves that propagate in a direction perpendicular to the direction of particle motion are called transverse waves.
- Waves that propagate in the same direction as the particle motion are called longitudinal waves.
- 

- The time taken by one particle to complete a single oscillation is called the period of oscillation.
- The number of oscillations of a single particle in one second is called frequency.
- Electromagnetic waves do not need a material medium for propagation.
- Sound waves are a type of longitudinal waves.
- Sound waves need a medium for propagation.
- Pitch, loudness and quality of sound are three main characteristics of sound.
- The pitch of a sound depends on the frequency of the wave.
- The loudness depends on the amplitude of the wave.
- The quality of sound depends on the shape of the wave form.
- Sounds with regular periods are pleasing to the ear. Sounds without regular periods produce noise.
- String instruments produce sounds through vibrations of strings, percussion instruments make sounds by vibrations of membranes, rods or metal plates and wind instruments make sounds by vibrations of air columns.
- The frequency range that can be heard by an animal is known as hearing range of that animal.
- Sounds of frequency below 20 Hz are called **infra-sound** and sounds of frequency above 20 000 Hz are called **ultrasound**.

Glossary

Mechanical waves	යාන්ත්‍රික තරංග	பொறிமுறை அலைகள்
Transverse waves	තිර්යක් තරංග	குறுக்கலைகள்
Longitudinal waves	අන්වායාම තරංග	நெட்டாங்கு அலைகள்
Period	ආවර්ත කාලය	ஆவர்த்தன காலம்
Frequency	සංඛ්‍යාතය	மீடிறன்
Electromagnetic waves	විද්‍යුත් චුම්බක තරංග	மின்காந்த அலைகள்
Electromagnetic spectrum	විද්‍යුත් චුම්බක වර්ණාවලිය	மின்காந்தத் திருசியம்
Ultraviolet radiation	පාරජම්බුල කිරණ	கழியூதாக் கதிர்ப்பு
Infrared radiation	අධෝරක්ත	செங்கீழ்க் கதிர்ப்பு
Micro waves	ක්ෂුද්‍ර තරංග	நுணுக்கலைகள்
Sound waves	ධ්වනි තරංග	ஒலி அலைகள்
Hearing range	ශ්‍රව්‍යතා පරාසය	கேள்தகு வீச்சு
Infrasound	අධෝධ්වනි	கீழொலி
Ultrasound	අතිධ්වනි	கழியொலி
Pitch	තාරතාව	சுருதி
Quality of sound	ධ්වනි ගුණය	ஒலியின் பண்பு
Loudness	හඬේ සැර	உரப்பு
Amplitude	විස්තාරය	வீச்சம்

Physics
05

Geometrical Optics

5.1 Reflection of light

We cannot see anything in the dark. The reason for this is that light is required to give rise to visual sensation. We would be able to see an object only if light from the object reaches our eyes.

Objects that emit light such as a candle flame or a light bulb are known as **luminous objects**. We can see them because our eyes receive light from them. Objects that do not emit light are known as **non-luminous** objects. When light from the Sun or some artificial light source falls on such objects they reflect part of the light and when the reflected light reaches our eyes we see the objects.

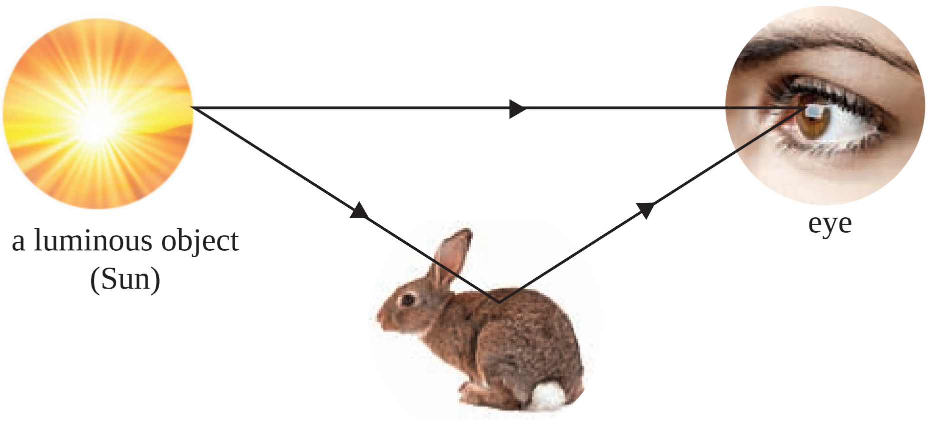


Figure 5.1 – Seeing luminous and non-luminous objects

Light passes through some objects. They are known as transparent objects (eg: glass, polythene). Objects through which light does not pass at all are known as opaque objects (eg: stones, bricks). Light passes through some materials with irregular changes of direction, making it impossible to see the objects on the other side clearly. Such materials are known as translucent materials (eg: tissue paper, oil paper).

A light ray is represented by a straight line with an arrow head marked on it. The arrow head is essential to indicate the direction of the light ray.

A light ray 

A bundle of light rays is known as a light beam. A bundle of parallel rays form a parallel light beam. A bundle of rays that meet at a certain point is known as a convergent light beam. A bundle of rays that travel away from a given point is known as a divergent beam.

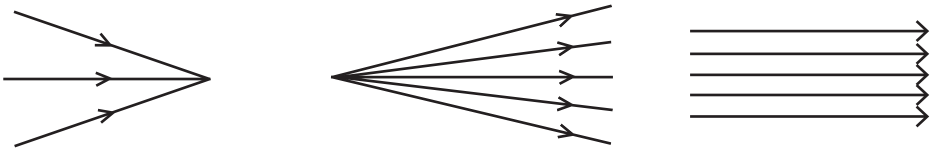


Figure 5.2 – Beams of light

Let us review what we have learned about the reflection of light before.

The dressing table mirrors familiar to you are plane mirrors. The change in the propagation direction of light rays incident on a plane mirror is known as reflection. Figure 5.3 shows how a light ray (*AB*) incident perpendicularly on a plane mirror is reflected. *BA* is the reflected ray.

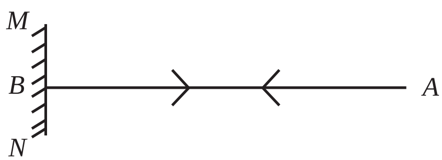


Figure 5.3 – The way a light ray incident on a plain mirror is reflected

- In figure 5.4, *MN* is a plane mirror. *AB* is a ray that is incident on point *B* of the reflecting surface of the mirror and it is known as the **incident ray**. This ray is reflected along *BC*.
- *BX* is an imaginary line drawn perpendicular to the mirror at the point of incidence. It is known as the **normal** to the reflecting surface at the point of incidence.
- The angle between the incident ray and the normal is known as the **angle of incidence** *(i)*. The angle between the reflected ray and the normal is known as the **angle of reflection** *(r)*.

MN - plane mirror
AB - incident ray
BC - reflected ray
BX - normal at the point incidence
$A\hat{B}X$ - angle of incidence (i)
$C\hat{B}X$ - angle of reflection (r)

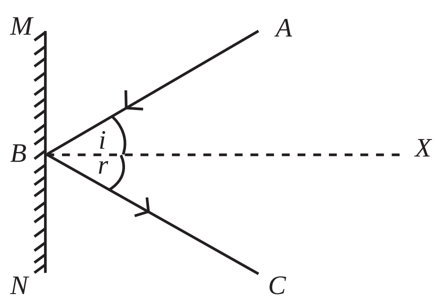


Figure 5.4 – Reflection of a light ray from a plane mirror

You have learnt two laws of reflection of light before.

First Law

The incident ray, the reflected ray and the normal at the point of incidence lie on the same plane.

Second Law

The angle of incidence is equal to the angle of reflection.
That is $i = r$

Now let us see how an image is formed when a point object is in front of a plane mirror.

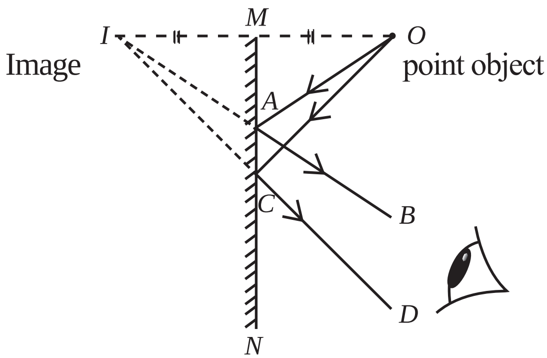


Figure 5.5 – The formation of an image of a point object by a plane mirror

In figure 5.5, a point object *O* is placed in front of a plane mirror *MN*. *OA* and *OC* are two rays propagating from the object towards the mirror. These two rays are reflected respectively along *AB* and *CD* and reach the eye of the observer.

Not just these two rays, but many such rays from *O* are reflected by the mirror and reach the observer's eye.

The observer sees these rays as coming from the point *I*. Therefore the observer sees as if the object is placed at *I*.

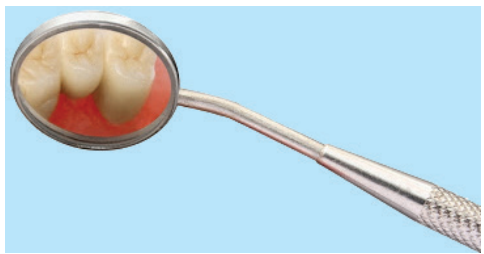
- No rays actually pass through this image. Because there are no light rays at the location of the image, this image cannot be projected on a screen.
- An image like this is known as a virtual image.
- All images formed by plane mirrors are virtual.
- Distance from the object to the mirror (object distance) is equal to the distance from the image to the mirror (image distance).
- Images formed by plane mirrors are identical to the objects, but they are lateral inverted. That means the right side of the object appears as its left side, and vice versa.

The term AMBULANCE written in the front face of ambulances is inverted (ƎƆИAJUBMA). However, when the ambulance is going behind another vehicle, the driver of the vehicle in front sees it through his rear view mirror as AMBULANCE.

5.2 Curved (Spherical) Mirrors

We know that the type of mirrors called convex mirrors are used in vehicles so that the driver can see the road behind him from both sides of the vehicle.

With these the driver can see a large area behind the vehicle, as a small image. In some shops, convex mirrors are used to observe a large part of the shop for security purposes.



Dentists use another type of curved mirrors called concave mirrors to view inside the mouth of patients. These mirrors show enlarged images of teeth.

Concave mirrors are used for shaving too. In both of these cases, the ability of concave mirrors to produce enlarged images is used.

Figure 5.6 shows an enlarged image from concave mirror and a diminished image from a convex mirror.

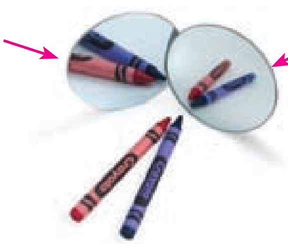


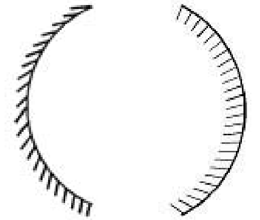
Figure 5.6 – Images formed by concave and convex mirrors

Now let us discuss more about curved mirrors.

Mirrors with curved reflecting surfaces are known as **curved mirrors**. If the curved surface is a part of a sphere, the mirror is known as a **spherical mirror**.

There are two main types of curved mirrors.

1. Concave mirrors
2. Convex mirrors



The reflecting surface of a concave mirror is curved inward. The reflecting surface of a convex mirror is curved outward.

Figure 5.7 shows that spherical mirrors are parts of hypothetical spheres.

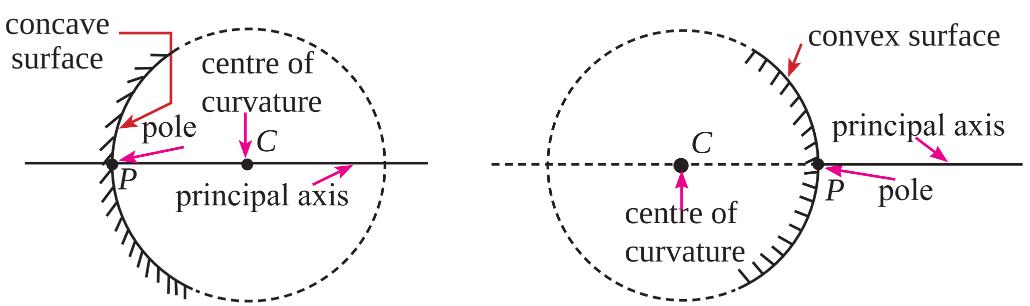


Figure 5.7 - Center of curvature, pole and principal axis of a spherical mirror

- The centre of each sphere (C) to which the mirror surface belongs is called the **centre of curvature** of the mirror.
- The centre point of the curved mirror (P) is called the **pole** of the mirror.
- The line joining the pole P and the centre of curvature C is called the **principal axis**.
- The principal axis is perpendicular to the mirror surface at P.

5.2.1 Focal point of a curved mirror

For light rays coming along the principal axis, the incident angle is zero and therefore the angle of reflection is also zero. Therefore light rays coming along the principal axis reflect back along the same path.

Rays coming parallel to the principle axis towards a concave mirror pass through a point on the principal axis after reflecting from the mirror. If a screen is placed on that point so as to allow the reflected rays to fall on it, a small bright spot would be visible. This point marked as F in Figure 5.8 is known as the **focus or the focal point** of the mirror.

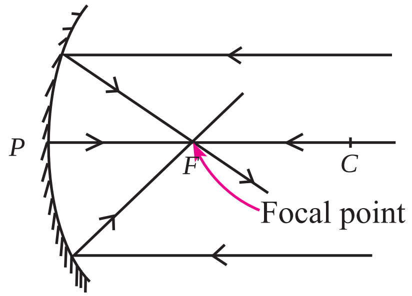


Figure 5.8 – Converging a parallel beam of light after reflection

Now let us see what happens in the case of convex mirrors. As shown in figure 5.9, rays coming parallel to the principal axis and incident on a convex mirror are reflected as a divergent beam. These divergent reflected rays appear to be coming from the focal point *F*.

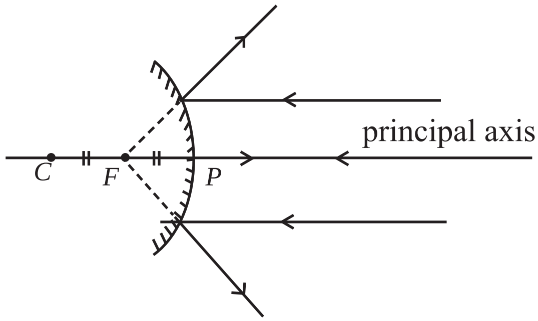


Figure 5.9 - Diverging a parallel beam of light upon reflection from a convex mirror

The focal point of a spherical mirror is situated at the mid-point on the line connecting the pole and the centre of curvature. The distance between the pole and the focal point is known as the focal length of the spherical mirror. The distance between the pole and the centre of curvature is known as the radius of curvature of the spherical mirror. The radius of curvature (r) is exactly twice the focal length (f).

5.2.2 Reflection from a concave mirror

(i) Rays coming along the principal axis of a concave mirror return along the principal axis after reflection.

In ray diagrams light rays are drawn as if they are reflected by the perpendicular line drawn to the principal axis at the pole *P*.

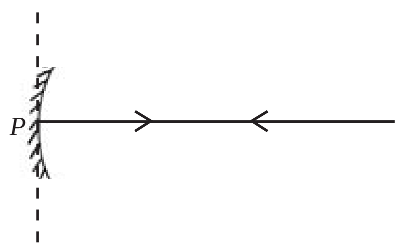


Figure 5.10 – Reflection of light coming along the principal axis of a concave mirror

(ii) Rays coming parallel to the principal axis pass through the focal point after being reflected by the concave mirror.

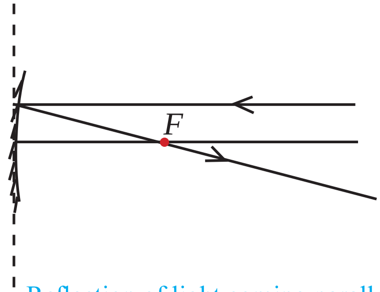


Figure 5.11 – Reflection of light coming parallel to the principal axis of a concave mirror

(iii) Rays coming towards a concave mirror through the focal point are reflected parallel to the principal axis.

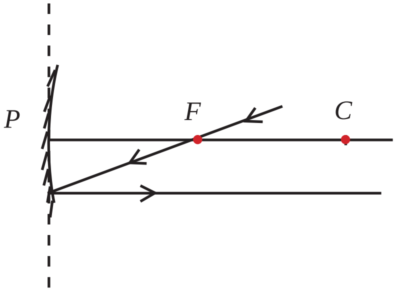


Figure 5.12 – Reflection of light coming through the focal point of a concave mirror

(iv) Rays coming towards a concave mirror through the center of curvature are reflected back through the center of curvature. The reason for this is that any line drawn to the surface of the mirror from the center of curvature is perpendicular to the surface of the mirror.

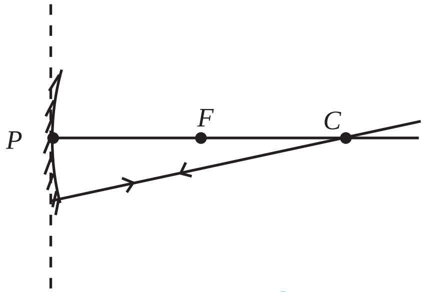


Figure 5.13 - Rays coming towards a concave mirror through the center of curvature

(v) Rays making a certain angle of incidence with the principal axis are reflected back with an equal angle of reflection. This means, in figure 5.14, $i = r$.

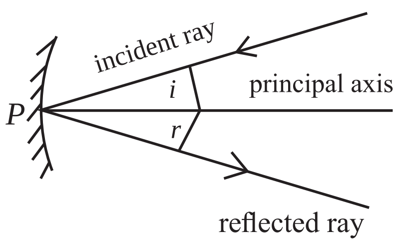


Figure 5.14 – Reflection of a ray coming to the mirror making some angle with the principal axis

Note

(1) Rays coming along the principal axis, return along the principal axis after reflection.
(2) A ray travelling parallel to the principal axis passes through the focal point after reflection.
(3) A ray that passes through the centre of curvature of the mirror is reflected back along its own path.

Images formed by concave mirrors

Observe your face through a plane mirror. The image seen in the mirror will be the same size as your face.

Observe your face through a concave mirror placed closer to the face than the focal length. You will observe a very large image of your face. In addition it will be an upright and virtual image.

Figure 5.15 – A concave mirror shows an enlarged image of your face

Let us do the activity 5.1 to find the focal length of the concave mirror.

Activity 5.1

Apparatus : concave mirror, white screen.

- Open the window of a room.
- Hold a concave mirror, turned towards the window as shown in figure 5.16.
- Hold a screen (or a white paper) in front of the concave mirror and adjust the distance between the concave mirror and the screen until a clear image of the scene outside the window is formed on the screen.
- Because this image is formed on the screen, it is a real image.
- Measure the distance between the mirror and the screen when you get a very clear, up side down image on the screen.

Because the light rays coming from a far away object can be considered as parallel, the distance from the mirror to the image can be considered to be approximately equal to the focal length of the mirror.

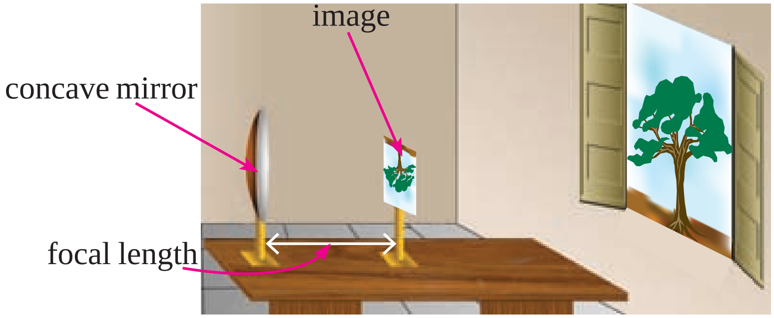


Figure 5.16 – Measuring the focal length of a concave mirror

Let us do the activity 5.2 to study the nature of the image formed by a concave mirror using a candle and screen.

Activity 5.2

Apparatus : concave mirror, white screen, candle.

- Fix a concave mirror on a stand and place it on a table.
- As in the activity 5.2 find the approximate focal length of the concave mirror.
- Keep a lighted candle on the table near the principal axis at a distance about five times the focal length from the mirror.
- Hold a screen in front of the concave mirror and move the screen till a sharp image of the flame is obtained.
- Now try to obtain the image on the screen while moving the candle towards the mirror and placing it at different distances from it.
- Is it possible to obtain an image on the screen when the candle is very close to the mirror?

The position of the image, the nature of the image and the size of the image formed by a concave mirror depend on the position of the object with respect to the mirror.

• Drawing ray diagrams for images formed by concave mirrors

The image of a point object placed in front of a mirror is formed at the point where two or more light rays coming from that point meet (or at the point where the extended light rays meet).

➢ To find the position of the image, it is necessary to consider rays coming from the top and bottom of the object separately.

➢ If the bottom of the object is situated on the principal axis, all the rays coming from the bottom travel along the principal axis. Therefore the image of the bottom of the object is formed on the principal axis.

➢ Therefore, the image of a vertical object which is located on the principal axis is formed on the principal axis.

Therefore, to draw the image of an object which is placed vertically on the principal axis it is sufficient to draw the rays which are coming from the top of the object. For this any two light rays mentioned under the note in pages 110,111 can be used.

The image of the top of the object is the point of intersection of these two rays.

A ray diagram can be used to find the nature of the image formed when an object is placed at different distances from the mirror.

1. Object between the mirror and the focal point

When the object is positioned between the mirror and the focal point, the image cannot be formed on a screen. This means that the image is not real. This image can be seen by viewing through the mirror. Such images are known as virtual images.

In order to find the location of the image in this instance, consider two rays coming from the top of the object. It would be convenient to choose one of these rays to be parallel to the principal axis and the other to pass through the center of curvature as shown in Figure 5.17. Drawing the ray parallel to the principal axis to return through the focal point after reflection and the ray coming through the center of curvature to return through the same path after reflection, the point of intersection of these two rays can be found by extending the two rays an shown by dotted line. This point is the position where the image of the top of the object is formed.

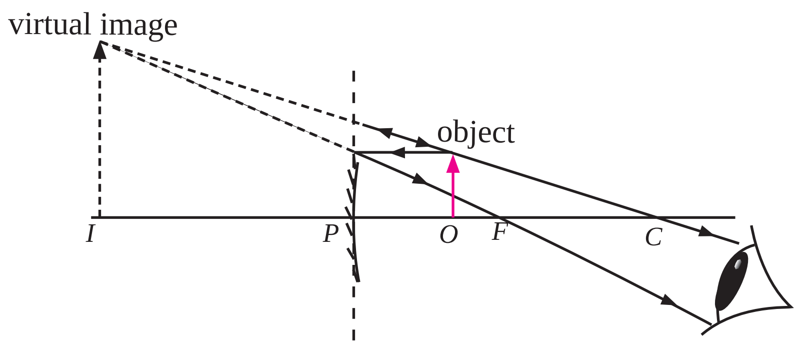


Figure 5.17-Formation of the image of an object placed between the mirror and the focal point

As shown in figure 5.17, for objects positioned between the focal point and the mirror (pole of the mirror), the images are upright, virtual and larger than the object.

2. Object on the focal point

The image of an object on the focal point must be formed at infinity. This can be shown by considering the paths of two rays, as shown in figure 5.18. If we assume that the two parallel rays meet at infinity, the image will be very large and inverted.

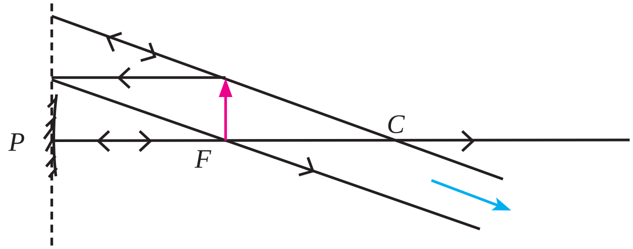


Figure 5.18 - Image of an object placed on the focal point

3. Object between the center of curvature and the focal point

For an object placed between the center of curvature and the focal point, it can be shown that the image is real, inverted, larger than the object and is formed beyond the centre of curvature, by considering a ray coming from the top of the object parallel to the principal axis and another ray passing through the center of curvature. The ray diagram for this case is shown in Figure 5.19.

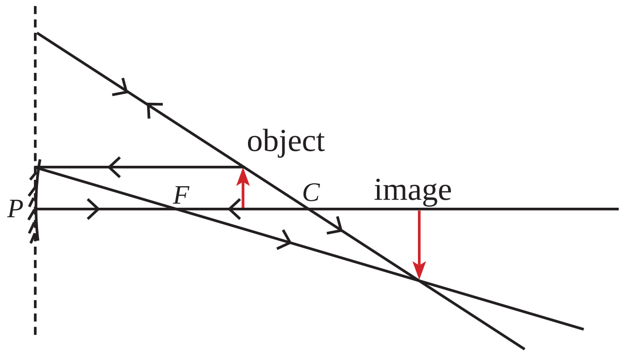


Figure 5.19 - Image of an object placed between the center of curvature and the focal point

4. Object on the center of curvature

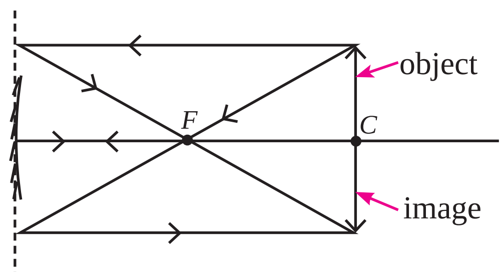


Figure 5.20 - Formation of the image of an object placed on the center of curvature

In order to find the position of the image for an object positioned at the center of curvature, we can consider a ray coming from the top of the object through the focal point and a ray coming parallel to the principal axis. As shown in Figure 5.20, the ray that passed through the focal point returns parallel to the principal axis while the ray that was parallel to the principal axis passes through the focal point after reflection. It can be shown that these two rays intersect at a point directly below the center of curvature and that the height of the image is equal to the height of the object. This too is an inverted real image.

5. Object at a point beyond the center of curvature

In order to find the location of the image in this instance, consider two rays coming from the top of the object. It would be convenient to choose one of these rays to be parallel to the principal axis and the other to pass through the center of curvature as shown in Figure 5.21. Drawing the ray parallel to the principal axis to return through the focal point after reflection and the ray coming through the center of curvature to return through the same path after reflection, the point of intersection of these two rays can be found. This point is the position where the image of the top of the object is formed. Here, the image is formed between *C* and *F*. This image is smaller than the object, inverted and real.

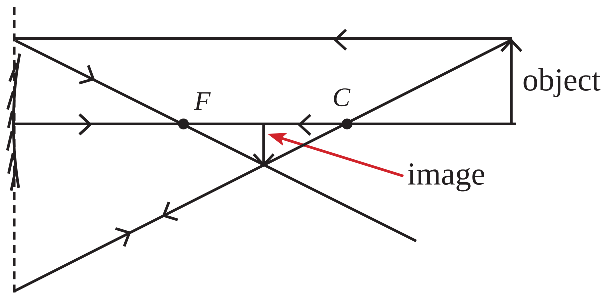


Figure 5.21 - Formation of the image of an object placed at a point beyond the center of curvature

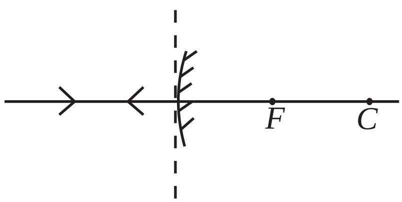
6. Object very far from the mirror

The image of an object placed very far from a concave mirror is formed on the focal point of the mirror, on the same side of the mirror as the object, smaller than the object and is inverted. Since this image can be seen on a screen, it is a real image.

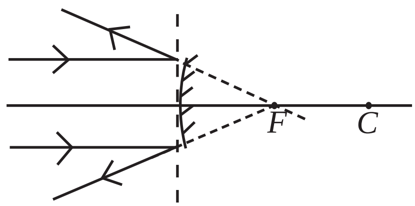
Table 5.1 - Images formed by concave mirror

Object distance	Position of the image	Real/ virtual	Upright/ inverted	Image size
less than focal length	greater than object distance	virtual	upright	larger than the object
focal length	infinity			
greater than focal length and less than twice the focal length	greater than twice the focal length	real	inverted	larger than the object
twice the focal length	twice the focal length	real	inverted	same size as the object
greater than twice the focal length	greater than focal length and less than twice the focal length	real	inverted	smaller than the object
very far	at focal point	real	inverted	much smaller than the object

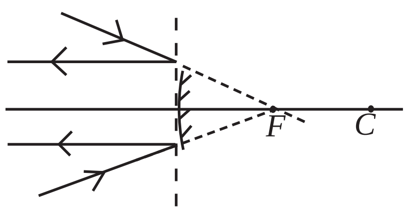
5.2.3 Reflection from a convex mirror



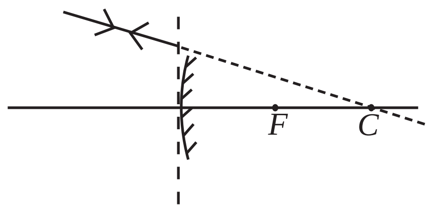
(a) Light rays coming along the principal axis.



(b) Light rays coming parallel to the principal axis.



(c) Rays coming toward the focus.



(d) Rays which are coming toward the centre of curvature.

Figure 5.22 - Reflection of light from a convex mirror

Figure 5.22 shows how reflection of light occur from a convex mirror.

- In a convex mirror too, rays coming towards the mirror along the principal axis are reflected back along the same path after falling on the mirror (figure (a)).
- Rays coming parallel to the principal axis are reflected as a divergent beam after falling on the mirror (figure (b)).
- These divergent rays appear to be coming from a single point on the principal axis inside the mirror. This point is known as its **focal point**.
- A ray that comes toward the focal point is reflected back along a path parallel to the principal axis (figure (c)).
- A ray that comes toward the centre of curvature of the mirror is reflected back along its own path (figure (d)). This is because any straight line drawn from the centre of curvature to the mirror surface is a normal to the surface.

Images formed by convex mirrors

Bring a convex mirror close to your face and observe the image formed in it. Image is upright and smaller image of your face.

Let us do the activity 5.3 to study the nature of image formed by convex mirror.

Activity 5.3

Apparatus : a concave mirror, a screen, a candle.

Try to repeat activity 5.2 using a convex mirror instead of a concave mirror.

You will find that convex mirrors do not form real images.

To obtain an image from a convex mirror, you have to look at the object through the convex mirror.

Regardless of the distance between an object and the mirror, you will always see an upright, virtual image from a convex mirror.

Figure 5.23 shows how the image of an object placed in front of a convex mirror is formed. Here too, the position of the image and its nature can be determined by tracing the paths of two rays coming from the top of the object after reflection just as was done with concave mirrors.

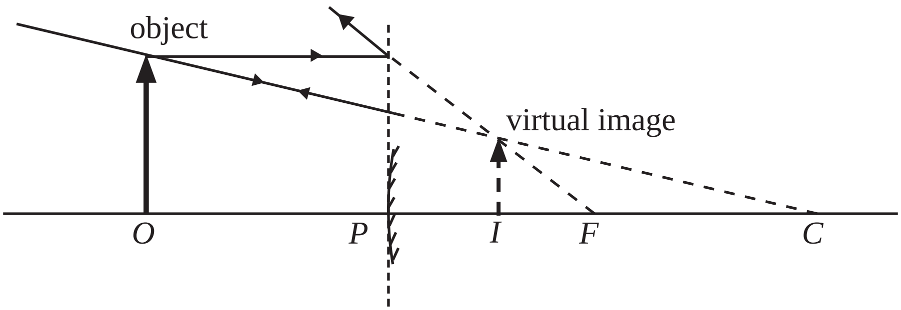


Figure 5.23 - Formation of an image from a convex mirror

5.3 Refraction of Light

Place a pencil inside a glass of water as shown in Figure 5.24 and view it from the top. You will see the pencil as if it is bent.

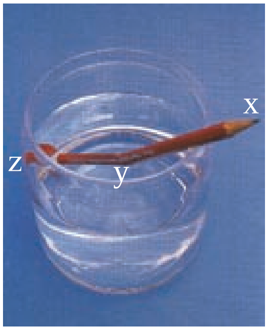


Figure 5.24 - A pencil inside a glass of water

The reason for this appearance is the bending of light rays when they enter from one medium to another medium with different optical properties. Light rays coming to the eye from the part of the pencil inside the water travel through water before reaching the eye through air. When light rays enter air from water, the direction of the light rays changes. However, the rays coming to the eye from the part of the pencil above the water level do not change their direction as they travel only through air before reaching the eye.

The bending of light rays upon entering one medium from another medium is known as **refraction of light**.

Look at a coin at the bottom of a container with water. The coin will appear to be slightly raised above the bottom level of the container. If the coin is in air, the rays from the coin will reach the eye straight. But when the coin is in water, the rays from the coin do not come to the eye straight. When they enter air from water, the rays bend away from the normal to the surface as shown in Figure 5.25. Therefore, the rays from the coin appear to come to the eye from a point slightly above the actual position.

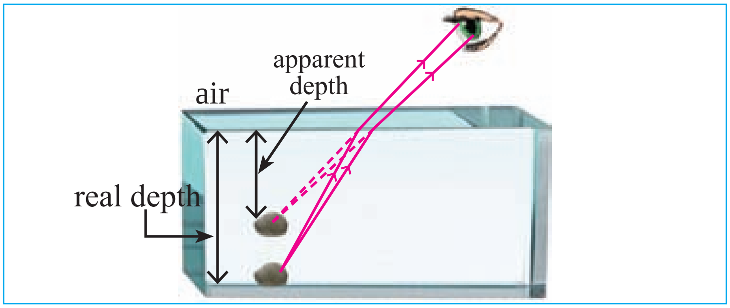


Figure 5.25- Slightly raised appearance of an object at the bottom of a vessel of water

When a page of a book is viewed through a block of glass placed on it, the script on the page seems to be raised up a little, also due to refraction.

A ray of light travelling in one medium bends upon entering a second medium as described above only if the rays arrive from a direction other than at a 90^{o} angle on the surface separating the two media. The reason for refraction is the difference in the speeds of light from one medium to another. Light travels at the speed of 3×10^{8} ms^{-1}. When light enters another medium from a vacuum, the speed reduces to a lower value. A medium with a lower speed of light compared to another medium is called a denser medium. The medium with the higher speed of light is called a rare medium.

Extra knowledge

The speed of light in several different media are given below.

Medium	Speed (km s^{-1})
Air	300 000
Water	225 000
Glass	197 000
Perspex	201 000
Diamond	124 000

In order to investigate how light is refracted in entering a block of glass from air and when entering from glass back to air let us engage in the following activity.

Activity 5.4

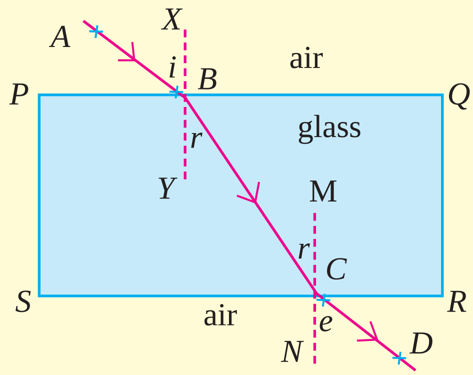


Figure 5.26 - Light refraction through a block of glass

- Place a piece of white paper on a drawing board and place a block of glass on it. Next, mark the edges of the block of glass with a pencil. In Figure 5.26, the position of the block of glass is marked as *PQRS*.
- Now place one pin (*A*) vertically at a short distance away from the surface *PQ* and another pin (*B*) in contact with the surface.
- Next, view the pins through the surface *SR* and place pin *C* in contact with the surface *SR* so as to be collinear with *A* and *B* and thereafter place pin *D* at some distance away from the surface so that all four pins appear to lie on the same line.
- Now remove the block of glass and the pins and draw lines *AB*, *BC* and *CD* connecting the points where the pins were placed. Draw also the normal lines to the surface *PQ* at point *B* and to the surface *SR* at point *C*. You will obtain a diagram like the one shown in Figure 5.26.

In this diagram, *ABCD* is the path of a ray travelling across the block of glass which entered the glass medium from air along the line *AB*. Since *AB* is the ray that was incident on the block of glass, it is known as the **incident ray**.
XY is the normal drawn to the glass surface at the point of incidence. The angle between the incident ray and the normal is known as the angle of incidence (*i*).

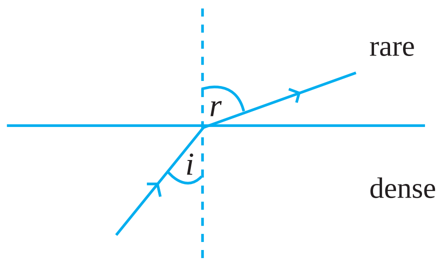
After entering the block of glass, the incident ray travels along *BC*. The refracted ray (*BC*) is bent towards the normal at point *B*.

The angle between the ray of refraction and the normal is known as the **angle of refraction** (*r*). This refracted ray travels back into air from glass at point *C*. This means that the ray has emerged back into air. Therefore the ray *CD* is known as the **emergent ray.** The angle between the transmitted ray and the normal drawn to the glass surface at the point of emergence *C* is known as the **angle of emergence** (*e*).

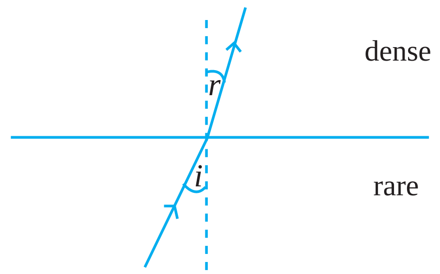
When light enters from air which is a rare medium to glass which is a dense medium, you will notice that the light rays are refracted towards the normal.

When light enters from glass which is a dense medium to air again, which is a rare medium, the light rays are refracted away from the normal. From this activity you will observe that a light ray entering a dense medium from a rare medium refracts towards the normal while a light ray entering a rare medium from a dense medium refracts away from the normal.

Refraction of light from dense medium to rare medium.



Refraction of light from rare medium to dense medium.



When a light ray travels from one medium to another medium if it bend towards the normal, the second medium is denser compared to the first medium. If the ray bends away from the normal, the second medium is a rare medium, compared to the first medium.

5.3.1 Laws of refraction

There are two laws of refraction.

First law

The incident ray, the refracted ray and the normal to the surface drawn at the point of incidence lie on the same plane.

Second law

When light refracts from one medium to another medium, the ratio of the sine of the incident angle to the sine of the refracted angle is a constant that depends only on the two media. This constant is called the refractive index of the second medium with respect to the first medium.

The second law above is also called Snell's law.

$$\text{Index of refraction } (n) = \frac{\text{sine of the incident angle}}{\text{sine of the refracted angle}} = \frac{\sin i}{\sin r}$$

For a light ray that travels from air to glass, the refractive index is written as ${}_a n_g$.

For rays that enter from glass to air, the refractive index is written as ${}_g n_a$.

$$\text{refractive index of water relative to air } {}_a n_w = 1.33$$
$$\text{refractive index of glass relative to air } {}_a n_g = 1.5$$

The refractive index defined above is the refractive index of one medium relative to another medium. Therefore, it depends on both media. If we use a vacuum instead of the first medium (if we consider a light ray entering from a vacuum to some medium), then the refractive index depends only on one medium. This is normally referred to as the refractive index of that medium.

For example, refractive index of water is the ratio of the sine of the incident angle to the sine of the refracted angle when a light ray travels from a vacuum to water. Because the velocity of light in air is only slightly different from that in a vacuum, and because it is practically difficult to make measurements of refractive index relative to a vacuum, often the refractive index of a medium relative to air is used as the refractive index of that medium. There are no units for the index of refraction.

5.3.2 Total Internal Reflection and Critical Angle

When a light ray travels from a dense medium to a rare medium, it bends away from the normal, as shown in Figure 5.27.

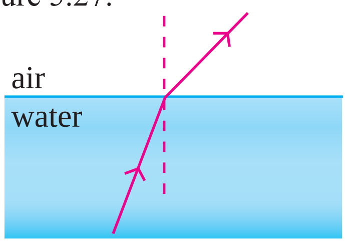


Figure 5.27 – A light ray traveling from water to air

When the incident angle inside the dense medium is gradually increased, the refracted ray bends further away from the normal. At a certain value of the incident angle, the refracted ray travels along the interface between the two media, as shown in Figure 5.28. In this case, the angle of refraction is 90°. The incident angle inside the denser medium when this happens is called the **critical angle**.

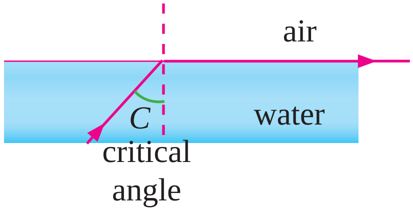


Figure 5.28 – Critical angle

If the incident angle is further increased, the incident light ray will be reflected back into the dense medium as shown in Figure 5.29. This reflecting back into the same medium is called **total internal reflection**.

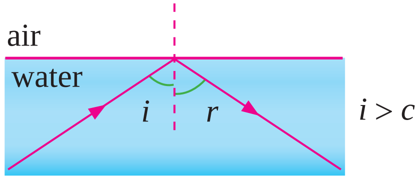


Fig. 5.29 – Total internal reflection

Extra knowledge

The table below shows the critical angle for a few different materials.

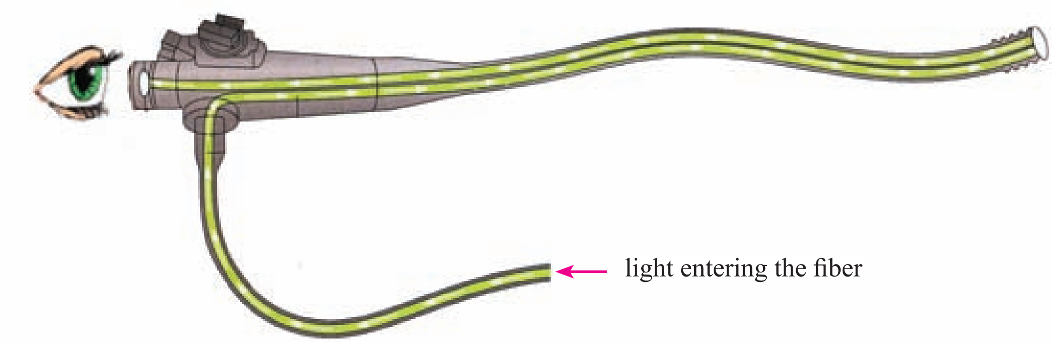
Material	water	glass	diamond
critical angle	49°	42°	24°

• Several applications of total internal reflection

Optical fibers

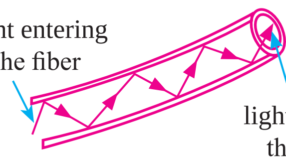
An optical fibre is a flexible transparent fiber made of glass or plastic. Light rays that enter through one end of an optical fiber travel through the fiber while undergoing total internal reflection and leave the fiber through the other end. Even if the fiber is many kilometers long, light will leave it without a significant loss of intensity.

The instrument called endoscope, which is used to observe the internal organs of the human body, makes use of optical fibers. Optical fibers are now widely used in telephone communication and in Internet connections. They are also used in decorations.



Endoscope

Endoscope



an optical fiber

Total internal reflection by prisms

A prism with one angle 90 degrees and the other two angles 45 degrees each can be used to produce total internal reflection. Such prisms are used in cameras, telescopes and binoculars. The critical angle of glass is 43 degrees. Therefore, if the incident angle inside glass is greater than 43 degrees, a light ray will undergo total internal refraction.

Figure 5.30 shows a light ray entering one face of a prism perpendicular to the surface. This ray is not refracted at that surface. Next if falls on the second face of the prism with an incident angle of 45 degrees. Because this incident angle is greater than the critical angle in glass, the light ray undergoes total internal reflection and travels perpendicular to the third face of the prism. The ray emerges from this face without bending. This technique allows us to bend a light ray by an angle of 90 degrees

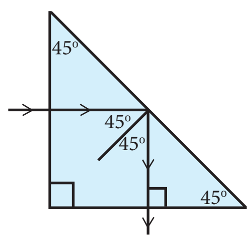


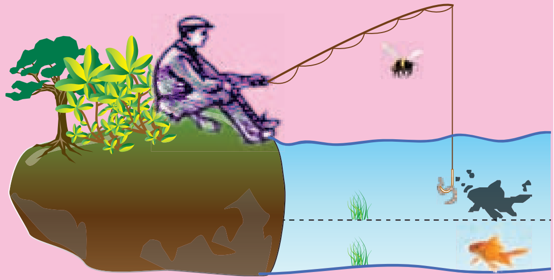
Figure 5.30 – Total internal reflection by a prism

5.1 Exercise

(1) The figure shows a man holding a fishing rod.

(i) The fish appears to the man at a slightly higher position. What is the reason for this?

(ii) Draw a ray diagram to show how the position appears to be raised.



5.4 Lenses

A lens is an optical device with curved surfaces, made of glass, plastic or any other transparent material. A lens alters the path of light rays that pass through it by refraction. Images on the retina of our eye are formed by a lens.

Lenses are used in telescopes and binoculars, which are instruments that help us see far away objects clearly. Lenses are also used in the microscope – the instrument that allows us to see very small objects that are not visible to the naked eye. The magnifying glass or the simple microscope that magnifies small objects is also a lens.

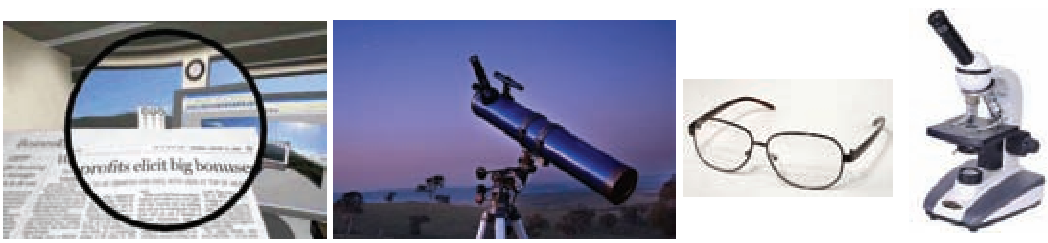


Figure 5.31 - Some instruments with lenses

Many lenses are made of glass. But now plastic is increasingly used for making lenses. Any transparent material can be used to make lenses. Sometimes even liquids such as water are used to make lenses.

Figure 5.32 shows several types of lenses. Lenses with two convex surfaces are called **bi-convex** lenses. When a lens has one convex surface and the other plane, it is called a **plano-convex** lens. In a **bi-concave** lens, both surfaces are concave while a lens with a concave surface and plane surface is called a **plano-concave** lens.

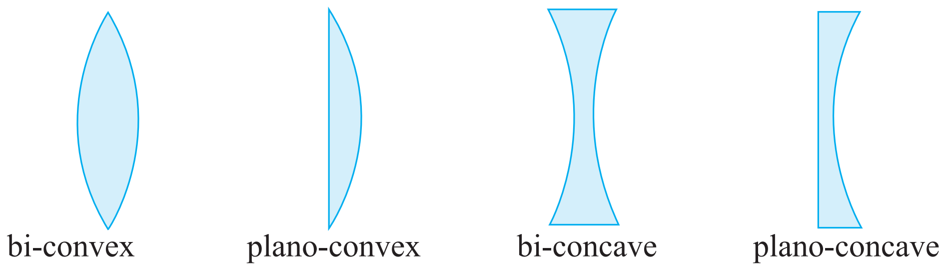


Figure 5.32 – Several types of lenses.

5.4.1 Convex lenses

The two surfaces of a convex lens can be considered as parts of two imaginary spherical surfaces, as shown in Figure 5.33.

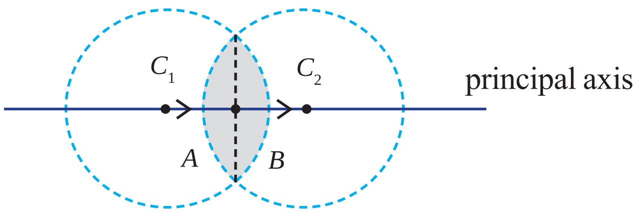


Figure 5.33 - Surfaces of a convex lens

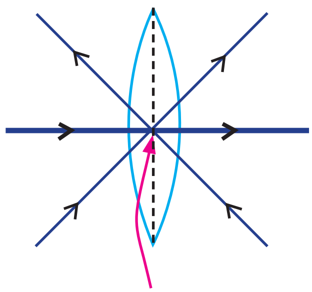


Figure 5.34 – Light rays traveling through the optical centre

In Figure 5.33 one surface of the convex lens is denoted as A and the other as B. The centre of the sphere that forms the surface A is denoted as C_2 and the centre of the sphere that forms the surface B is denoted as C_1. The line that joins these two centres C_1 and C_2 is called the principal axis of the lens. At the points where the principal axis intersects with the surfaces of the lens, the principal axis is perpendicular to the surfaces. Therefore, a light ray that enters the lens along the principal axis will leave the lens without bending. The mid point between the two surfaces of the lens is called the optical centre of the lens. It is possible to show that any light ray that travels through the optical centre passes through the lens without any bending, as shown in figure 5.34.

Activity 5.5

- When there is bright Sun light, hold a convex lens to Sun light as shown in figure 5.35 and place a white paper in front. Adjust the distance between the paper and the lens until you get a very small patch of light on the paper.
- Because the Sun is very far from us, we can consider all rays of light coming from the Sun to be parallel. In this activity you will observe that, when parallel light from the Sun passes through the lens, all of the rays are focused to a single point.

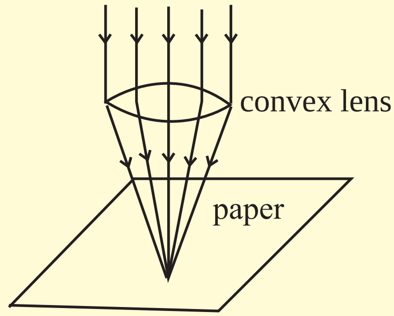


Figure 5.35 – Focusing of light with a convex lens

What will happen to the light rays travelling parallel to the principal axis of a convex lens? After refracting from the lens, they bend towards the principal axis (converge) and travel through a single point on the principal axis. This point is called the **focus** or the **focal point** of the lens.

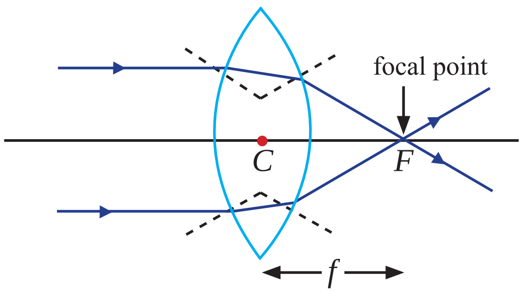


Figure 5.36 – The way the rays parallel to the principal axis are refracted by a convex lens

In order to understand how the light rays entering a convex lens parallel to the principal axis, refract when they go through the lens, let us look at figure 5.36.

The broken lines in this figure are normals drawn to the lens surface at each point where a light ray crosses the surface.

- When such a ray enters the lens, they enter a denser medium from a rarer medium.
- Then this ray bends towards the normal to the surface. When this ray leaves the lens, it enters a rarer medium from a denser medium. Therefore, it bends away from the normal.
- According to figure 5.36, in both cases the light ray bends towards the principal axis.
- It is possible to show that all rays that enter the lens parallel to the principal axis, after bending as discussed above travel through a single point on the principal axis.

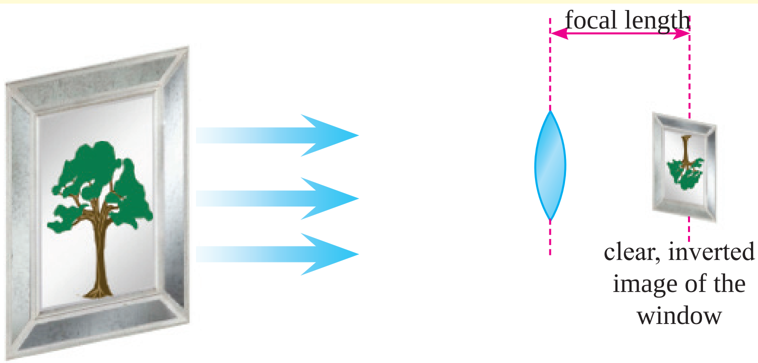
- This point is called the **focus or the focal point** of the lens. The distance from the optical centre of the lens to the focal point is called the **focal length** of the lens.

Because light can enter from either side of the lens, it is possible to identify two focal points for a lens. Both these points have the same distance to the optical centre of the lens. Normally, when ray diagrams are drawn, the focal point is denoted as F and the focal length is denoted by f.

• Images formed by convex lenses

Activity 5.6

- Open the window of a room.
- Hold a convex lens, turned towards the window.
- On the opposite side of the lens, hold a screen (or a white paper) and adjust the distance between the lens and the screen until a clear image of the scene outside the window is formed on the screen.
- Measure the distance between the lens and the screen when you get a very clear, up side down image on the screen.



This distance you measure will be the focal length of the lens.

The image in the above activity is formed when light rays coming from objects outside the window are refracted by the lens and come together on the screen. Because this image is formed by light rays that actually reach the screen, it is a real image.

• Drawing ray diagrams for images formed by convex lenses

The size, nature and position of the images formed by convex lenses depends on the distance between the lens and the object.

In drawing ray diagrams for images formed by convex lenses, it is convenient to use the specific rays shown in figure 5.37.A light ray passing through the optical axis is shown in figure 5.37 (a), This type of rays pass through the lens straight, without any refraction. A ray that enters a lens parallel to the principal axis, as shown in figure 5.37 (b), passes through the focal point after emerging from the lens. A light ray that passes through the focal point on one side of the lens, as shown in figure 5.37 (c) emerges parallel to the principal axis after refracting by the lens.

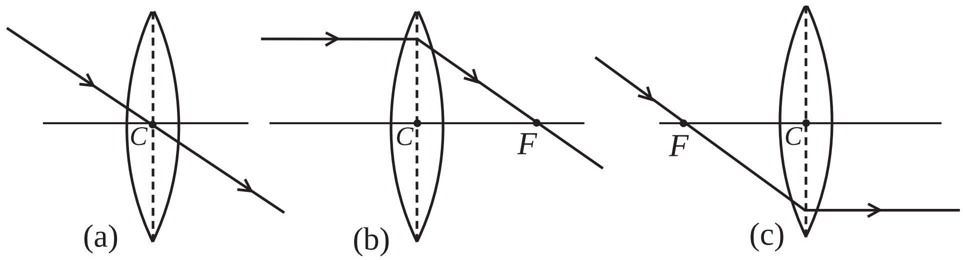


Figure 5.37 – A few special rays used in drawing ray diagrams

1. When the object is between the lens and its focal point

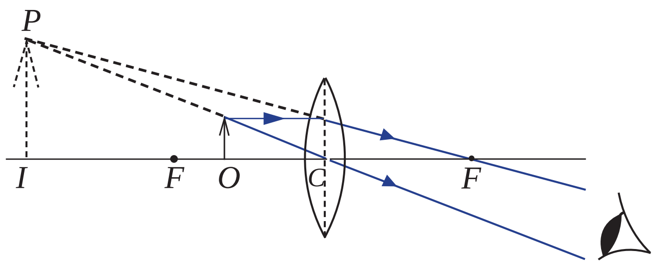


Figure 5.38 – When the object is between the lens and its focal point

Figure 5.38 shows an object placed at point *O* which is between the lens and the focal point *F*. A light ray coming from the top of the object and traveling parallel to the principal axis will go through the focal point *F* on the opposite side of the lens. Another ray coming from the top of the object and traveling through the optical axis *C* will go straight without any refraction. When these two rays are extended in the opposite direction, they will intersect at a point *P*. The top of the image will be at this point. Because the object is vertical, the image should also be vertical. Therefore, the image must be on the vertical line drawn to the principal axis from point *P*. This image is larger than the object and it is up right. This image can be seen when the eye is placed as shown in the figure. However, because the rays do not actually meet at point *P*, this image cannot be formed on a screen. Therefore, it is a virtual image.

2. When the object is on the focal point

Figure 5.39 shows a ray diagram for an image of an object places at the focal point of a convex lens. A light ray coming parallel to the principal axis, after going through the lens, travels through the focal point. A ray that goes through the optical centre (C) travels directly, without any refraction. Both these rays, when reaching the eye travel as parallel rays. Therefore, the image formed is at infinity. This image is larger than the object.

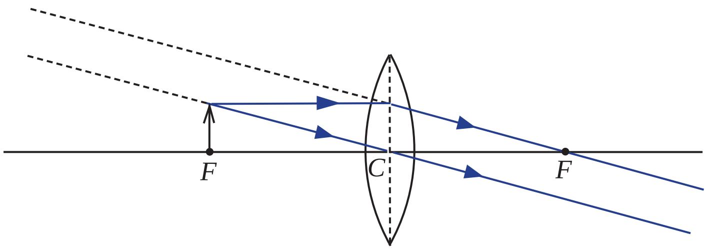


Figure 5.39 – Ray diagram for an image of an object on the focal point of a lens

3. When the object is between the focal length and twice the focal length

When the object is at a distance between f and $2f$, the image is formed on the opposite side of the lens at a distance greater than $2f$. As shown in figure 5.40, this image is a magnified inverted real image.

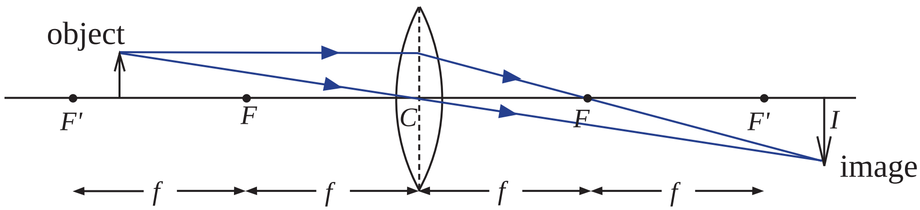


Figure 5.40 – The image of an object placed between distances f and $2f$

4. When the object distance is equal to twice the focal length

The image formed in this case is at a distance $2f$ on the other side of the lens. The height of the image is equal to that of the object. It is a real, up side down image. The ray diagram is shown in figure 5.41

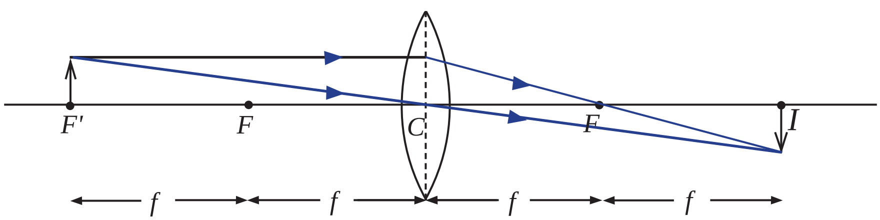


Figure 5.41 - Image of an object when the object distance is $2f$

5. When the object distance is greater than twice the focal length

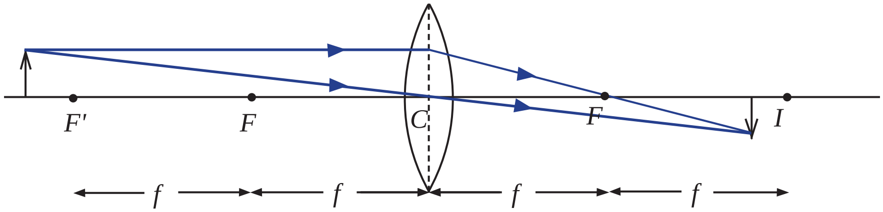


Figure 5.42 - Image of an object placed at a distance greater than 2*f*

In this case, the image is formed on the opposite side of the lens, at a point between the focal length (*f*) and twice the focal length (2*f*). This image is diminished, real and up side down. The ray diagram is shown in figure 5.42.

The image becomes smaller as the object distance increases.

- The following table shows how images are formed by a biconvex lens. at different object distances.

Table 5.2 - Images formed by convex lens

Object distance	Position of the image	Real/ Virtual	Upright/ inverted	Size of the image
less than focal length	greater than object distance, on the same side as the object	virtual	upright	larger than the object
focal length	infinity			
greater than focal length and less than twice the focal length	greater than twice the focal length, on the opposite side	real	inverted	larger than the object
twice the focal length	twice the focal length, on opposite side	real	inverted	same size as the object
greater than twice the focal length	greater than focal length and less than twice the focal length, on opposite side	real	inverted	smaller than the object
infinite	at focal point on the opposite side	real	inverted	much smaller than the object

5.4.2 Concave Lenses

Figure 5.43 shows how the surfaces of a concave lens can be understood as parts of spheres.

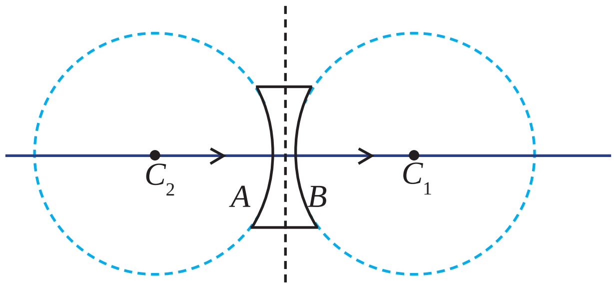


Figure 5.43 – Surfaces of a concave lens

The centre of the sphere that forms surface A is C_2 and the centre of the sphere that forms surface B is C_1. The line that joins these two centre points is called the principal axis of the lens. In both convex lenses and concave lenses, a light ray that travels through the principal axis passes through the lens without bending.

The centre point of the lens, labeled as C is called the optical centre. Any light ray that goes through the optical centre travels straight, without bending.

Next we have to consider light rays that enter a concave lens parallel to the principal axis. Such rays, as shown in figure 5.44, are refracted away from the principal axis after passing through the lens. That means they diverge. The point from which these divergent rays appear to come from is called the focal point of that lens.

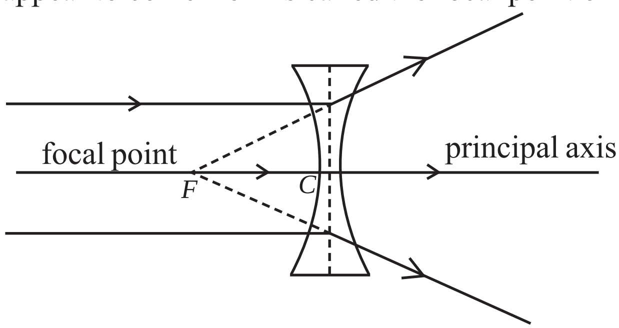


Figure 5.44 – Rays parallel to the principal axis, after passing through a concave lens, appear to come from a single point

• Images formed by concave lenses

In order to understand images formed by concave lenses, let us do activity 5.7.

Activity 5.7

- Place a bright object (eg: a lighted candle) in front of a concave lens.
- On the other side of the lens, place a screen and try to obtain a real image on the screen by suitably adjusting the lens.

You will find that concave lenses do not form real images. To obtain an image from a concave lens, you have to look at the object through the lens. Then you will see an image smaller than the object. This is a virtual image. Whatever the distance between the lens and the object, what you see will be an upright, diminished virtual image. Figure 5.45 shows a ray diagram for an image formed by a concave lens.

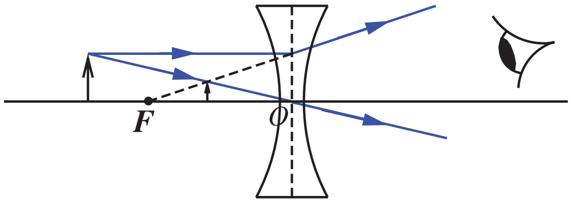


Figure 5.45 - A ray diagram for an image formed by a concave lens

5.4.3 Hand Lens or Simple Microscope

A convex lens makes an object look bigger when the object is placed in front of the lens at a distance less than the focal length of the lens. This property of convex lenses is used to view magnified images of objects.

A convex lens fitted with a handle is called a hand lens or a simple microscope. It is also commonly known as a magnifying lens. Figure 5.46 shows the ray diagram for a magnified lens. Magnifying glasses are commonly used for viewing small insects, parts of flowers etc.

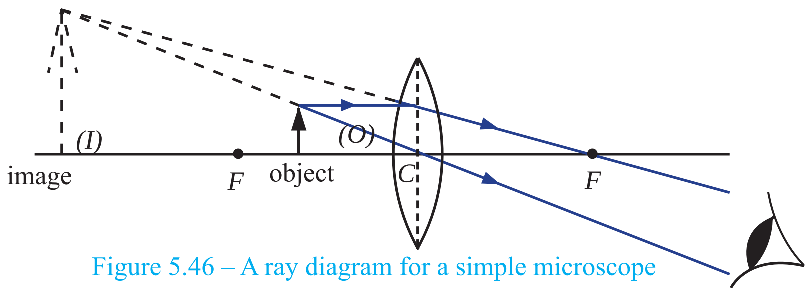


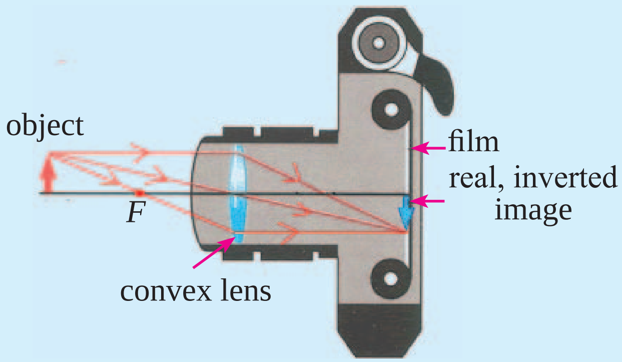
Figure 5.46 – A ray diagram for a simple microscope

- **The Principle of reversibility of light**

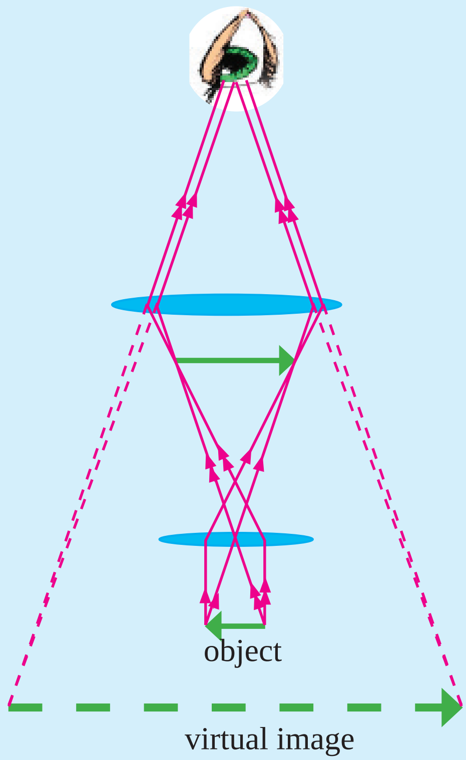
If the direction of a light ray is reversed, it will follow exactly the same path backward. This is called the principle of reversibility of light. This principle is valid even if the light ray is subjected to a combination of many reflections and refractions.

For your knowledge

- In cameras, images are formed on a film using convex lenses. When one adjusts the lens, the distance between the screen and the lens changes. Clear images of objects at different distances can be obtained on the screen this way.



- The complex microscope is used to observe tiny objects which are not visible to the naked eye. It has two lenses called objective and eye piece. This combination of lenses produce a very high magnification.



5.2 Exercise

(1) (i) Name two types of mirrors that always produce virtual images.

(ii) Answer the following questions regarding the image formed when an object is placed between the mirror and the focal point of a concave mirror.

(a) Is the image upright or inverted?

(b) Is the image larger than the object or smaller than the object?

(c) Is the image real, or virtual?

(d) When the object is moved toward the pole of the mirror, will the image become smaller or larger?

(iii) At what object distance do you get the largest image from a concave mirror? Is that image upright or inverted?

(iv) Place an object in front of a convex lens at different positions and observe the image in each case. Write two properties common to all those images.

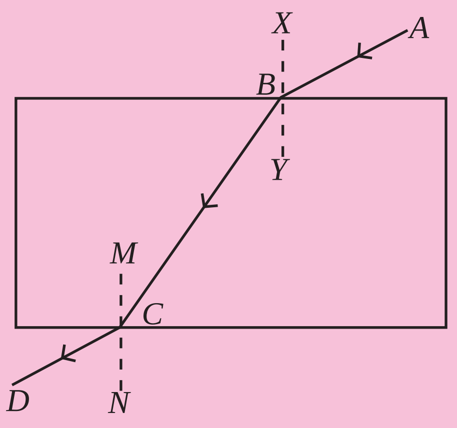
(2) (i) What is meant by the term refraction of light?

(ii) Draw ray diagrams to show how refraction occurs when light enters

(a) a dense medium from a rare medium,

(b) a rare medium from a dense medium.

(iii) Name the rays and the angles of the following ray diagram.



AB ray ....

BC ray ....

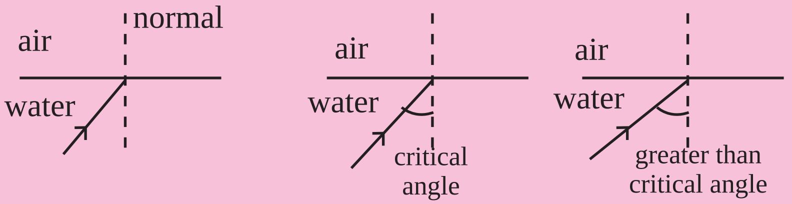
CD ray ....

ABX angle ....

YBC angle ....

NCD angle ....

(3) The figure shows different light rays entering a rare medium from a dense medium.



(i) Copy these figures and complete the ray diagrams.

(ii) What is meant by the term *total internal reflection*?

(iii) Give an example for a situation where total internal reflection occurs.

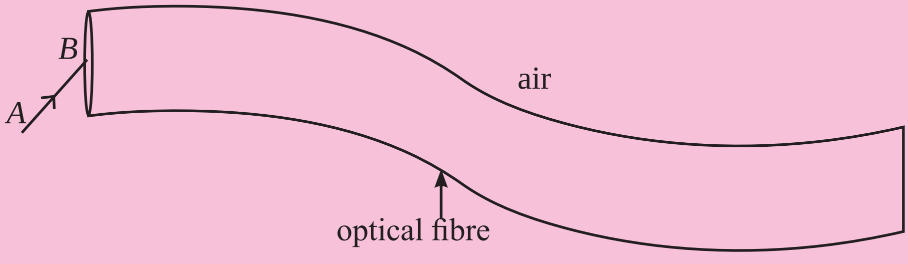
(4) Draw a ray diagram to show how an image is formed when an object is placed in front of a convex lens, at a distance greater than twice the focal length.

(a) Is that image real or virtual?

(b) Describe a simple activity to find out whether the image is real virtual.

(c) Is that image smaller or larger than the object?

(5) (i) The figure shows a light ray entering an optical fibre.



(a) Draw a ray diagram to show what happens to that ray inside the optical fibre.

(b) State what changes occur to the speed of the ray as it follows this path from the source. Calculations are not required.

(ii) (a) At what object distance do you get the largest real image when an object is placed in front of a convex lens?

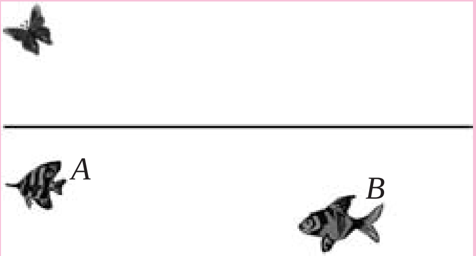
(b) Write down two other properties of that image.

(c) At what object distance do you get the smallest real image when an object is placed in front of a convex lens?

(6) A bag contains lenses with focal lengths 10 cm, 20 cm and 25 cm which are not marked with their focal length. Describe a simple activity to identify the three types lenses.

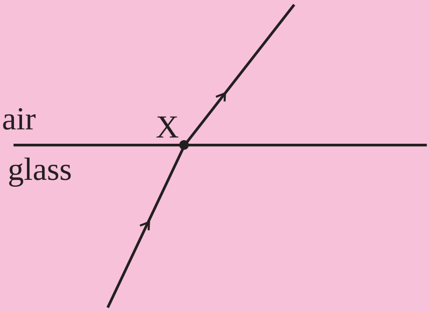
(7) (a) Light changes direction when it passes from air to water.
(i) Give the name of the process that produces this change of direction.
(ii) Explain why this change of direction occurs.

(b) The diagram shows some fish under water and a butterfly above water.



(i) Draw a ray to show the path of a light ray travelling from the butterfly to the eye of fish *B*.
(ii) Explain what critical angle is.
(iii) Explain how rays from fish *A* could reach the eye of fish *B* through two different paths. Draw rays in the diagram to show these two paths.

(8) A student carries out an experiment to investigate the refraction of light as it passes from glass into air. He shines a ray of light through a glass block and into the air as shown.



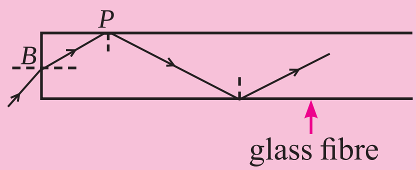
(a) Complete this diagram and show the angle of incidence i and the angle of refraction r . Measure these two angles.

i = ...

r = ...

(b) The student increases the angle of incidence and notices that, above a certain angle, the light no longer passes into air. Explain this observation.

(9) The figure shows a light signal travelling through an optical fibre made of glass.



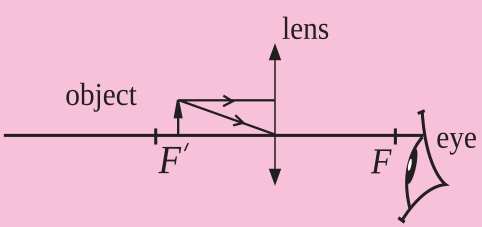
(a) State two changes light when it enters the fibre from air at point *B*.
(b) Explain why the light ray, after hitting point *P*, travels along the path shown.

(10) Lenses are used in many optical devices.
(a) Complete the table below by writing information about the images formed by each optical device.

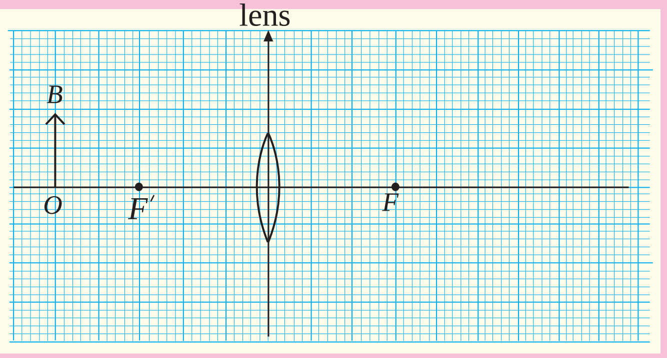
optical device	nature of image	size of image	position of image
eye	real		
projector		magnified	
magnifying glass			further from lens than the object

(b) The figure shows an object placed in front of a convex lens, at a distance less than its focal length.

(i) Complete the ray diagram and draw the image formed.
(ii) Use your ray diagram to describe three properties of the image.

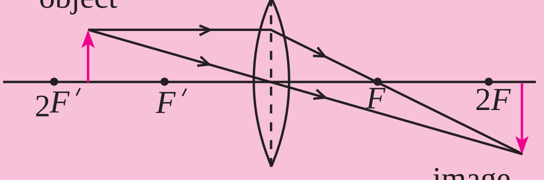


(11) The figure shows an object OB in front of a convex lens. The two focal points are marked as F and F'. An image of OB will be formed on the right of the lens.



(a) Draw two rays from the top of the object (B), that pass through the lens and reach the image.
(b) Draw the image formed and label it as I.
(c) Calculate the ratio of the image size to the object size.

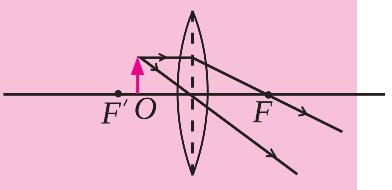
(12) The diagram shows a convex lens forming a real image of an object.



State two changes that occur to the image when the object is moved towards F.

(13) The diagram shows an object placed at O, in front of a convex lens. Focal length of the lens is 30 mm O is 20 mm from centre of lens and the object is 15 mm high.

(a) By drawing this diagram to a suitable scale find the position of the image.
(b) State two properties of the image.
(c) By measuring the heights of the image and the object, find the ratio of their heights.



Summary

- There are two types of mirrors - plane mirrors and curved mirrors. Curved mirrors can be either convex mirrors or concave mirrors.
- Images formed by plane mirrors are virtual and upright. They are the same size as the object.
- The incident ray, the reflected ray and the normal to the surface at the point of reflection lie on the same plane.
- When light is reflected from a mirror, the angle of incidence is equal to the angle of reflection.
- When an object is placed in front of a convex lens, the images are diminished, upright and virtual, irrespective of the object distance
- The bending of light when passing from one medium to another is called refraction of light
- When light travels from a rare medium to a dense medium, the ray bends towards the normal.
- When light travels from a dense medium to a rare medium, the ray bends away from the normal.
- When light undergoes refraction, the incident ray, the refracted ray and the normal to the surface at the point of refraction lie on the same plane.
- $$\text{Index of refraction} = \frac{\text{Sine of the angle of incidence}}{\text{Sine of the angle of refraction}}$$
- When light travels from a denser medium to a rare medium, at a certain value of the angle of incidence, the refracted ray travels along the surface between the two media. The angle of incidence in this situation is called the critical angle (c).
- When a ray of light travels from a denser medium to a rare medium with an angle of incidence greater than the critical angle, the ray is reflected back into the denser medium. This is called total internal reflection.
- Light travels through optical fibers by undergoing total internal reflection.
- There are many types of lenses such as bi-convex lenses, bi-concave lenses, plano-convex lenses, and plano-concave lenses.
- When an object is placed in front of a bi-convex lens, the image is upright, diminished and virtual, irrespective of the object distance.

Glossary

Reflection	- පරාවර්තනය	- தெறிப்பு
Total internal reflection	- පූර්ණ අභ්‍යන්තර පරාවර්තනය	- முழுஅகதெறிப்பு
Mirrors	- දර්පණ	- ஆடிகள்
Apparent depth	- දෘශ්‍ය ගැඹුර	- தோற்ற ஆழம்
Binoculars	- දෙනෙතිය	- அரிய இருவிழியன்
Focal	- නාභිය	- குவிவு
Incident ray	- පතන කිරණය	- படுகதிர்
Angle of incidence	- පතන කෝණය	- படுகோணம்
Refraction	- වර්තනය	- முறிவு
Refractive index	- වර්තනාංකය	- முறிவுச் சுட்டி
Refracted	- වර්තිත	- முறிவடைதல்
Angle of refraction	- වර්තිත කෝණය	- முறிவுக் கோணம்
Convex lens	- උත්තල කාචය	- குவிவு வில்லைகள்
Concave lens	- අවතල කාචය	- குழிவு வில்லைகள்
Convex mirror	- උත්තල දර්පණය	- குவிவு ஆடி
Concave mirror	- අවතල දර්පණය	- குழிவு ஆடி
Real image	- තාත්වික ප්‍රතිබිම්බය	- உண்மை விம்பம்
Virtual image	- අතාත්වික ප්‍රතිබිම්බය	- மாய விம்பம்

Biological processes in human body 06

Many different biological processes take place in the human body. We will discuss about those processes and the systems specialized to perform them.

6.1 Process of food Digestion

Energy is required for different biological processes that take place in human body. Energy is obtained through food that we take into the body. These food contain nutrients such as carbohydrates, lipids and proteins. Carbohydrates, lipids and proteins are complex organic molecules that do not dissolve in water. These compounds cannot be absorbed into the human body. Therefore they should be broken down into small particles.
The process by which the complex organic compounds are converted into simple organic products to be absorbed into the human body is called digestion of food.

Food digestion takes place in two process namely mechanical and chemical processes
During mechanical process the physical nature of the food is altered,
E.g. :- Breaking down of food into small pieces by teeth inside mouth.
During chemical process, the insoluble complex compounds are broken down into simple molecules by the action of enzymes.
E.g. :- Starch is converted into maltose by **salivary amylase (ptyalin)** enzyme inside mouth.

There are some nutrients, that can be used by the body without any digestion, such as mineral salts, some vitamins, glucose, fructose and galactose.

The organs involved in food digestion, are collectively called as digestive system.

Human digestive system

Human digestive system is a single tube, that runs from mouth to anus. According to the requirement, the structure has changed at different places, and the glands (salivary glands, pancreas, liver) that supply enzymes and other substances (bile) connect at different sites. The functions take place in the digestive system are f**ood digestion, absorption of digested end products** and **removal of undigested materials** from the body.

Let us see the structures that belong to the digestive tract.

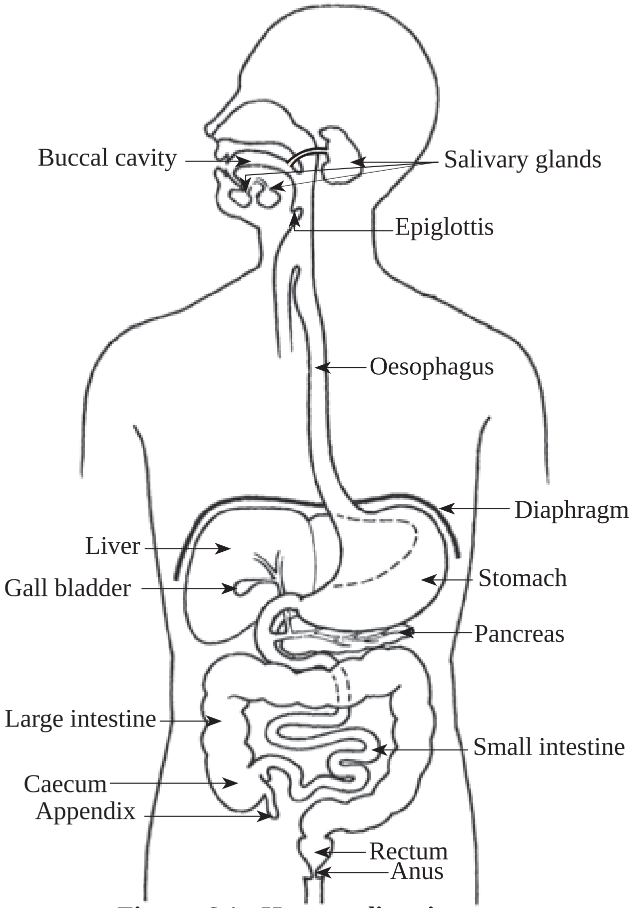


Figure. 6.1 - Human digestive system

Assignment - 6.1

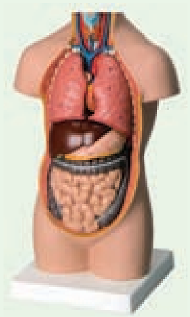


Figure. 6.2 - Human torso

- Identify the parts of the human digestive tract in the human torso
- Concern about the nature, size and location of those parts

Let us observe the changes that occur in food at first part of the digestive tract, the buccal cavity.

Digestion in the buccal cavity

Mouth opens the buccal cavity to the environment. It is surrounded by muscular lips at the bottom and top. The buccal cavity is made up of upper and lower jaws. Only the lower jaw can be moved. Teeth are present in both jaws. Buccal cavity is surrounded by cheeks. The tongue is attached to the floor of the buccal cavity. Three salivary glands are present in the buccal cavity. They secrete saliva and the tongue helps in identification of taste, mixing of food with saliva and swallowing.

A sweet taste is sensed when chewing rice or bread for sometime. Let's discuss why it is sweet?

The salivary amylase (ptyalin) enzyme, acts on starch in digestion of food. Starch will be partially digested into maltose. Digestion of food starts in the mouth.

$$\text{Starch} \xrightarrow{\text{salivary amylase}} \text{Maltose}$$

When rice or bread is chewed for sometime starch is digested into maltose. As maltose is sweet, we sense the sweet taste.

Initially digested food is formed into a bolus and pushed to the posterior part of the buccal cavity. Next food is pushed into the pharynx.

Pharynx is a common area to both respiratory and digestive systems.

There is a movable organ called epiglottis found just above the opening of trachea. When bolus is swallowed the epiglottis moves down to close the opening of trachea. Then bolus enters into oesophagus without entering into trachea.

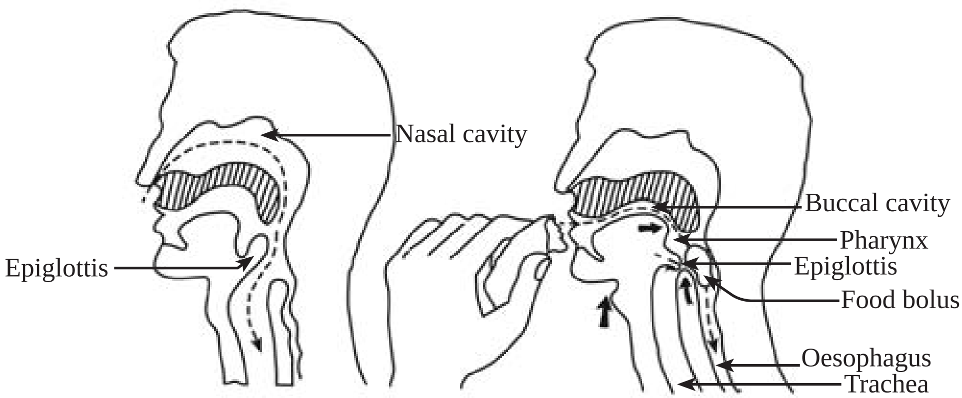


Figure. 6.3 - Trachea is closed with epiglottis when food enter into oesophagus

Epiglottis helps to prevent entering food into the trachea. When food enters to pharynx, respiratory track is blocked by epiglottis. This prolong blockage of trachea may cause death. If the food is not removed instantly, the person may die due to blockage of respiratory tract.

Oesophagus is a constricted tube. How is food moved along a constricted tube? The bolus passes through the oesophagus by peristaltic movements. As oesophagus is a muscular structure, due to contractions and relaxations of its wall the peristaltic movements appear as waves. These peristaltic movements provide the force to propel the bolus forward.

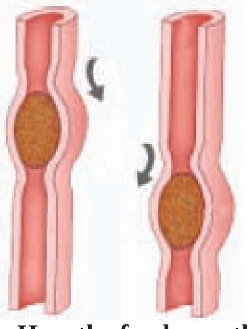


Figure. 6.4 -How the food pass through oesophagus

Then food is moved into stomach by peristaltic movements.

Digestion in the stomach

The stomach is a dilated sac like organ. Due to the peristaltic activity of muscles in the stomach wall the bolus is broken down and mixed well into a **chyme**. Several secretions ooze out into the stomach. It is collectively called the **gastric juice**.

The gastric juice contains mainly hydrochloric acid (HCl) and pepsin enzyme. HCl activates pepsin and pepsin starts the protein digestion to produce polypeptides. Renin present in infants causes coagulation of milk. Food retain in stomach for about three hours. Although the digested end products are not absorbed but some water, glucose and some drugs may absorb.

Chyme containing partially digested proteins, digested and undigested carbohydrates, undigested lipids, water, minerals and vitamins are released into the proximal part of small intestine, duodenum part by part.

When the stomach is empty, it continues to contract. When the stomach is empty for a longer period of time, the rate of contraction is also high. So it causes a pain. It gives a sense about hunger. Hunger is a signal that indicates the need of food.

Digestion in the small intestine

The chemical digestion of food mainly takes place in the small intestine. Pancreatic enzymes as well as intestinal enzymes involve in this digestion.

The small intestine is about 7 m in length. The proximal part of the small intestine is C shaped and known as duodenum. The duct of the pancreas and the gall bladder opens into the duodenum via a single pore. **Pancreatic juice** is secreted into the duodenum through pancreatic duct. It contains three main enzymes. They are trypsin, amylase and lipase. The bile carried through the bile duct is added to it. Bile is produced in the liver and stored in the gall bladder.

Bile contains bile pigments, bile salts, bicarbonate ions and water.

Due to mixing of bile with food at duodenum, the lipids in food are broken down into small droplets by the process called **emulsification**. Due to this action, enzymes get a greater surface area to act on lipid food.

Intestinal juice secreted by the wall of the intestine contains, maltase, sucrase, lactase, peptidase and mucus. Mucus lubricates food and then ease the passage of food materials along the gut. It protects the inner lining of gut wall. Proteins present in wall of stomach and intestine is protected by the protein digestive enzymes as there is a layer of mucus on the wall.

Let us summarize food digestion takes place in small intestine (See table 6.1)

Table 6.1 - Enzymes in food digestion in small intestine

Organ	Enzyme	Substrate/food	End products
Pancreas	Trypsin	Protein	Polypeptides
	Amylase	Starch	Maltose
	Lipase	Lipids	Fatty acids and glycerol
Small intestine	Maltase	Maltose	Glucose
	Sucrase	Sucrose	Glucose and Fructose
	Lactase	Lactose	Glucose and galactose
	Peptidase	Polypeptides	Amino acids

These are the end products of digestion

Carbohydrates $\longrightarrow$ Monosaccharides (Glucose / Fructose / Galactose)

Protein $\longrightarrow$ Amino acids

Lipids $\longrightarrow$ Fatty acids + Glycerol

What happens to the end products of food digestion?

The absorption of digested end products into body takes place mainly in the small intestine. The small intestine is adapted to increase its efficiency of absorption in different ways.

- Being a long tube
- Presence of circular folds in the inner wall
- Presence of finger like projections called villi in the circular folds
- Presence of microvilli in the epithelial cells of villi
- Thin epithelial lining on villi
- Villi are highly vascularised

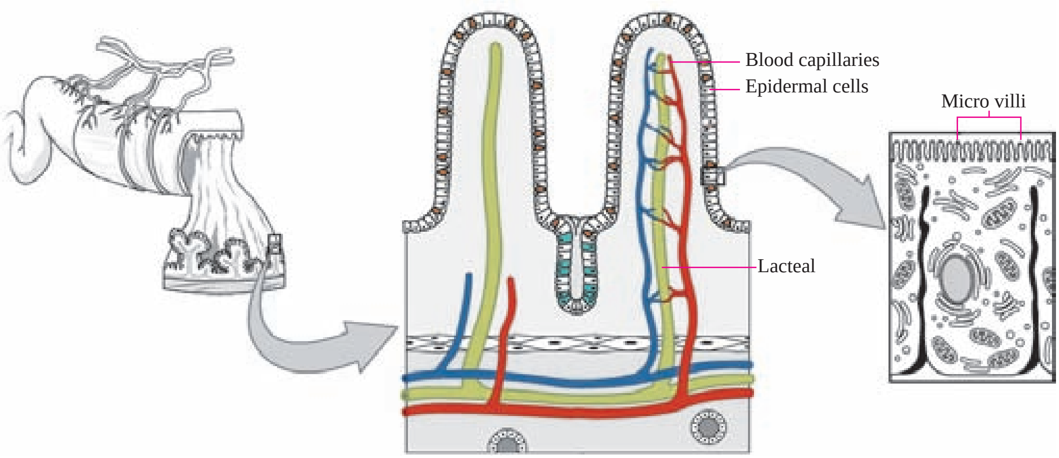


Figure. 6.5 - Structure of villi in small intestine

The digestive end products given below are absorbed into the **blood capillaries** of villi.

- Amino acids
- Vitamins
- Mineral salts
- Monosaccharides (Glucose/ Galactose/ Fructose)

Fatty acids and glycerol formed by digestion of lipids are absorbed into lacteals. Finally they enter into blood circulatory system. When there is high amount of glucose in blood, they are converted into glycogen and stored in liver. In the same way when the concentration of glucose is decreased, glycogen breaks down to form glucose and is added to blood. The unabsorbed materials in small intestine are sent to the large intestine.

Processes in the large intestine

Length of the large intestine is about 1.5 m. It starts with caecum and ends up at anus. The dilated part of the large intestine is the rectum. The opening of it, is the anus. The materials entering into the large intestine contain a very small amount of nutrients. Mainly it contains undigested cellulose and water. A small blind ended tubular structure starts at the end of the caecum. It is known as the appendix. It is very small in humans and it may be infected and become swollen. This disease is known as appendicitis.

The main function of the large intestine is to absorb water from matter received from ileum. Thereby making it into semi solid. The matter enterd into large intestine is known as faecal matter. Faecal matter is yellow in colour due to bile pigments in it. Undigested food, microorganisms, epithelial cells and mucus are present in faecal matter.

When large intestine fills with faecal matter, it passes out from the rectum.

The diseases and disorders associated with digestive system

The chance of getting infections to the digestive tract is high as materials are entered into it from outside frequently. Therefore digestive tract catches many diseases and disorders.

Engage in the assignment 6.2 to get knowledge about the diseases and disorders associated with digestive system.

Assignment - 6.2

Prepare a booklet about the diseases and disorders associated with digestive tract and how to prevent them. Discuss with doctors and refer news papers, magazines for information.

Gastritis

Inflammation of inner lining of mucosa of stomach is known as gastritis. It is a common disease among people. Generally known as acidity. The symptoms are, regurgitation of acid to mouth, burning feeling and pain in stomach. When the condition becomes worse, ulcers appear in stomach and duodenal wall. Bleeding can take place.

The reasons for this disorder are as follows,

- Skipping of meals
- Consumption of acidic and spicy food
- Excessive smoking and alcohol consumption
- Mental stress

By following healthy food diets and good habits one can avoid the above disease.

Constipation

Difficulty in defaecation due to hardening of faecal matter is known as constipation. Faeces remain in the large intestine for a longer period of time and absorption of water takes place excessively, Thereby this condition may occur.

Reasons for constipation are as follows,

- Consumption of food with low dietary fibres
- Not taking required volume of water
- Postponing of defaecation

By avoiding above conditions and habits one can avoid this disease. Some drugs may cause constipation. Due to forceful defaecation, the anal canal may damage and bleeding can occur. Due to constant constipation, haemorrhage may occur.

Typhoid

Typhoid is caused by a bacterium. The pathogen is transmitted through food and water. The bacterium can enter into the body through mouth while swimming and bathing in contaminated water. It may enter into the body through faecal matter of patient, consumption of contaminated food and flies. Pain in arms and legs, headache and fever are main symptoms. It is a disease which gradually becomes worse. At initial stages constipation can occur. Tongue is covered by a plaque. After sometime stomachache and diarrhoea can occur. Ulcers can form in the small intestine and cause bleeding. Therefore blood is released with faecal matter. Due to ulcers, the wall can be damaged. Disease can be identified by a blood test or stool test. Typhoid can be prevented by getting a vaccine.

Diarrhoea

Diarrhoea occurs when the intestines are infected with a virus, bacteria or a parasite. This disease is transmitted by the faeces of an infected person. The main symptom is release of faecal matter in liquid state. Absorption of water in the large intestine will not occur properly. Dehydration may occur due to loss of fluid. If dehydration becomes worse due to diarrhoea, it may be fatal. So it is needed to consume more water and consult a doctor immediately.

The above two diseases can be avoided by taking preventive measures given below

- Consumption of boiled drinking water
- Removal of breeding places of flies and cover the food to prevent entering of flies to food
- Avoid consumption of food which are sold in open places
- Use of water seal latrines
- Proper washing of hands with soap after using the toilet

6.2 Process of respiration

Respiration is a biological process. Gas exchange can be observed in some animals externally.

Respiration in a human is a complex process and it occurs in three stages.

1. Gas exchange between external environment and lungs
2. Gas exchange in alveoli
3. Cellular respiration

Intake of oxygen into lungs and removal of gaseous waste in cells occurs in external gas exchange.

Engage in the activity 6.1 to demonstrate external gas exchange

Activity - 6.1

Demonstration of gas exchange using a model

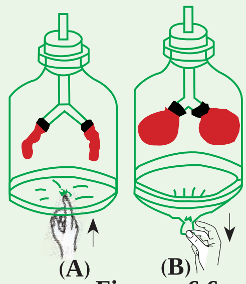


Figure - 6.6

Materials required :- Small bell jar, gas tube, a cork bore, two rubber balloons, balloon membrane or polythene sheath, several rubber bands

Method :- Set the apparatus as shown in the diagram. Push and release the balloon membrane and observe the condition of balloons

When rubber membrane is pulled down in the above activity the volume inside the bell jar increases. Then external gas enters and balloons get inflated. When rubber sheath is released, gas inside balloons go out as the volume of bell jar decreases. Likewise gas exchange between external environment and lungs occurs due to changes of volume of lungs.

The system involved in entering O_2 into lungs and release of gaseous waste products produced during biological processes is the respiratory system.

The diagram 6.7 shows the human respiratory system.

Function of the respiratory system

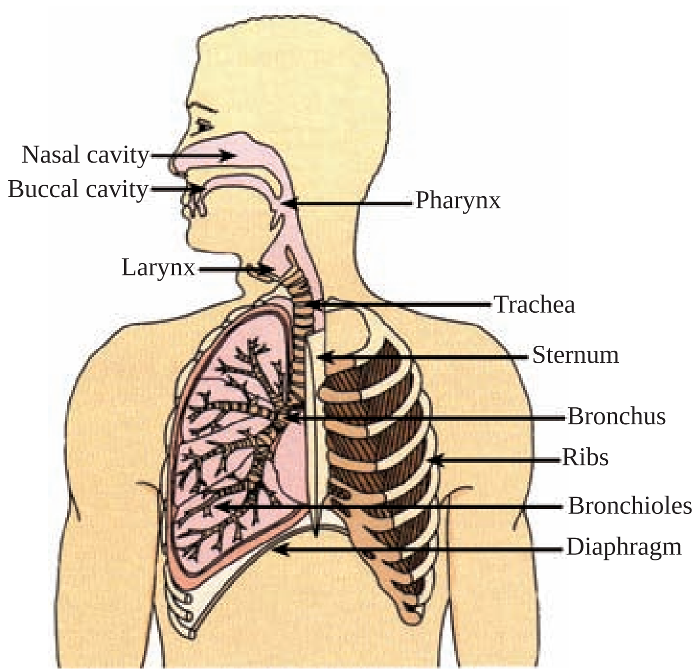


Figure 6.7 - Human respiratory system

Main parts of respiratory system are nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and alveoli. Internal surface of nasal cavity is covered with mucus. Due to the presence of mucus in the nasal cavity, the lining of it is moist. There are numerous cilia present on the lining of the nasal cavity. The bacteria, dust and other wastes found in inhaled air stick onto the mucus. This prevents the entry of them into the lungs. By rhythmic movement of cilia the waste materials are sent out. The materials that are collected at pharynx are removed out with saliva.

The changes that take place when inhaled air passes through the nasal cavity are as follows.

- Moisturizing/ Humidifying inhaled air
- Warming up of inhaled air up to body temperature
- Removal of foreign matter from inhaled air

Lungs are present in thoracic cavity. Thorasic cavity is protected by ribs. Inter - costal muscles are present within ribs. The lower limit of thoracic cavity is the diaphragm. Let's study about the initial activity, in the respirotry system. That is the gas exchange between external environment and lungs.

Inspiration

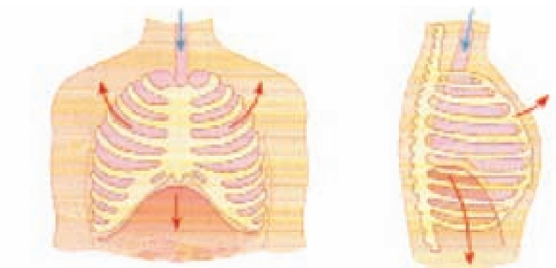


Figure 6.8 - Inspiration

During inspiration, air enters into lungs. For that, the volume of the lungs should increase. To increase the volume of the lungs, volume of the thoracic cavity should be increased. This occurs due to following changes.

Inter-costal muscles contract, therefore ribs move up and sternum moves forward.

At the same time the diaphragm contracts and reduce its curvature. Due to above activities the volume of the thoracic cavity increases and with that volume of lungs increase. So air enter into lungs through the nose.

Expiration

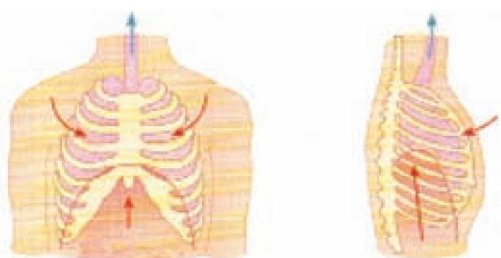


Figure 6.9 - Expiration

For expiration to occur, the volume of the thorasic cavity should decrease to reduce the volume of the lungs.

This occurs due to the following changes.

Inter-costal muscles relax. So the sternum and ribs move into its original position. The diaphragm relax and becomes curved.

Due to these activities the volume of the lungs decreases, thereby gas inside lungs move out through trachea and then nasal cavity.

The gas exchange that takes place in alveoli

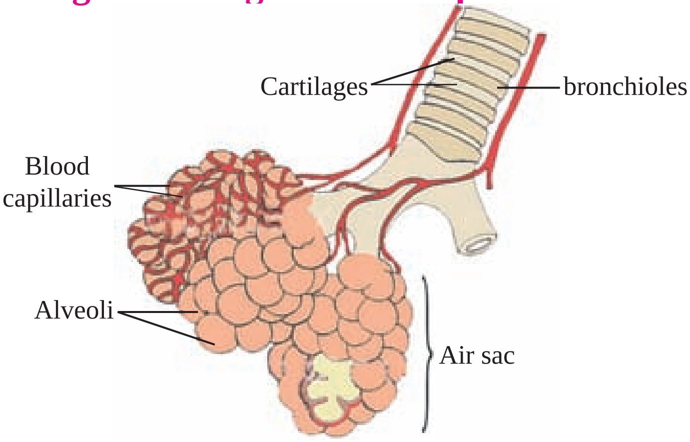


Figure 6.10 - Air, sacs, alveoli and blood capillaries in lungs

The inhaled air finally reach the alveoli, through nasal cavity, trachea, bronchi, and bronchioles. The O_2 concentration in alveoli is greater than that of the blood capillary network around it. Therefore O_2 diffuse out of the alveoli into the blood capillaries. Similarly CO_2 and water vapour concentration is greater in blood capillaries than air inside alveoli, diffuse into the exhaled air.

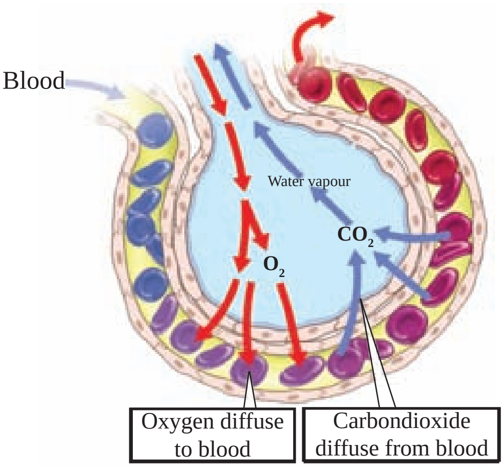


Figure 6.11 - Air exchange between alveoli and blood capillaries

Gas exchange takes place in alveoli and it is shown in the diagram in Fig 6.11. The place where gas exchange between external environment and blood takes place is known as **respiratory surface**. Accordingly, the respiratory surface of human is the **wall of alveoli**. The exchange of gases takes place by **diffusion.**

Characteristics of a respiratory surface

The adaptations of the respiratory surfaces for efficient gas exchange are as follows.

- Surface should be moistened and permeable for gas exchange
- Surface should be thin for diffusion of gases
- A larger surface area to exchange large volume of gas according to the needs of animals
- Surface should be highly vascularized

In many animals, body cover acts as the respiratory surface and gases exchange through the body cover. The respiratory surface of human is the **wall of alveoli** and the adaptations of the alveoli for efficient gas exchange are as follows.

- Thin alveolar wall
- Moist alveolar surface
- Presence of a blood capillary network around alveoli
- Presence of large number of alveolar sacs

Cellular respiration

Oxygen moved through alveoli reacts with simple organic compounds (glucose) in cells. In this chemical reaction energy is released, therefore **respiration is the process of oxidation of simple foods to produce energy for biological activities within living cells.**

Let us build a word equation for respiration

Glucose + Oxygen $\longrightarrow$ Carbon dioxide + Water + Energy

The balanced chemical equation for respiration is given below.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

According to the requirement of oxygen two types of respirations can be identified.

Aerobic respiration and Anaerobic respiration

We discussed the respiration that takes place inside cells in the presence of oxygen. The respiration that takes place in the presence of oxygen is called **aerobic respiration.**

Some organisms can respire without O_2 . Respiration carried out by organisms without O_2 is known as **anaerobic respiration**.

Anaerobic respiration that takes place in plants and yeast cells is known as **alcohol fermentation.** The anaerobic respiration that takes place inside these cells can be given by the following word equation.

Glucose $\longrightarrow$ Carbon dioxide + Ethyl alcohol + Energy

When Yeast carries out anaerobic respiration during fermentation, CO_2 and Ethyl alcohol is produced. This process is an example for alcohol fermentation.

Animals including human cells also perform anaerobic respiration. The anaerobic respiration that takes place within animal cells is referred to as **lactic acid fermentation.** The products of that is given in the equation given below.

Glucose $\longrightarrow$ Lactic acid + Energy

Have you faced an incident of muscle pain and cramp due to an instant activity like 100m race. That is due to lactic acid, accumulated in muscles. That is a result of anaerobic respiration.

Energy produced during aerobic respiration is higher than energy produced during anaerobic respiration. This is because of the incomplete break down of glucose in anaerobic respiration and complete break down of glucose in aerobic respiration.

Energy is produced during anaerobic respiration as well as in aerobic respiration. Part of this energy is lost as heat and rest will be stored in ATP (Adenosine Tri - Phosphate) as chemical energy.

The energy needed for biological processes is released during break down of ATP.

Functions of ATP

- Storage of energy.
- Release of energy.
- Act as an energy carrier.

Extra knowledge

The energy stored in ATP is used for the following requirements

- Movement of muscles
- Active transportation
- Chemical reactions that take place within organisms
- Synthesis of complex compounds from simple compounds (E.g.:- Amino acids $\longrightarrow$ Proteins)
- Production of new cells
- Illumination of some organisms. (E.g.:- firefly)
- Generation of electricity in some organisms (E.g. :- Electric eel)

Diseases associated with respiratory system

- **Common cold**

Causative agent of common cold is a virus. Headache, sneezing, running nose, cough are the symptoms of this disease. There is no medical treatment as it is a viral infection. But can treat for symptoms. By avoiding dust and mist like conditions which are good for viral growth can recover quickly.

- **Pneumonia**

Causative agent of pneumonia is a bacteria or a virus. The lungs are infected and a fluid may accumulate in the lungs. Prolong cold and cough is a reason for pneumonia. It is important to go for immediate medical treatment.

- **Asthma**

Asthma is an inflammation that occurs in the body. Dust, pollen, saw dust, fur, smoke are some causative agents. Due to those substances, the bronchioles get inflammated and the cross area of them are reduced causing difficulty in breathing with a sound.

- **Bronchitis or bronchiolar inflammation**

The bronchioles swell up due to inflammations that occur by viral or bacterial infections. Heavy cough and difficulty in breathing are symptoms. Other than bronchioles, larynx may get infected. As a result, voice may not exit properly.

- **Tuberculosis**

Tuberculosis is caused by a bacterium. Due to multiplication of the particular bacterium within the lungs, the tissues are damaged. Mainly, the lungs are infected. But it may affect other parts of the body. Parts of tissue can be released with phlegm. The lungs are deteriorated and get perforated. Blood release with phlegm due to breakdown of blood vessels.

Symptoms of tuberculosis

- Tiredness
- Loss of appetite
- Weight loss
- Release of blood during coughing
- Fever

It is important to take precautions and vaccines to avoid tuberculosis. Tuberculosis can be cured by proper treatment.

Diseases associated with smoking

Smoking cause, lung cancer, bronchitis and some other diseases. Sometimes it may cause death.

Carbon monoxide (CO) in cigarette smoke is absorbed into blood. CO readily binds with haemoglobin and avoid binding of O_2 with haemoglobin. Therefore carrying capacity of O_2 in blood reduces.

Nicotine found in cigarette smoke increases the heart rate temporally.

Due to destruction of cilia in the respiratory tract, bronchioles may swell up and get inflamed. It may cause difficulty in breathing. As these epithelial cells expose to cigarette smoke, they may form abnormal cells which develop into cancers.

Passive smokers also get same harmful effects due to cigarette smoke.

Silicosis

Workers work in quarries, coal mines and glass industry expose to silicon containing compounds. When these people inhale air with those compounds, they accumulate in alveoli. Then lung tissues get deteriorated gradually. This disease is known as silicosis.

Asbestosis

This disorder occurs due to inhalation of air containing asbestos particles and fibres. Tissues of respiratory tract get destroyed due to accumulation of these particles.

Assignment - 6.3

Collect more information about diseases associated with respiratory system and preventive measures to prepare a small booklet.

6.3 Process of excretion

Summation of bio chemical reactions that take place in the living body is known as **metabolism**

Examples for several metabolic activities are given below

- Production of carbondioxide, water and energy during cellular respiration
- Production of urea, uric acid in protein catabolism in liver

When metabolic processes occur in the cells, necessary as well as unnecessary materials are produced. These unnecessary materials should be removed from the body.

The waste products that are produced during metabolic process are called excretory materials. **Removal of excretory products produced during metabolism from the body is called excretion.**

Different excretory materials, organs through which the excretory materials are excreted and the form of excretion is shown in table 6.2.

Table 6.2 - Different excretory materials

Excretory materials	Excretory organ	Form of Excretion
CO_2 ,Water vapour	Lungs	Exhale air
Urea, Uric acid, Salts, Water	Kidney	Urine
Urea, Uric acid, NaCl, Water	Skin	Sweat

Why faecal matter is not an excretory substance?

Faeces is the undigested materials of the digestion process. Digestion takes place within the digestive system. Digestion of food is not a bio chemical reaction that takes place in the cells. So faeces is not considered as an excretory material. The bile pigments that is released with faeces is an excretory substance.

Urinary System

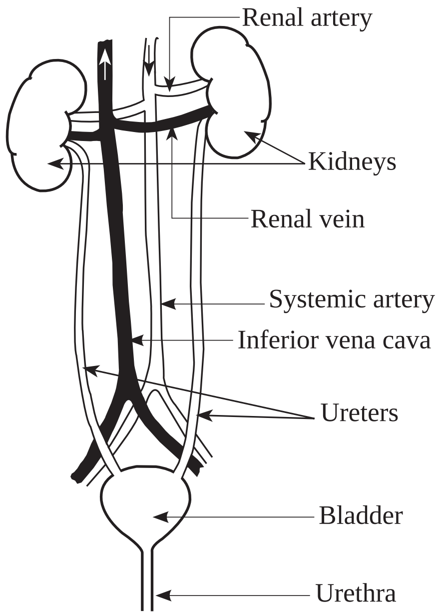


Figure 6.12 - Human urinary system

The main organ that carries out nitrogenous excretion is the kidney.

A pair of kidneys and other organs are organized to form urinary system.

The main parts of the urinary system are as follows

- Pair of kidneys
- Pair of ureters
- Urinary bladder
- Urethra

The waste materials in blood enter through renal arteries are filltered inside the kidney. This filtrate is known as urine and it is transported through ureters and stored temporary in urinary bladder. Next it is released out of the body through urethra.

Activity - 6.2

Observation of internal structure of a kidney

Required materials :- A specimen of a kidney of a goat or a cow or a model of human kidney.

Method :-
- Observe the above specimen carefully (get the assistance from your science teacher)
- Identify the parts of kidney

Parts of a human kidney is shown in figure 6.13.

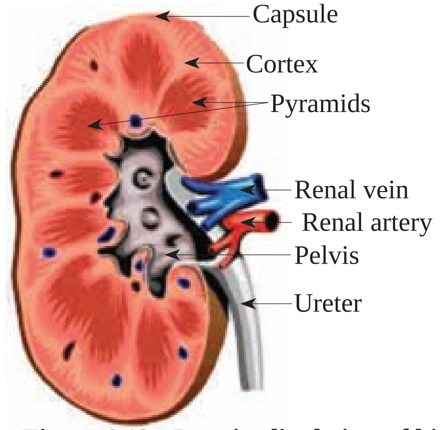


Figure 6.13 - Longitudinal view of kidney

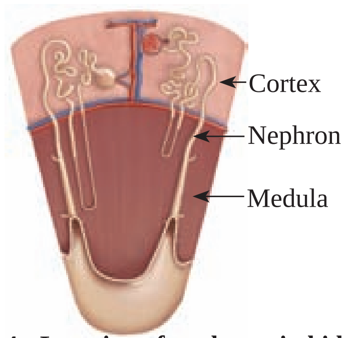


Figure 6.14 - Location of nephrons in kidney

The structural and functional unit of kidney is nephron. Nephron is microscopic and there are about one million of them in a kidney. The parts of a nephron can be identified as in the diagram 6.15.

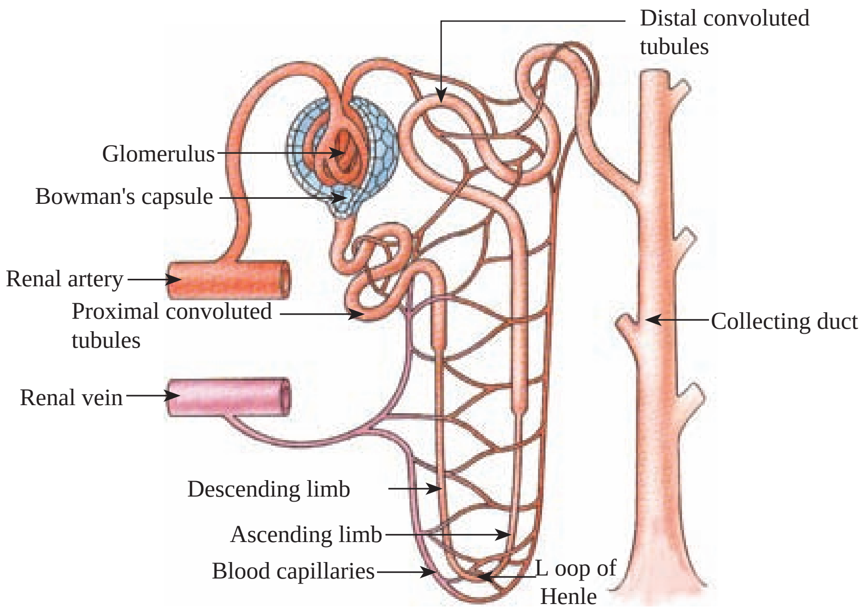


Figure 6.15 - Structure of a nephron

Process of urine formation

Urine formation in kidney follows three main processes,

1. Ultra filtration
2. Selective reabsorption
3. Secretion

Ultrafiltration

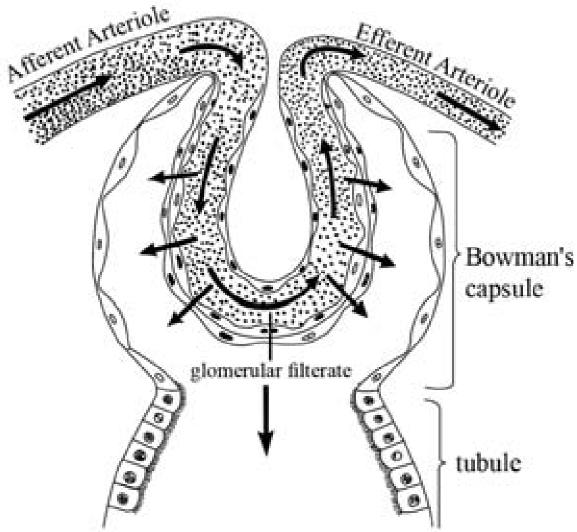


Figure 6.16 - Glomerular filterate collected into the cavity of bowman's capsule

Each afferent arteriole enters into each Bowman's capsule, where they further divide forming a dense network of capillaries. It is known as **glomerulus**. The blood flow through the glomerulus is having a high blood pressure because the diameter of efferent arteriole is smaller than diameter of afferent arteriole. So blood gets filtered through the wall of glomerulus and the inner wall of the bowman's capsule and collected into the cavity of Bowman's capsule. This process is known as **ultrafiltration.** This filtered fluid is referred to as **glomerular filtrate**. Large molecules like plasma proteins and blood cells are not filtered into the glomerular filtrate. Glomerular filterate is as same as blood plasma. The constituents of glomerulur filtrate are water, glucose, amino acids, vitamins, drugs, various ions, hormones and urea.

Selective reabsorption

When glomerular filterate moves along the nephron most of the constituents absorb again into the blood capillaries associated with nephron. This is called **Selective reabsorption**. 90% of the water, all glucose, amino acids and vitamins part of salts, small amount of urea, uric acid and durgs reabsorb into blood. The composition of glomerular filtrate change with selecteve reabsorption. Then the glomerular filtrate is released into collecting ducts and then to the pelvis. The volume of glomerular filterate formed during one minute in a healthy adult is about 120 cm^3. But 95% of the glomerular filtrate reabsorb when it moves along the nephron.

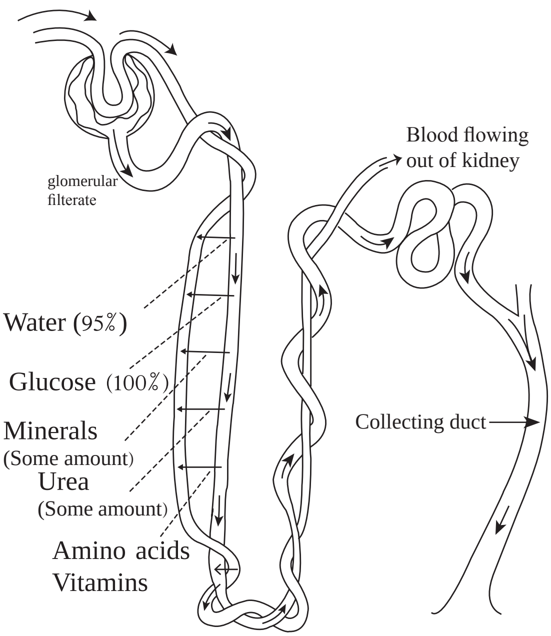


Figure 6.17 - Materials reaborsobed during urine formation

100% of glucose is reabsorbed in a healthy adult. But in diabetes patients glucose is not totally reabsorbed. The remaining glucose is released with urine.

Secretion

Some of the materials in the blood capillaries associated with nephron enter the tubules of nephron. This process is known as secretion.

E.g :- Hydrogen ions (H^+), Potasium ions (K^+), Ammonium ions (NH_4^+), Creatinine, drugs, Vitamin B

Removal of urine from the body

Urine released into the pelvis is transported along ureters into bladder and is temporally stored in bladder. Release of urine takes place according to the need of urination.

The composition of urine in a healthy person is given below in the table 6.3

Table **6.3 - Composition of urine in a healthy person**

Constituent	Composition
Water	About 96%
Salts	About 2%
Urea	About 2%
Uric acid	Trace
Creatinine	Trace

Diseases associated with urinary system

Assignment 6.4

Write a report on diseases associated with urinary system to make aware the society about them.

Let us discuss some of the diseases associated with urinary system.

Renal failure

Kidneys fail to function due to the weakening of urine filteration process in nephrons. Infections by microoganisms, heavy metals (mercury, arsenic) various medicine and carbon tetrachloride (CCl_4) may cause renal failure. The basic symptom is oedema and increase of blood pressure due to accumulation of water and salts. pH of blood decreases due to accumulation of urea and other excretory materials. By taking immediate treatments and healthy life style one can maintain a healthy kidney. If treatments are not taken immediately after the symptoms, **acute renal failure** may occur within 8-14 days. Then blood is filtered by a machine in a process called **dialysis**. When both kidneys are failed, a healthy kidney from a donor should be transplanted.

Nephritis

Nephritis or swelling of kidney occurs due to infections and toxins. Infections in ureters and other changes that occur in the body are reasons for nephritis. During nephritis, it affects glomerulus and also uriniferous tubules. Due to damages occur in glomerulus, the volume of blood flow through it, reduces. So the amount of urine formed also reduces. Therefore the waste materials remaining within the body become high. Sometimes due to damages that occur in glomerules, filtering process is affected and as a result, red blood cells can be passed into the glomerular filtrate. Similarly proteins also can be filtered and due to loss of these essential proteins, strokes may occur. Medical advice should be taken immediately for this condition.

Calculi in kidney and bladder

Crystalization of calcium oxalate in kidney and bladder is the reason for this condition. When these stones block ureters, severe pain would occur. Removal of these stones can be done by drugs or a surgery.

These stones can be crushed by applying laser rays / ultra sound waves, and this technique is called Lithotripsy technology.

The feeding habit of a person is also a reason for these stones. Postponing of urination is also a reason for the above disorder. Drinking of required volume of water daily is helpful to avoid this condition.

6.4 Process of blood circulation

Glucose and oxygen are the main components to produce energy in the body. Blood is the transport medium of both the above components to the cells and the waste out of the cells.

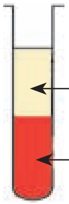


Figure 6.18 - Blood corpuscles and plasma

Blood is a special connective tissue. It is a red colour fluid. When blood is centrifuged and kept aside, there will be two different layers. The dark red layer consists of blood corpuscles while the pale yellow layer contains the plasma. On this basis, blood which is seen as a homogeneous fluid, contains a plasma and a suspension of corpuscles. When a slide with a blood smear observed through the microscope there will be several types of corpuscles in it.

- Blood
  - Corpuscles
    - Red Blood cells
    - White Blood cells
      - Granulocytes
        - Neutrophils
        - Eosinophils
        - Basophils
      - Non-granulocytes
        - Lymphocytes
        - Monocytes
    - Platelets
  - Plasma

Red Blood cells (Erythrocytes)

Figure 6.19 - Red blood cells under electron microscope

One cubic millimetre of human blood contain about five million of red blood cells. These red coloured and biconcave disc-like cells are clearly visible among the other corpuscles. They form in red bone marrow. The life span of RBC is about four months (120 days). Absence of nucleus in red blood cells provides a large surface area to absorb more oxygen. A pigment called haemoglobin is present in red blood cells. Haemoglobin binds with oxygen and form oxyhaemoglobin to transport oxygen to cells.

White Blood cells (WBC)

A type of corpuscle, larger than the size of red blood cells, but smaller in number is present in blood. They are with nuclei and form in bone marrow. They are colourless and known as white blood cells. The ratio between red blood cells to white blood cells is 600:1

Two Types of WBC present in blood

- Granulocytes
- Non-granulocytes

Granulocytes are further divided into three types,

- Neutrophils
- Eosinophils
- Basophils

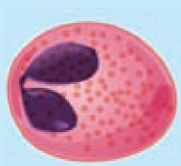
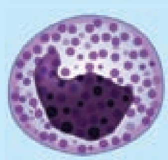
Non-granulocytes are in two types,

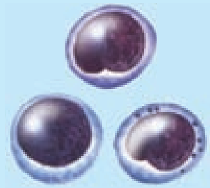
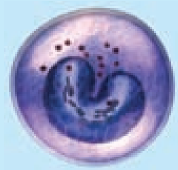
- Lymphocytes
- Monocytes

One cubic millimeter (1 mm^3) of human blood contains 4 000 - 11 000 number of WBC.

The following table shows the percentages of WBC in a healthy person.

Table **6.4 - Percentages of WBC in a healthy person**

Type of corpuscle	Variety and morphology	Percentage %
Granulocytes	Neutrophils 	50 - 70
	Eosinophils 	1 - 4
	Basophils 	0 - 1

Non-granulocytes	Lymphocytes 	20 - 40
	Monocytes 	2 - 8

WBC destroy infectious particles that enter the body by phagocytosis. Therefore percentages of WBC increase above the normal levels in microbial infections. Investigation of WBC counts in blood helps to diagnose diseases.

The function of WBC is to protect the body from infectious particles that enter the body. This is done by **phagocytosis** and by producing **antibodies**.

Platelets

In addition to RBC and WBC there are fragments of cells that cannot be considered as cells in human blood. These corpuscles without nuclei are known as platelets. One cubic milimetre of blood contains 150 000-400 000 platelets. They form in bone marrow. Life span of platelets is approximately 5-7 days. Due to diseases like Dengue and Leptospirosis, platelet count drops drastically. Platelets contain thromboplastin which help in coagulation of blood.

Blood plasma

92% of blood plasma is water. Other than water the second most abundant compound is protein. Nutrients, nitrogenous waste, hormones, enzymes, gases and ions are present in blood plasma.

Blood Plasma

Water

protein
- Albumen
- Globulin
- Fibrinogen

Nutrients
- Monosaccharides
- Amino acids
- Fatty acids
- Glycerol
- Vitamin

Ions
- Na^+
- K^+
- Ca^{2+}
- Mg^{2+}
- Cl^-
- PO_4^{3-}
- SO_4^{2-}
- HCO_3^-

Nitrogenous byproducts
- Urea
- Uric acid
- Creatinine

Gases
- O_2
- CO_2
- N_2

Hormones

Anibodies

Antigens

Function of blood

- Transportation of materials (digested end products, respiratory gases, excretory byproducts, hormones, mineral ions and proteins)
- Protect body against pathogenic microbes by phagocytosis and by producing antibodies.
- Maintenance of chemical coordination and homeostatis among tissues and organs

Blood Circulation

Do the activity 6.3 to observe blood circulation in capillaries.

Activity - 6.3

Observation of blood circulation in blood capillaries

Materials required:- A small live fish or tadpole, A glass slide, Wet cotton, A microscope

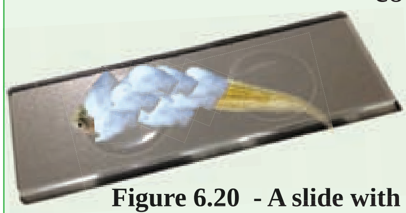


Figure 6.20 - A slide with a tadpole

Method :-

- Place the small live fish or tadpole on the slide and cover the gills with wet cotton
- Observe the blood capillaries in tail area through light microscope
- Change the specimen in 10 minutes time to keep it live

You have observed the flow of blood within the blood vessels in the above activity. The force generated by the heart helps to distribute blood through the body. Carry out Activity 6.4 to understand the structure of the heart.

Activity - 6.4

Observe the structure of the heart

Materials required:- A specimen or a model of a heart

Method :-

- Observe the external structure of the heart
- Observe its internal chambers, connected arteries and veins, bicuspid and tricuspid valves.
- Observe that the atrial walls are thinner than ventricular walls and the thickest wall in the left ventricle.
- Use the diagram 6.21 to identify the parts.

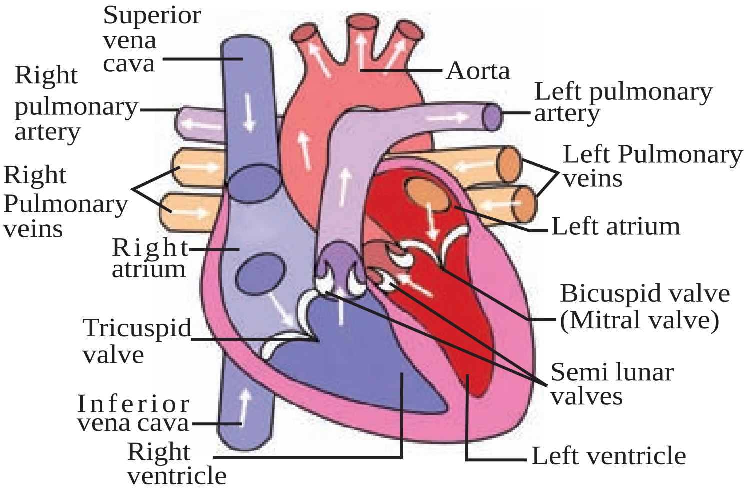


Figure 6.21 - A longitudinal section of the human heart

Arterial system consists of all the arteries in the blood circulatory system. It transports oxygenated blood. But pulmonary artery transports deoxygenated blood to the lungs. Venous system consists of all the veins in the blood circulatory system. It transports deoxygenated blood. But pulmonary veins transport oxygenated blood from lungs to the left atrium. The two systems are shown in figure 6.22

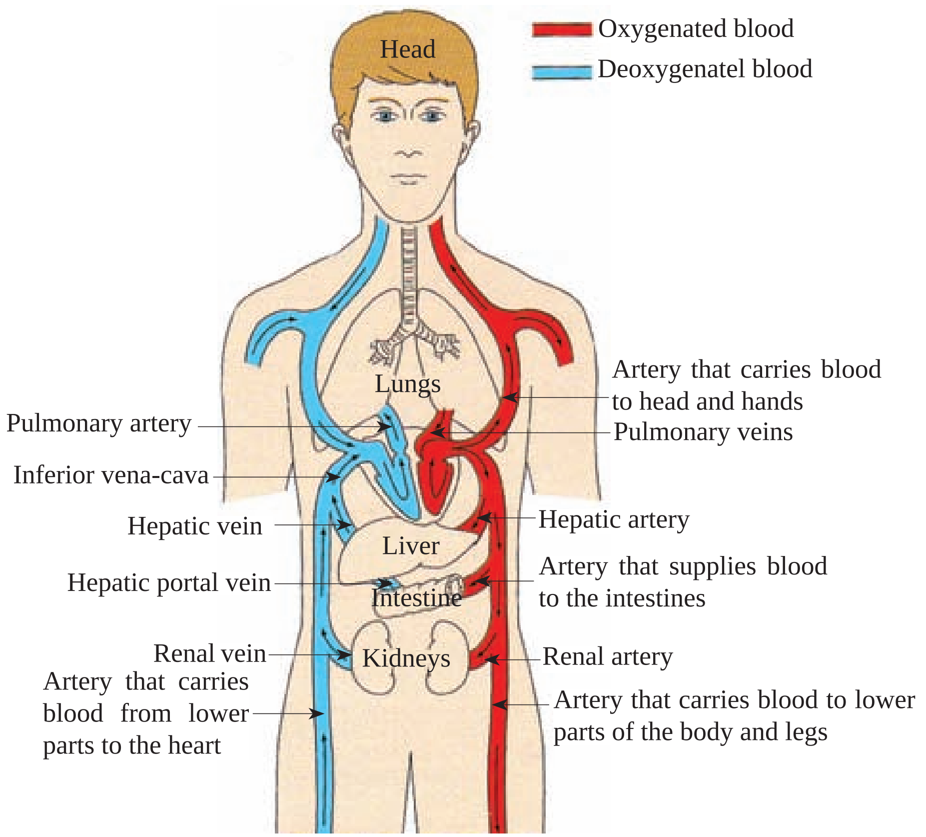


Figure 6.22 - Blood circulation of human

Double blood circulation

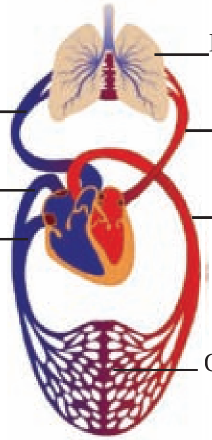


Figure 6.23 - Double circulation

The circulation where blood flows through lungs is known as **pulmonary circulation.** The circulation where blood flows through the rest of other organs is known as **systemic circulation.** Right ventricle of the heart acts as the pump for the pulmonary circulation, and left ventricle for the systemic circulation. So it is clear that blood flows twice through heart before entering into systemic artery. In human, when the blood circulates once through the body it flows twice through the heart. This is called as **double circulation.**

Heart beat

Atria and Ventricles of heart contract to pump blood out of the heart. These contractions and dilations of heart muscle are known as **heart beat**. The heart beat rate of a healthy person at rest, is 72 beats per minute. Pulse rate is also similar to heart beat rate.

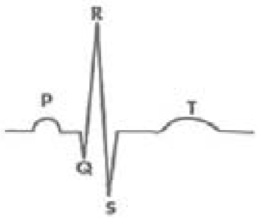
Cardiac cycle

In one heart beat atria contract when ventricles dilate. Next ventricles contract, atria dilate. Contraction of atria is known as **diastole** (0.1 seconds) whereas contraction of ventricles is known as **systole** (0.3 seconds). After that atria and ventricles are in relax mode and it is known as **intervening** (0.4 seconds).

Cardiac cycle refers to a complete heart beat from its generation to the beginning of the next beat. The stages of cardiac cycle are as follows;

1) Diastole - Atrial contraction
2) Systole - Ventricular contraction
3) Intervening - Atrial and Ventricular relaxation (complete cardiac diastole)

Electro cardio gram (E.C.G) is used to get information about heart function. This tracing denote the potential changes take place in cardiac muscle cells during heart function. Three stages of cardiac cycle can be identified in ECG (Figure 6.24).



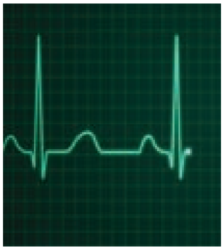


Figure 6.24 - Electro cardio gram of a healthy person

P - Atrial contraction
QRS - Ventricular contraction
T - Intervening

ECG wave patterns deviate from normal patterns due to dysfunction of heart. **Lub - Dup** sound in heart beat can be heard by keeping ear or stethoscope on chest. Lub sound is longer than Dup sound. Lub sound is produced when bicuspid and tricuspid valves close in atrial contraction. Next produce Dup sound and it is shorter. This Dup sound is resulted when semi lunar valves close.

Blood pressure

When heart beats, it contracts and pushes blood through the arteries to the rest of the body. This force creates pressure on the ateries. This is called **systolic blood pressure.**

Figure 6.25 - Measuring of blood pressure

Normal systolic blood pressure is 110-120 mmHg. **Diastolic blood pressure** is the pressure in the arteries when heart rests between beats. A normal diastolic blood pressure is between 70-80 mmHg. Blood pressure is measured in millimeters of mercury (mmHg).

Normal resting blood pressure is mentioned as follows

Blood pressure (B.P) = 120/80 mm Hg

Ageing, sex, stressful mentality, diseases of a human are the factors that can increase blood pressure.

Another transportation system closely linked with blood circulatory system is present in human body and it is known as Lymphatic system.

Lymphatic system

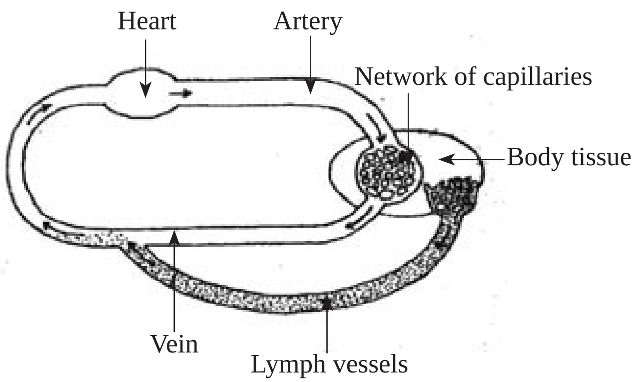


Figure 6.26 - Relationship between blood circulation and lymph circulation

Blood capillaries transport blood through cells in the tissues. Blood capillary walls are very thin but only WBC and blood plasma can move through the capillary wall. RBC and some plasma proteins cannot move through capillary wall. This fluid moved to tissue is known as **tissue fluid**. Materials exchanged within somatic cells and blood occurs through this tissue fluid.

Part of tissue fluid is absorbed back to capillaries. Excess tissue fluid within intercellular spaces connect with blood circulatory system through a special tubular system known as **lymphatic system**.

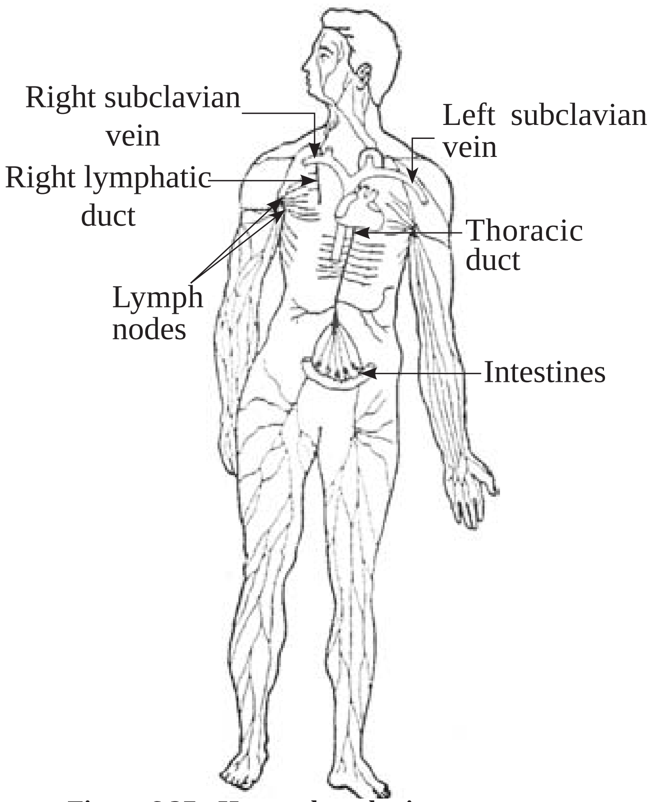


Figure 6.27 - Human lymphatic system

The tissue fluid flowing in the lymphatics is called **lymph.**

Lymphatic system consists of **lacteals**, **Lymph capillaries** and **lymph nodes**. Lymph is flowing due to pressure caused by muscles around lymph vessels. All the lymph vessels in the body form two main vessels. They are,**Thoracic duct** and **right lymphatic duct**. Thoracic duct empties lymph to left subclavian vein. Right lymphatic duct empties lymph to right sublavian vein and then to the venous circulation at last.

Main function of lymphatic system is destruction of infectious organisms like bacteria. WBC in lymph nodes destroy them by phagocytosis. Then these lymph nodes become more active and swollen (Kuddeti). Lymph nodes can be found mostly around liver, heart, intestines, skin, arm pits and throat.

Diseases associcted with blood circulatory system

Assignment 6.5

Prepare a booklet about diseases associated with blood circulatory system and preventive measures to control them. Collect information about following disorders and compare them with given facts.

- Artherosclerosis
- Heart attack
- Hypertension
- Thrombosis

Artherosclerosis

Cholesterol is an essential lipid compound produced by the liver. As cholesterol is insoluble in water it is transported as lipo proteins by combining with proteins. Lipo proteins are of two types. Low density lipo proteins (**LDL**) and High density lipo proteins (**HDL**). Excessive amount of low density lipo proteins deposit in coronary arteries and other arteries. Thereby the size of the lumen in arteries reduces. The lipid deposits like this in arteries are called Atheroma and the condition that occur is called Artherosclerosis.

Due to blocking of coronary arteries, the blood supply to heart is affected. Some parts of the cardiac muscle will be failed to function causing **angina** (Chest pain). Due to blockage of coronary arteries the region of the cardiac muscle will not receive blood and that region is failed. This condition is called heart failure.

The reason to increase LDL is consumption of food containing high amount of saturated fatty acids (beef, pork, mutton, full cream milk, egg yolk, prawns, and liver). By controlling such food types and regular exercises can control artherosclerosis.

Hypertension and hypotension

Due to deposition of cholesterol inside arteries, the size of the lumen reduces. Therefore blood supply to different organs get lowered. So to supply required amount of blood, heart has to exert more pressure. The higher pressure exerted onto the arterial wall is called hypertension pressure. Reduction of elasticity of the artery or arteriole wall also a reason for hypotension.

Reduction of consumption of saturated fatty acid is important to control this condition. One has to avoid smoking, consumption of alcohol, mental stress, obesity to control hypertension.

Hypotension is the low blood pressure. The blood become less than the normal. Low blood pressure occurs mostly due to nutrient deficiencies. During this condition one has to get treatments to increase blood pressure to normal quickly.

Thrombosis

When blood supply to a certain organ is affected due to a blood clot in a blood vessel is called thrombosis. If blood supply to a part of the brain is affected due to a blood clot, the organs that are controlled by that part of the brain fail. This condition is normally called **paralysis**. If the function of heart is affected due to a blood clot in the coronary artery it is called **coronary thrombosis**. Due to this, **heart attack** may occur.

Thrombosis can be controlled by steps taken from child hood. They are as follows,

- Avoiding alcohol and smoking
- Reduction of consumption of food containing saturated fatty acids.
- Consumption of food with more fibre
- Reduce salt consumption
- Reduce body weight by proper food habits
- Regular physical exercises
- Peaceful mental status

If there is a record about heart attacks, hypertension, diabetes in family history, one has to be more careful about this condition.

6.5 Coordination and homeostasis in human

Do you remember taking away your leg, when a thorn pricks your foot? This action has taken place as living beings have the ability to respond to stimuli coming from external and internal environments. That is known as irritability.

Above response is due to **adaptation of body according to the changes of external and internal environments.** That is called **coordination**. The change that takes place in the external environment which is detectable by the sensory organs is called a **stimulus.** The organs that can detect (sense) the stimuli are called sensory organs (receptors). Eye, nose, ear, tongue and skin act as sensory organs.

Assignment - 6.6

Complete the table using different receptor organs and the stimulus that can be detected.

Sensory organ	Stimulus that is detected
Eye	Light energy
Ear	....
Nose	....
Tongue	....
Skin	....

The reaction for a stimulus is known as a **response**. The response is done by effectors. Muscles and glands act as effectors.

Recall the incident about the thorn prick. Touch due to the thorn prick on the leg is the stimulus. The receptor of that stimulus is the skin. Taking the foot away is the response to that stimulus. Responding is done using muscles of the foot and that is the effector.

Assignment - 6.7

When you sense smell of tasty food, saliva is secreted into the mouth. State the stimulus, sensory organ, response and effector in this action.

You will understand that there should be a proper communication between organs/ tissues to carry out body functions smoothly. Identification of the changes in the external and internal environments and responding accordingly is done by the coordination.

For coordination, two inter connected but different systems present in the human body.

- Nervous system
- Endocrine system

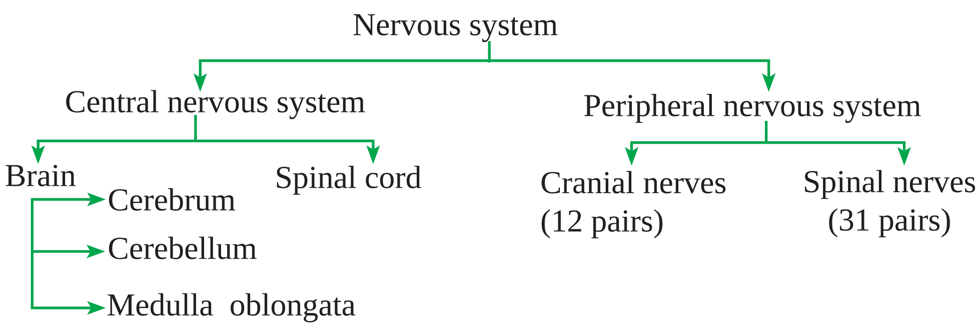
The coordination done by nervous system, is called nervous coordination, and coordination by endocrine system is called chemical coordination. In nervous coordination, impulses transmit through nerves and these impulses aim at a specific effector. In chemical coordination hormones secrete to blood and according to the concentration of hormone the particular effector respond to it.

Nervous coordination

Due to an electro chemical change in the nerves, impulses are transmitted through nerves. A proper coordination is maintained between the receptor and the effector. The nervous coordination takes place with the involvement of the nervous system. **The structural unit of the nervous system is the neuron.** There are three types of neurons in the nervous system.

- Sensory neuron
- Motor neuron
- Inter neuron

The nervous system is mainly composed of two components. They are the central nervous system and peripheral nervous system. The structure of it can be shown by the following simplified diagram.



Central nervous system

Central nervous system is very important in controlling of activities and coordination. Brain and spinal cord belong to central nervous system. Skull provides protection to the brain. Vertebral column provides protection to the spinal cord.
Brain and spinal cord are covered by meninges. There is a special fluid found within the cavities of brain and between meninges. It is known as cerebro spinal fluid. The functions of cerebro spinal fluid are given below,

- Support bouncy to brain and spinal cord
- Absorption of shocks and jerks
- Protection against microbial infections and desiccation
- Protect from temperature fluctuations.

• Brain

Brain is protected by the cranium and surrounded by three linings called meninges. The brain is about 1/50 of the body weight. There are about hundred billion of neurons. Other than neurons another accessory cells called neuroglia are present in brain. The brain is composed of three main parts, as Cerebrum, Cerebellum and Medulla oblongata. (Figure 6.28)

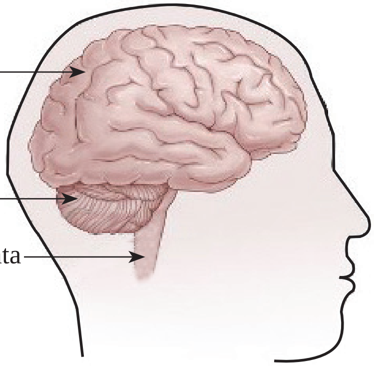


Figure 6.28 - External view of human brain

The peripheral region of the brain is composed of **grey matter** made up of cell bodies and the interior with **white matter** due to myelin sheath made up of nerve fibres.

Assignment - 6.5

Observation of parts of brain

Take a model / live specimen of a mammalian brain and identify the parts of it with the guidance of the teacher.

Cerebrum

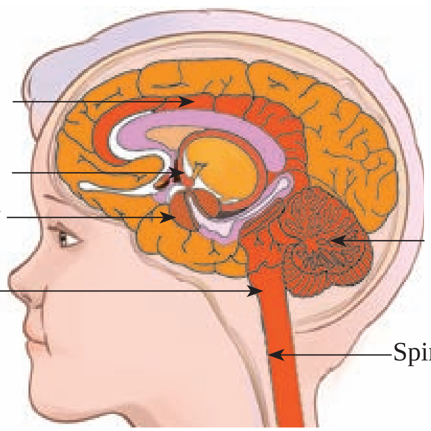


Figure 6.29 - Longitudinal section of human brain

Cerebrum is the largest and most highly developed part of the brain. It is divided into left and right hemispheres. The cortex of the cerebrum is highly convoluted to increase the surface area. The left cerebral hemisphere controls the right half of the body and the right cerebral hemisphere controls the left part of the body.

Functions of cerebrum

- Perception of impulses from receptors, identification of received sensory information and storage of those information.
- Perception of senses about vision, taste, smell, hearing, pain and temperature
- Perform high mental activities such as learning, intelligence and thinking.
- Controlling of voluntary muscle contraction.

Cerebellum

This is located just below the latter part of the cerebrum. It consists of two hemispheres. It is of grey matter in the outer layer and white matter in the interior layer.

Functions of cerebellum

- Maintenance of body balance
- Control of voluntary muscle activity
- Involve in maintenance of body movement

Medulla oblongata

It is located anteriorly interior to cerebellum. It is an important centre in controlling many life processes.

Functions of medulla oblongata

- Control involuntary actions such as rate of heart beat and rate of respiration
- Control reflex actions such as vomiting, coughing and swallowing.

• Spinal cord

It is a tubular structure starting from medulla oblongata inferiorly and runs through vertebral column. Peripherally **white matter** and interiorly **grey matter** is present in the spinal cord. The spinal nerves start symmetrically at either side of the spinal cord.

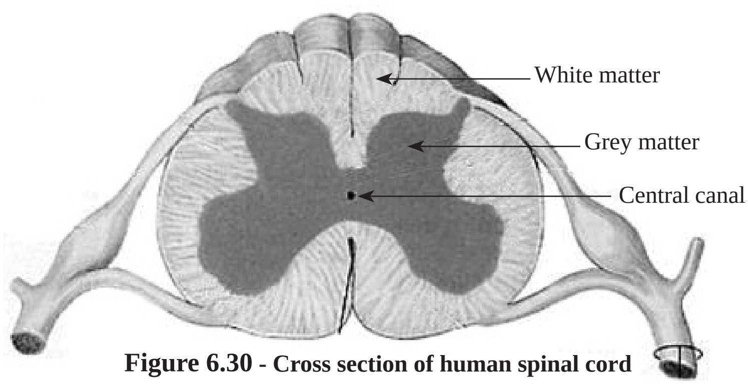


Figure 6.30 - Cross section of human spinal cord

Reflex arc

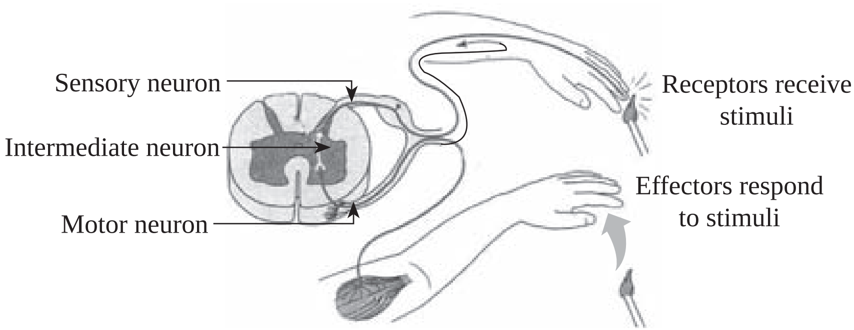


Figure 6.31 - Reflex arc

Stimulation of the pain receptors in the skin $\xrightarrow{\text{Sensory Neuron}}$ Spinal cord (Inter neuron) $\xrightarrow{\text{Motor Neuron}}$ Effector (Muscles of leg)

We know that there is a proper coordination maintained by nervous system between the receptors and effectors in the body. The impulses are sent from receptors to the central nervous system and from central nervous system into the effectors. The **functional unit of the nervous system** that maintains the coordination is called the **reflex arc**.

Three types of nerve cells involve in a reflex arc. They are sensory neuron, inter neuron and motor neuron. The reflex actions take place with the involvement of the reflex arc.

Reflex actions

A sudden, involuntary response to a particular stimulus is called a **reflex action**. They take place without the consciousness of the involvement of the brain.
The reflex actions are of two types as, **spinal reflexes** and **cranial reflexes**.

Examples for spinal reflexes

- Moving the hand away when it contacts with a hot surface
- Lifting the leg when you step on a thorn

Examples for cranial reflexes

- Sneezing
- Salivation
- Blinking eyelids

Assignment - 6.8

State the reflexes you encounter in day today life

Autonomic nervous system

The nervous supply from the autonomic nervous system is to the internal organs of the body which are involuntarily controlled. This nervous system coordinates involuntary activities in the body.

The coordinating centres of the autonomic nervous system are hypothalamus and medulla oblongata. The autonomic nervous system is composed of two parts.

- Sympathetic nervous system
- Parasympathetic nervous system

The sympathetic and parasympathetic nervous systems cause opposite effects. The sympathetic system activates when a person is at emergency. It causes fight or flight effects.

Figure 6.32 - Fight or flight effect caused by sympathetic system

The changes that occur due to the activities of sympathetic system, will be neutralised by the parasympathetic system.

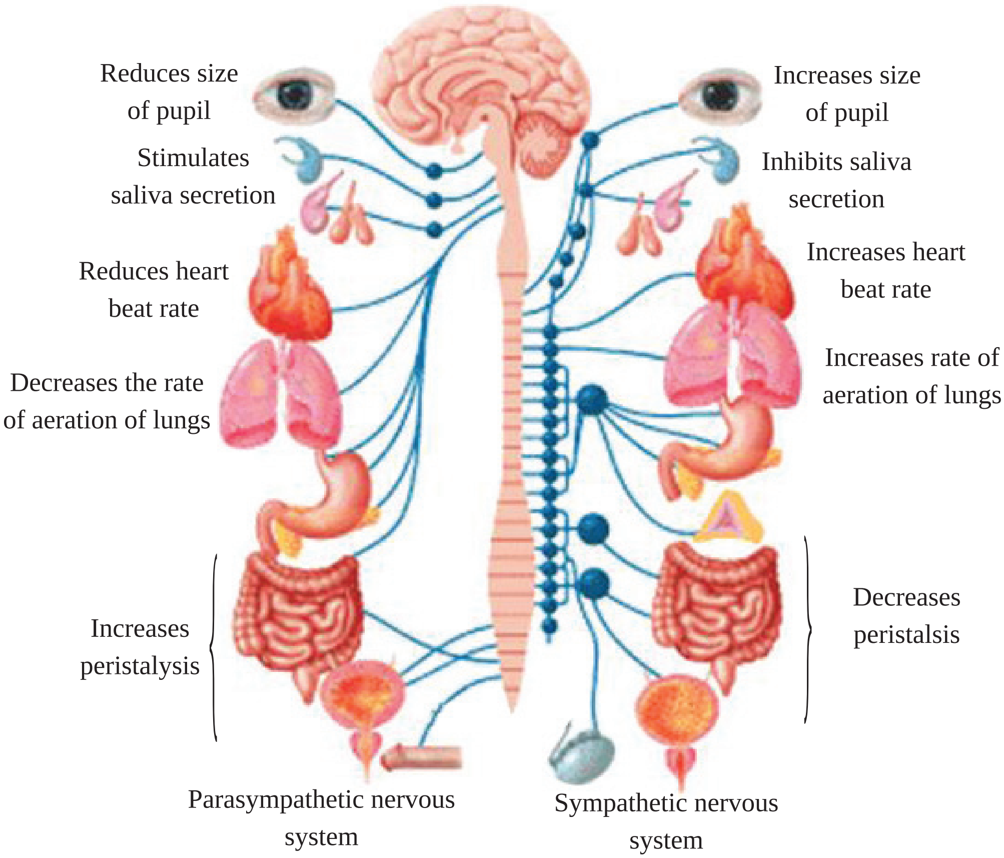


Figure 6.33 - Parasympathetic and sympathetic nervous supply on body organs

Chemical co-ordination

Chemical co-ordination is also important as nervous co-ordination to the survival of organism. Hormones secreted by endocrine glands are used in chemical co-ordination. Endocrine glands or ductless glands secrete hormones, directly into blood stream. So hormones are transported through blood.

Features of hormones

- Hormones are organic compounds
- They are transported through blood
- Produced at one site and act on another site
- Stimulate target organs or target cells
- Small concentration is required

The endocrine glands of human body

There are several endocrine glands located in human body. (Figure 6.34) The main endocrine glands are mentioned below.

- Pituitary
- Thyroid
- Pancreas
- Adrenal gland
- Gonads (testes and ovaries)

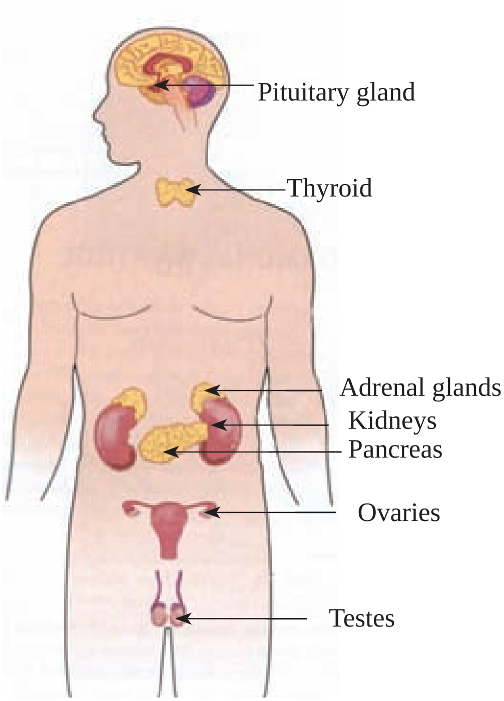


Figure 6.34 - Location of endocrine glands in human body

The facts of several hormones are given in table 6.5.

Table 6.5 - Several hormones secreted by endocrine glands of human

Gland	Location of gland	Hormone	Utility
Pituitary	Below the hypothalamus in the cerebrum	Growth hormone	Increase protein synthesis. Growth of ordinary body tissues. Growth of long bones.
Thyroid	Posterior to tracheal and dorsal part of neck	Calcitonin Thyroxin	Reduce calcium level in blood. Control metabolic rate
Pancreas	In the bend of duodenum between stomach and large intestine	Insulin Glucogen	Convert glucose into glycogen Convert glycogen into glucose
Adrenal glands	On the surface of kidneys	Adrenaline	Prepare body to activate in an emergency

Testes	Outside the abdominal region in testes.	Testosterone	Development of secondary sexual Characteristics in boys Induces Spermatogenesis
Ovaries	Below the kidneys	Oestrogen Progesterone	Development of secondary sexual Characteristics in girls Maintenance of pregnancy and menstrual cycle

Homeostasis

Maintenance of constant internal environment is called homoeostasis.

The **internal environment** is the immediate surrounding of the cell which provides medium for the cell to survive. The **tissue fluid** around cells, the **plasma around blood cells and lymph** are included into the internal environment.

When internal environment is constant, the conditions inside cells is also constant. If there is a small change in the internal environment it highly affects the cellular activities. Therefore the internal environment should maintain stable conditions or within a narrow range, which can be tolerated by the cells. If not, automatic control system will be active with feedback mechanisms.

The factors in the internal environment that has to be regulated

- Blood glucose level
- Body temperature
- Water balance

Regulation of blood glucose level

Blood glucose level of a healthy adult is 80-120 mg/100 ml of blood. When blood glucose level is greater than the normal level beta cells in islets of langerhans in pancreas secrete more insulin. This hormone converts glucose into glycogen and then glycogen store in liver. Further excess glucose is converted to fat and stored in adipose tissue.

When blood glucose level is less than normal (when a person is starving) alpha cells in islets of langerhans in pancreas are stimulated to secrete more glucogen. This glucogen acts on glycogen stored in liver to convert it into glucose and release into blood. The blood glucose level will be increased to normal level.
Due to the activities of insulin and glucogen, blood glucose level is regulated. Due to absence of beta cells or secretion of insulin will cause diabetes.

Regulation of body temperature

Human is a homoithermic organism. Homoithermic means maintenance of constant body temperature irrespective to the fluctuations of temperature in the environment. Normal body temperature of human is 37 ^{0}C. But it can vary from 36 ^{0}C to 37.5 ^{0}C.

Thermo regulatory centre of the human is present in the hypothalamus of the brain. When environmental temperature drops to avoid the decrease of body temperature, hypothalamus stimulates and carries out the activities below.

- Reduce blood supply to skin to reduce heat loss, by contracting blood capillaries in the skin.
- Reduce production of sweat in sweat glands and reduce heat loss.
- The hairs become erect and trap an air layer to act as a heat insulating layer.
- If the heat loss is high, heat is generated by shivering.

When temperature of the internal environment increases, to prevent the increase of body temperature, the hypothalamus stimulates to activate the processes as follows,

- Dilate blood vessels in the skin and thereby increase blood supply to skin and increase heat loss.
- Increase sweat production by sweat glands. When sweat is evaporated heat is absorbed by body and decrease body temperature.

Regulation of body temperature is done by the hypothalamus.

Regulation of water balance

When the water level of blood drops, pituitary secretes ADH (Antidiuresis hormone). This ADH acts on kidney to increase reabsorption of water, thereby reduce the amount of water released with urine.
When water level in blood is high, the reabsorption of water decreases and the amount of water released with urine increases.

Accordingly water balance in the body is regulated.

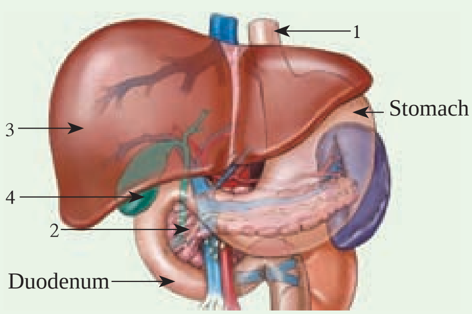
Summary

- Digestion, respiration, blood circulation, excretion and coordination are several biological processes that take place in human body.
- Food digestion is the process by which the complex organic compounds are converted into simple organic products which get absorbed into the human body.
- Enzymes are important in food digestion. Glucose from carbohydrates, fatty acids and glycerol from lipids and amino acids from protein are the end products of food digestion.
- Bile helps to emulsify lipids in lipid digestion.
- Several medicine, vitamins, alcohol and glucose are some of the materials absorbed directly into blood, without digestion.
- Respiration is the process of oxidation of simple foods within living cells.
- Respiratory system involves in taking oxygen into lungs and release of gaseous waste products out of lungs.
- Part of energy produced during anaerobic and aerobic respiration is lost as heat and rest will be deposited in ATP as chemical energy.
- Excretion is the removal of excretory products, produced during metabolism.
- Kidneys, skin and lungs are the organs which carry out excretion of human.
- The functional and the structural unit of kidney is nephon. The excretory materials produced in nephrons is referred to as urine.
- Urinary system is the anatomical system which involves in the production and removal of urine from the body.
- Circulating substances in the body and protecting the body from micro orgamisms are the function of the blood circulatory system.
- Blood is composed of blood cells and plasma
- Heart functions as a pumping machine of the blood circulatory system. It is a double circulation which consists of the systemic and pulmonary circulation.
- The diastole, the systole and the intervening phase are the three major stages of a cardiac cycle.

- In the lymphatic system, places where lymphatic vessels aggregate are called lymph nodes. Germs that enter the body are destroyed within the lymph nodes.
- Maintaining proper balance between stimulus and response is called as coordination.
- The nervous system and the endocrine system involve in maintaining coordination.
- The structural unit of the nervous system is the neuron where as the functional unit of nervous system is reflex arc.
- Brain and spinal cord belong to central nervous system.
- Reflex arc consists of motor neuron, sensory neuron and inter neuron.
- Autonomic nervous system is important to control involuntary body functions.
- Autonomic nervous system is organized to control opposite actions via sympathetic and parasympathetic nervous systems.
- Hormones which are secreted to the blood from the glands regulate the chemical coordination of the body.
- Homeostasis is the maintenance of a constant internal environment free from the changes in the external environment.
- Regulating blood glucose, body temperature and water balance is important in homeostasis.

Excercise

(1)



A part of the human digestive system is shown in the figure. Answer the questions raised on it.

I. Name the parts 1, 2, 3, 4

II. In the food that reaches stomach

a) Name one enzyme that could be present in it.

b) Name a product of digestion that could be present in it.

III. a) Name two enzymes which are added to the food in the stomach.

b) Proteins are digested partially in the stomach. Explain this using the changes that occur in proteins.

IV. a) Name the enzymes which are in the digestive juice/ fluid secreted by the organ No 2 to duodenum.

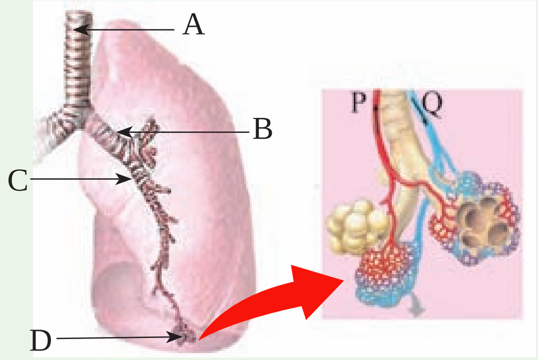
b) Name two secretions that influence lipid digestion.

c) Name the organs from which they are secreted.

V. Gastritis is a common disease of the digestive system. State three reasons for this disease

VI. Why protein digestive enzymes do not digest the wall of the digestive system.

(2)



An organ which is related to the respiratory process and its internal structure is shown in the figures.

a) Answer the following questions.

i). Name the parts A, B, C, D

ii). What is the respiratory surface shown in the diagram.

iii). Write two adaptations of that respiratory surface for the efficient gas exchange.

iv). What are the differences in blood composition of the vessels P and Q?

v). To which chamber does the blood flow through P ?

vi). What is the illness which shows symptom, swelling of B, C parts due to bacteria or virus infections?

b) Choose the correct answer

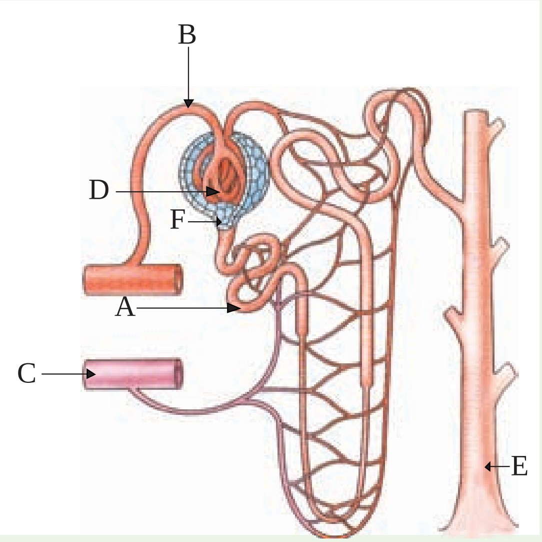
i) What is the respiratory product produced only in animals?

1) Energy 2) CO_2 3) Ethyl alcohol 4) Lactic acid

ii)Which of the following is not produced using anaerobic respiration

1) Alcohol 2) Biogas 3) Bread 4) Yogurt

(3) A figure of the structural and functional unit of the kidney is shown below.



i) What is this unit called?

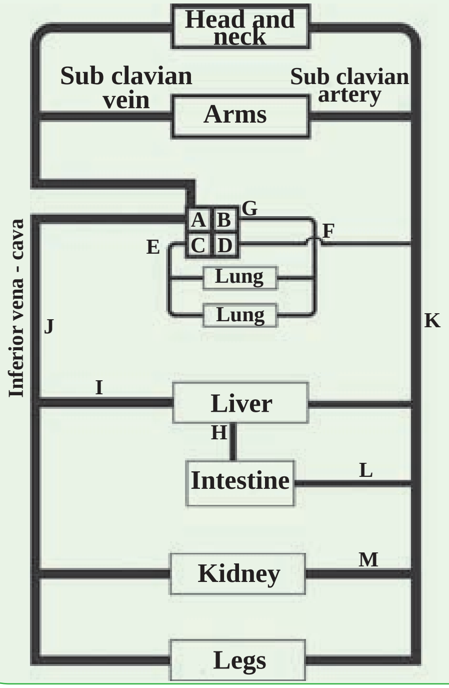
ii) Name the parts A, B, C, D, E.

iii) Briefly explain the functions that occur in D.

iv) Name two substances absorbed into blood capillaries from the fluid that flows through tube A.

v) A urine test of a person revealed that urine had glucose in it. What is the disease that person is having. What are the reasons for it?

(4) Following is a diagram of a model of the human blood circulatory system. Answer the following questions regarding that.



i. Name the chambers A to D.

ii Name the following blood vessels

a) E (c) G

b) F (d) H

iii In which form part of glucose is stored in liver?

iv Write the path of a glucose molecule in blood from the liver to the kidney. using given letters.

v How many times does the glucose molecule pass through the heart when transporting to the liver?

vi Write two differences in blood at E and F.

(5) i) Name the part of brain which involves in the following functions.
a. Higher mental cognitive activities
b. Controlling the heart beat rate
c. Controlling swallowing
d. Controlling functions of the voluntary muscles
(ii) Name the neurons which involve in the peripheral nervous system.
(iii) What is the sub system of the autonomic nervous system that functions mainly in an emergency.

Technical terms

Digestive system	ආහාර ජීරණ පද්ධතිය	சமிபாட்டுத் தொகுதி
Digestion	ජීරණය	சமிபாடு
Pharynx	ග්‍රසනිකාව	தொண்டை
Oesophagus	අන්නස්‍රෝතය	களம்
Salivary glands	බේට ග්‍රන්ථි	உமிழ் நீர்
Epiglottis	අපිජිහ්විකාව	மூச்சுக்குழல்வாய் மூடி
Bile	පිත	பித்தம்
Emulsification	තෛලෝද්කරණය	குழம்பாக்குதல்
Peristalsis	ක්‍රමාකුංචනය	சுற்றுச் சுருங்கல் அசைவு
Chyme	ආමලසය	இரைப்பைப் பாகு
Appendix	උණ්ඩුක පුච්ඡය	குடல் வளரி
Anus	ගුද මාර්ගය	குதவழி
Faeces	මල	மலம்
Constipation	මල බද්ධය	மலச்சிக்கல்
Diaphragm	මහා ප්‍රාචීරය	வயிற்றோட்டம்
Respiratory system	ශ්වසන පද්ධතිය	சுவாசத் தொகுதி
Respiration	ශ්වසනය	சுவாசம்
Lungs	පෙනහැලි	நுரையீரல்
Ribs	පර්ශු	விலாவென்பு
Intercostal muscles	අන්තර් පර්ශුක පේශි	பழுவுக்கிடை தசைகள்
Aerobic respiration	සවායු ශ්වසනය	காற்றுச் சுவாசம்

Anaerobic respiration	නිර්වායු ශ්වසනය	காற்றின்றிய சுவாசம்
Nitrogenous excretory products	නයිට්‍රජනීය බහිස්‍රාවී ද්‍රව්‍ය	நைதரசன் கழிவுப் பொருள்
Excretory system	බහිස්‍රාවී පද්ධතිය	கழிவகற்றல் தொகுதி
Excretion	බහිස්‍රාවය	கழிவகற்றல்
Kidney	වෘක්කය	சிறுநீரகம்
Ureter	මූත්‍රවාහිනිය	சிறுநீர்
Renal vein	වෘක්කීය ශිරාව	சிறுநீரக நாளம்
Renal artery	වෘක්කීය ධමනිය	சிறுநீரக நாடி
Bladder	මූත්‍රාශය	சிறுநீர்ப்பை
Urethra	මූත්‍ර මාර්ගය	சிறுநீர் வழி
Nephron	වෘක්කාණුව	சிறுநீரகத்தி
Glomerulus	ගුච්ඡිකාව	கோளவுருவானவை
Reabsorption	ප්‍රතිශෝෂණය	மீள் அகத்துறிஞ்சல்
Glomerular filtrate	ගුච්ඡිකා පෙරණය	மயிர்துளை
Afferent arteriole	අභිවාහි ධමනිකාව	உட்காவுநாடி
Efferent arteriole	අපවාහි ධමනිකාව	வெளிக்காவு நாடி
Bowman capsule	බෝමන් ප්‍රාවරය	மோமனின் உறை
Collecting duct	සංග්‍රාහක නාලිකාව	சேகரிக்கும் குழாய்
Blood circulation	රුධිර සංසරණය	சுருதி சுற்றோட்டம்
Blood corpuscles	දේහාණු	குருதிக் கலங்கள்
Blood plasma	රුධිර ප්ලාස්මය	குருதி திரவவிழையம்
Red blood corpuscle	රතු රුධිරාණු	செங்குருதிக் கலம்
Granulocytes	කණිකාමය සුදු රුධිරාණු	சிறுமணி கொண்ட வெண்குழியம்
Non- granulocycts	කණිකාමය නොවන සුදු රුධිරාණු	சிறுமணியற்ற வெண் குழியம்
Atrium	කර්ණිකාව	இதயவறை
Ventricle	කෝෂිකාව	சோணையறை
Bicuspid valve	ද්විතුණ්ඩ කපාටය	இருகூர் வால்வு
Pulmonary vein	පුප්ඵුසීය ශිරාව	நுரையீரல் நாளம்

Pulmonary circulation	පුප්පුසීය සංසරණය	நுரையீரல் சுற்றோட்டம்
Lymphatic system	වසා පද්ධතිය	நிணநீர்த் தொகுதி
Systemic circulation	සංස්ථානික සංසරණය	தொகுதி சுற்றோட்டம்
Blood capillaries	රුධිර කේශනාලිකා	குருதி மயிர்துளைக் குழாய்
Systemic artery	සංස්ථානික ධමනිය	தொகுதிப் பெருநாடி
Arterial system	ධමනි පද්ධතිය	நாடித் தொகுதி
Venous system	ශිරා පද්ධතිය	நாளத்தொகுதி
Coronary thrombosis	කිරීටක ත්‍රොම්බෝසිය	முடியுரு துரொம்போசிஸ்
Co-ordination	සමායෝජනය	இயைபாக்கம்
Homeostasis	සමස්ථිතිය	ஒருசீர்த்திடநிலை
Reflex arc	ප්‍රතීක චාපය	தெறிப்பு வில்
Reflex actions	ප්‍රතීක ක්‍රියා	தெறிவினை
Central nervous system	මධ්‍ය ස්නායු පද්ධතිය	மைய நரம்புத் தொகுதி
Autonomic nervous system	ස්වයං සාධක ස්නායු පද්ධතිය	தன்னாட்சி நரம்புத் தொகுதி
Parasympathetic system	ප්‍රත්‍යානුවේගී ස්නායු පද්ධතිය	பராபரிவு நரம்புத் தொகுதி
Sympathetic system	අනුවේගී ස්නායු පද්ධතිය	பரிவு நரம்புத் தொகுதி
Endocrine system	අන්තරාසර්ග පද්ධතිය	அகஞ்சுரக்குந் தொகுதி

Chemistry

07

Acids, Bases and Salts

Acids, bases and salts are used for various activities in our day to day life. To inquire into your prior knowledge about acids, bases and salts, do the following assignment.

Assignment - 7.1

Given below are several substances which we frequently use in our day to day life. Classify them as acids, bases and salts and tabulate.
Lime juice, Jeewani solution, antacid tablets, milk of magnesia, toothpaste, vinegar, salt, lime, soap, vitamin C tablets, saline solution

7.1 Acids

When you were answering the assignment 7.1 above, you could have classified lime juice, vinegar and vitamin C in that list under the acids.

You have used various acids in the laboratory experiments also. Hydrochloric acid (HCl), nitric acid (HNO_3) and sulphuric acid (H_2SO_4) are some acids that are often used in the laboratory.

Figure 7.1 - Some acids that are being frequently used

When considering the formulae of the above acids it is clear that hydrogen (H) is a component element in all those acids.

- ### What is an acid?

An acid is a compound that releases hydrogen ions (H^+) in an aqueous medium. Hydrochloric acid ionises as follows in the aqueous medium and releases H^+ ions.

$$HCl\,(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

Based on the strength of releasing H^+ ions in the aqueous medium, acids are classified as **strong acids** and **weak acids**.

Strong acids

The acids that release H^+ ions by complete ionisation in aqueous medium are strong acids. It means that all such acid molecules are dissociated into H^+ ions and the corresponding negative ions in water. For example, in an aqueous solution of hydrochloric acid which is a strong acid, there are only H^+ ions and Cl^- ions but no free HCl molecules.

Given below are a few examples for some strong acids and how they ionise in the aqueous medium.

- Hydrochloric acid (HCl)

$$HCl\,(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

- Sulphuric acid (H_2SO_4)

$$H_2SO_4\,(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

- Nitric acid (HNO_3)

$$HNO_3\,(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$$

Weak acids

The acids which release H^+ ions in aqueous medium by incomplete or partial ionisation are called weak acids. This means that in aqueous medium, only a fraction of such acid molecules are dissociated into H^+ ions and relevant negative ions. The unionised molecules remain as molecules themselves in aqueous solution.

Examples for weak acids:

Acetic acid (CH_3COOH)

Carbonic acid (H_2CO_3)

Phosphoric acid (H_3PO_4)

Most of the acids in laboratory stores are **concentrated acids**. **Dilute acids** of required concentration can be prepared by mixing such concentrated acids with water. Acids of low concentration are known as dilute acids.

• Properties of acids

★ Pay your attention to the warning symbol in Figure 7.2 seen in the label of the bottles containing concentrated acids. This is a warning about the corrosive nature of the relevant chemical. That is, when they come into contact with substances like wood, metals or cloth they corrode them and if spilled on the skin, they cause severe burns. This shows that acids have corrosive properties.

Figure 7.2

★ Recall the taste of lime juice. It is sour. A common feature of acids is that they have a characteristic sour taste.

Caution: You should not taste the acids used in the laboratory.

★ Dilute acids react with metals above hydrogen in the reactivity series forming the salt of the metal and hydrogen gas.

$$Mg\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$$

★ Think back on the experiment carried out to prepare carbon dioxide gas in the laboratory. Carbon dioxide was prepared by adding diluted hydrochloric acid to calcium carbonate.

$$CaCO_3\,(s) + 2HCl\,(aq) \longrightarrow CaCl_2\,(aq) + H_2O\,(l) + CO_2\,(g)$$

Production of carbon dioxide by reacting with carbonates/bicarbonates is a characteristic feature of acids.

★ Acids react with bases to form salts and water.

The salt sodium sulphate (Na_2SO_4) and water are formed as the products of the following acid - base reaction.

$$H_2SO_4\,(aq) + 2NaOH\,(aq) \longrightarrow Na_2SO_4\,(aq) + 2H_2O\,(l)$$

★ Acids turn the colour of blue litmus red. This is a simple test used to identify acids.

Uses of some acids

- **Hydrochloric acid**

★ Removal of rust in steel objects

★ Making gelatin from bony materials in food technology

★ Making aqua regia (aqua regia is a mixture of concentrated nitric acid and concentrated hydrochloric acid mixed in the proportion of 1 : 3. Aqua regia is used to dissolve metals like gold and platinum)

- **Sulphuric acid**

★ Production of fertilizers such as ammonium sulphate and triple superphosphate

★ Making battery acid (Battery acid is diluted sulphuric acid)

★ Production of paints, plastics and detergents

★ Concentrated sulphuric acid is used as a dehydrating agent

★ Drying gases (For drying a gas, the relevant gas is bubbled through concentrated sulphuric acid)

- **Acetic acid**

★ Processing food where vinegar is used

★ Coagulation of rubber latex

★ Production of photographic films

★ Used in the paper industry

★ Production of synthetic threads in textile industry

7.2 Bases

Pay your attention to the substances classified under bases in the table prepared during assignment 7.1. Milk of magnesia, toothpaste, soap and lime are examples for bases.

Many bases are encountered as solids. Ammonia is a gas showing basic properties. Aqueous solutions prepared by dissolving bases in water are used in laboratory experiments. Sodium hydroxide (NaOH), potassium hydroxide (KOH) and ammonia solution (NH_4OH) can be given as the bases frequently used in the laboratory.

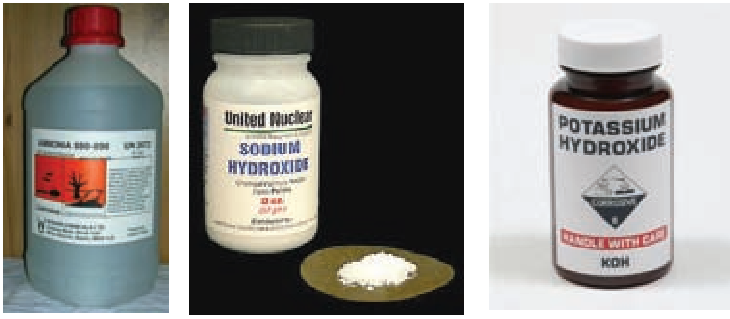


Figure 7.3 - Some frequently used bases

• What is a base?

A base is a chemical compound that increases the hydroxyl ion (OH^-) concentration of an aqueous solution. For instance, in aqueous solution, sodium hydroxide (NaOH) ionises as follows and contributes to raise the OH^- ion concentration.

$$NaOH\ (aq) \longrightarrow Na^+\ (aq) + OH^-\ (aq)$$

• Strong bases

The bases that completely ionise in aqueous solution are called strong bases. Examples for some strong bases and how they ionise in aqueous solution are given below.

- Sodium hydroxide

$$NaOH\ (aq) \longrightarrow Na^+\ (aq) + OH^-\ (aq)$$

- Potassium hydroxide

$$KOH\ (aq) \longrightarrow K^+\ (aq) + OH^-\ (aq)$$

• Weak bases

The bases which partially ionise in aqueous solution are known as weak bases.

Ex : Ammonia solution (NH_4OH)

• Properties of bases

★ They have a slimy texture as in soap.

Caution : Do not touch bases in the laboratory.

★ Bases react with acids to give salts and water.

$$2NaOH\ (aq) + H_2SO_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + 2H_2O\ (l)$$

★ Bases turn red litmus blue. This is a simple test used to identify bases. Of the bases, those that readily dissolve in water are called alkalis.

Ex : Sodium hydroxide (NaOH)

Potassium hydroxide (KOH)

Ammonia solution (NH_4OH)

• Uses of some bases

- **Sodium hydroxide**

★ Production of soap, paper, artificial silk and paints

★ Used in the laboratory as a strong base

★ Refining petroleum products

- **Magnesium hydroxide**

★ Magnesium hydroxide suspension (milk of magnesia) is used as an antacid to relieve gastritis (acidity in stomach)

★ Purification of molasses in sugar industry

Identification of acids and bases by indicators

Activity 7.1

Identification of acids and bases by indicators

Materials required : Blue litmus, red litmus, methyl orange, phenolphthalein, lime juice, dilute hydrochloric acid, dilute sulphuric acid, vinegar, dilute sodium hydroxide solution, soap solution

Add the given indicators to the solutions given above and record the observations.

Table 7.1

Solution	Litmus red/blue	Methyl orange	Phenolphthalein
Dilute hydrochloric acid			
Lime juice			
Dilute sulphuric acid			
Vinegar			
Dilute sodium hydroxide			
Soap solution			

Compare your observations with the following table and identify the relevant solution as an acid or a base.

Table 7.2

Indicator	Acid colour	Base colour
Litmus	Red	Blue
Phenolphthalein	Colouress	Pink
Methyl orange	Red	Yellow

Identification of acids and bases by indicators is not a very accurate method. Moreover, by using it, a value for the strength of acids or bases cannot be obtained. Indicators help to identify a given substance as an acid or a base approximately.

• pH scale

The pH scale is used to indicate how acidic or basic a given solution is. The scale generally consists of a series of numbers from 0 to 14. Each number corresponds to a colour.

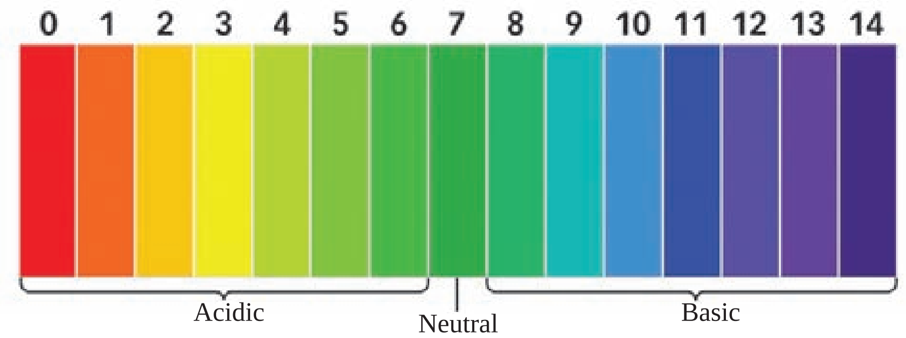


Figure 7.4 - pH scale and colour code of pH papers

According to this scale the pH value of neutral substances such as water is 7. The pH value of acidic solutions is less than 7 whereas the pH value of basic solutions is greater than 7. Acidity decreases from 0 to 6 while the basicity increases from 8 to 14.

• pH papers

Like the litmus papers, these are available in the form of books or rolls in the laboratory. These have been prepared by mixing several indicators. The pH value can be found by dipping a pH paper in the relevant solution and comparing the colour of the paper with the colour code. Accordingly, the acidity, basicity or the neutrality of the solution can be identified. Further, it gives an idea about the strength of the acid or the base.

7.3 Salts

The common salt (NaCl) that we use in our day to day life is a salt. The Jeewani solution given during ailing conditions such as diarrhoea and the saline solution given to patients are mixtures containing salts.

Acids react with bases to form salts.

Ex (¡ Hydrochloric acid reacts with sodium hydroxide forming sodium chloride.

$$NaOH\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

Hydrochloric acid reacts with potassium hydroxide to form potassium chloride.

$$KOH\,(aq) + HCl\,(aq) \longrightarrow KCl\,(aq) + H_2O\,(l)$$

Nitric acid upon reacting with magnesium hydroxide gives magnesium nitrate.

$$Mg(OH)_2\,(aq) + 2HNO_3\,(aq) \longrightarrow Mg(NO_3)_2\,(aq) + 2H_2O\,(l)$$

Depending on the strength of the acid or the base reacting, the salt shows acidic, basic or neutral properties.

Ex (The salts formed by the reaction between a strong acid and a strong base show neutral properties.

Sodium hydroxide is a strong base. Hydrochloric acid is a strong acid. Sodium chloride formed by the reaction between them is a neutral salt.

$$NaOH\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

Salts are crystalline, solid compounds. Most of the salts dissolve in water. Generally salts have high melting points and boiling points.

• Uses of some salts

- **Sodium chloride**

★ Used to flavour food during their preparation

★ Used as a food preservative

★ Used to produce chemicals such as chlorine and hydrochloric acid, to produce sodium hydroxide to produce sodium carbonate by solvay process, to glaze earthenware, to make soap and also used in tanning

Figure 7.5 - Sodium chloride

- **Copper sulphate**

Figure 7.6
Copper sulphate

- Used as a fungicide in agriculture
- Used in making chemical reagents (Benedict solution and Fehling solution)
- Used in electroplating
- Used in paint industry

7.4 Neutralisation

You know that antacid tablets which contain a basic substance are used to relieve the discomfort caused by the acidity in stomach. Have you inquired into the reason for it?

You have studied the fact that when acids react with bases, salts and water are produced. Let's consider the reaction between hydrochloric acid and sodium hydroxide again.

$$HCl\,(aq) + NaOH\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

Let's investigate how water was formed as a product in the above reaction. The H^+ ions released by the ionisation of the acid combine with the OH^- ions given by the ionisation of the base to form water molecules. it can be represented by a chemical equation as follows.

$$H^+\,(aq) + OH^-\,(aq) \longrightarrow H_2O\,(l)$$

In all acid - base reactions, the above common reaction occurs. This process is known as neutralisation.

Neutralisation is the combination of H^+ ions released by an acid with OH^- ions released by a base to form water molecules.

Hence, when an acid reatcs with a base their acidic properties as well as the basic properties disappear.

• Applications of the acid - base neutralisation reactions

- ⋆ Milk of magnesia or such an antacid (a weak base) is used to neutralise the acidity in the stomach.
- ⋆ Basic substances such as ash and quicklime (calcium oxide) are added to soil to reduce soil acidity.
- ⋆ Bee sting is painful because of an acidic poisonous substance injected into the skin. By applying a weak basic substance such as baking soda ($NaHCO_3$) or calcium carbonate ($CaCO_3$) on the place of the sting, the pain is relieved.
- ⋆ Wasp sting is basic. Application of a weak, dilute acid such as lime juice or vinegar on the place of sting reduces the venomous nature as well as the pain.

Summary

- The substances that release H^+ ions in aqueous solution are called acids.
- The substances that increase the OH^- ion concentration in aqueous solution are known as bases.
- An acid reacts with a base to form salt and water.
- The acids that release H^+ ions undergoing complete ionisation in aqueous solution are strong acids whereas the acids that release H^+ ions by partial ionisation are weak acids.
- The bases that increase the OH^- concentration undergoing complete ionisation in aqueous medium are called strong bases. The bases that increase the OH^- concentration by partial ionisation in aqueous solution are weak bases.
- Both acids and bases change the colour of indicators.
- An acid has a low pH value while a base has a higher pH value.
- Acids react with many metals liberating hydrogen gas. Acids react with carbonates or bicarbonates with the evolution of carbon dioxide gas.
- By reacting an acid with a base, salts are formed.
- A salt shows acidic or basic or neutral properties. It depends on the strength of the acid or the base contributed to form the salt.
- In the reaction between acids and bases, the combination of H^+ ions released by the acid with the OH^- ions released by the base, to form water molecules is called neutralisation.
- Hydrochloric acid, sulphuric acid and acetic acid are frequently used acids for various purposes.
- Sodium hydroxide and magnesium hydroxide are two bases used in various tasks.
- Sodium chloride and copper sulphate are two salts used for various tasks.

Exercises

01. Complete the following sentences.

i. Sodium hydroxide and .... acid react to form sodium chloride and water.

ii. Calcium carbonate and hydrochloric acid react liberating .... gas.

iii. Potassium hydroxide and sulphuric acid react to form .... and......................... .

iv. .... acid and .... hydroxide react giving magnesium nitrate.

v. .... acid reacts with magnesium liberating .... gas and forming the salt ....

02. You are provided with three unlabelled solutions of sodium hydroxide, dilute hydrochloric acid and sodium chloride. You are given only blue litmus papers. Using only them how do you identify the above three solutions?

03. Fill in the blanks with the solutions selected from the following list of solutions.

$H_2SO_4(aq)$, $HCl\ (aq)$, $NH_3(aq)$, $H_2O(l)$, $Ca(OH)_2\ (aq)$, $CH_3COOH(aq)$

i. .... and .... turn red litmus blue.

ii. .... and .... act as strong acids.

iii. In .... and ...., pH is greater than 7.

iv. Vinegar used at home is diluted.............................. .

v. .... causes severe burns in the skin when spilled.

vi. Calcium sulphate salt is formed by the reaction between .... and ....

04.

i. Arrange the following solutions in the ascending order of pH.

sodium hydroxide, sulphuric acid, water, vinegar

ii. Of the solutions dilute hydrochloric acid, dilute sodium hydroxide and acetic acid, which does not react with sodium carbonate?

iii. When somebody comes into contact with the plant (kahambiliya), it causes itching and a severe burning sensation due to formic acid it contains. Suggest a suitable substance to apply on the skin to relieve that sensation.

Glossary

Acid	-	අම්ලය	-	அமிலம்
base	-	හස්මය	-	மூலம்
Salt	-	ලවණ	-	உப்பு
Neutralisation	-	උදාසීනිකරණය	-	நடுநிலையாக்கம்
Strong acid	-	ප්‍රබල අම්ලය	-	வன்னமிலம்
weak acid	-	දුබල අම්ලය	-	மென்னமிலம்
Strong base	-	ප්‍රබල හස්මය	-	வன் மூலம்
weak base	-	දුබල හස්මය	-	மென் மூலம்
pH scale	-	pH පරිමාණය	-	pH அளவுத்திட்டம்
pH papers	-	pH කඩදාසි	-	pH தாள்

Heat Changes Associated with Chemical Reactions

Chemistry

08

Recall again about the evidences you have learnt in grade 10 to ensure that a reaction has taken place. Do the following activity to study further about it.

Activity 8.1

Materials required ; - Two small beakers about 100 cm^3 , A thermometer, a glass rod, solid sodium hydroxide (NaOH), solid ammonium chloride (NH_4Cl)

Method; - Add about half full of water to a beaker, measure its temperature and note it down. Add a little amount of solid sodium hydroxide to the same beaker, stir with the glass rod and again measure and record the temperature. State your observations.

Fill half of a beaker with water and record its temperature. Add a little amount of solid ammonium chloride to this beaker. Stir with the glass rod and record the temperature again. State your observations.

It can be observed that when solid sodium hydroxide dissolves in water the temperature rises whereas when solid ammonium chloride dissolves in water, the temperature falls. The reason for the temperature changes happening in the above two instances is the heat changes accompanying them.

What is the reason for the increase in temperature when solid sodium hydroxide dissolves in water? The temperature increases because of the loss of heat.

Why did the temperature decrease when solid ammonium chloride was dissolved in water?

In this case, temperature decreased because of the absorption of heat.

The temperature change can be considered as a measure of the amount of heat either evolved or absorbed.

In order to explore further about the heat changes occurring in a chemical reaction, let us conduct the following activity.

Activity 8.2

Materials required: - A small beaker, a piece of magnesium strip, dilute hydrochloric acid, a thermometer

Method: - Add about 10 cm^3 of dilute hydrochloric acid to a small beaker and measure its temperature. Add a piece of magnesium ribbon about 2 cm long into it. Measure the temperature at the end of the reaction again. Record your observations.

When magnesium metal reacts with hydrochloric acid, the temperature has increased. That means, when this reaction happens heat is lost. **The chemical reactions happening with the evolution of heat are called exothermic reactions. Exothermic reactions can be represented simply as follows.**

$$\text{Reactants} \longrightarrow \text{Products} + \text{Heat}$$

The exothermic reaction studied in activity 8.2 can be represented by the following equation.

$$Mg\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g) + \text{Heat}$$

The reason for the evolution of heat in an exothermic reaction is that the energy contained in the products is less than the energy content of the reactants.
An exothermic reaction can be illustrated by an energy level diagram as follows.

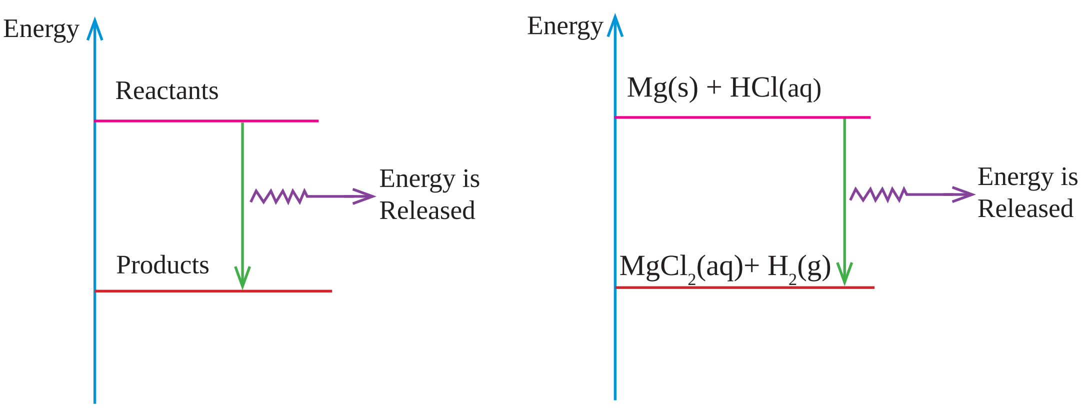


Figure 8.1 Energy level diagram for an exothermic reaction

Activity 8.3

Materials required : - A small beaker, a solution of citric acid, a solution of sodium bicarbonate

Method : - Add about 10 cm^3 of the citric acid solution to a small beaker and record its temperature. Record the temperature of the sodium bicarbonate solution also. Add about 10 cm^3 of the sodium bicarbonate solution to the beaker containing citric acid, stir and note the temperature. State your observations.

When the reaction between citric acid and sodium bicarbonate occurs, the temperature decreases. The reason for this decrease in temperature is the absorption of heat during the reaction. **The reactions taking place with the absorption of heat are known as endothermic reactions.**
An endothermic reaction can be simply represented as follows.

$$\text{Reactants} + \text{Heat} \longrightarrow \text{Products}$$

The reason for the absorption of heat during an endothermic reaction is the fact that the energy in the products is greater than the energy in the reactants.
An endothermic reaction can be represented by an energy level diagram as follows.

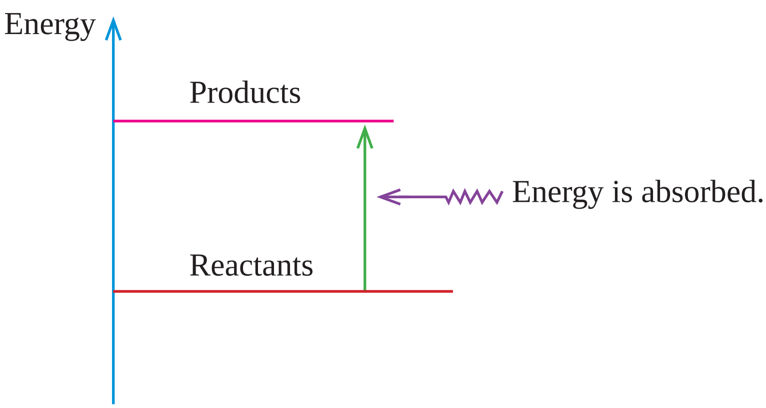


Figure 8.2 Energy level diagram for an endothermic reaction

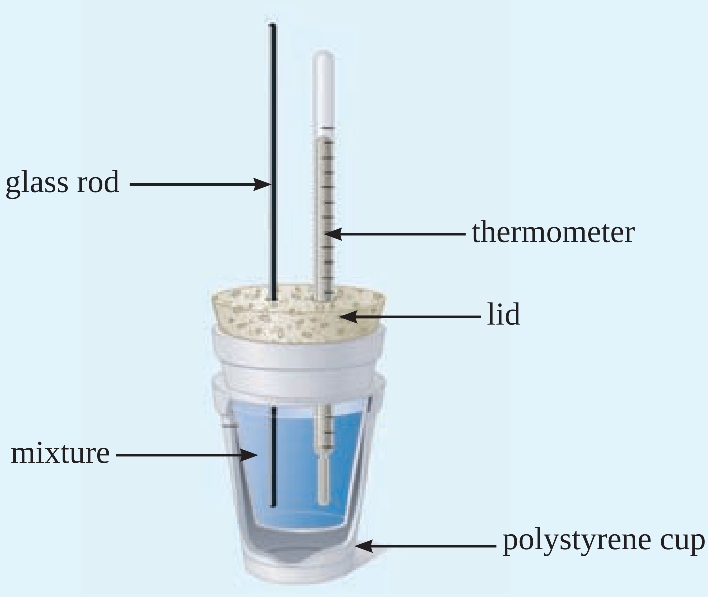
Let's do the following activity to find the energy change of a chemical reaction quantitatively.

Activity 8.4

Experimental determination of the heat change of the reaction between sodium hydroxide (NaOH) and hydrochloric acid (HCl)

Materials required : - 50 cm^3 of 2 mol dm^{-3} sodium hydroxide solution, 50 cm^3 of 2 mol dm^{-3} hydrochloric acid solution, two 100 cm^3 beakers, a thermometer of range 0-100 ^0C, a polystyrene cup, a glass rod

Method : -



To two beakers, measure 50 cm^3 of the sodium hydroxide solution and 50 cm^3 of the hydrochloric acid solution separately using the measuring cylinder. With the thermometer, measure the initial temperatures of the two solutions.

(After measuring the temperature of the solution of the base, wash the thermometer before measuring the temperature of the acid solution . Mix these two solutions in a polystyrene cup, stir with the glass rod and record the maximum temperature.

The heat change associated with the reaction can be calculated using the following equation.

$$Q = m c \theta$$

m = Mass of the substance accompanying the exchange of heat

c = Specific heat capacity of the substance related to the heat change

θ = Temperature change in the mixture (maximum temperature - initial temperature)

If the temperatures of the solutions of the base and acid are different, their mean should be taken as the initial temperature.

This calculation is based on the assumption that the entire quantity of heat of the reaction between sodium hydroxide and hydrochloric acid is used to raise the temperature of 100 cm^3 of the solution. Since dilute solutions were used for mixing, it is also assumed that the specific heat capacity of the solution is equal to that of water and the density of the solution is equal to that of water.

Specific heat capacity of water	= 4200 J kg^{-1} $^0C^{-1}$
Density of water	= 1 g cm^{-3}
Mass of 100 cm^3 of water	= 100 g

Let us assume that the observed temperature change in the experiment is 10 ^0C

$$Q = m c \theta$$

$$= \frac{100}{1000} \text{ kg x } 4200 \text{ J kg}^{-1} \, {}^0\text{C}^{-1} \text{ x } 10 \, {}^0\text{C}$$

$$= 4200 \text{ J}$$

The experiment gives the heat change that results when 50 cm^3 of the 2 mol dm^{-3} sodium hydroxide solution reacts with 50 cm^3 of 2 mol dm^{-3} hydrochloric acid solution.

Extra knowledge

This experiment gives the quantity of heat evolved when the amount of moles of sodium hydroxide in 50 cm^3 of the solution reacts with the amount of moles of hydrochloric acid in 50 cm^3 of the solution used.

Amount of moles of NaOH in 50 cm^3 of the 2 mol dm^{-3} NaOH solution $= \frac{2}{1000} \times 50$ mol

$= 0.1$ mol

Amount of moles of HCl in 50 cm^3 of the 2 mol dm^{-3} HCl solution $= \frac{2}{1000} \times 50$ mol

$= 0.1$ mol

Referring to this, the quantity of heat that evolves when 1 mol of sodium hydroxide reacts with 1 mol of hydrochloric acid can be calculated.

The quantity of heat released when 0.1 mol of NaOH reacts with 0.1 mol of HCl $= 4.2$ kJ

Quantity of heat released when 1.0 mol of NaOH reacts with 1.0 mol of HCl $= \frac{4.2 \text{ kJ}}{0.1 \text{ mol}}$

$= 42 \text{ kJ mol}^{-1}$

This is the heat of reaction of the reaction between sodium hydroxide and hydrochloric acid.(This is an experimental value).

When conducting this experiment loss of heat to the surroundings and absorption of heat by the container occur. Neglecting these leads to an error in the calculation. To minimize it, a thermally insulating polystyrene cup is used. To keep the temperature uniform throughout the mixture, the mixture should be stirred well with a stirrer or a glass rod.

In the above experiment, we determined the heat change associated with the reaction between aqueous sodium hydroxide and aqueous hydrochloric acid.

$$HCl\,(aq) + NaOH(s) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

The above experiment can be carried out using solid sodium hydroxide (NaOH (s)) too. But the heat change here is different from the previous value.

Therefore, when expressing the heat change accompanying a reaction, the physical state of the reactants and the products should be indicated (Solid, liquid, gas, aqueous)

Exothermic and endothermic reactions are important in various activities in day to day life. We meet our energy requirements by burning fuels. Coal, bio gas (methane), and petrol (a mixture of hydrocarbons) are few examples. The energy liberated during the combustion of these fuels are used for various tasks such as running vehicles and operating machinery in factories. Combustion of fuels is an exothermic reaction. The neutralisation reactions taking place between acids and bases are also exothermic reaction. Cellular respiration taking place in live bodies are also exothermic reactions.

In the production of slaked lime, water is added to quicklime. During this process, lot of heat is liberated. This is also an exothermic reaction.

$$CaO\,(s) + H_2O\,(l) \longrightarrow Ca(OH)_2\,(s)$$

Next, let us consider about endothermic processes. You have studied the photosynthesis happening in green plants. In this, simple sugars are produced by absorbing solar energy. It is an endothermic process.

$$6CO_2\,(g) + 6H_2O\,(l) \xrightarrow[\text{chlorophyll}]{\text{solar energy}} C_6H_{12}O_6\,(s) + 6O_2\,(g)$$

Thermal decomposition of many chemical compounds is also an endothermic process. Consider the production of quicklime by burning limestone. This reaction also absorbs heat.

$$CaCO_3\,(s) \longrightarrow CaO\,(s) + CO_2\,(g)$$

Summary

- During every chemical reaction, a heat change also occurs.
- Reactions during which heat is released to the surroundings are called exothermic reactions.
- Reactions in which heat is absorbed from the surroundings are called endothermic reactions.
- The amount of heat released or absorbed during a reaction can be calculated using the equation $Q = mc\theta$

Exercises

01. (a) What do you mean by an exothermic reaction and an endothermic reaction

(b) Are the following reactions exothermic or endothermic?

1. Burning of a candle
2. Putting a piece of sodium into water
3. Dissolving the fertilizer urea in water
4. Adding glucose to water
5. Adding water to quicklime

(c) The quantity of heat evolved during the following reaction is 822 kJ mol^{-1}

$$2\,Na\,(s) + Cl_2\,(g) \longrightarrow 2\,NaCl(s)$$

Represent this using an energy level diagram.

02. 40 cm^3 of a vinegar (dilute acetic acid) solution was mixed with 60 cm^3 of a very dilute solution of lime water. (calcium hydroxide)Then, the temperature of the mixture increased by 10 ^0C

i) Calculate the heat change occurred during the above reaction

ii) What were the assumptions you made in (i) above? Is this reaction exothermic or endothermic?

Density of water = 1000 kg m^{-3}

Specific heat capacity of water = 4200 J $kg^{-1}\,{}^0C^{-1}$

Glossary

exothermic reaction	-	තාපදායක ප්‍රතික්‍රියාව	-	புறவெப்பத்தாக்கம்
endothermic reaction	-	තාප අවශෝෂක ප්‍රතික්‍රියාව	-	அகவெப்பத்தாக்கம்

Introduction

This textbook was compiled by the Educational Publications Department in accordance with the syllabus prepared by the National Institute of Education for the use of Grade 11 students in the Sri Lankan school system with effect from 2016.

An effort has made here to arrange the subject content to suit the national educational goals, common national competencies, the objectives of teaching science and the content of the syllabus .

The subject of science directs the student towards a more active learning process in a manner as to develop knowledge, skills and attitudes needed for a developmental scientific thought.

Each chapter is compiled based on the three main subject areas that comprise the Science subject; Biology, Chemistry and Physics. Pictures, charts, graphs, activities and assignments are included to enable the easy understanding of the related concepts of the subject.

At the end of each chapter, a summary was included and it provides the opportunity to identify the basic concepts of each chapter and to revise the subject matter. Furthermore, there is a series of exercises at the end of each chapter. It will contribute to measure the expected learning outcomes through a self evaluation.

Activities, self evaluative questions, solved examples, assignments and exercises are planned in a manner as to develop the higher order skills such as It enables the students to develop knowledge as well as the higher order skills such as comprehension, application, analysis, synthesis and evaluation.

For the purpose of directing the student to study further about the subject matter, more information is included in the “For extra knowledge”. It is given only to broaden the subject area of the child and certainly not to ask questions at term tests. Some of the activities mentioned in the textbook could be performed at home and some of them should be performed in the science laboratory of the school. Activity based learning helps to create a liking towards learning science in the students and it will easily establish the concepts .

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