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

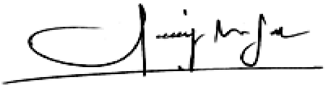
The past two decades have been significant in the world history due to changes that took place in technology. The present students face a lot of new challenges along with the rapid development of Information Technology, communication and other related fields. The manner of career opportunities are liable 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.

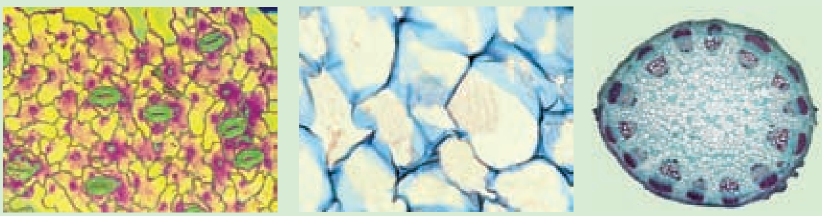


Figure. 1.1 - View of different plant tissues under optical microscope

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.

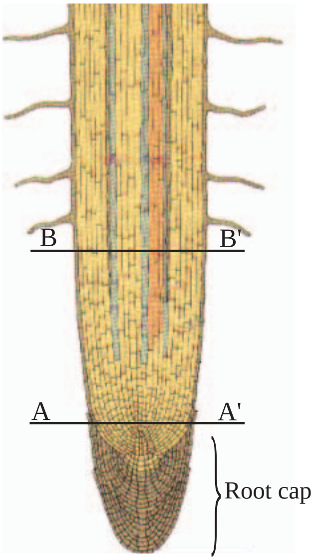


Figure 1.3 - Microscopic view of longitudinal section of root apex

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.

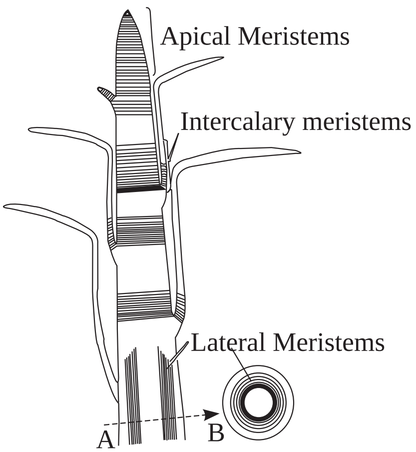


Figure 1.4 - Locations of meristematic tissues

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

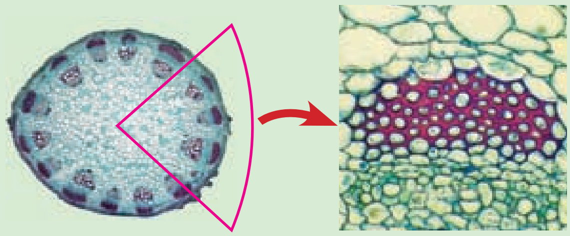


Figure 1.5 - Microscopic view of cross section of dicot stem

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).

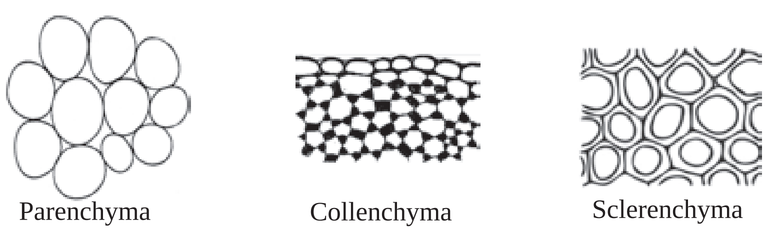
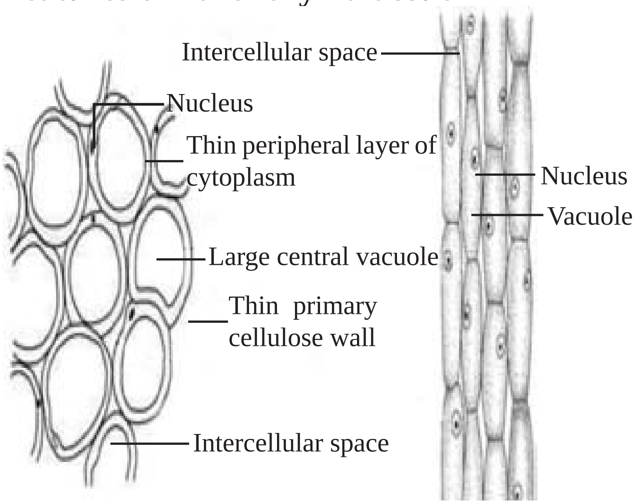


Figure 1.6 - Simple permanent tissue types

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
- Fleshy parts of fruits
- Leaves (mesophylls)
- Pith and cortex of roots
- Seeds (endosperm)

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.

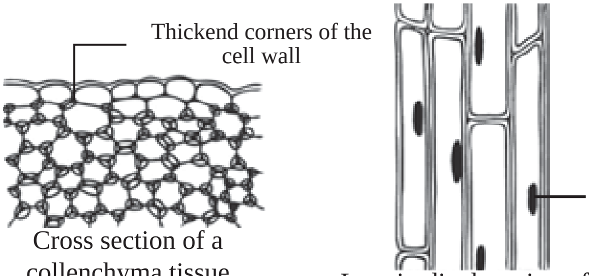


Figure 1.8 - Collenchyma tissue

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

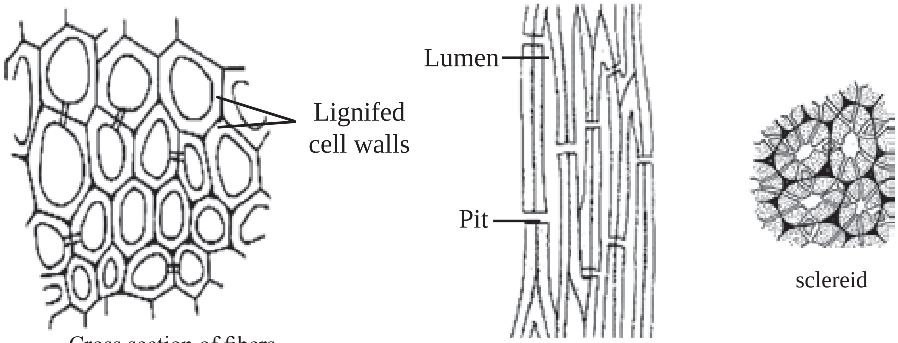


Figure 1.9 - Sclerenchyma tissue

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).

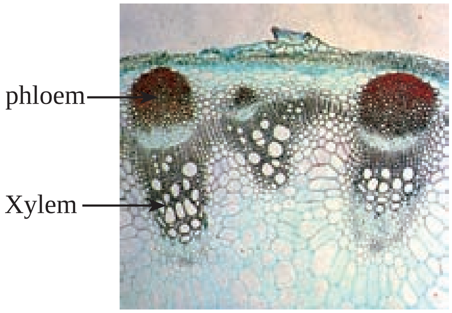


Figure. 1.10 - Complex permanent tissue

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

Xylem tissue

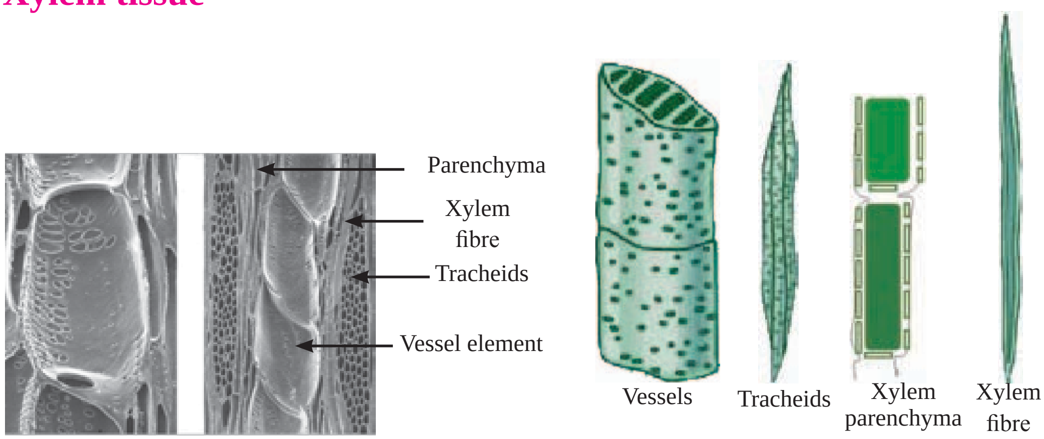


Figure 1.11 - Xylem tissue

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

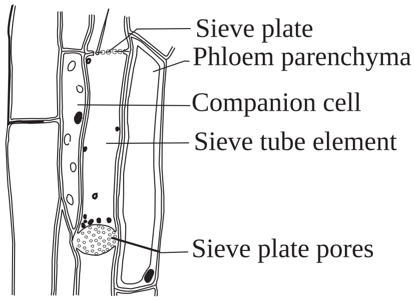


Figure. 1.12 - Longitudinal section of the phloem tissue

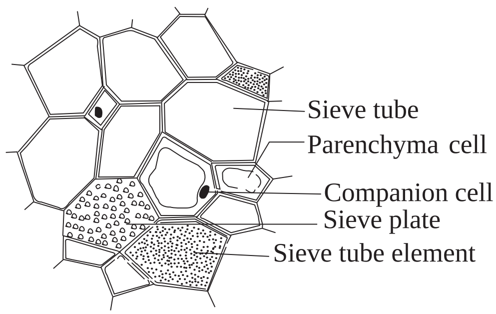


Figure. 1.13 - Cross section of the phloem tissue

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

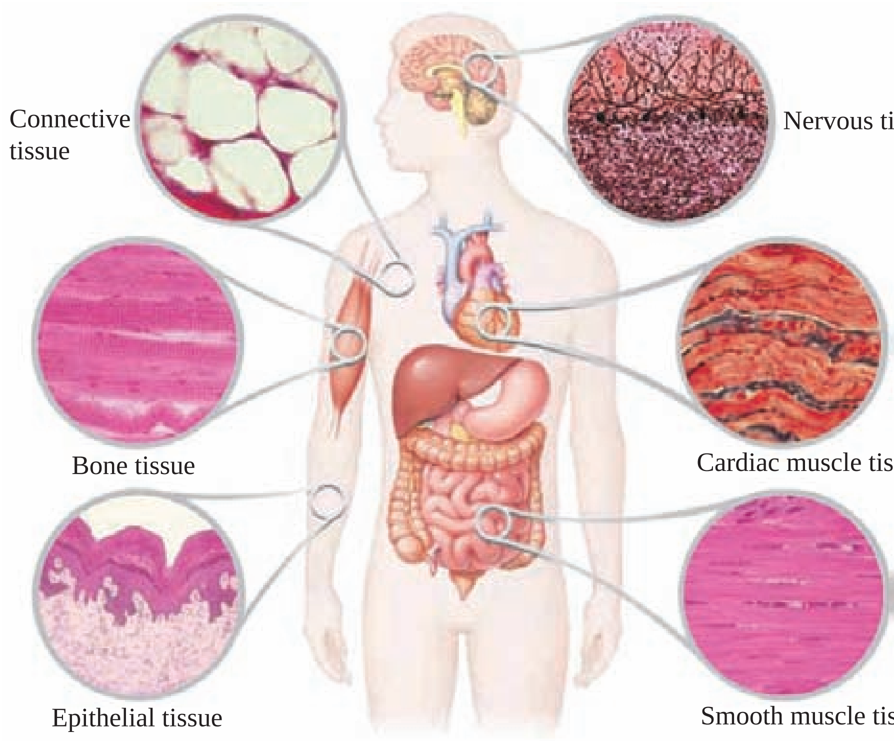


Figure 1.14 - Different tissues in human body

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

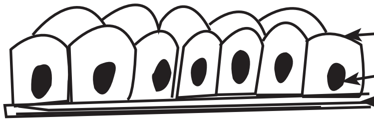


Figure 1.15 - Epithelial tissue

- 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

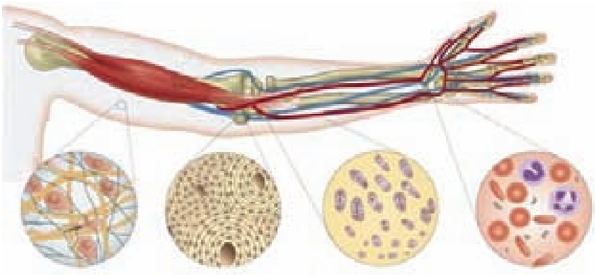


Figure 1.16 - Different Connective tissue present in human arm

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

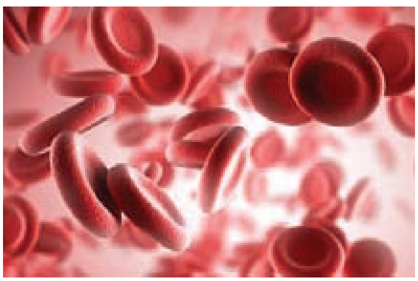


Figure 1.17 - Blood tissue

- 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

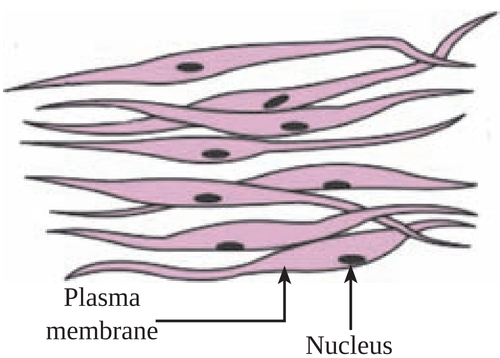


Figure 1.18 - smooth muscle tissue

- 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

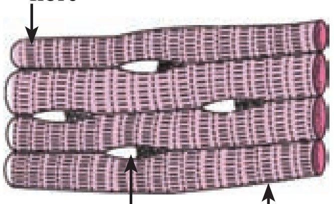


Figure 1.19 - Skeletal muscular tissue

- 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

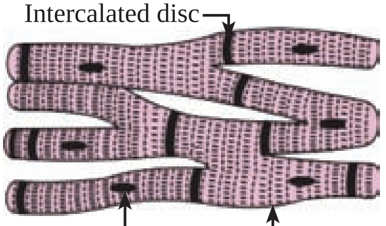


Figure 1.20 - Cardiac muscle tissue

- 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

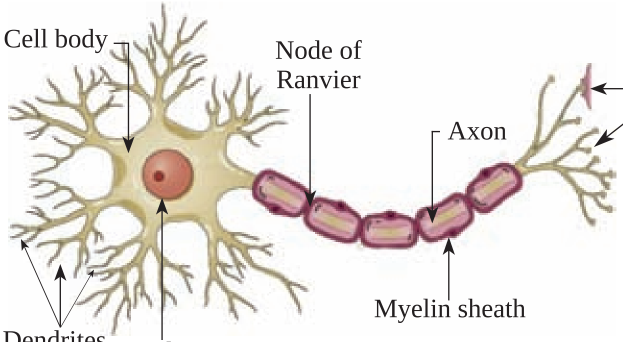


Figure 1.21- Structure of a typical neuron

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

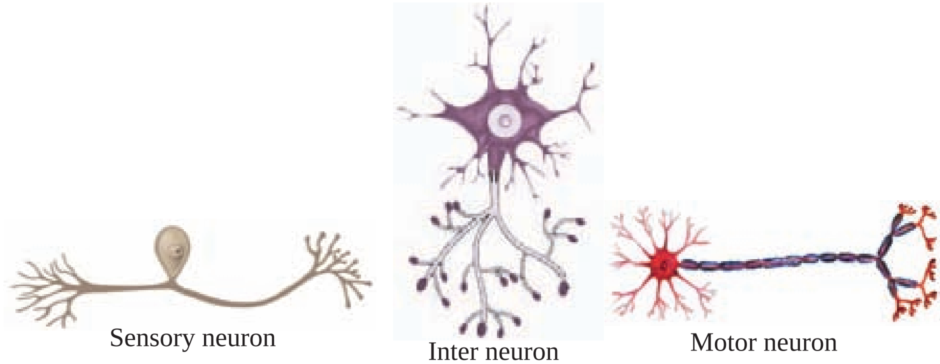


Figure 1.22 - Types of neurons

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.

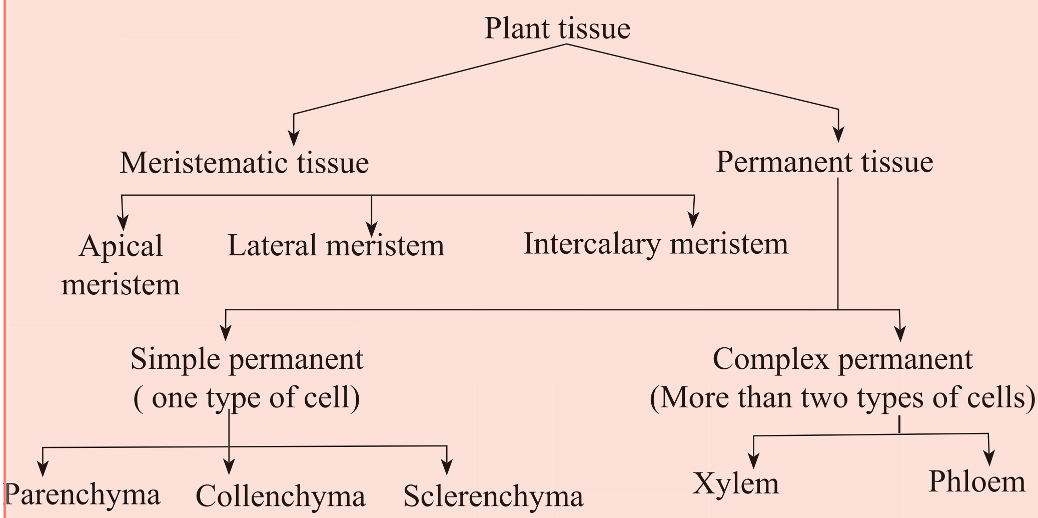
The function of the motor neuron is to transmit impulses from central nervous system to effector (muscles).

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



- 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

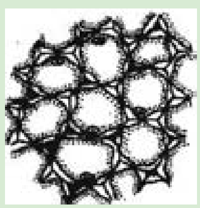
v. When a student observes an animal tissue under the microscope, he observed the cells present on a basement membrane. The tissue is,
   1. Epithelial tissue 2. Posseses connective tissue
   3. Muscle tissue 4. Nervous tissue

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)

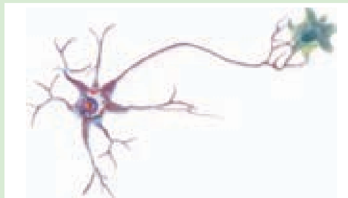

(b)

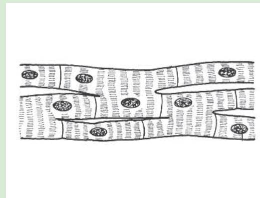

(c)

(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.

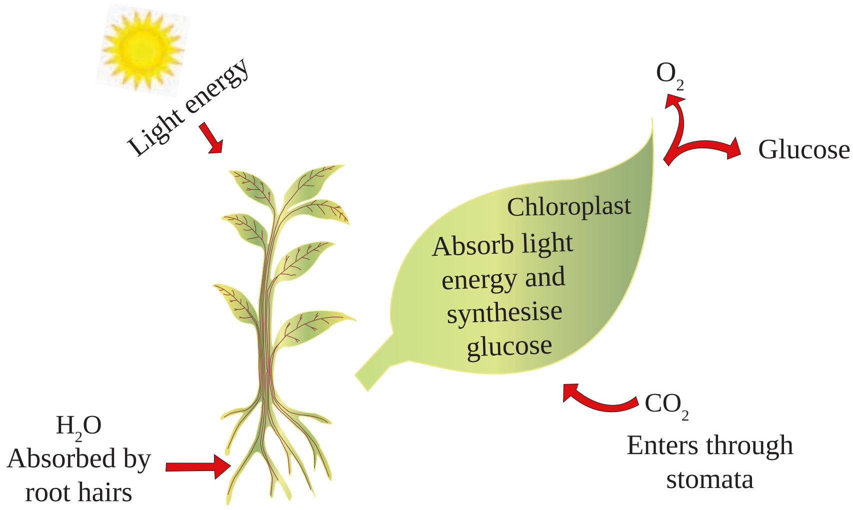


Figure. 2.2 - Factors necessary for photosynthesis and its products

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.

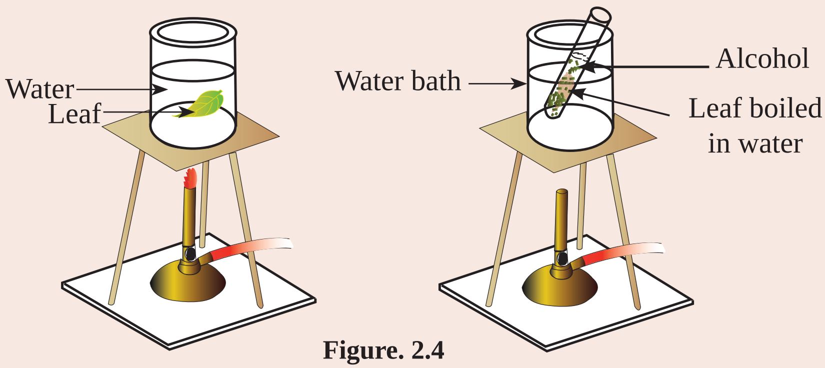


Figure. 2.4

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

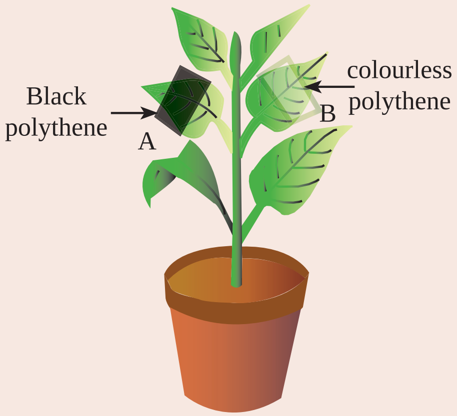


Figure. 2.5

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.

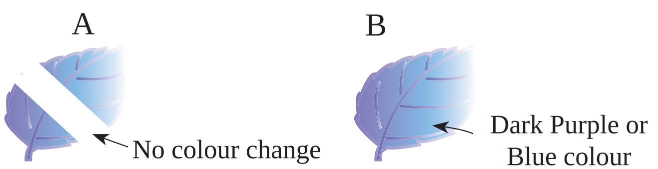


Figure. 2.6

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

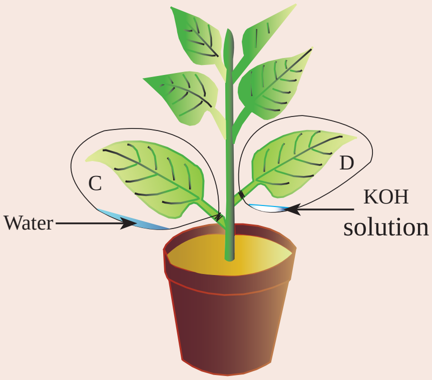


Figure. 2.7

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.

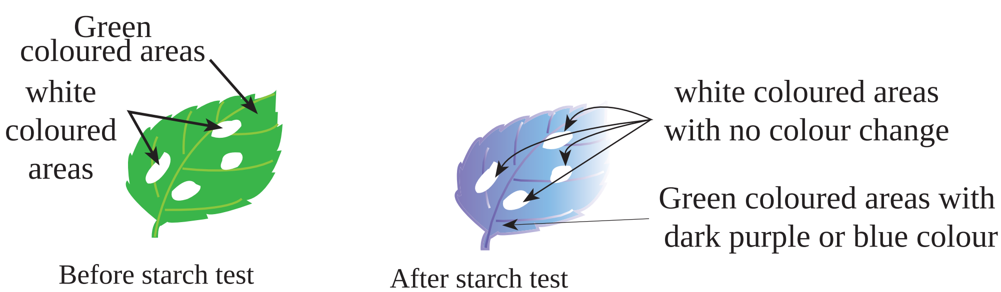


Figure. 2.9

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.

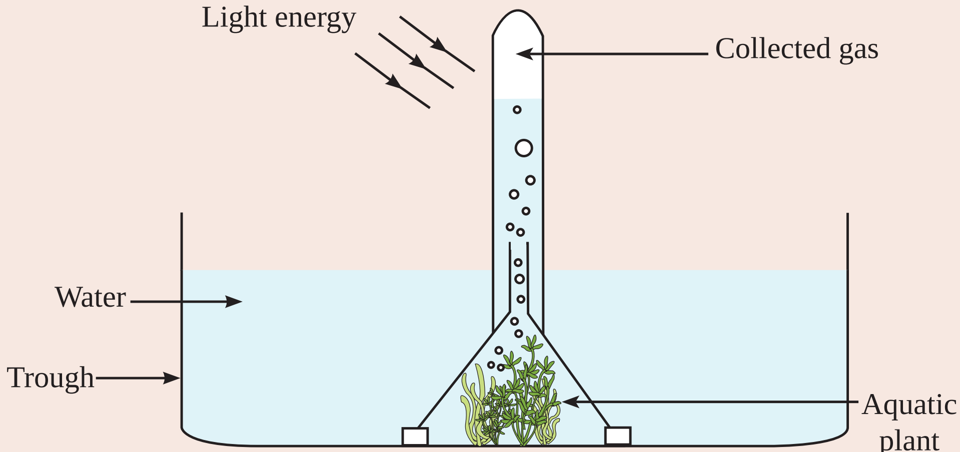


Figure. 2.10

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

Chemistry

03

Mixtures

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

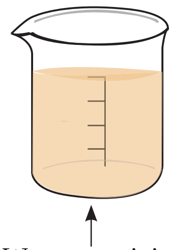


Figure 3.1.1

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.

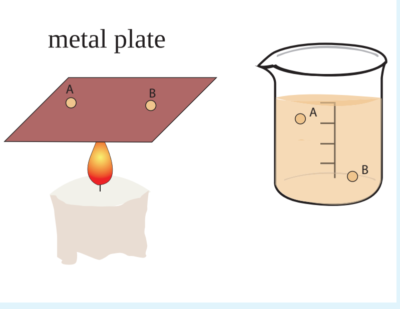


Figure 3.1.2

(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.

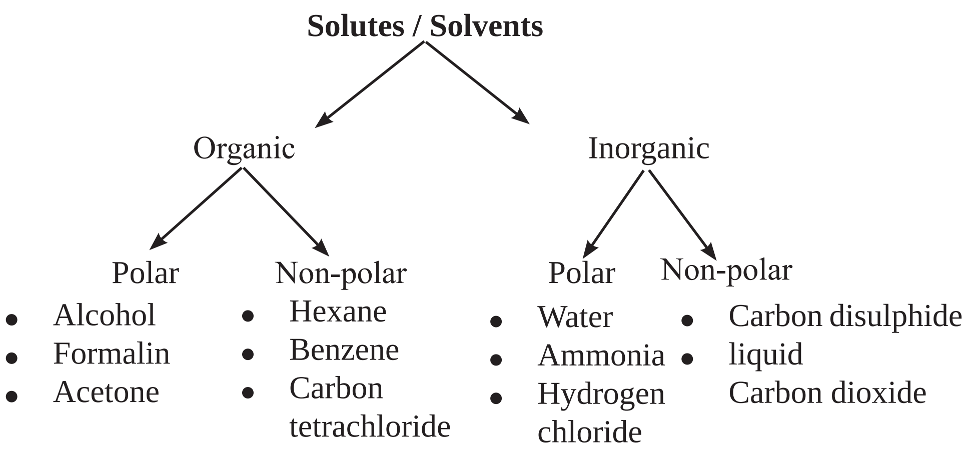
1. Temperature
2. Nature of the solute
3. Nature of the solvent

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.



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.

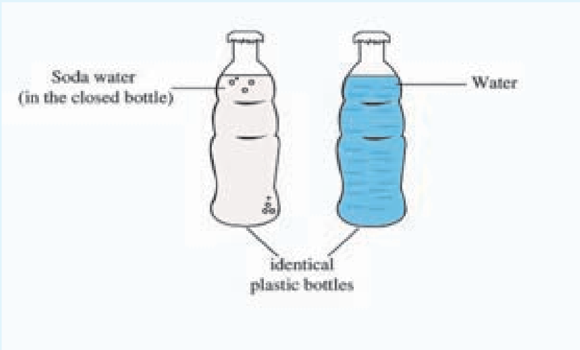


Figure 3.1.3

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

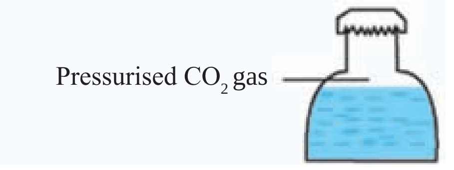


Figure 3.1.4

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.

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

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.

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

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

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

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

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

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 $= \frac{12\text{ g}}{20\text{ g}} = 0.6$

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 $= \frac{4\text{ mol}}{2\text{ dm}^3} \times 1\text{ dm}^3$

$= 2\text{ mol}$

Concentration of sodium hydroxide in the solution $= \dfrac{2\text{m ol}}{1\text{ dm}^3}$

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

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 $= 180$ g

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

$= 180 \text{ g}/ 2$

$= 90 \text{ g}$

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.

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

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

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

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

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.

Figure 3.2.2 - Preparation of a standard solution

- 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.
- 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)

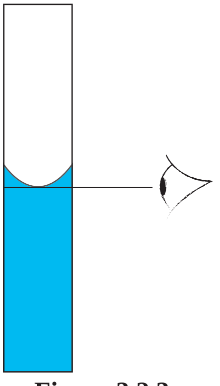


Figure 3.2.3

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 $= \{23+14+(16x3)\}\text{g mol}^{-1}$

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

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

$= 0.2 \text{ mol}$

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

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

$= 1$

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

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

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 $= \{(39x2)+12+(16x3)\}\text{g mol}^{-1}$

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

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

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

$= 69 \text{ g}$

Mass of potassium carbonate required $= 69 \text{ g}$

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 $= \frac{1 mol}{60\ g} \times 12\ g$

$= 0.2\ mol$

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 $= \{(12 \times 6) + (1 \times 12) + (16 \times 6)\}\ g\ mol^{-1}$

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

Amount of moles of glucose in 180 g = 1 mol

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

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

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

$= 0.4\ mol$

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.

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

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

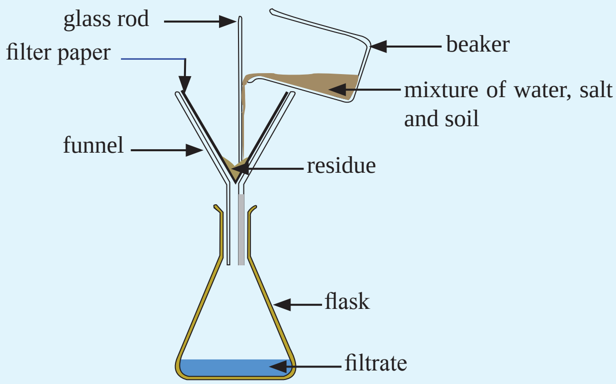


Figure 3.3.1

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.

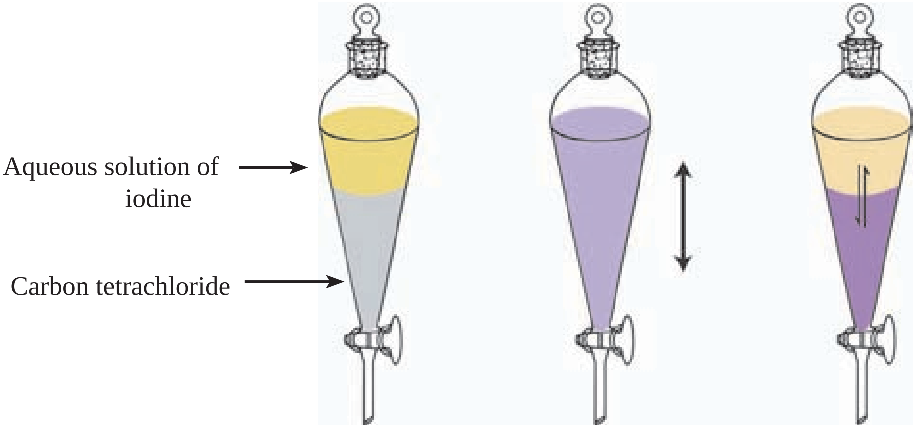


Figure 3.3.2

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.

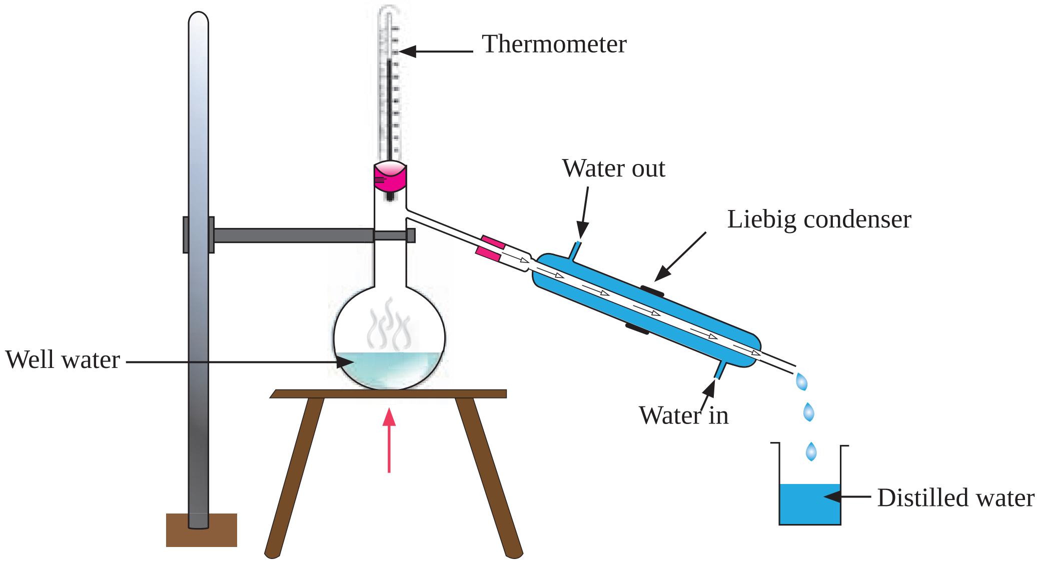


Figure 3.3.4 - Simple distillation

• 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.

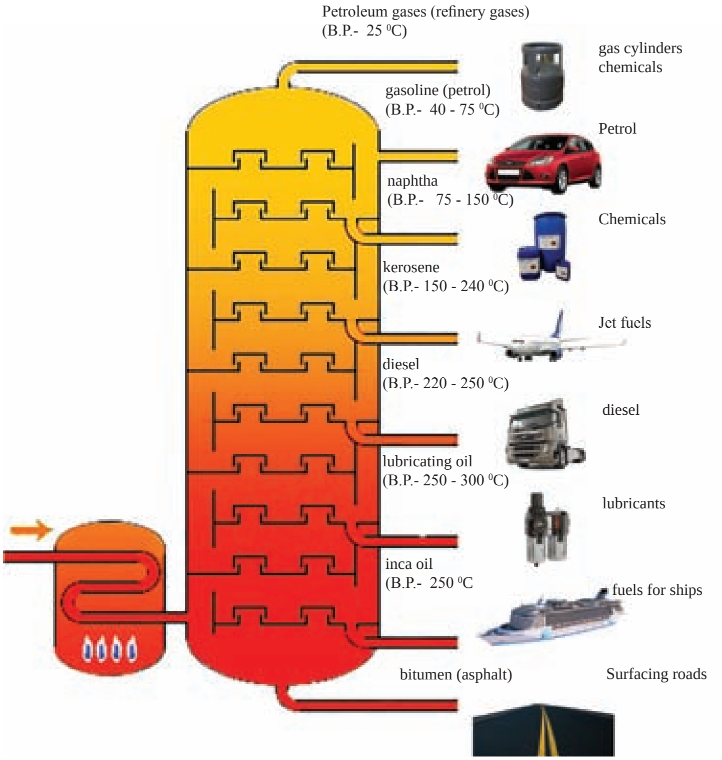


Figure 3.3.5 - Fractionating tower

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.

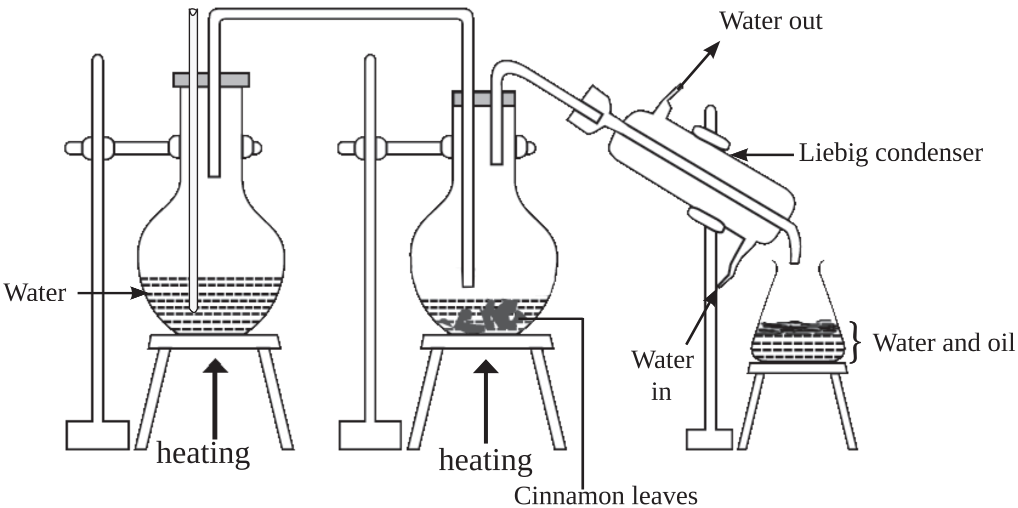


Figure 3.3.6 - Steam distillation

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.

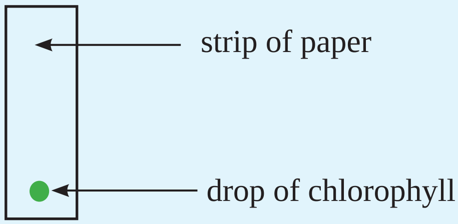


Figure 3.3.7

- 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.

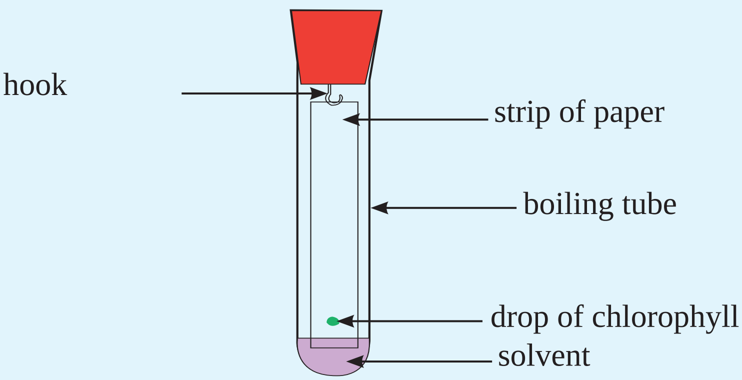


Figure 3.3.8

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 :

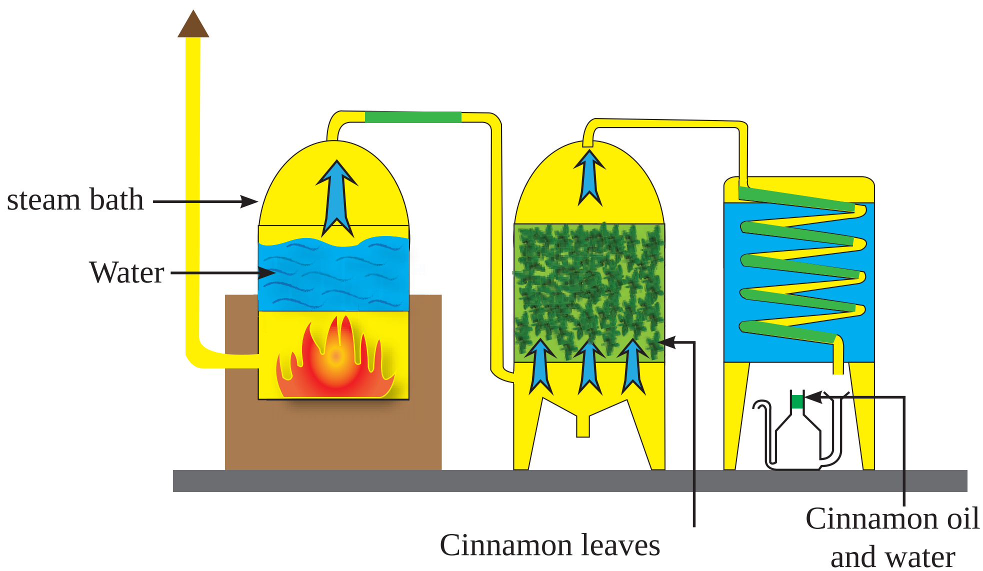
- Cinnamon leaf oil
- Cinnamon bark oil
- Citronella oil
- Pepper oil
- Cardamom oil
- Nutmeg oil
- Clove bud oil
- Eucalyptus oil

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	$\frac{0.25}{200}$ x 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	-	ආසූතය	-	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

Waves and their applications

Physics
04

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.

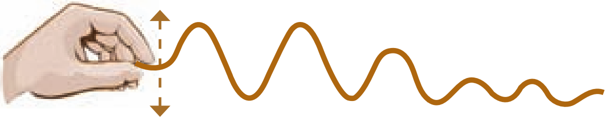


Figure 4.2 – Formation of ripples on a horizontal string

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.

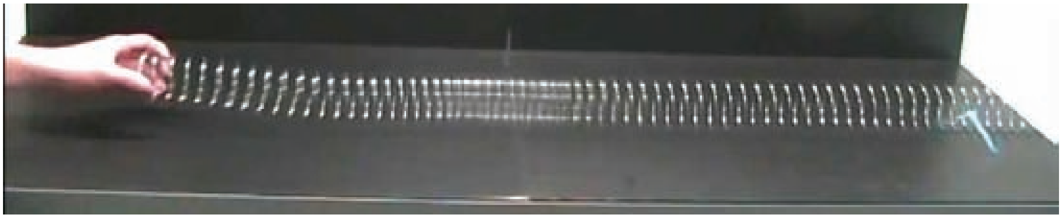


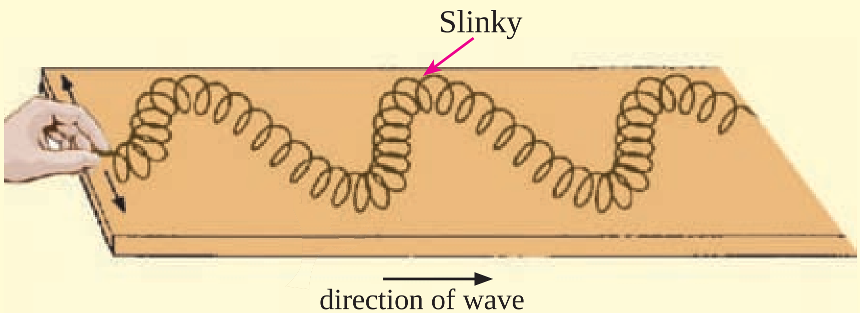
Figure 4.3 - Figure of a slinky

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.

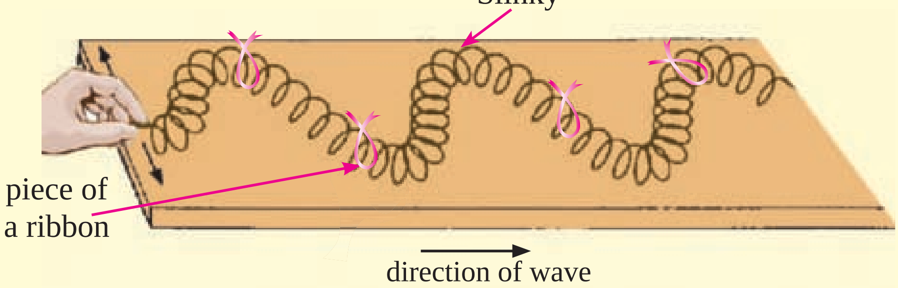
1. Transverse waves
2. Longitudinal waves

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.

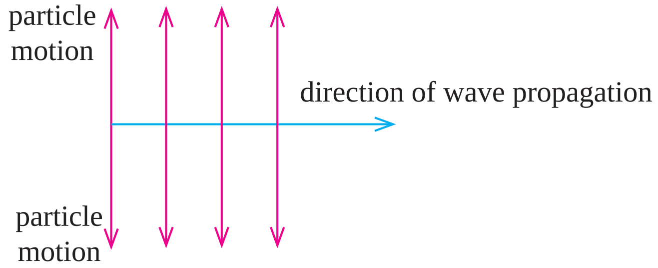


Figure 4.6 Direction of motion of the particles of the medium

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.

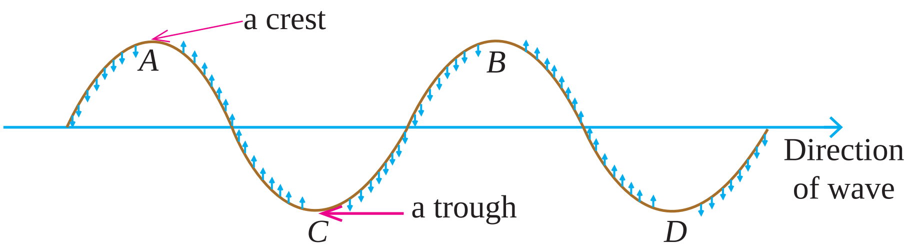


Figure 4.7 – Cross section of a water wave

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.

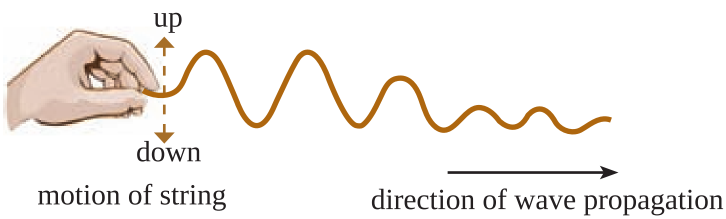


Figure 4.8 - Formation of transverse waves in a string

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.

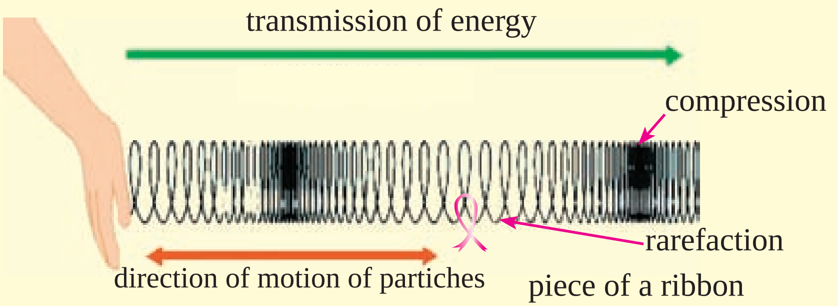


Figure 4.9. Demonstration of the formation of longitudinal waves using a slinky

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.

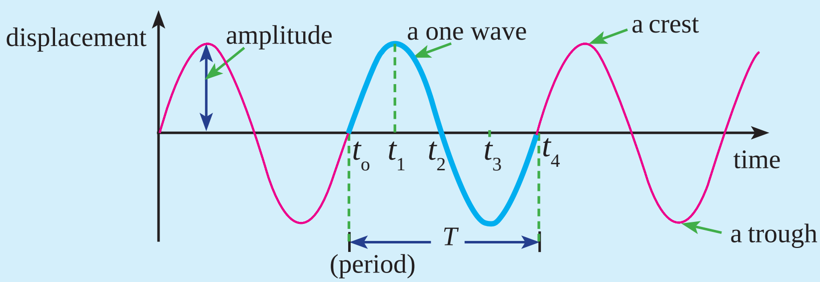


Figure 4.10 – Variation of displacement of a single particle, with time

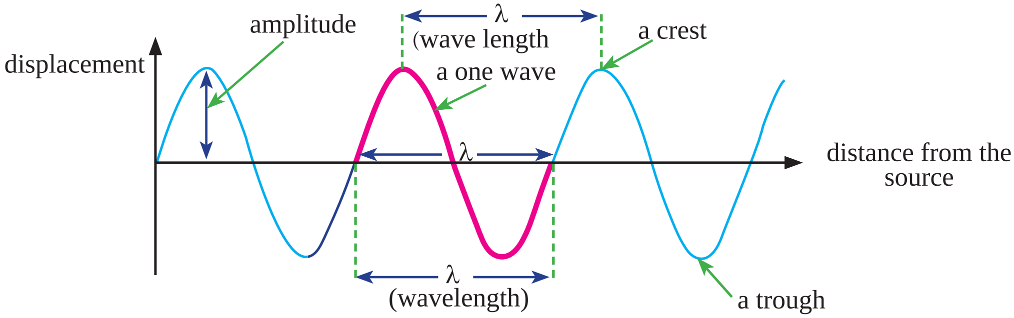


Figure 4.11 – Variation of displacement of particles with the distance from the source, at a given moment

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.

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

- **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)	×	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.

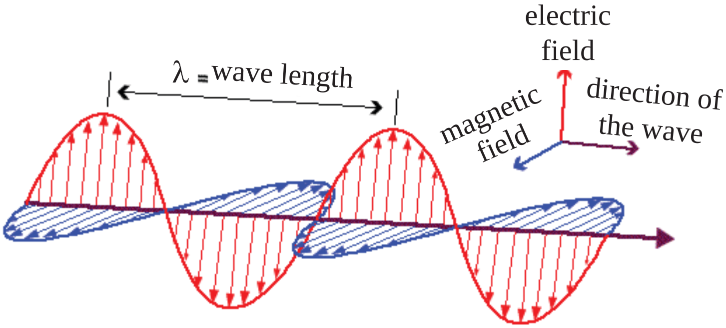


Figure 4.12 - Electric and magnetic fields of an electromagnetic wave

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	$< 3 \times 10^{9}$

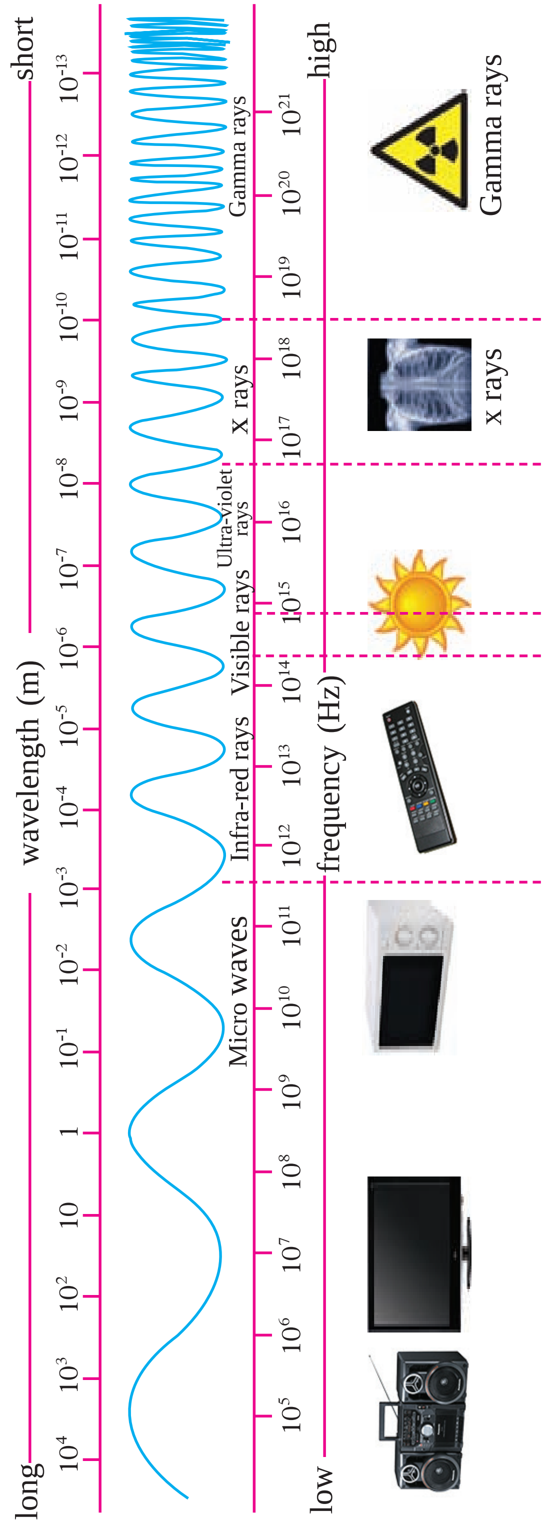


Figure 4.13 – Electromagnetic spectrum

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.

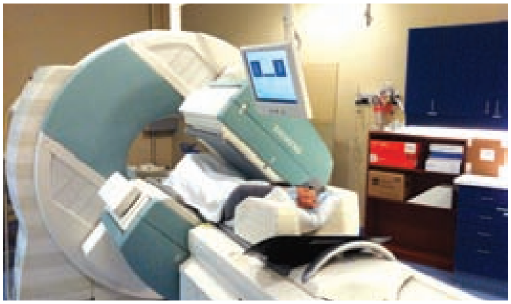


Figure 4.14 – An instance where gamma rays are used

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.

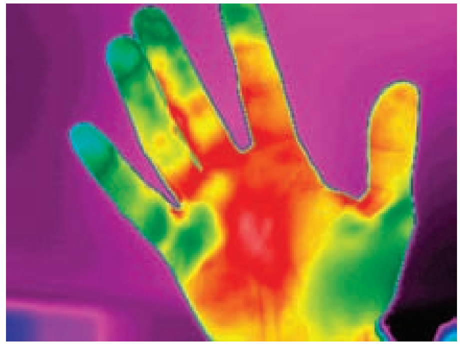
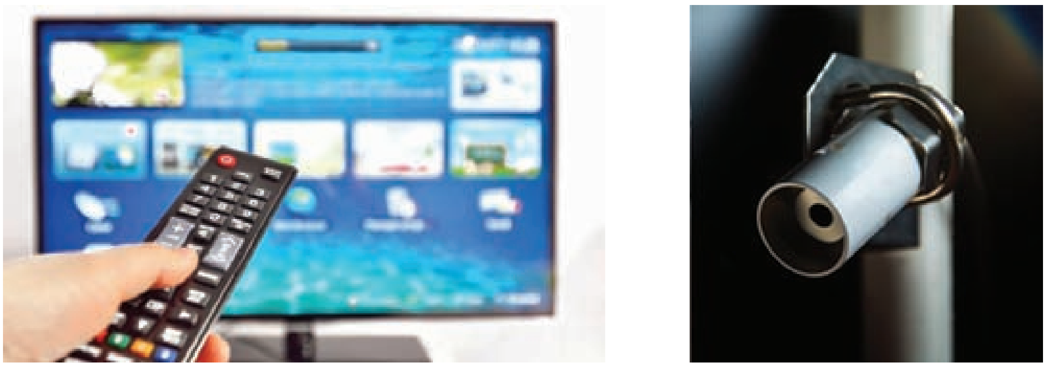


Figure 4.17 - A heat photograph

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.

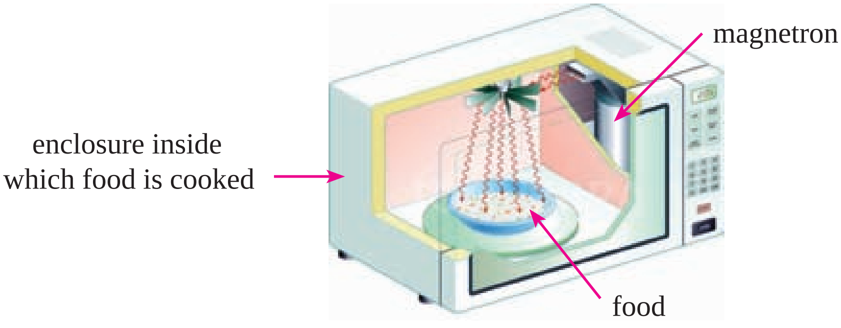


Figure 4.19 – A microwave oven

- **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.

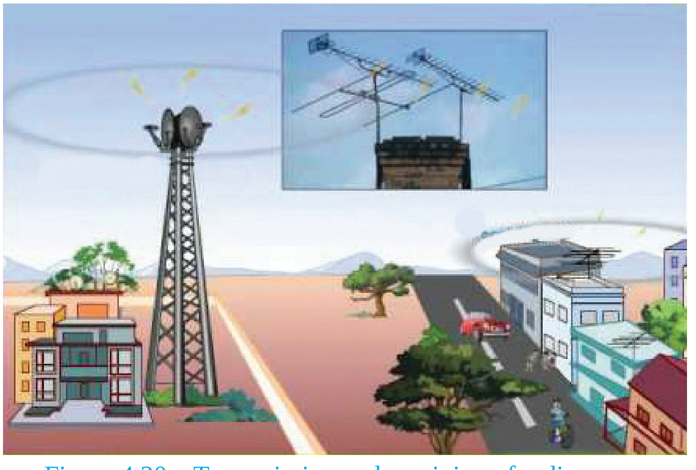


Figure 4.20 – Transmission and receiving of radio waves

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.

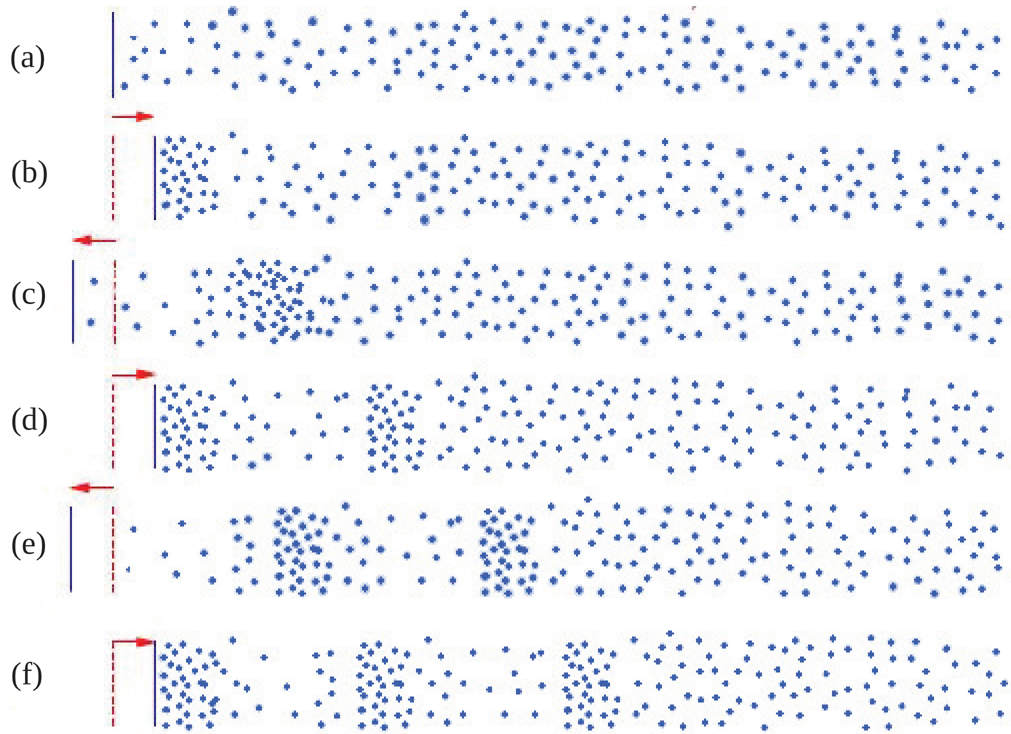


Figure 4.23 – Propagation of sound as longitudinal waves

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.

Figure 4.24 - Communication by whales using sound waves

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

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.

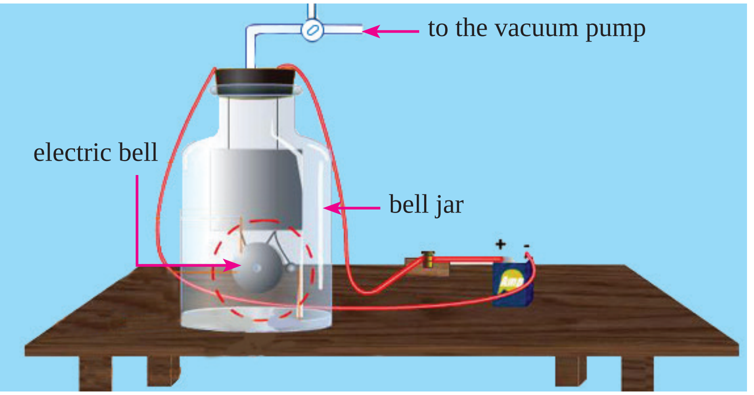


Figure 4.26 – Illustrating that sound waves needs a medium for propagation

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


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

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.

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.

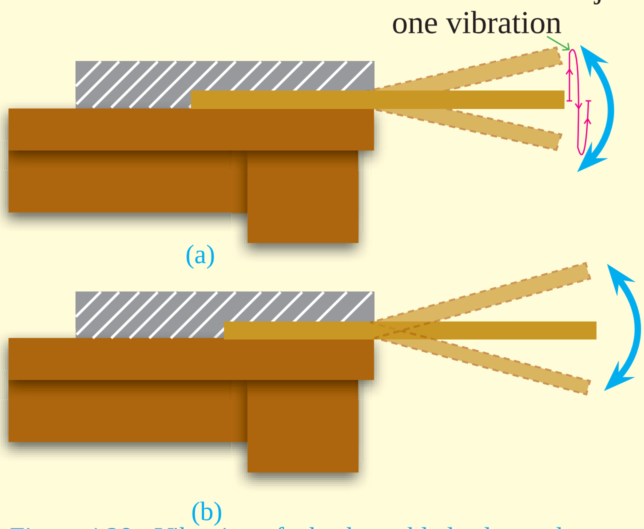


Figure 4.28 - Vibration of a hacksaw blade clamped at one end

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.

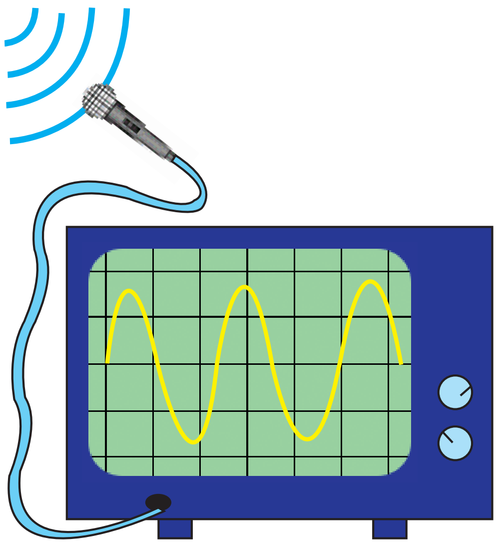
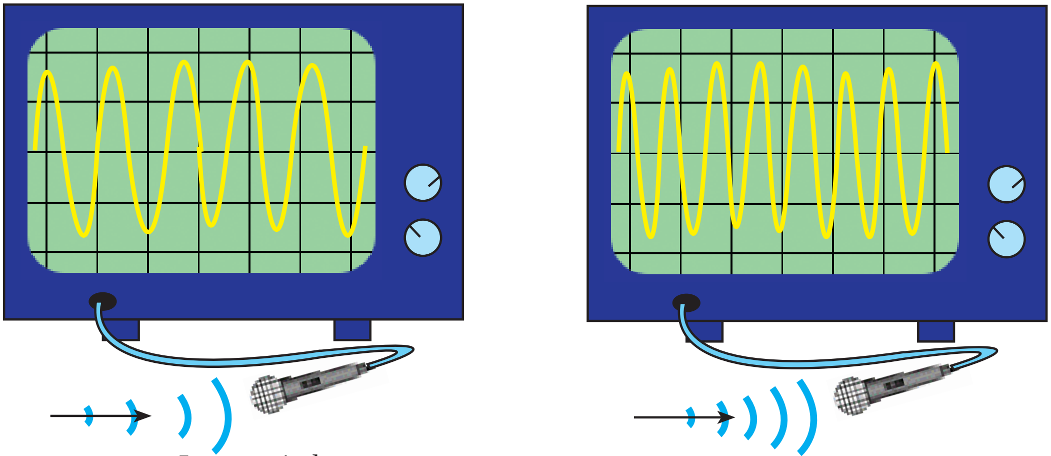


Figure 4.29 - The shape of a sound wave displayed on the screen of a cathode ray oscilloscope

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.



Lower pitch
(Lower frequency and longer period)

Higher pitch
(Higher frequency and shorter period)

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.

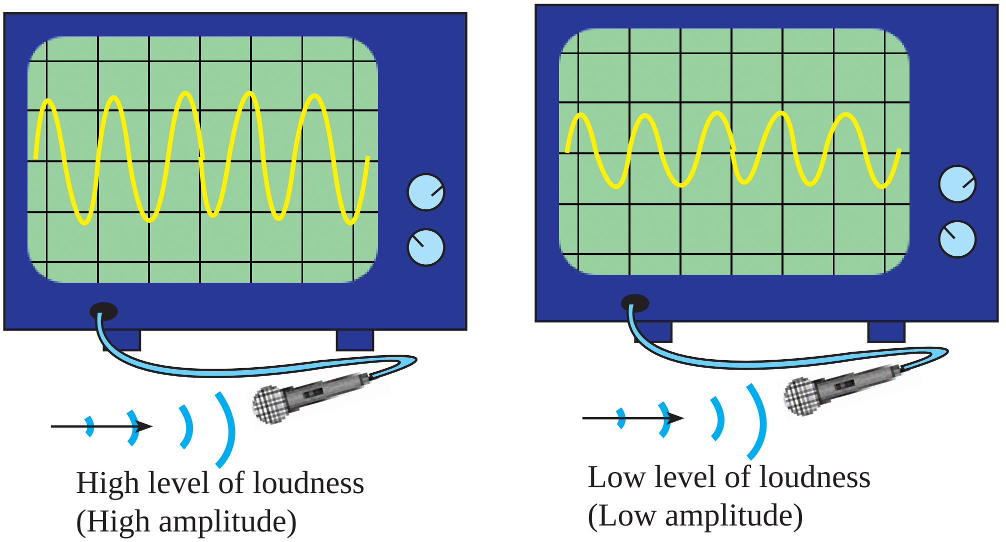


Figure 4.31 – Waveforms of two notes with high and low levels of loudness

• 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.

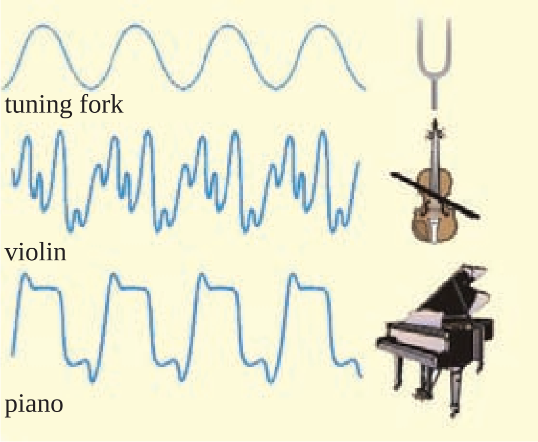


Figure 4.33 – Wave forms of the same note with the same pitch played by different instruments

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.

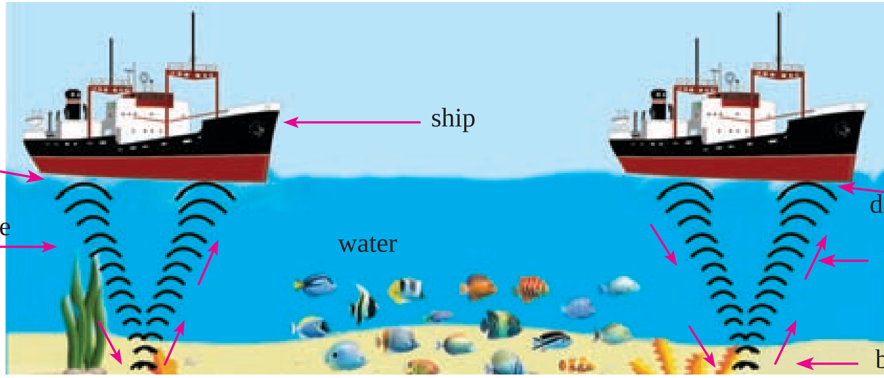


Figure 4.36 - Finding the depth of the sea using ultrasound waves

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}).

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

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

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.

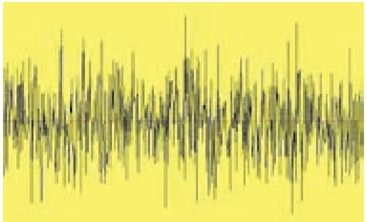


Figure 4.40 – Wave form of a noise

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?

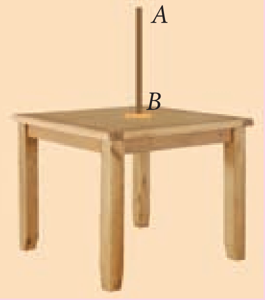
(ii) Suppose you place a paper boat on the water surface and disturb the water surface a small distance away from the boat. What change would you observe in the paper boat? What does it illustrate?

(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?

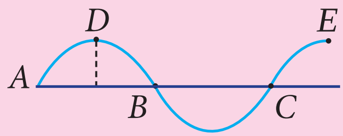
(v) (a) What is the sound characteristic that depends on the frequency?

(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.



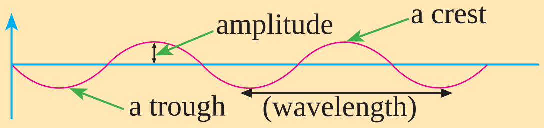
   (a) What physical quantity of a wave is the distance between the points D and E equal to?
   (b) The same distance above is shown by the distance between two other points in the figure. What are these two letters?

(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

Geometrical Optics

Physics 05

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.

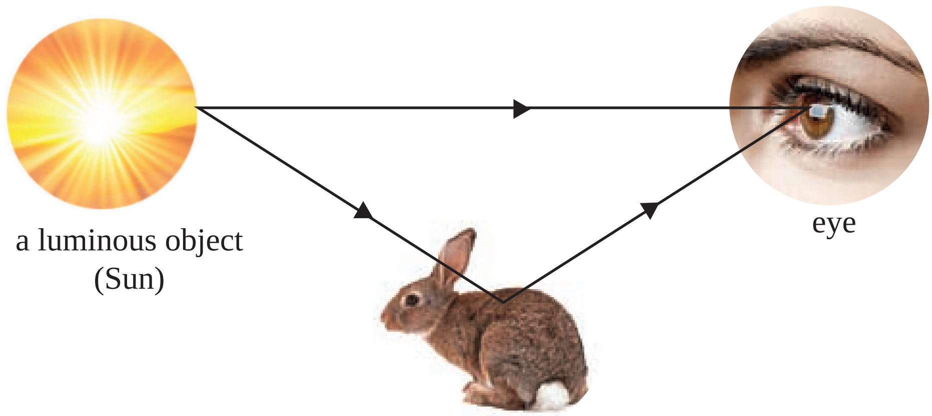
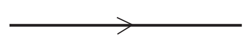


Figure 5.1 – Seeing luminous and non-luminous objects

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.

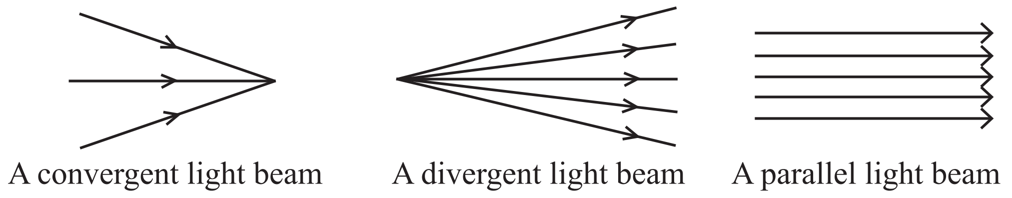


Figure 5.2 – Beams of light

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.

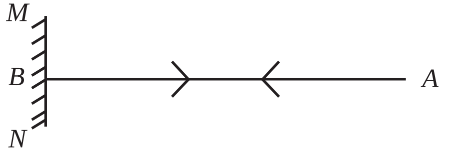


Figure 5.3 – The way a light ray incident on a plain mirror is reflected

- 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)

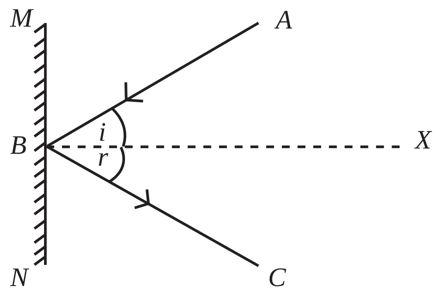


Figure 5.4 – Reflection of a light ray from a plane mirror

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.

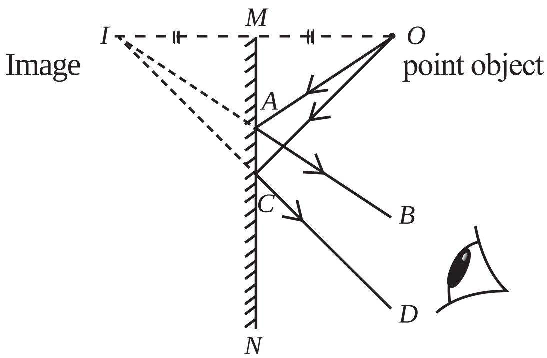


Figure 5.5 – The formation of an image of a point object by a plane mirror

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 (ƎƆИA⅃UBMA). 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.

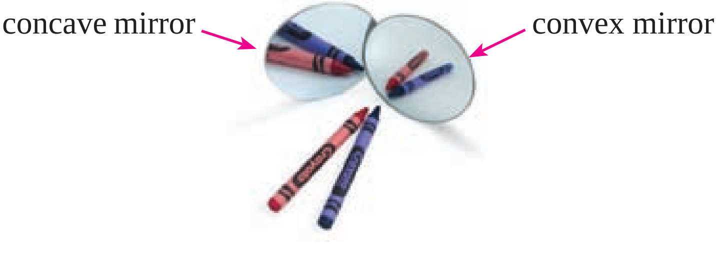


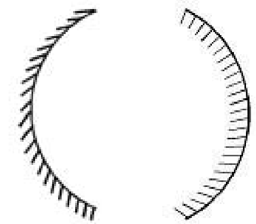
Figure 5.6 – Images formed by concave and convex mirrors

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.

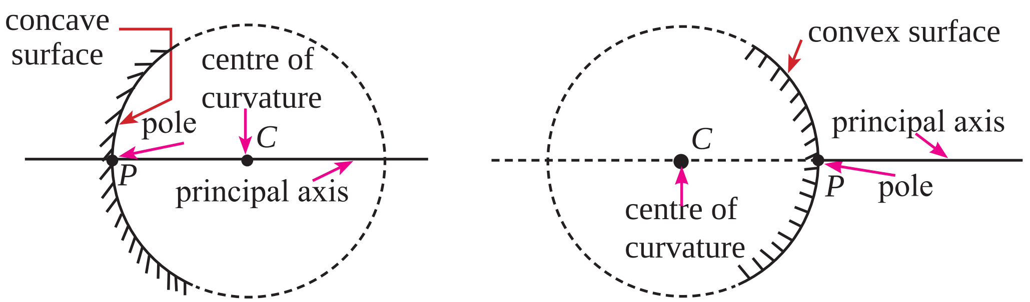


Figure 5.7 - Center of curvature, pole and principal axis of a spherical mirror

- 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.

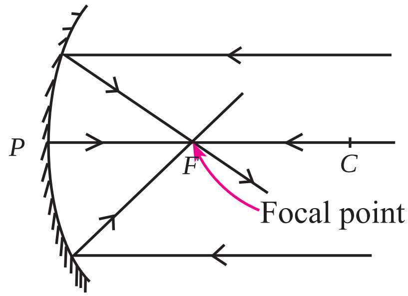


Figure 5.8 – Converging a parallel beam of light after reflection

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*.

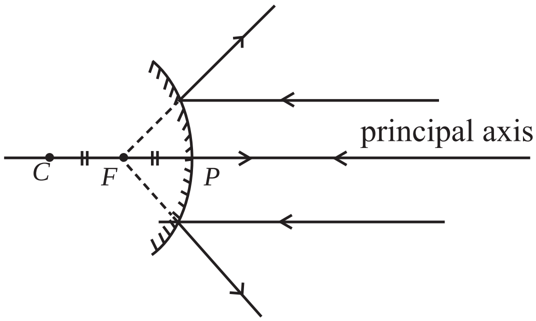


Figure 5.9 - Diverging a parallel beam of light upon reflection from a convex mirror

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*.

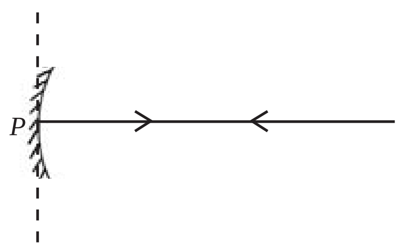


Figure 5.10 – Reflection of light coming along the principal axis of a concave mirror

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

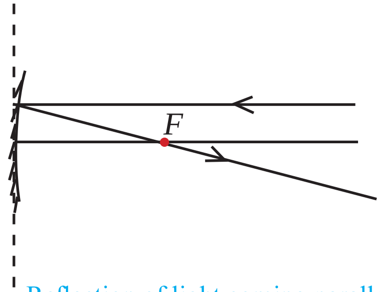


Figure 5.11 – Reflection of light coming parallel to the principal axis of a concave mirror

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

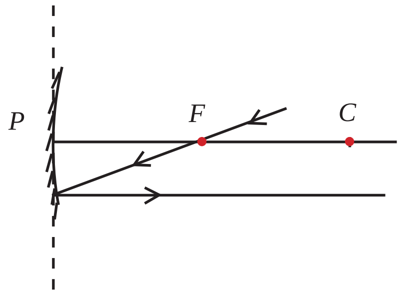


Figure 5.12 – Reflection of light coming through the focal point of a concave mirror

(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.

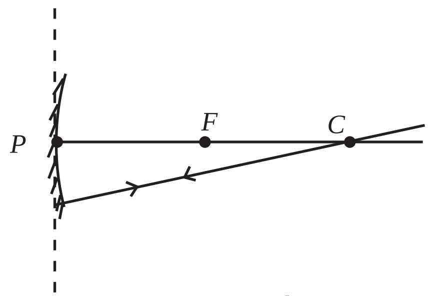


Figure 5.13 - Rays coming towards a concave mirror through the center of curvature

(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, $i = r$.

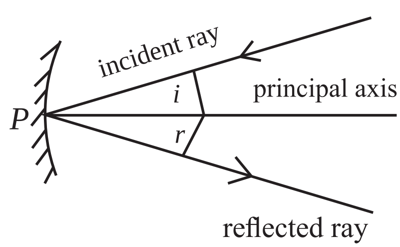


Figure 5.14 – Reflection of a ray coming to the mirror making some angle with the principal axis

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.

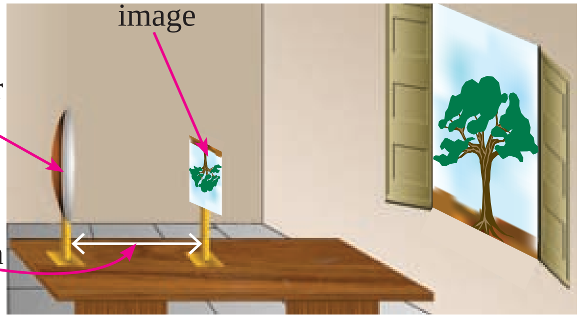


Figure 5.16 – Measuring the focal length of a concave mirror

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.

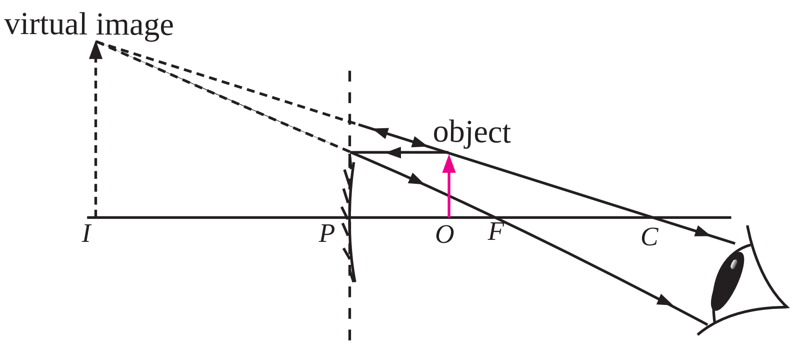


Figure 5.17-Formation of the image of an object placed between the mirror and the focal point

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.

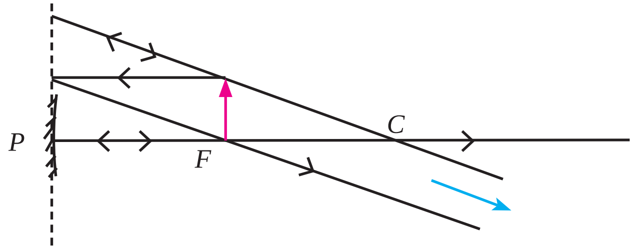


Figure 5.18 - Image of an object placed on the focal point

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.

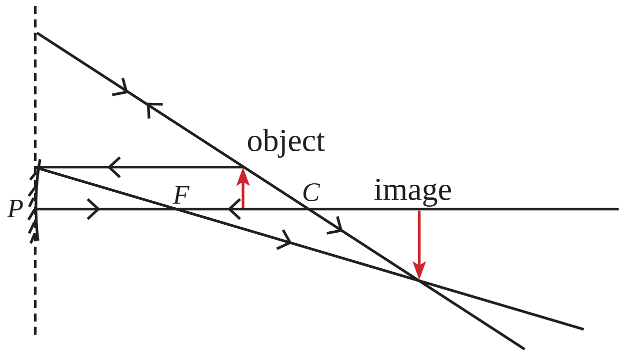


Figure 5.19 - Image of an object placed between the center of curvature and the focal point

4. Object on the center of curvature

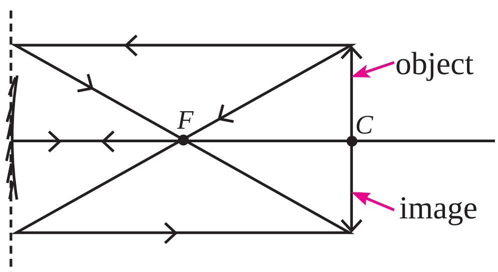


Figure 5.20 - Formation of the image of an object placed on the center of curvature

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.

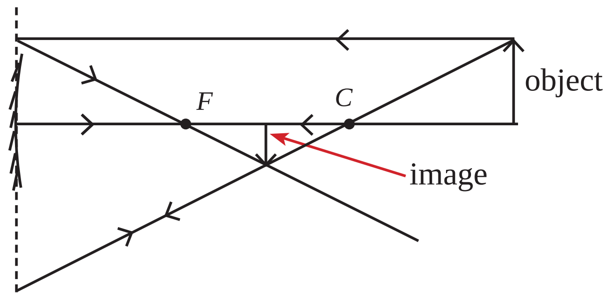


Figure 5.21 - Formation of the image of an object placed at a point beyond the center of curvature

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

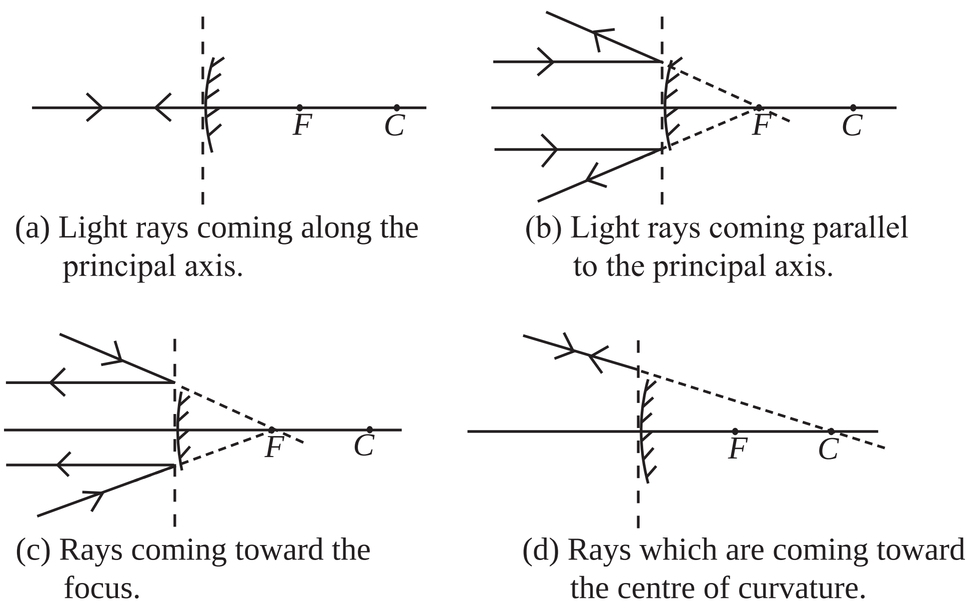


Figure 5.22 - Reflection of light from a convex mirror

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.

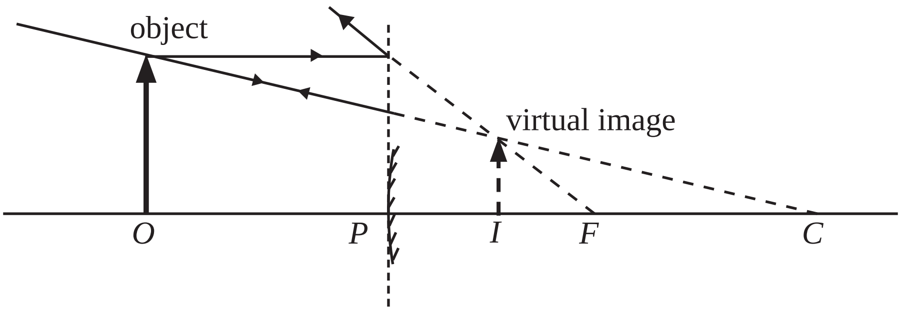


Figure 5.23 - Formation of an image from a convex mirror

5.3 Refraction of Light

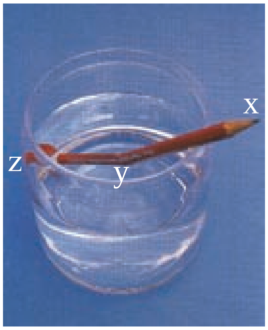


Figure 5.24 - A pencil inside a glass of water

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.

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.

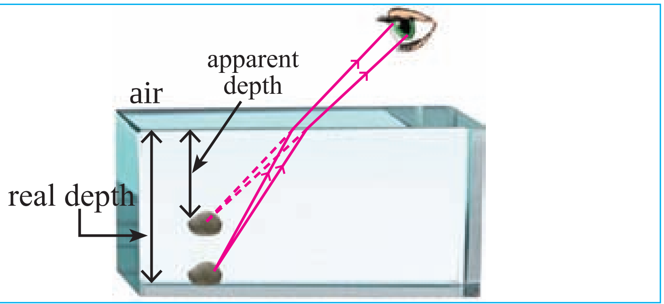


Figure 5.25- Slightly raised appearance of an object at the bottom of a vessel of water

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

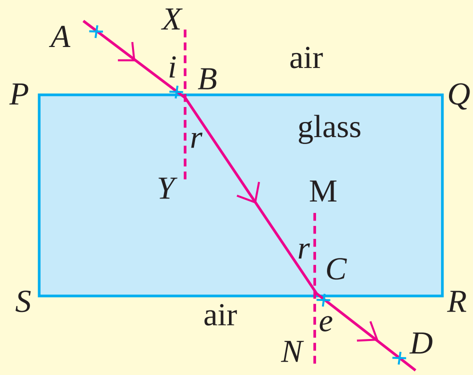


Figure 5.26 - Light refraction through a block of glass

- 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*).

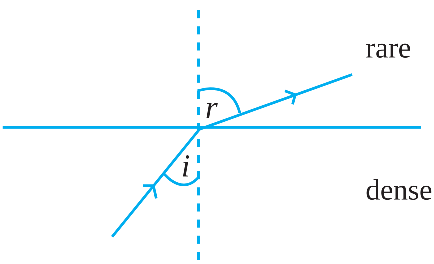
After entering the block of glass, the incident ray travels along *BC*. The refracted ray (*BC*) is bent towards the normal at point *B*.

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*).

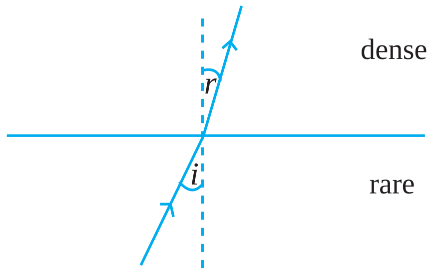
When light enters from air which is a rare medium to glass which is a dense medium, you will notice that the light rays are refracted towards the normal.

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 ${}_{g}n_{a}$.

refractive index of water relative to air ${}_{a}n_{w}$ = 1.33
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.

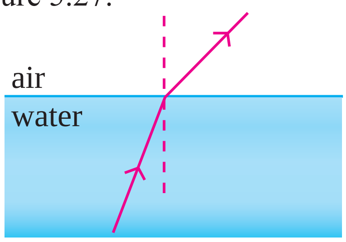


Figure 5.27 – A light ray traveling from water to air

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**.

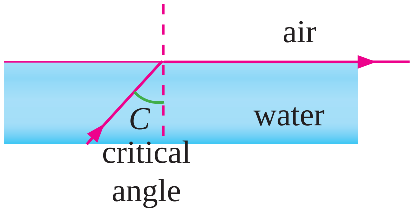


Figure 5.28 – Critical angle

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**.

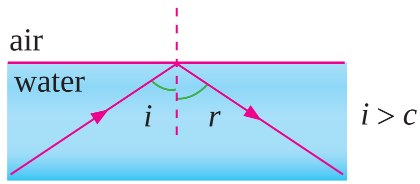


Fig. 5.29 – Total internal reflection

Extra knowledge

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

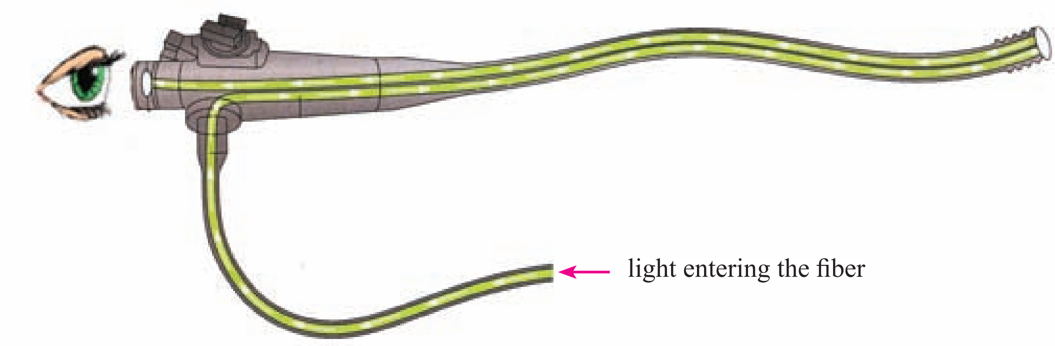
Material	water	glass	diamond
critical angle	49°	42°	24°

• Several applications of total internal reflection

Optical fibers

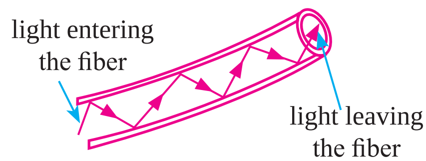
An optical fibre is a flexible transparent fiber made of glass or plastic. Light rays that enter through one end of an optical fiber travel through the fiber while undergoing total internal reflection and leave the fiber through the other end. Even if the fiber is many kilometers long, light will leave 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

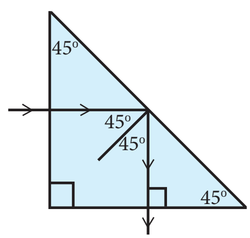


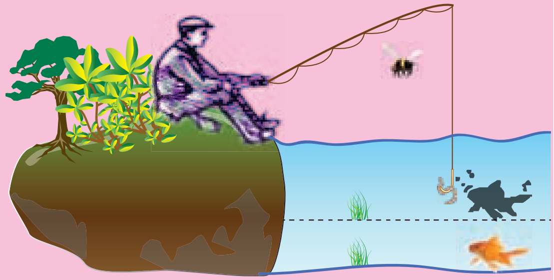
Figure 5.30 – Total internal reflection by a prism

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.

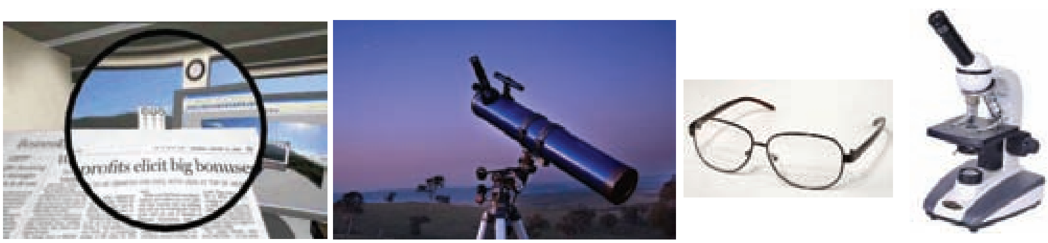


Figure 5.31 - Some instruments with lenses

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.

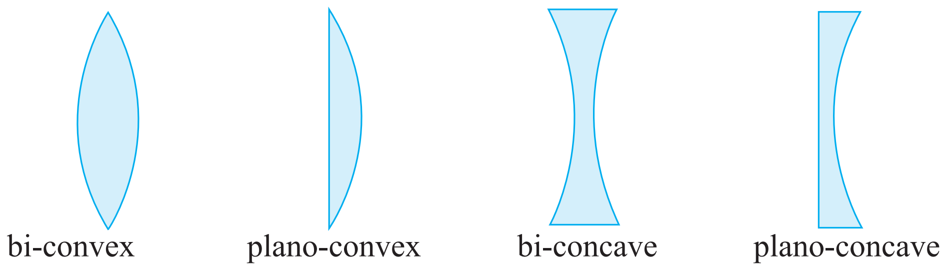


Figure 5.32 – Several types of lenses.

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.

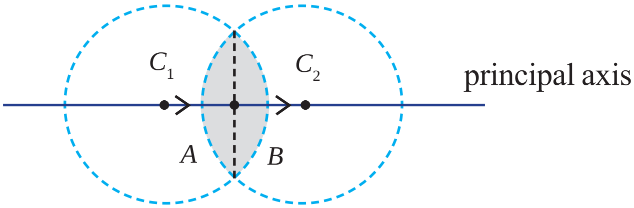


Figure 5.33 - Surfaces of a convex lens

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.

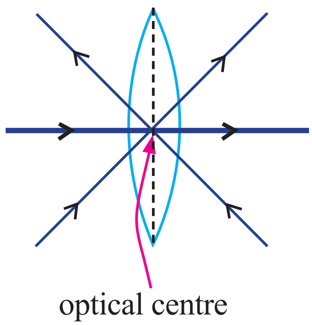


Figure 5.34 – Light rays traveling through the optical centre

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.

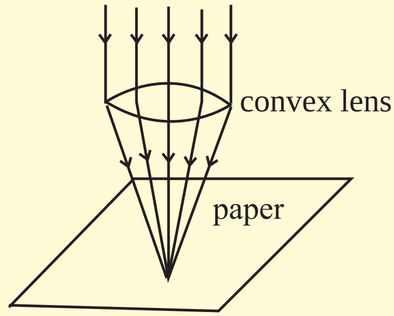


Figure 5.35 – Focusing of light with a convex lens

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.

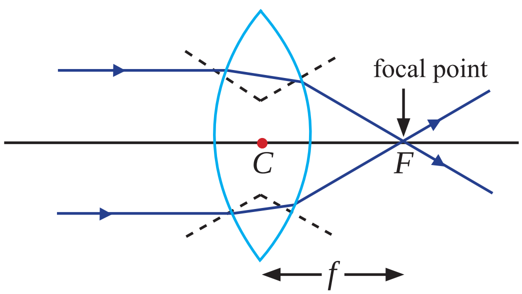


Figure 5.36 – The way the rays parallel to the principal axis are refracted by a convex lens

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.

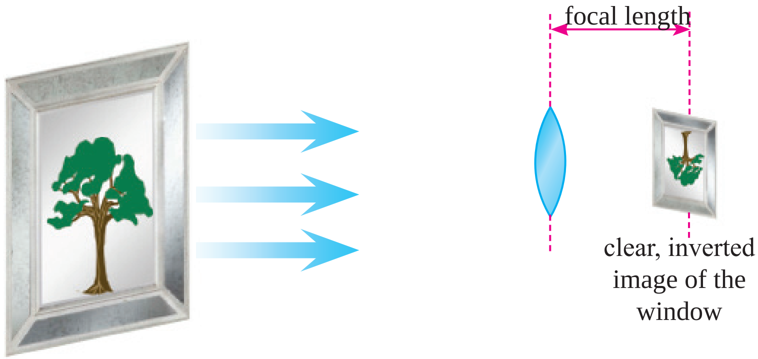
- This point is called the **focus or the focal point** of the lens. The distance from the optical centre of the lens to the focal point is called the **focal length** of the lens.

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.

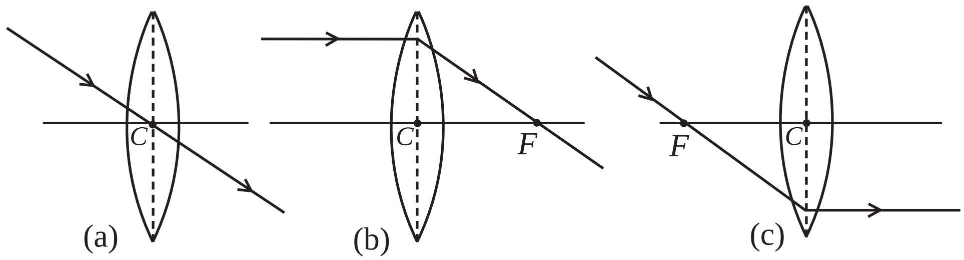


Figure 5.37 – A few special rays used in drawing ray diagrams

1. When the object is between the lens and its focal point

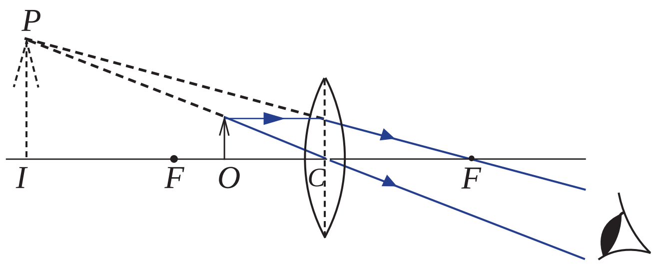


Figure 5.38 – When the object is between the lens and its focal point

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.

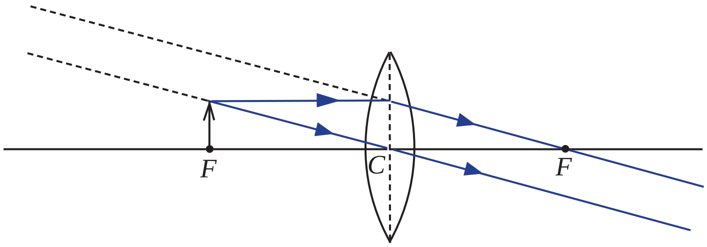


Figure 5.39 – Ray diagram for an image of an object on the focal point of a lens

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.

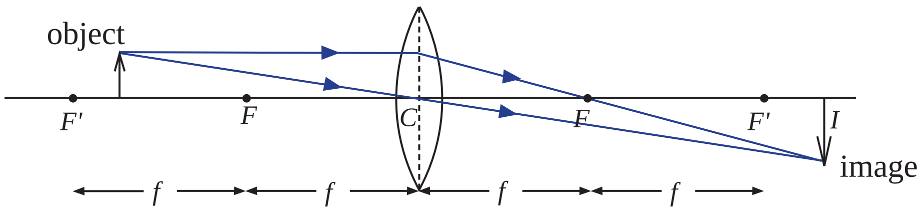


Figure 5.40 – The image of an object placed between distances f and $2f$

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

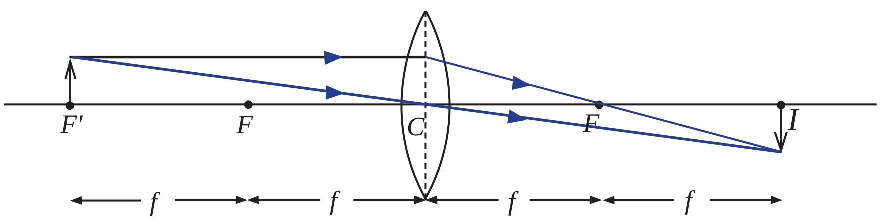


Figure 5.41 - Image of an object when the object distance is $2f$

5. When the object distance is greater than twice the focal length

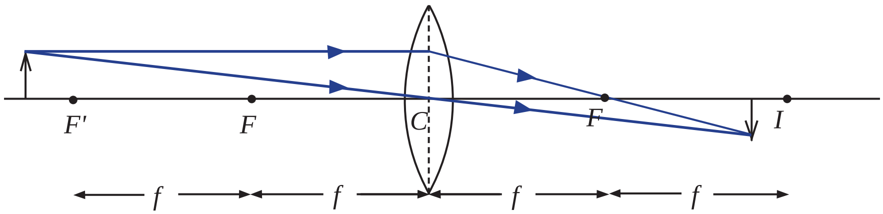


Figure 5.42 - Image of an object placed at a distance greater than $2f$

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 ($2f$). 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.

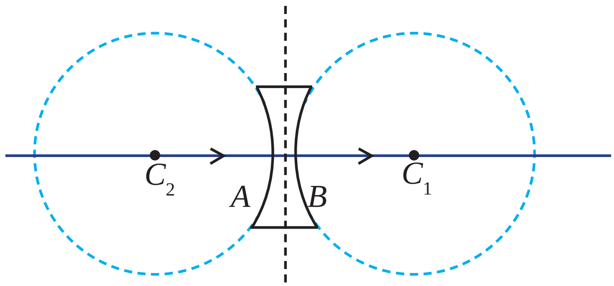


Figure 5.43 – Surfaces of a concave lens

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.

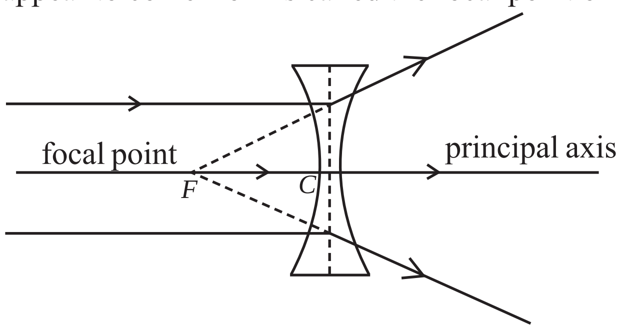


Figure 5.44 – Rays parallel to the principal axis, after passing through a concave lens, appear to come from a single point

- **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.

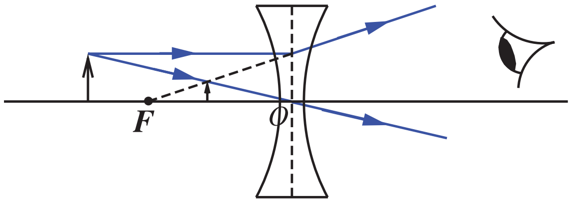


Figure 5.45 - A ray diagram for an image formed by a concave lens

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.

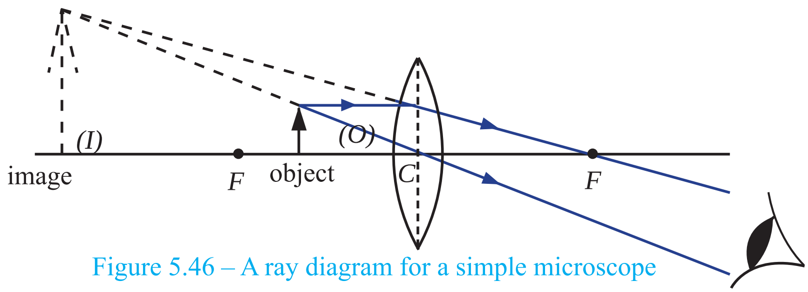


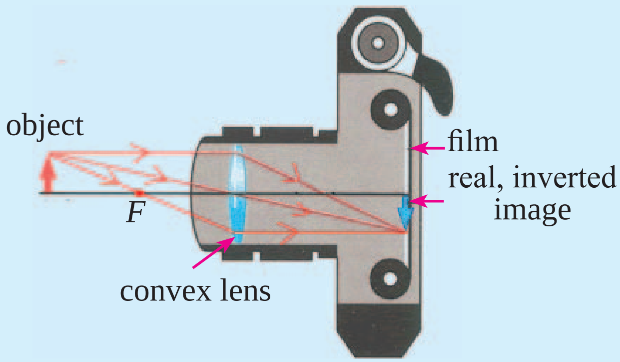
Figure 5.46 – A ray diagram for a simple microscope

- **The Principle of reversibility of light**

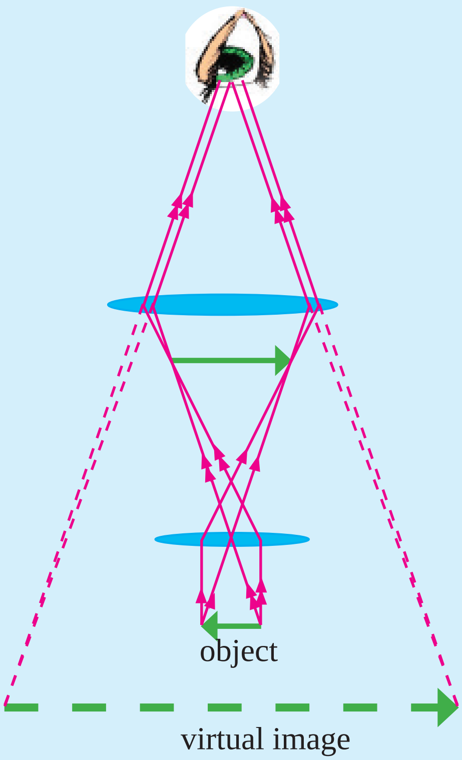
If the direction of a light ray is reversed, it will follow exactly the same path backward. This is called the principle of reversibility of light. This principle is valid even if the light ray is subjected to a combination of many reflections and refractions.

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.

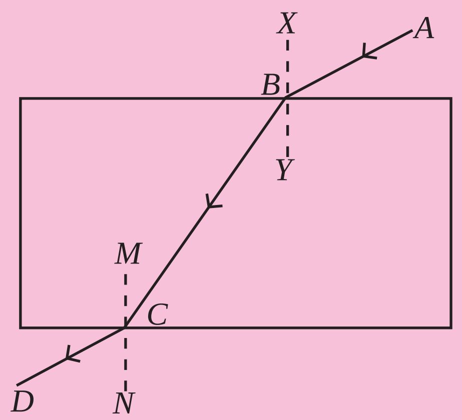
(2) (i) What is meant by the term refraction of light?

(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 ....

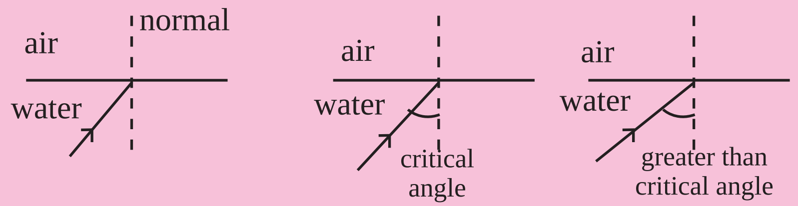
CD ray ....

ABX angle ....

YBC angle ....

NCD angle ....

(3) The figure shows different light rays entering a rare medium from a dense medium.

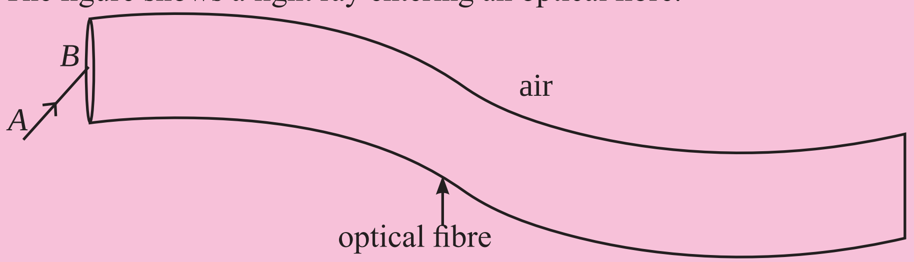


(i) Copy these figures and complete the ray diagrams.
(ii) What is meant by the term *total internal reflection*?
(iii) Give an example for a situation where total internal reflection occurs.

(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?

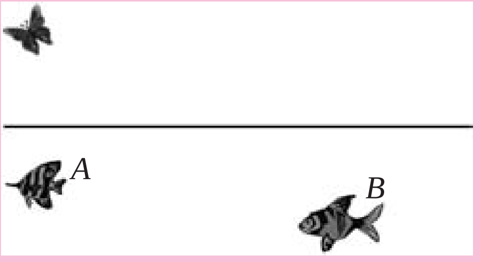
(6) A bag contains lenses with focal lengths 10 cm, 20 cm and 25 cm which are not marked with their focal length. Describe a simple activity to identify the three types lenses.

(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.

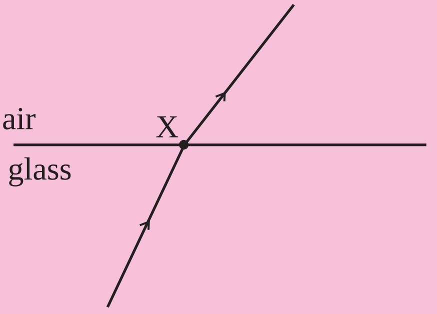


(i) Draw a ray to show the path of a light ray travelling from the butterfly to the eye of fish *B*.

(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.



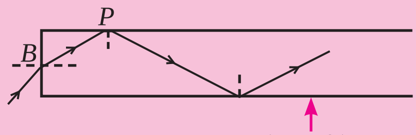
(a) Complete this diagram and show the angle of incidence i and the angle of refraction r . Measure these two angles.

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.



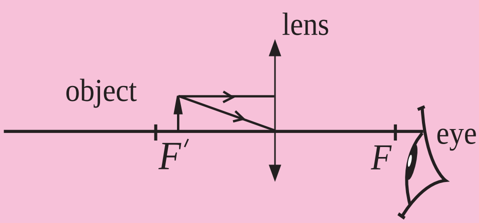
(a) State two changes light when it enters the fibre from air at point *B*.
(b) Explain why the light ray, after hitting point *P*, travels along the path shown.

(10) Lenses are used in many optical devices.
(a) Complete the table below by writing information about the images formed by each optical device.

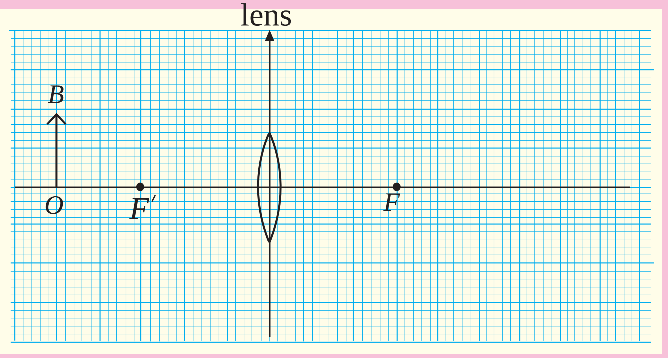
optical device	nature of image	size of image	position of image
eye	real		
projector		magnified	
magnifying glass			further from lens than the object

(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.

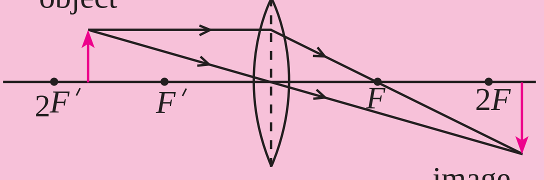


(11) The figure shows an object OB in front of a convex lens. The two focal points are marked as F and F'. An image of OB will be formed on the right of the lens.



(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.

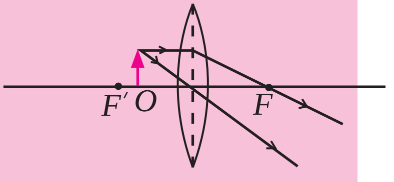
(12) The diagram shows a convex lens forming a real image of an object.



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.

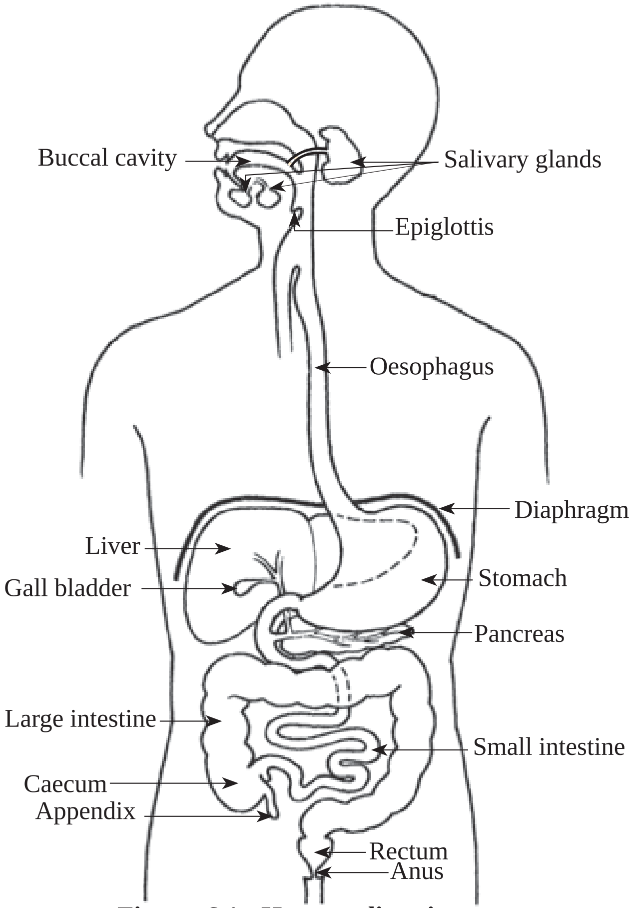


Figure. 6.1 - Human digestive system

Assignment - 6.1

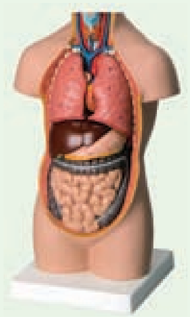


Figure. 6.2 - Human torso

- 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.

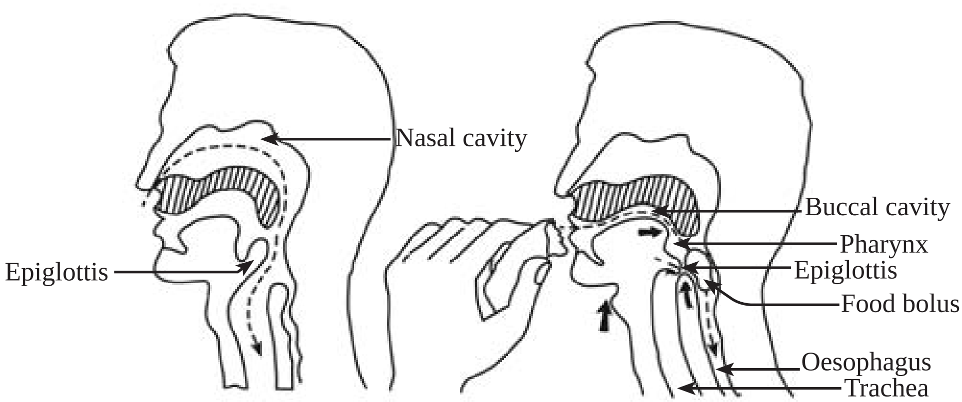


Figure. 6.3 - Trachea is closed with epiglottis when food enter into oesophagus

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.

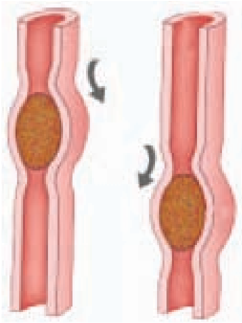


Figure. 6.4 -How the food pass through oesophagus

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 ⟶ Monosaccharides (Glucose / Fructose / Galactose)

Protein ⟶ Amino acids

Lipids ⟶ 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

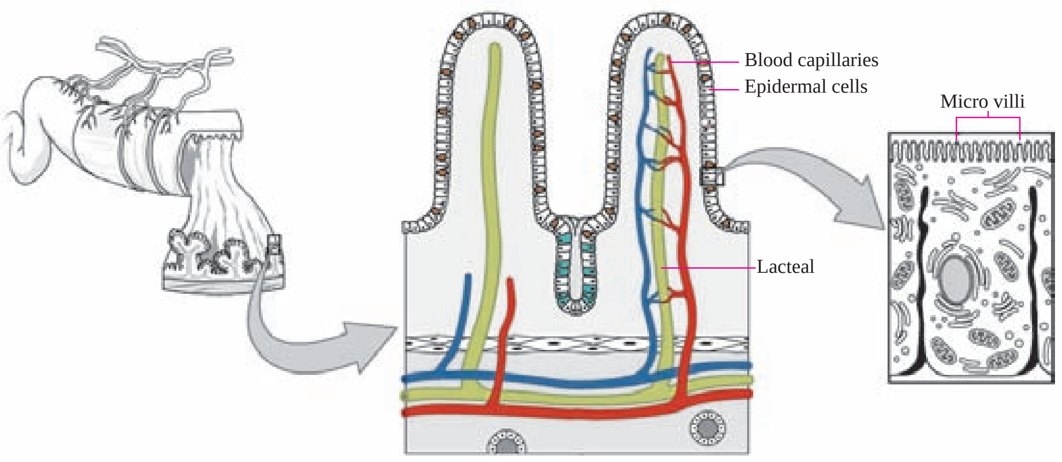


Figure. 6.5 - Structure of villi in small intestine

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

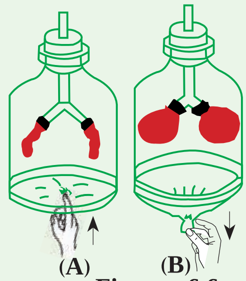


Figure - 6.6

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

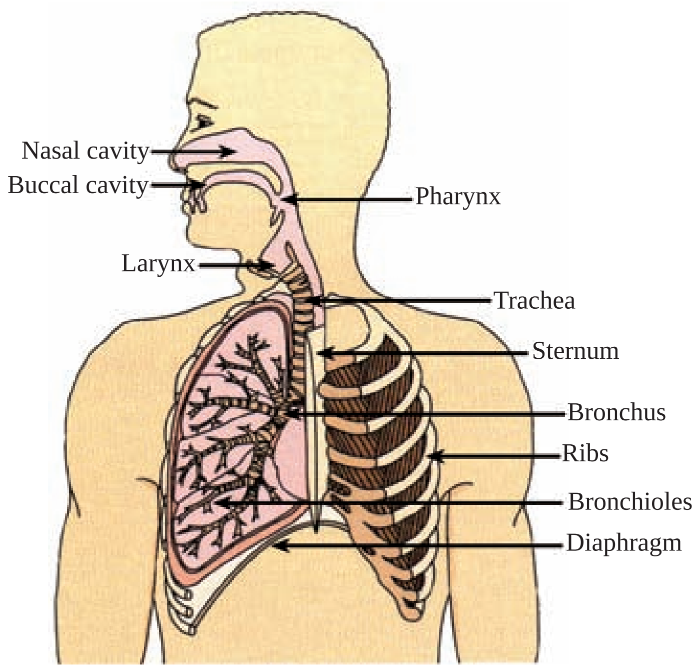


Figure 6.7 - Human respiratory system

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

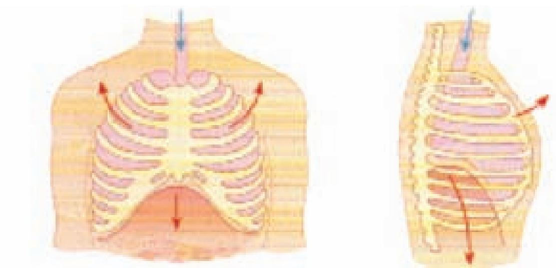


Figure 6.8 - Inspiration

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

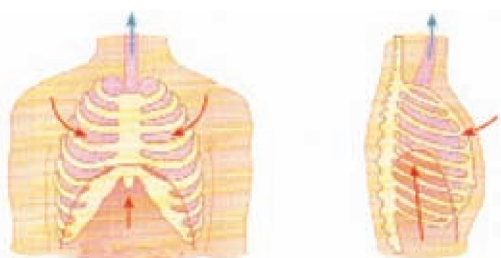


Figure 6.9 - Expiration

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

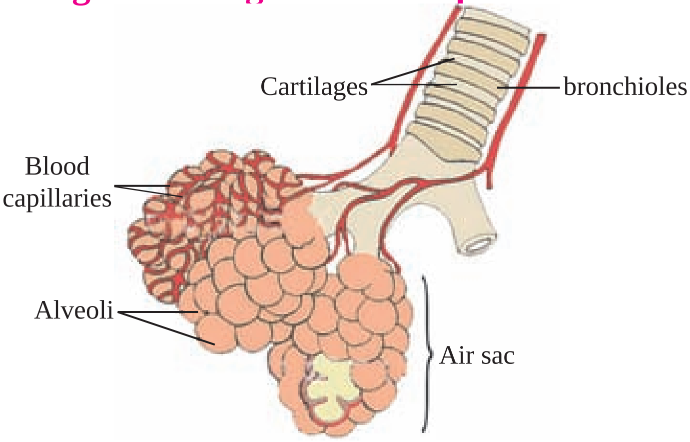


Figure 6.10 - Air, sacs, alveoli and blood capillaries in lungs

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.

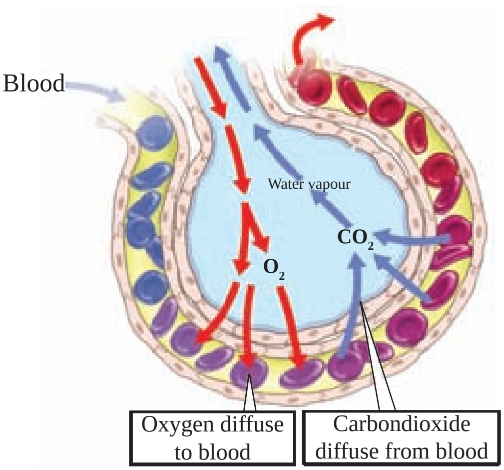


Figure 6.11 - Air exchange between alveoli and blood capillaries

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 ⟶ 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 ⟶ 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.

$$\text{Glucose} \longrightarrow \text{Lactic acid} + \text{Energy}$$

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

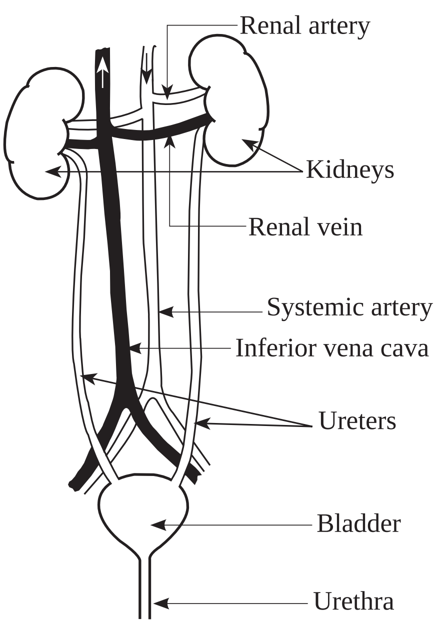


Figure 6.12 - Human urinary system

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.

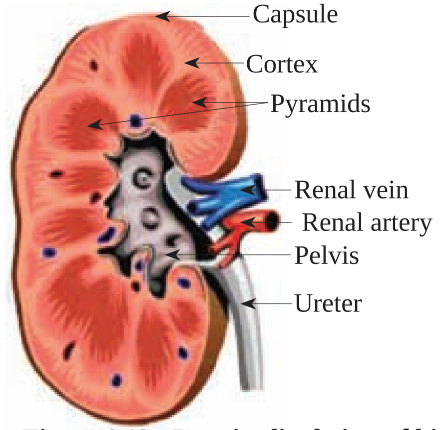


Figure 6.13 - Longitudinal view of kidney

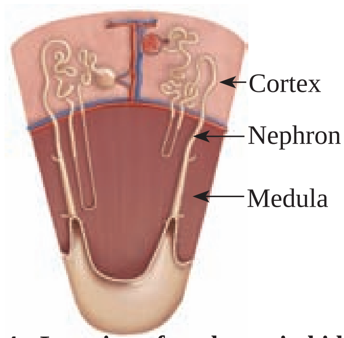


Figure 6.14 - Location of nephrons in kidney

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.

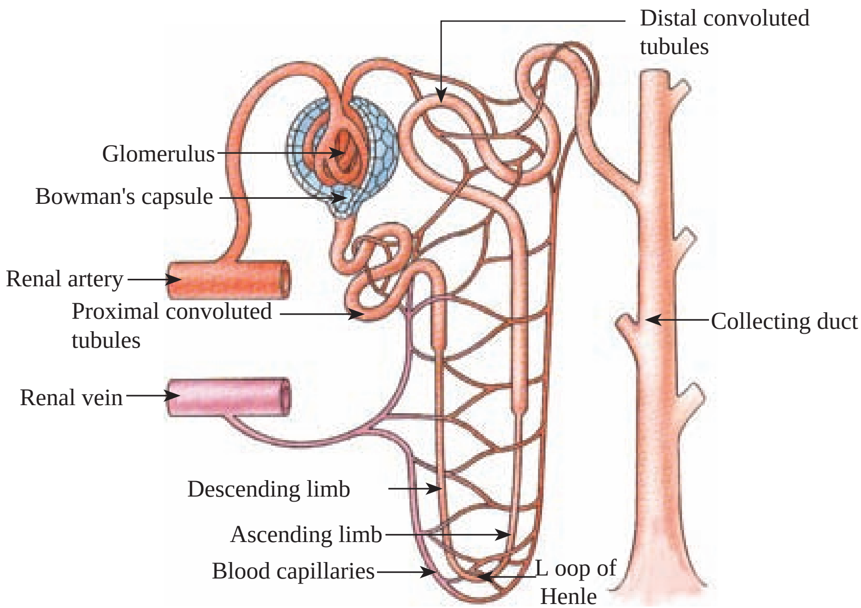


Figure 6.15 - Structure of a nephron

Process of urine formation

Urine formation in kidney follows three main processes,

1. Ultra filtration
2. Selective reabsorption
3. Secretion

Ultrafiltration

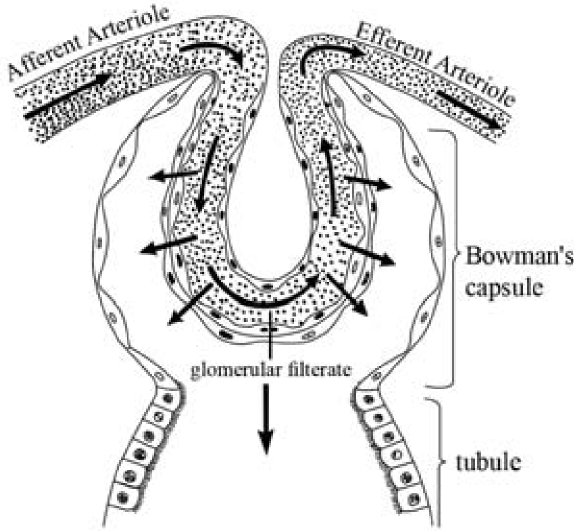


Figure 6.16 - Glomerular filterate collected into the cavity of bowman's capsule

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.

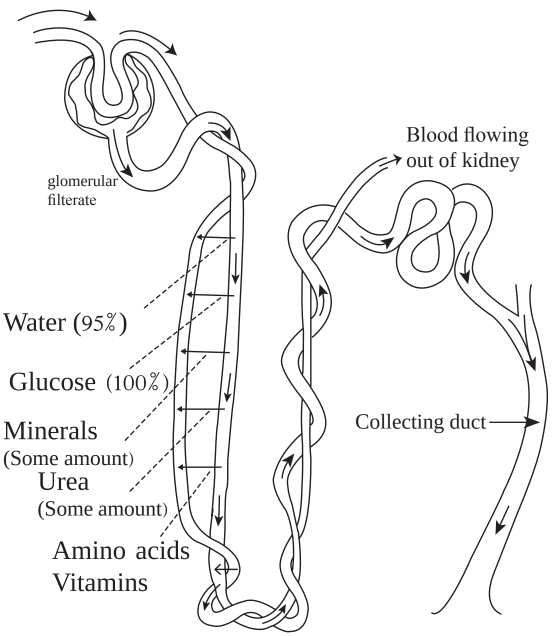


Figure 6.17 - Materials reaborsobed during urine formation

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.

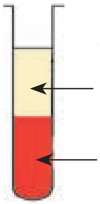


Figure 6.18 - Blood corpuscles and plasma

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

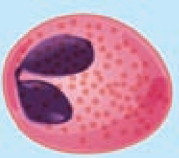
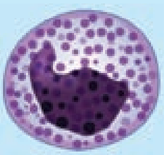
Non-granulocytes are in two types,

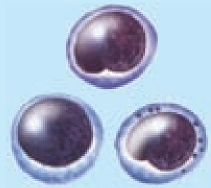
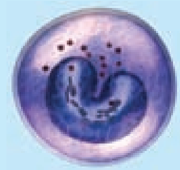
- Lymphocytes
- Monocytes

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

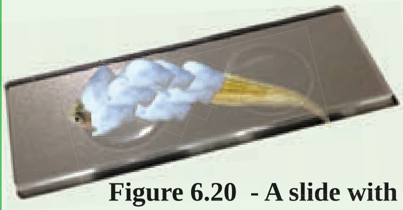


Figure 6.20 - A slide with a tadpole

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.

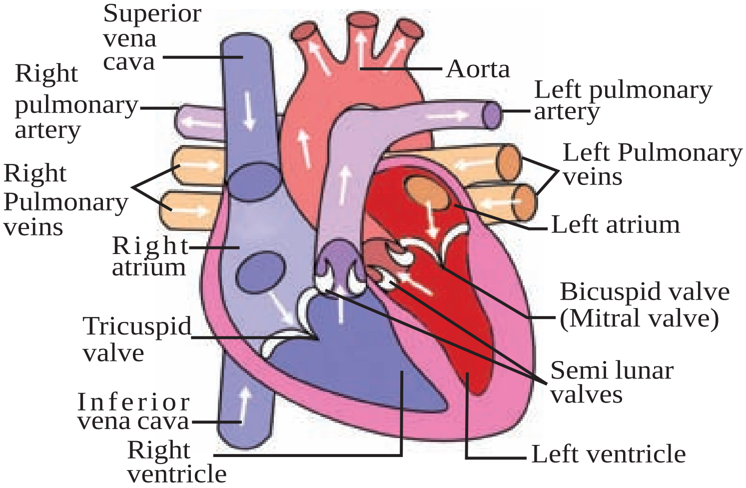


Figure 6.21 - A longitudinal section of the human heart

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

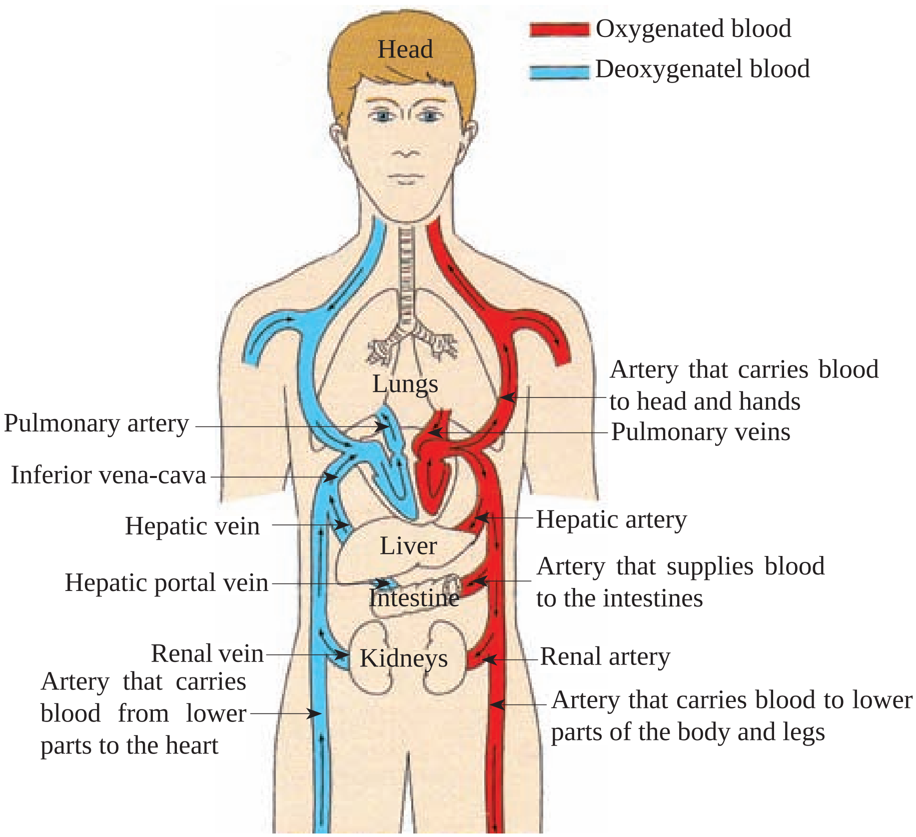


Figure 6.22 - Blood circulation of human

Double blood circulation

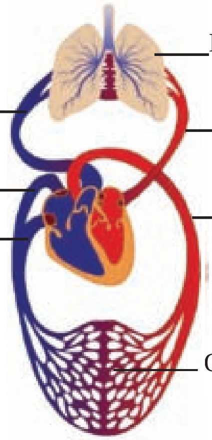


Figure 6.23 - Double circulation

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).

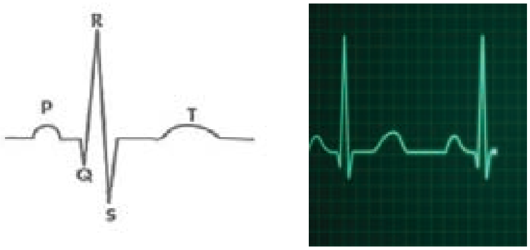


Figure 6.24 - Electro cardio gram of a healthy person

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

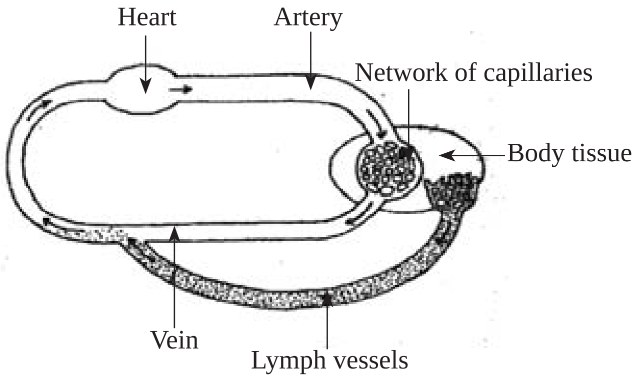


Figure 6.26 - Relationship between blood circulation and lymph circulation

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**.

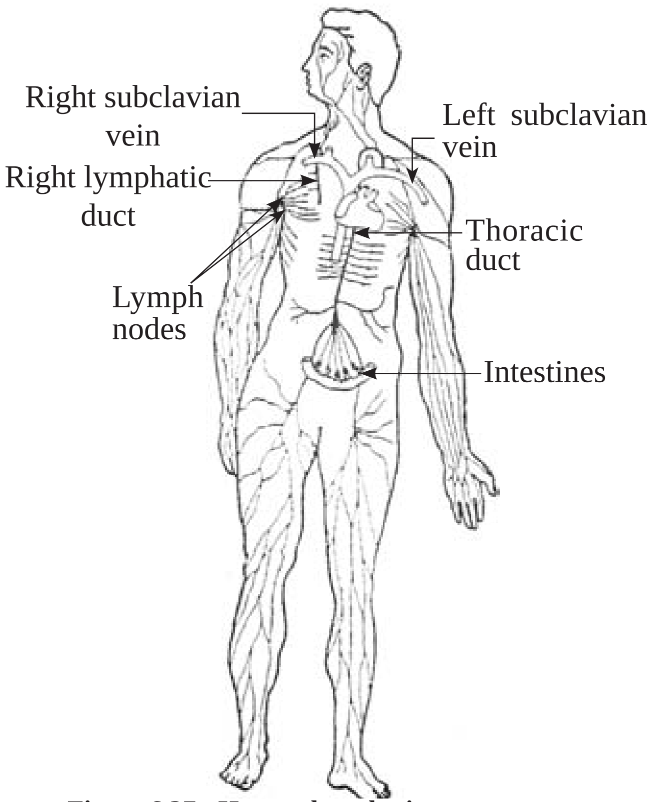


Figure 6.27 - Human lymphatic system

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 associted 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

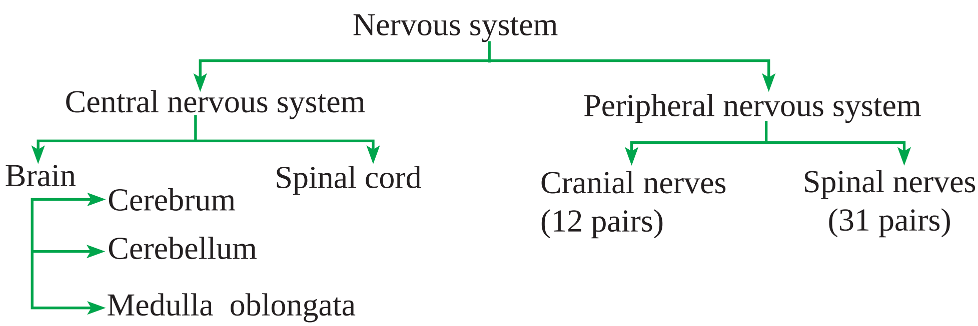
The coordination done by nervous system, is called nervous coordination, and coordination by endocrine system is called chemical coordination. In nervous coordination, impulses transmit through nerves and these impulses aim at a specific effector. In chemical coordination hormones secrete to blood and 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)

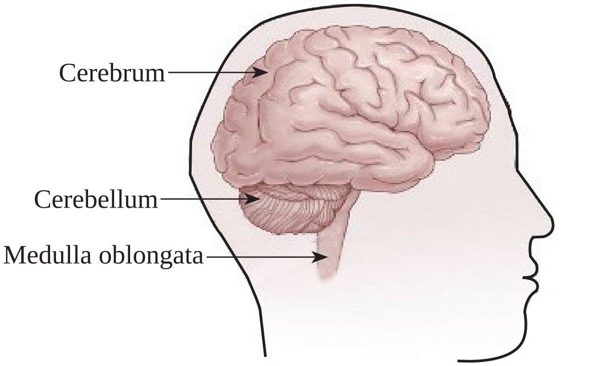


Figure 6.28 - External view of human brain

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

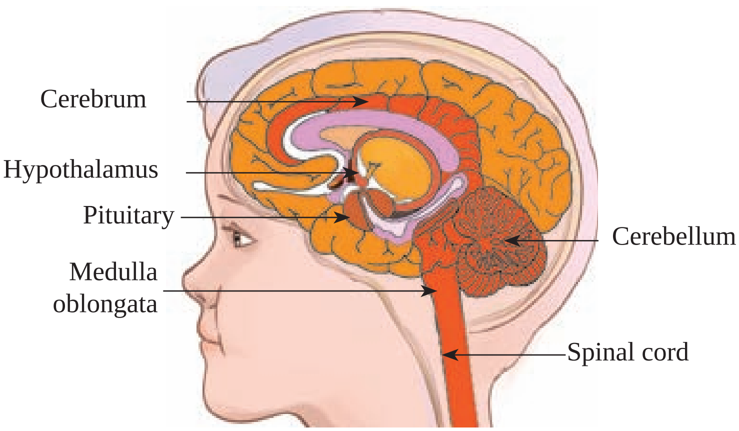


Figure 6.29 - Longitudinal section of human brain

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

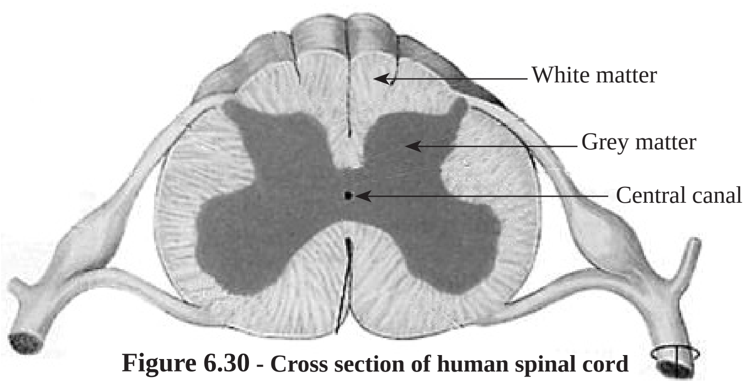


Figure 6.30 - Cross section of human spinal cord

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.

Reflex arc

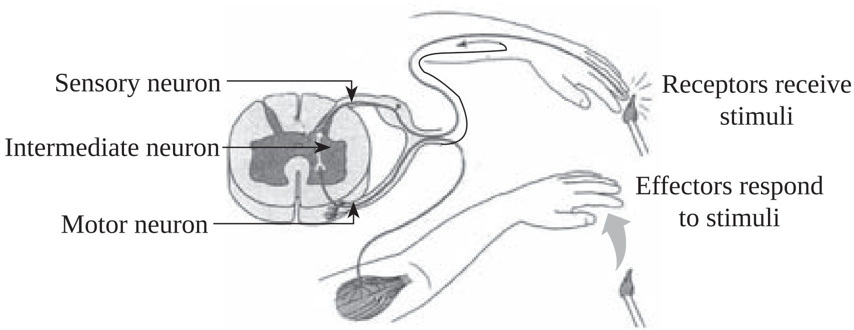


Figure 6.31 - Reflex arc

Stimulation of the pain receptors in the skin → (Sensory Neuron) → Spinal cord (Inter neuron) → (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.

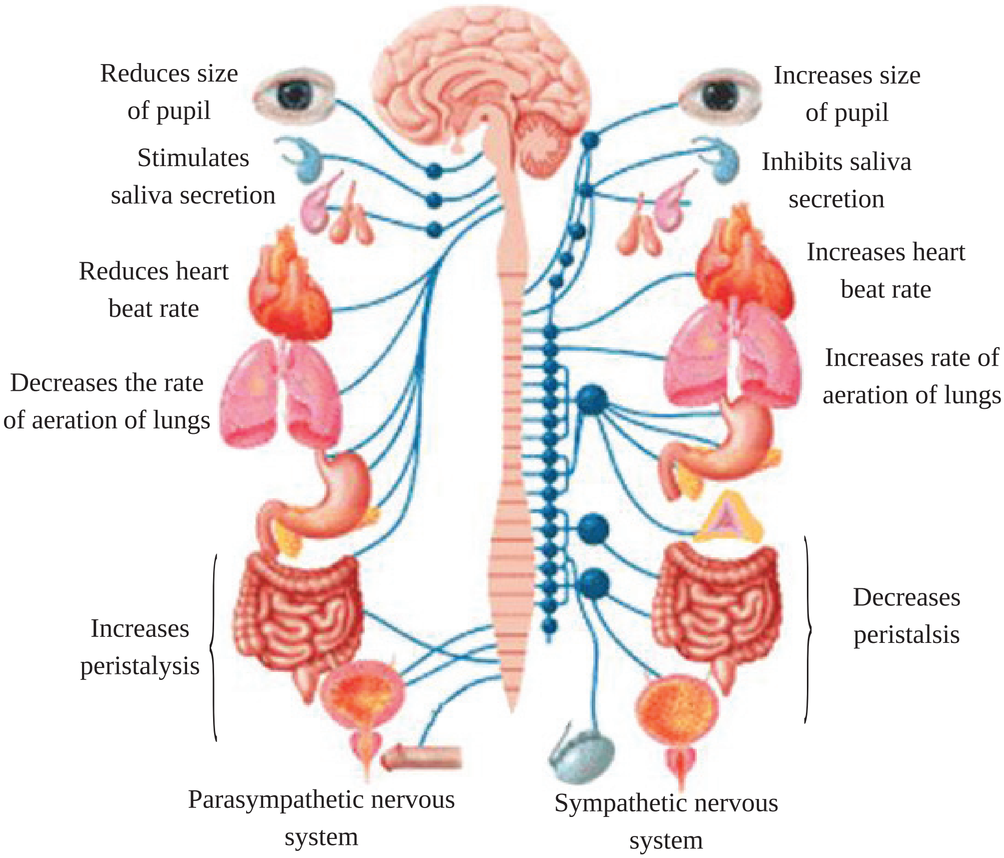


Figure 6.33 - Parasympathetic and sympathetic nervous supply on body organs

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)

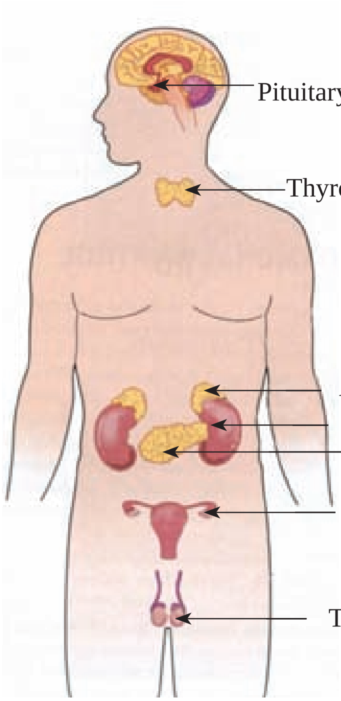


Figure 6.34 - Location of endocrine glands in human body

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.

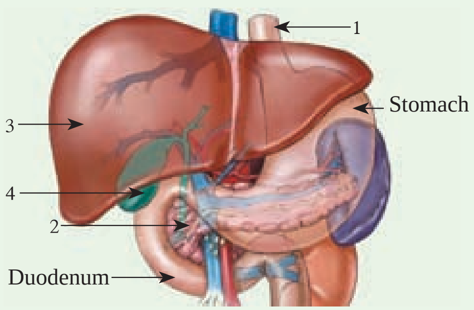
Summary

- 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.

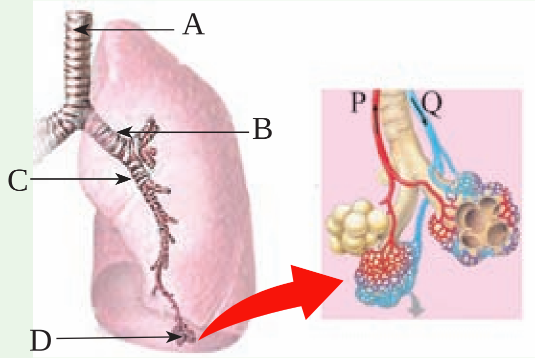
b) Name two secretions that influence lipid digestion.

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

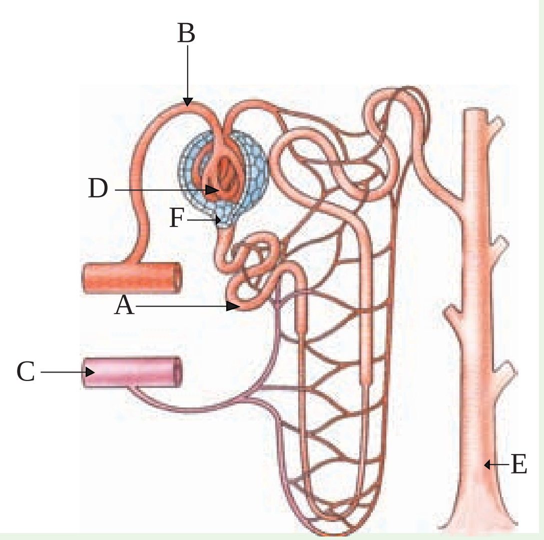
i) What is the respiratory product produced only in animals?

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?

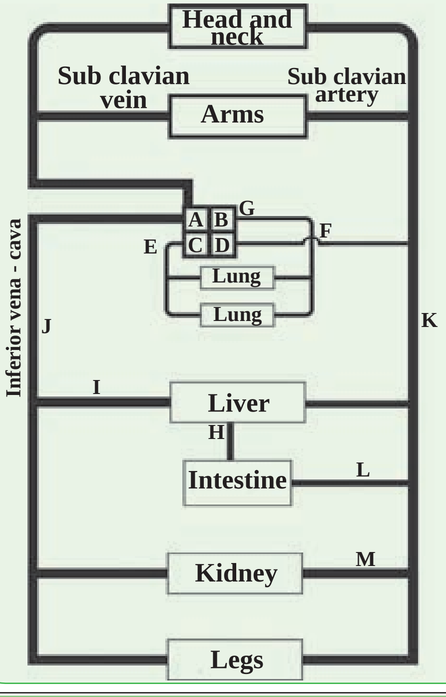
ii) Name the parts A, B, C, D, E.

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 බහිස්ස්‍රාවී ද්‍රව්‍ය	நைதரசன் கழிவுப் பொருள்
Excretory system	බහිස්ස්‍රාවී පද්ධතිය	கழிவகற்றல் தொகுதி
Excretion	බහිස්ස්‍රාවය	கழிவகற்றல்
Kidney	වෘක්කය	சிறுநீரகம்
Ureter	මුත්‍රවාහිනිය	சிறுநீர்
Renal vein	වෘක්කීය ශිරාව	சிறுநீரக நாளம்
Renal artery	වෘක්කීය ධමනිය	சிறுநீரக நாடி
Bladder	මුත්‍රාශය	சிறுநீர்ப்பை
Urethra	මුත්‍ර මාර්ගය	சிறுநீர் வழி
Nephron	වෘක්කාණුව	சிறுநீரகத்தி
Glomerulus	ගුච්ඡිකාව	கோளவுருவானவை
Reabsorption	ප්‍රතිශෝෂණය	மீள் அகத்துறிஞ்சல்
Glomerular filtrate	ගුච්ඡිකා පෙරණය	மயிர்துளை
Afferent arteriole	අභිවාහී ධමනිකාව	உட்காவுநாடி
Efferent arteriole	අපවාහී 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

Acids, Bases and Salts

Chemistry 07

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.

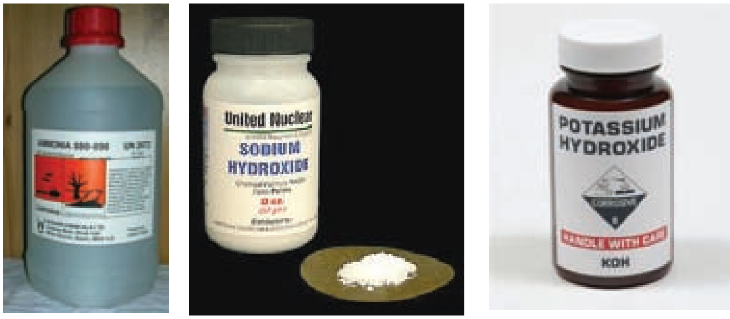


Figure 7.3 - Some frequently used bases

• 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.

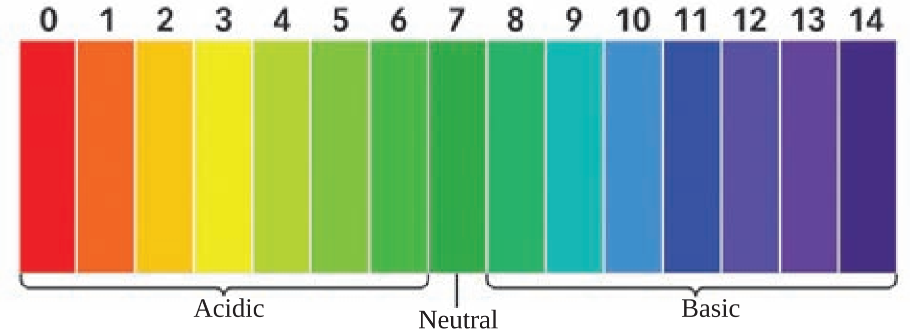


Figure 7.4 - pH scale and colour code of pH papers

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	-	භස්මය	-	மூலம்
Salt	-	ලවණ	-	உப்பு
Neutralisation	-	උදාසීනීකරණය	-	நடுநிலையாக்கம்
Strong acid	-	ප්‍රබල අම්ලය	-	வன்னமிலம்
weak acid	-	දුබල අම්ලය	-	மென்னமிலம்
Strong base	-	ප්‍රබල භස්මය	-	வன் மூலம்
weak base	-	දුබල භස්මය	-	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.

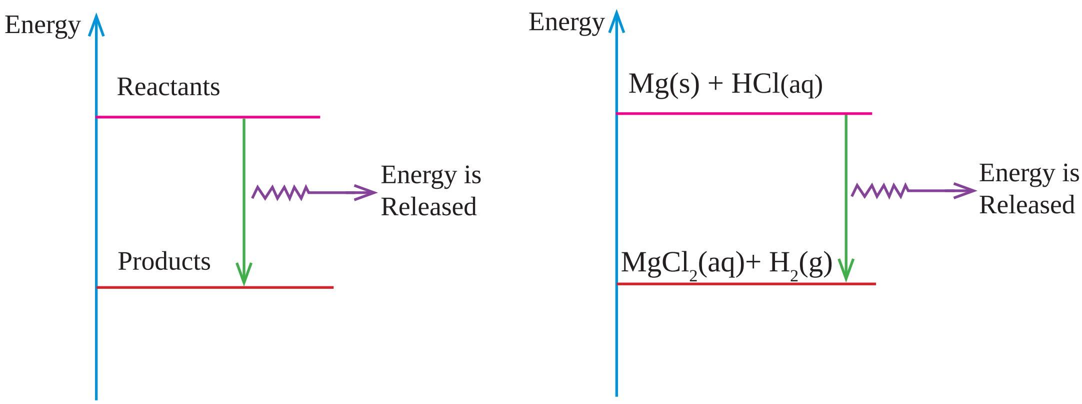


Figure 8.1 Energy level diagram for an exothermic reaction

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.

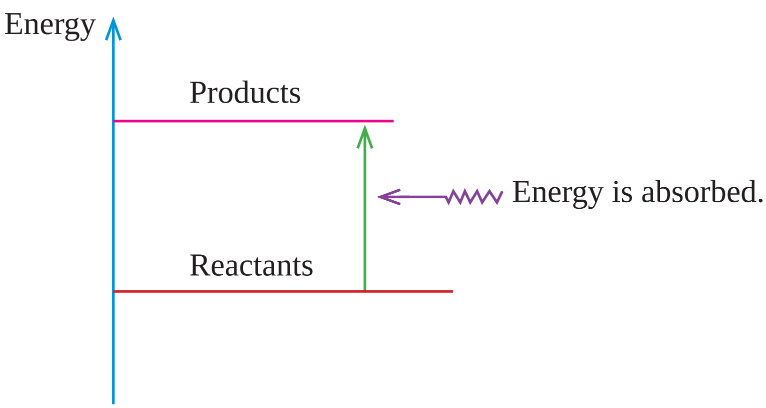


Figure 8.2 Energy level diagram for an endothermic reaction

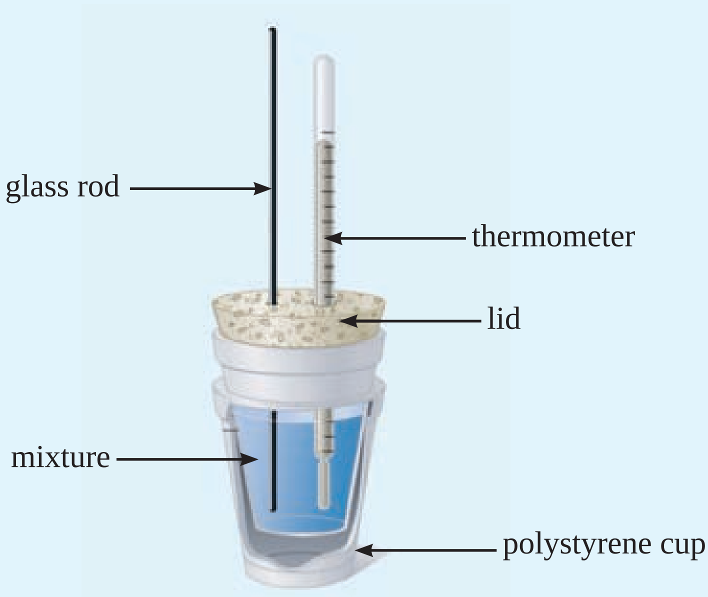
Let's do the following activity to find the energy change of a chemical reaction quantitatively.

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 $= \frac{4.2 \text{ kJ}}{0.1 \text{ mol}}$

$= 42$ 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 .

We would like to bestow our sincere thanks on Professor T.R.Ariyarathne, University of Colombo and the Chief Project Officer(Retired) W.D.Wijesinghe of the National Institute of Education and the In service advisor L.Gamini Jayasuriya of the Divisional education office-Wennapuwa and the senior lecturer Asoka de Silva of the National Institute of Education who is on leave for Ph.D.

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SCIENCE

Grade 11

Part - II

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

අපි වෙමු එක මවකගෙ දරුවෝ
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අප කය තුළ දුවනා

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කිසි කල නොම දිරනා

- ආනන්ද සමරකෝන් -

ஒரு தாய் மக்கள் நாமாவோம்
ஒன்றே நாம் வாழும் இல்லம்
நன்றே உடலில் ஓடும்
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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

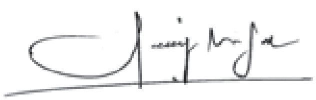
The past two decades have been significant in the world history due to changes that took place in technology. The present students face a lot of new challenges along with the rapid development of Information Technology, communication and other related fields. The manner of career opportunities are liable 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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Educational Publications Department,
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2019.04.10

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Physics

Heat 09

9.1 Temperature

Daily weather report transmitted through television channels may be familiar to you. Do you remember hearing that the lowest temperature was reported from Nuwaraeliya while the highest temperature was reported from Trincomalee on a particular day?

Can you remember that it is difficult to dry washed clothes on rainy days and that they dry fast on warm sunny days?

Figure 9.1

Try to recall the coolness experienced in eating an ice-cream and the warmness felt in drinking a hot cup of tea.

The physical quantity that describes each of the instances above is the temperature.

Temperature can be specified as a fundamental property of any material object. An ice cube has a very low temperature. Temperature of warm water is higher than the temperature of cold water.

Our body too has a temperature. Therefore we can say whether the temperature of a certain object is higher than or lower than the temperature of our body by touching the object.

Temperature is measure of the mean kinetic energy possessed by the particles that form an object.

9.1.1 Measuring temperature

By touching various objects we can get a rough idea about their temperature. However, since the temperature felt by touching is not so accurate and cannot be expressed as a numerical value, it is not a suitable method for measuring temperature. Therefore, the scientists in the past had realized the necessity for constructing a device for measuring temperature.

• Thermometers

The device employed to measure temperature is known as the thermometer. World's first thermometer was invented by Galileo Galilei around 1600 A.D.

Figure 9.2 -Thermometer constructed by Galileo

Figure 9.3- Galileo Galilei

Various types of thermometers are in use at present. We will only be focusing on the glass - mercury thermometer and the glass-alcohol thermometer in this chapter.

Glass-mercury Thermometer

The glass – mercury thermometer is constructed by connecting a narrow glass tube to a bulb containing mercury. When the temperature rises, the mercury in the bulb expands and moves up along the narrow tube. The temperature can be read from the scale marked on the tube according to the length of the mercury column.

Although the volume expansion due to a small temperature difference is small, the length of the mercury column rises up by a clearly visible amount as the diameter of the narrow tube containing mercury is very small. A glass – mercury thermometer is shown in Figure 9.4.

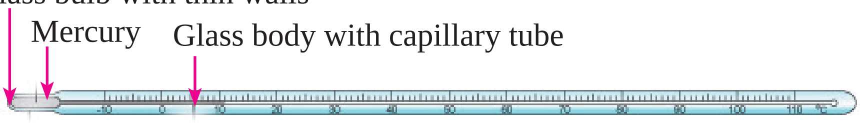


Figure 9.4 – A glass-mercury thermometer

Mercury is commonly used in thermometers as it has a uniform expansion over a broad range of temperatures, is a good thermal conductor and is a liquid over a broad range of temperatures (from - 39 ^{o}C to 357 ^{o}C). However, due to the toxicity of mercury, use of glass-mercury thermometers is on the decline.

Glass-Alcohol Thermometer

Glass-alcohol thermometer is constructed in the same manner as the glass - mercury thermometer, but replacing mercury by ethyl alcohol (ethanol). Since the melting point of ethanol is -115 ^{o}C, it is suitable for measuring low temperatures much below 0 ^{o}C. Ethanol is a suitable liquid for thermometers as it has a high expansion relative to most other liquids and as the expansion increases uniformly with temperature. Since purified ethanol is a colorless liquid, it is colored with a coloring material in order to see the alcohol column clearly.

Digital Thermometer

In addition the thermometers mentioned above, digital thermometers from which the temperature can be read directly are also commonly used today. In constructing digital thermometers, an electrical property such as the resistance which depends on the temperature is used instead of the expansion caused by an increase in temperature.

Figure 9.5 - A Digital thermometer

9.1.2 Temperature Scales

There are three temperature scales widely used for temperature measurements. They are the Celsius, Fahrenheit and the Kelvin scales.

- ### Celsius Scale

The Celsius scale has been formed by taking the temperature at which pure ice melts into liquid water under the pressure of one atmosphere as the zero temperature (0 ^{o}C) and the temperature at which water vaporizes into steam under the same pressure as 100 ^{o}C.

These two temperatures have been chosen for the Celsius scale as the temperature at which ice melts into water and the temperature at which water boils can be easily obtained and as these temperatures have fixed values apart from the variation with pressure.

The definite temperatures used in forming a temperature scale are known as **fixed points**. For the Celsius scale, these two fixed points are divided into 100 divisions.

• Fahrenheit Scale

For the Fahrenheit scale too, the melting point of ice and the boiling point of water are used as the two fixed points. However, here the melting point of ice is taken as 32 ^{o}F and the temperature range between the two fixed points are divided into 180 divisions. Accordingly, the boiling point of water is 212 ^{o}F.

• Kelvin Scale

The zero values of the Celsius and the Fahrenheit scales have been chosen according to the wishes of the people who introduced them. However, the British scientist Lord Kelvin later showed that there is a minimum value to the temperature that any object can reach. This temperature is known as the **absolute zero** temperature.

The temperature of an object is a measure of the mean kinetic energy of the particles that constitute the object. The temperature of the object decreases when the kinetic energy of the particles decreases. When the kinetic energy of all the particles become zero, the temperature of the object reaches the absolute zero. Its temperature cannot be decreased below this value. This temperature has been found to be - 273.15 ^{o}C according to the Celsius scale.

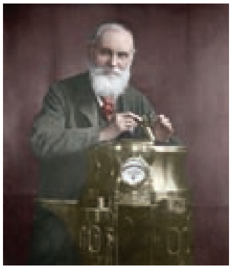


Figure 9.6 -Lord Kelvin

The Kelvin scale is defined so that its zero (0 K) is at the absolute zero temperature. However, in this scale, a temperature difference equal to 1 K is chosen to be equal to a temperature difference of 1 ^{o}C.

Accordingly, the melting temperature of ice is 273.15 K and the boiling temperature of water is 373.15 K. These temperatures are approximately taken as 273 K and 373 K respectively.

The international unit of measuring temperatures is the Kelvin (K).

For extra knowledge

- Celsius scale was introduced by Anderse Celsius (1701 – 1744).
- Fahrenheit scale was introduced by Gabriel Fahrenheit (1686 – 1736).
- Kelvin scale was introduced by Lord Kelvin (1824 – 1907).
- Clinical thermometer was constructed by Clifford Olbert (1836 - 1925).

9.1.3 Relationship between Celsius and Kelvin scales

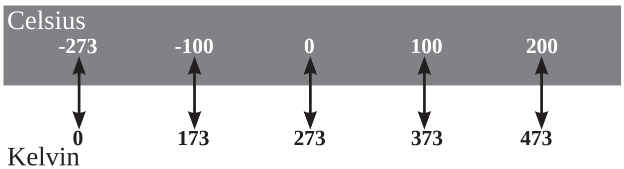


Figure 9.7 - Celsius and Kelvin scales

Since the difference between the Kelvin and Celsius scales lies only in the temperature chosen for their zero values, in order to convert a temperature measured in Celsius into the Kelvin scale one only needs to add 273. In order to convert a temperature measured in Kelvin into the Celsius scale one has to subtract 273.

Example 1

(i) How many divisions in the Kelvin scale are equal to one division in the Celsius scale?
(ii) What has to be done in order to convert a temperature value given in Celsius into Kelvin?
(iii) Indicate the temperature 50 ^{o}C in Kelvin.
(iv) What has to be done in order to convert a temperature value given in Kelvin into a value in Celsius?
(v) Indicate the temperature 373 K in degrees Celsius.

Solution

(i) 100 Celsius divisions = 100 Kelvin divisions
1 Celsius division = 1 Kelvin division

(ii) 273 Has to be added to the given value.

(iii) 50 ^{o}C = 50 + 273 K
= 323 K

(iv) 273 Has to be subtracted from the given value.

(v) 373 K = 373 – 273 ^{o}C
= 100 ^{o}C

Exercise 9.1

(1) Convert the temperatures given in degrees Celsius below into Kelvin.

(i) 10 °C (ii) 27 °C (iii) 87 °C (iv) 127 °C (v) 100 °C

(2) Convert the temperatures given in Kelvin below into degrees Celsius.

(i) 0 K (ii) 100 K (iii) 273 K (iv) 373 K (v) 400 K

9.2 Heat

Let us put equal volumes of water into two identical vessels at room temperature. Next let us insert two thermometers and arrange the set up above two bunson burners as shown in the Figure 9.8. Now let us light up the bunson burner in Figure 9.8(b) while leaving that in Figure 9.8(a) as it is.

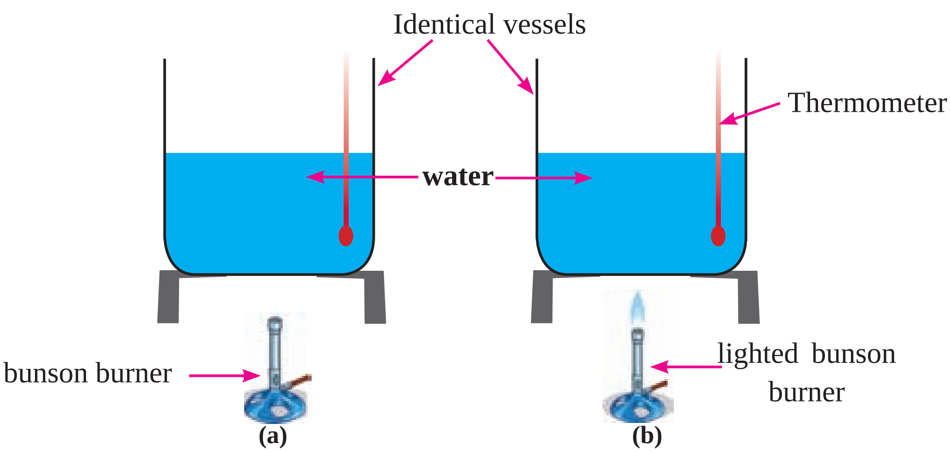


Figure 9.8

The temperature of the water in Figure 9.8(a) remains unchanged. The temperature of the water in Figure 9.8(b) can be seen to increase gradually.

Only the bunson burner in Figure 9.8(b) has been lighted. Therefore the temperature of water in that vessel has increased. From this it is clear that something has transferred from the candle flame to the water and that the temperature of the water has risen as a result of it. Here, heat has transferred to the water.

Therefore, the energy transfers from one object to another as a result of the temperature difference existing between the two objects is known as the **heat**.

For extra knowledge

American national Benjemin Thompson (Count Ramford) (1753 – 1814)has first described heat as a form of energy. In 1798, he experimentally showed that heat is a form of energy and thereafter it was a scientist named James Joule, who experimentally investigated about heat in 1840.

9.2.1 Heat Transfer

Let us investigate what happens when we put a heated piece of iron into a cold water vessel.

Activity 9.1

Apparatus required: A heated block of iron, A thermometer, A stirrer, A vessel with water at room temperature.

- Put a heated piece of iron into a cold water vessel.
- Observe the temperature of the water.

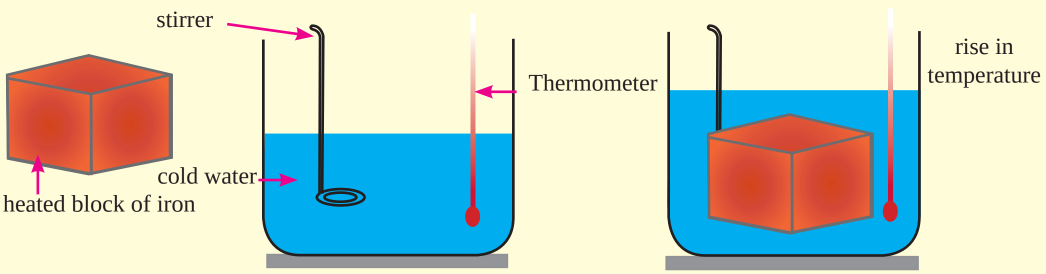


Figure 9.9

You will observe that the temperature of the water rises.

What happens here is the flow of heat from the iron which is at a higher temperature into the water which is at a lower temperature.

As the temperature of the water increases, the vessel also heats up as a result of absorbing heat. As heat flows out from the iron block, its temperature gradually decreases. After a while, the temperatures of the water and the iron block become equal. After reaching this common temperature, heat does not flow to the water from the iron block or to the iron block from the water. This state is known as **thermal equilibrium**. Just as water flows from a higher level to a lower level, heat also flows from a body at a higher temperature to a body at a lower temperature.

Therefore,

- Heat transfers from a body at a higher temperature to a body at a lower temperature.
- Then the temperature of the body at the lower temperature increases.
- At the same time, the temperature of the body at the higher temperature decreases.

Since heat is a form of energy, heat can be measured in Joules (J). The international unit for measuring heat is the Joule. In addition to this, the unit known as the Calorie is also frequently used to measure heat (thermal energy).

9.2.2 Heat Capacity of an Object

Activity 9.2

Apparatus required : Three identical beakers, Water, Coconut oil, Three thermometers, Three bunson burners a stirrer

- Obtain three identical beakers and pour a measured volume of water into one of them.
- Pour an equal volume of coconut oil into another beaker.
- Pour water with a volume equal to twice the initial volume into the third beaker.
- Measure the temperatures of the liquids in all three beakers.
- Now place all three beakers on three identical stands and heat them up for an equal time interval (about 5 minutes) using three identical candles.
- At the end of the time interval measure the temperatures of the liquids.

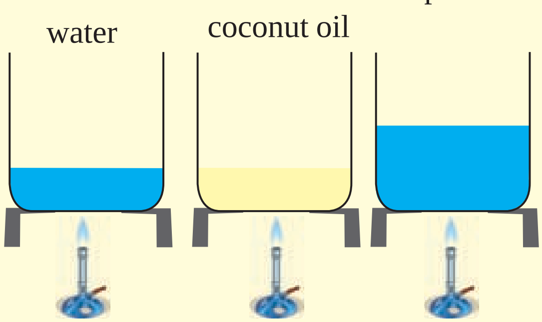


Figure 9.10

Even though there could be minor differences in the candles, we could assume that approximately the same amount of heat was supplied to each of the three beakers. However you will observe that the temperature rise in the three beakers are different.

You will understand from this activity that when the same amount of heat is supplied to different quantities of the same substance or the same quantities of different substances, their temperatures rise in different amounts.

Since the temperature rise in the three beakers of the above activity were not equal although the same amount of heat was supplied to all three beakers, we can conclude that the heat capacities of the substances in the three beakers are different.

The amount of heat required to increase the temperature of an object by one unit is known as the **heat capacity** of the object.

- The international unit for measuring heat capacity is Joules per Kelvin ($J\ K^{-1}$).
- Heat capacity can also be expressed in Joules per degree Celsius ($J\ {}^{o}C^{-1}$).

The heat capacity of an object depends on the substance that the object is made of and it's mass. Two objects made out of the same substance but with different masses have different heat capacities. Even though the masses are the same, two objects made out of different substances can have different heat capacities. The heat capacity of a substance is indicated by the symbol C.

• Specific Heat Capacity

It can be experimentally shown that the heat capacity of different masses of the same substance is proportional to the mass. This means that the heat capacity doubles when the mass is doubled. However the heat capacity of a unit mass of a given substance or the amount of heat required to increase the temperature of a unit mass of the substance by one degree is a property that depends on the substance.

The amount of heat required to increase the temperature of a unit mass of a given substance by one degree is known as the **specific heat capacity** of the substance.

Since the specific heat capacity is the amount of heat that should be supplied to increase the temperature of a unit mass of a given substance by one degree, it can also be described as the heat capacity of a unit mass. Therefore, the heat capacity of an object can be obtained by multiplying the specific heat capacity of an object by its mass.

Heat capacity = Mass × Specific heat capacity

$$C = mc$$

Units of specific heat capacity is $J\ kg^{-1}\ K^{-1}$ (Joules per kilogramme per Kelvin) or $J\ kg^{-1}\ {}^{o}C^{-1}$ (Joules per kilogramme per degree Celsius).

The specific heat capacity of a substance is indicated by the symbol c.

Specific heat capacities of some substances are given in table 9.1.

Table 9.1 - Specific heat capacities of some substances.

Substance	Specific heat capacity $J\ kg^{-1}\ K^{-1}$
Water	4200
Ice	2100
Kerosene oil	2140
Coconut oil	2200
Alcohol	2500
Rubber	1700
Aluminium	900

Substance	Specific heat capacity $J\ kg^{-1}\ K^{-1}$
Concrete	3000
Iron	460
Asbestos	820
Copper	400
Zinc	380
Mercury	140
Lead	130

• Finding the Quantity of Heat

When a substance absorbs or releases heat its temperature changes. In order to find the quantity of heat flow, the following relation can be established.

If the specific heat capacity of a substance is c,

- Quantity of heat required to increase the temperature of 1 kg by 1 °C $= c$
- Quantity of heat required to increase the temperature of m kg by 1 °C $= mc$
- Quantity of heat required to increase the temperature of m kg by θ °C $= mc\theta$

If the quantity of heat is Q,

$$\text{Quantity of heat } (Q) = \text{mass } (m) \times \text{specific heat capacity } (c) \times \text{temperature change } (\theta)$$

$$Q = mc\theta$$

Q – quantity of heat (J)
m – mass (kg)
c – specific heat capacity ($J\ kg^{-1}\ K^{-1}$ or $J\ kg^{-1}\ {}^{o}C^{-1}$)
θ – temperature difference (K or °C)

This means that the amount of heat required to increase the temperature of a given mass of a substance by a certain amount is equal to the product between the increase in temperature and the heat capacity.

In terms of magnitude, one Kelvin and one degree of Celsius are the same. Therefore, when we consider a temperature range, we can specify it in Celsius instead of using Kelvin, without making any change in the value.

Let us find the amount of heat required to increase the temperature of 6 kg of copper by 20 K. Specific heat capacity of copper is 400 $J\ kg^{-1}\ K^{-1}$.

Heat required to increase the temperature of 1 kg of copper by 1 K $= 400$ J
Heat required to increase the temperature of 6 kg of copper by 1 K $= 6 \times 400$ J
Heat required to increase the temperature of 6 kg of copper by 20 K $= 6 \times 400 \times 20$ J
$= 48\,000$ J

Example 1

Find the amount of heat required to increase the temperature of 2 kg of water by 10 K. Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

The amount of heat required $= mc\theta$,
$= 2 \times 4200 \times 10$ J
$= 84\,000$ J

Example 2

The mass of a block of aluminium is 500 g. Find the amount of heat required to increase the temperature of the block from 30 ^oC to 50 ^oC. Specific heat capacity of aluminium is 900 J kg^{-1} $^oC^{-1}$.

The amount of heat required $= mc\theta$
$= 0.5 \times 900 \times (50 - 30)$ J
$= 9000$ J

Example 3

If 20 000 J of heat is transferred to 2 kg of copper at a temperature of 30 ^oC, what is the final temperature? (Specific heat capacity of copper is 400 J kg^{-1} K^{-1}).

If the change of temperature is θ,

$$Q = mc\theta$$
$$20\,000 = 2 \times 400 \times \theta$$
$$\theta = \frac{20\,000}{2 \times 400}\ ^oC$$
$$\theta = 25\ ^oC$$

$\therefore$ Final temperature of copper $= 30\ ^oC + 25\ ^oC$
$= 55\ ^oC$

Example 4

A copper vessel contains 1 kg of water. Mass of the vessel with water is 1.6 kg. The temperature of the water is 25 ^oC. Find the amount of heat required to heat the water until it boils.

(Specific heat capacity of water is 4200 J kg^{-1} K^{-1}; specific heat capacity of copper is 400 J kg^{-1} K^{-1}.)

Since both the vessel and the water heats up in this case,

Required total quantity of heat = heat absorbed by the vessel + heat absorbed by water

The mass of the copper vessel = total mass – the mass of water

$= 1.6 \text{ kg} - 1.0 \text{ kg} = 0.6 \text{ kg}$

Heat absorbed by the vessel $= mc\theta$

$= 0.6 \times 400 \times (100 - 25) \text{ J}$

$= 0.6 \times 400 \times 75 \text{ J}$

$= 18\,000 \text{ J}$

Heat absorbed by the water $= mc\theta$

$= 1 \times 4200 \times (100 - 25) \text{ J}$

$= 315\,000 \text{ J}$

Required total quantity of heat $= 18\,000 \text{ J} + 315\,000 \text{ J}$

$= 333\,000 \text{ J}$

Exercise 9.2

(1) Specific heat capacity of iron is 460 J kg^{-1} K^{-1}. Find the quantity of heat required to increase the temperature of 2 kg of iron at a temperature of 25 °C up to 65 °C?

(2) Find the temperature of 0.8 kg of aluminium at a temperature 30 °C when 14 400 J of heat is transferred to it?
(Specific heat capacity of aluminium is 900 J kg^{-1} K^{-1}.)

(3) The mass of a glass vessel is 500 g. It contains 400 g of water at 25 °C temperature. Find the quantity of heat required to boil the water.(Specific heat capacity of glass is 840 J kg^{-1} K^{-1}, specific heat capacity of water is 4200 J kg^{-1} °C^{-1}.)

9.3 Change of State of Matter

You have learnt before that there are three states of matter known as solid, liquid and gas. As an example, when it is being heated ice melts into water and water converts into vapor. By absorbing or releasing heat, water changes from one state to another state.

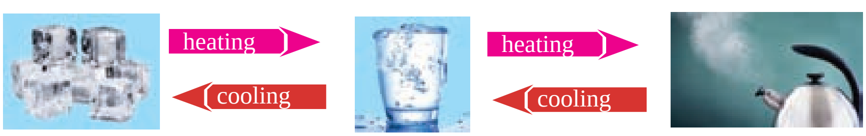


Figure 9.11

The conversion of the state of a substance from solid, liquid or gas into another state is known as a **change of state**. **Condensation** of a gas, **melting** of a solid, **solidification** of a liquid, **boiling** of a liquid are examples of changes of state.

Melting Point

The temperature at which a solid substance that is being heated changes state from the solid state to the liquid state is known as its **melting point**. The melting point of a given substance depends of the pressure.

Freezing Point

The temperature at which a liquid substance that is being cooled changes state from the liquid state to the solid state is known as its **freezing point**. The freezing point of a given substance depends of the pressure.

The melting point and the freezing point of a given substance have the same value.

Melting points of some solids are given in table 9.2.

Table 9.2 - Melting points of some solids (under the pressure of 1 atmosphere)

Substance	Melting point °C
Ice	0
Paraffin	54
Naphthalene	80
Sulphur	114
Lead	330

Substance	Melting point °C
Zinc	410
Aluminium	660
Gold	1063
Tungsten	5385
Iron	1535

Boiling Point

The temperature at which a liquid starts to boil (i.e. the temperature at which the liquid turns to vapour by forming bubbles inside the liquid) is known as its **boiling point.**

The temperature at which changes of states of matter occur depend on the pressure. Normally, the boiling points and melting points of materials are specified as the temperatures at which boiling or melting occur under the pressure of 1 atmosphere.

Boiling points of some solids are given in table 9.3.

Table 9.3 - Boiling points of some solids (under the pressure of 1 atmosphere)

Substance	Water	Ethanol	Mercury	Zinc	Copper	Iron	Oxygen
Boiling point (°C)	100	78	357	907	2310	2750	-183

9.3.1 Latent Heat

The change of state of a substance takes place as a result of supplying heat to the substance or removing heat from it. Atoms of substances that exist as solids at room temperature possess some amount of kinetic energy. When heat is supplied, this kinetic energy increases gradually and along with it the temperature of the substance increases. When heat is continuously supplied, at a certain point the kinetic energy of the atoms becomes large enough to break the bonds between the atoms and allow the atoms to move freely. This is the point that the substance changes state from the solid state to the liquid state.

At the point that the change of state takes place, the heat supplied is spent on breaking the bonds between molecules and therefore, the temperature of the substance does not increase. When the change of state of all atoms is complete, the heat supplied is spent again on increasing the temperature of the system.

The heat absorbed by the system without changing its temperature while the change of state is taking place is known as the **latent heat**.

Consider an instance when heat is being supplied to a block of ice at a temperature slightly below 0 °C.

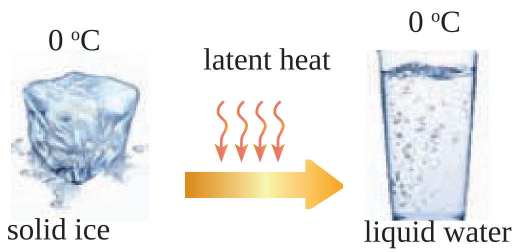


Figure 9.12

At first, its temperature would increase gradually up to 0 °C. Since 0 °C is the melting point of ice, the heat supplied thereafter is spent on doing work against the intermolecular attractive forces between the water molecules and the ice at 0 °C becomes water at 0 °C. If heat is supplied further after the block of ice has completely melted into water, then the heat supplied will be spent on increasing the temperature of the water again.

Conversion of a solid into a liquid is known as **fusion** and the heat absorbed in the conversion of ice at 0 °C into water at 0 °C is known as the **latent heat of fusion**.

Any solid substance that undergoes fusion absorbs latent heat, not only ice. If the fused substance is cooled, it solidifies again, releasing the same amount of heat that it absorbed during fusion. Therefore, when the water mass at 0 °C is cooled, the same quantity of latent heat is released and the water becomes ice.

Now let us consider an instance where heat is supplied to water at 100 °C.

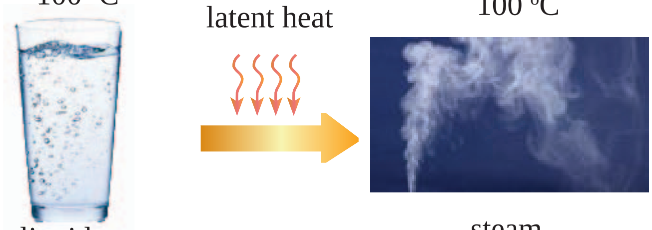


Figure 9.13

Since water is at its boiling point, here too a change of state takes place. Here again, work has to be performed against the intermolecular attractive forces. Therefore, the heat supplied is first spent on doing work against the intermolecular attractive forces and the temperature does not change until all the water at 100 °C becomes steam. The latent heat absorbed in this instance is known as the **latent heat of vaporization**.

Any liquid that vaporizes absorbs latent heat while this vapor releases the same amount of latent heat upon condensation back into the liquid.

• Specific Latent Heat of Fusion

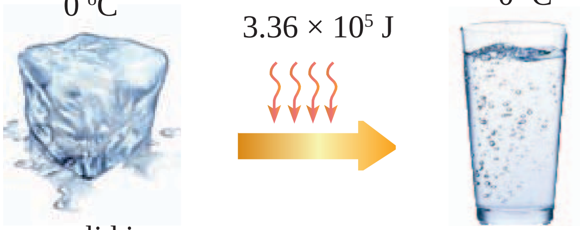


Figure 9.14

The amount of latent heat that has to be supplied in order to convert 1 kg of ice at 0 °C into liquid water at the same temperature is 3.36×10^5 J. This quantity of heat is known as the specific latent heat of fusion of ice.

The amount of heat required to change the state of a unit mass of a solid substance at its melting point into the liquid state is known as the **specific latent heat of fusion** of the substance.

- ### Specific Latent Heat of Vaporization

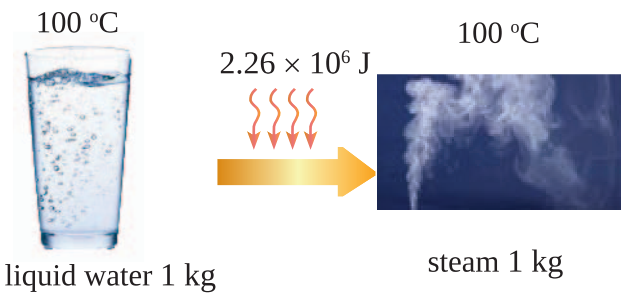


Figure 9.15

The amount of latent heat required in order to convert 1 kg of water at 100 °C into steam at the same temperature is 2.26×10^6 J. This quantity of heat is known as the specific latent heat of vaporization of water.

The amount of heat required to change the state of a unit mass of a solid substance at its boiling point into the gas state is known as the **specific latent heat of vaporization** of the substance.

Evaporation and Vaporization

The conversion of a liquid into a gaseous state is called **vaporization**. Liquid into a gaseous can happen in one of two ways. One is the **boiling** that takes place at the boiling point of a liquid when further heat is supplied. The other is the conversion of the liquid into a gas gradually at temperatures below the boiling point. The conversion of a liquid at a temperature below the boiling point is known as **evaporation**.

In vaporization due to either of the processes boiling and evaporation, latent heat is absorbed. Generally, evaporation takes place only at the surface of a liquid exposed to air. However in boiling vaporization takes place even below the liquid surface. This is why bubbles are formed in a boiling liquid.

In drying clothes and in perspiring to regulate our body temperature, evaporation is the process that plays an important role. Since the specific latent heat of vaporization has a fairly large value, in the evaporation of water through the process of perspiration taking place from our skin, a large amount of heat is removed from our body.

9.4 Thermal Expansion

You may have experienced that two glasses washed and one inserted inside the other (*A* inside *B*) are found to be stuck together when you examine them after a few days. At such an instance the two glasses can be separated by pouring cold water into the inner glass and inserting the outer glass in a vessel containing warm water.

In this case it becomes possible to separate the two glasses because the glass inserted in warm water expands slightly while the glass into which cold water was poured contracts slightly.

Figure 9.16

The increase in dimensions of a substance subjected to an increase in temperature is known as **thermal expansion**. That is, the increase in its length, area or volume is called expansion. Similarly, the decrease in dimensions of a substance subjected to a decrease in temperature is known as **contraction**. That is, the decrease in its length, area or volume is called contraction.

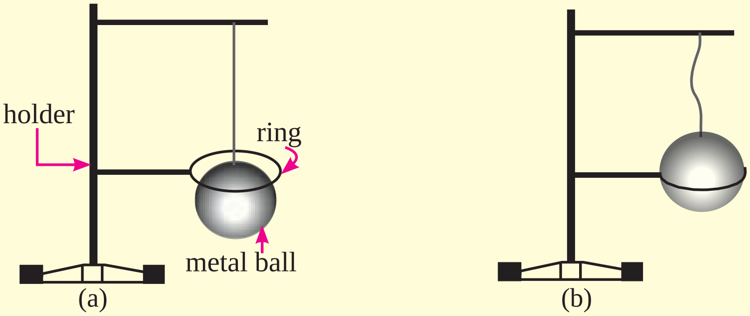
9.4.1 Expansion of Solids

Let us engage in activity 9.3 to demonstrate the expansion of solids.

Activity 9.3

Apparatus required: A metal ball, A holder, A ring through which the iron ball just passes.

- Obtain an iron ball and a ring through which the iron ball just passes.
- Heat up the ball and see if it can be passed through the ring.
- Also observe that the iron ball passes through the ring again after being cooled.



(a) Before heating up the iron ball passes through the ring.

(b) After heating up the iron ball cannot pass through the ring.

Figure 9.17 - Modelling expansion of solids

It will be clear from this activity that solids expand when they are heated up and they contract upon being cooled.

• Influences and Applications of Expansion of Solids

- When fitting iron rims to wooden cart wheels, the diameter of the iron rim is chosen to be slightly less than that of the wooden wheel. Then the iron rim is heated and expanded until the wheel can be inserted into it. After inserting the wooden wheel into the iron rim, it is allowed to cool and thus contract, fitting it into the wheel securely.
- In railways, a small gap is left between two rails allowing them to expand when the temperature rises, thus preventing the rails from being deformed due to expansion.

Figure 9.18

- Telephone wires and cables carrying electricity are loosely fitted between posts in order to allow them to contract without breaking the wires when the environmental temperature drops.

Figure 9.19

- Tight fitting metallic bottle lids can be easily opened by heating them up to expand slightly.

  The reason for this is that the expansion of metals is larger than that of glass making the lid slightly larger than the bottle when they are heated up.

- In electrical appliances such as electric irons and rice cookers, bimetallic strips consisting of two different metals that have different expansions for a given temperature difference are used to regulate the temperature.

Figure 9.20(a) shows such a bimetallic strip. It consists of two metallic strips with inequal expansions rigidly riveted together. One of its ends is rigidly fixed to a piece of metal while the other end remains free. When the temperature of the bipolar strip is increased, one of the strips expands more than the other. Then the two strips bend as shown in figure 9.20(b).

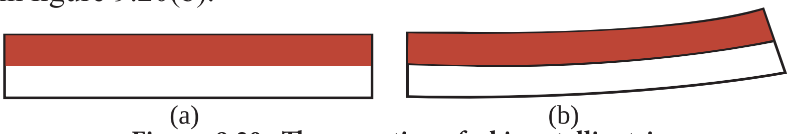


Figure 9.20 –The operation of a bi-metallic strip

By connecting the bipolar strip to an electric circuit as shown in the figure 9.21, power can be disconnected from the circuit when the temperature is increased by supplying power to the heater.

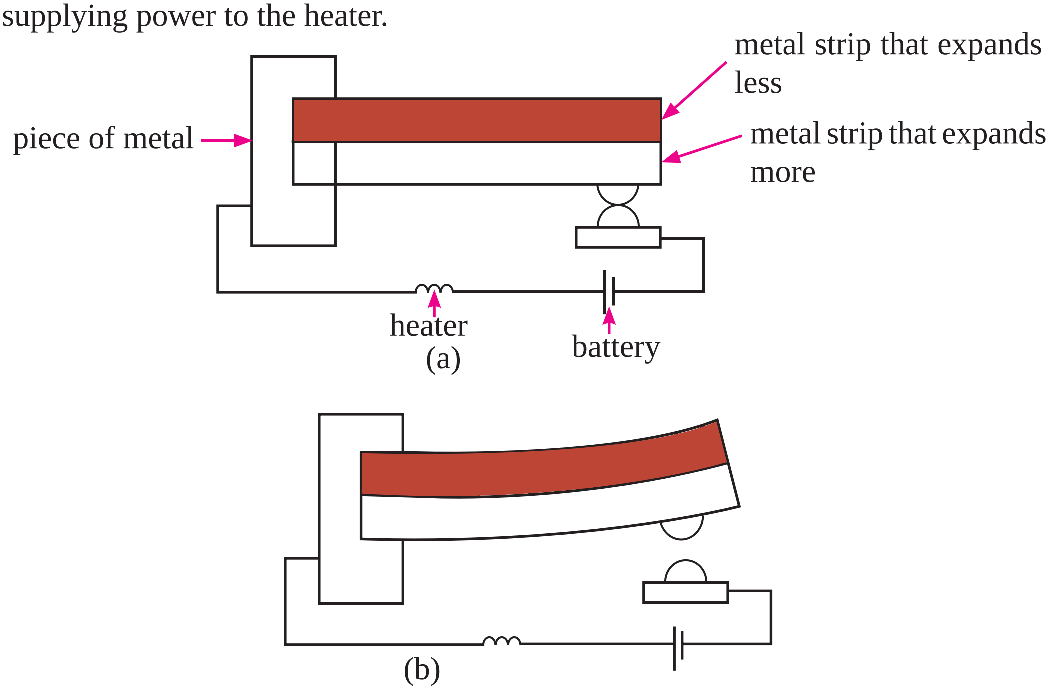


Figure 9.21 – Connecting a bimetallic strip to an electric circuit

Assignment 9.1

Explore other instances where expansion of solids are utilized and record your data.

9.4.2 Expansion of Liquids

Let us engage in activity 9.4 to illustrate the expansion of liquids.

Activity 9.4

Apparatus required: A test tube, Colored water

- Fill a test tube with colored water and fix a rubber stopper with a glass tube to the test tube as shown in the figure 9.22(a).
- Mark the water level on the glass tube
- Insert the glass tube in a warm water vessel for a few minutes and examine it.
- When heating up, the test tube expands and the liquid level goes down to *B* and when the liquid expands, the liquid level rises upto *C*.

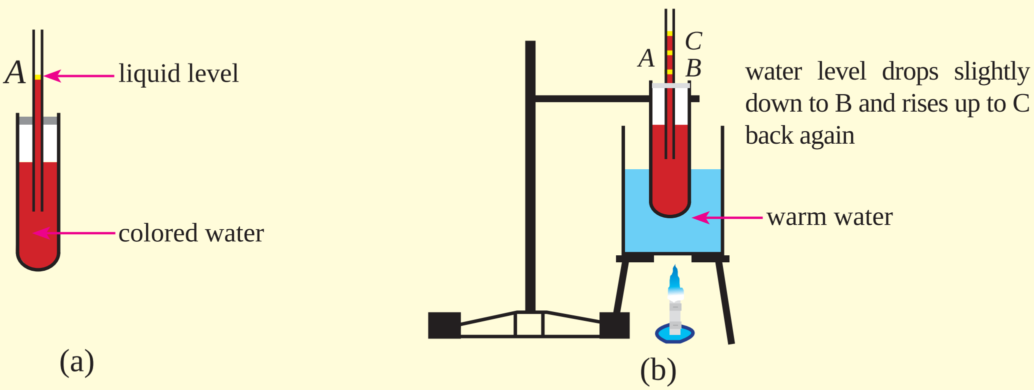


Figure 9.22 - Illustrating expansion of liquids

In this experiment, first the test tube expands when the temperature of the water increases. Then the liquid level drops down slightly. However when the liquid inside the test tubes heats up, the liquid also begins to expand. When the expansion of the liquid exceeds that of glass, the liquid level rises up again. When making thermometers, thermal expansion of liquids is commonly used. In mercury and alcohol thermometers, the expansion of liquid volume is used for measuring temperature.

9.4.3 Expansion of Gases

Let us engage in activity 9.5 to illustrate the expansion of gases.

Activity 9.5

Apparatus required: Ice, An empty plastic bottle, A balloon.

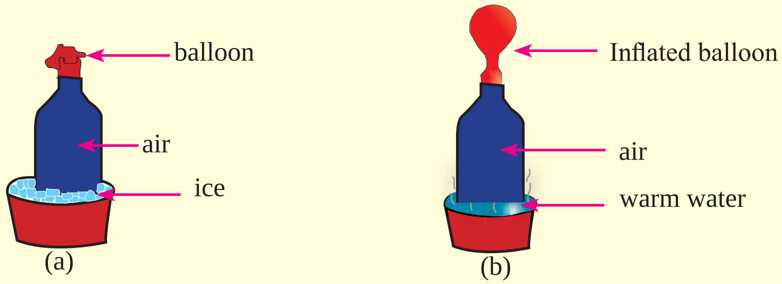


Figure 9.23 - Illustration of expansion of gases

- Place an empty plastic bottle without a lid vertically in a vessel containing ice and water for a short while.
- Then attach a balloon to the opening as shown in Figure 9.23(a).
- Next place the bottle in another empty vessel and pour hot water into the vessel as shown in Figure 9.23(b).
- Observe that the balloon inflates slightly.
- Also observe that the balloon shrinks when left outside for a while.

When the bottle is placed inside the ice vessel, the temperature of the air inside the bottle is close to 0 ^{o}C. When it is placed inside the warm water bottle the temperature of the cool air in the bottle increases close to the room temperature and the air expands. This air cannot leave the bottle because of the balloon attached to it. Instead, the balloon inflates. When the bottle is taken out, the air cools down to the room temperature shrinking again.

From this experiment it is clear that the air inside the bottle expands when it heats up and contracts when the air cools down.

9.5 Heat Transfer

If you touch the far end of a metal spoon inserted in a hot cup of tea you would feel that it gets warmer gradually. Similarly if you hold your hand above a burning fire, you would feel that the hand gets warmer. What has happened in these instances is that heat has transferred along the spoon in the first case and upwards away from the flame in the second. Heat passing from one place to another in this manner is known as **heat transfer**.

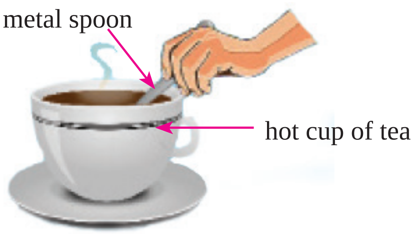


Figure 9.24

Figure 9.25

Heat transfer occurs from the place with the higher temperature to the place with the lower temperature. The energy known as thermal energy (heat) of an object is actually present as the kinetic energy resulting from the random motion of the particles that form the object. This energy can be the translational, rotational or vibrational kinetic energy of the particles. Heat transfer is the spreading of kinetic energy from a region with atoms having a high degree of random motion (with a high temperature) to a region of atoms having a low degree of random motion (with a low temperature).

There are three methods of transferring heat.

(1) Conduction
(2) Convection
(3) Radiation

Let us investigate these methods in a simple way.

9.5.1 Conduction

The handle of a metal spoon held in a hot water soon gets warm. Heat passes along the spoon by conduction.

Some examples where heat transfers by condition are given below.

- Heat flow along a metallic rod in contact with a flame.
- Heat flow from the bottom to the interior of a vessel placed on a cooker.

The main method of heat transfer through solids is conduction.

Since the atoms of a solid are tightly bound to one another, they cannot freely move throughout the volume of the solid. In such substances, heat exists as the vibrational kinetic energy of atoms. In metallic substances, part of the thermal energy exists as kinetic energy of freely moving electrons (free electrons) in addition to this. Conduction is the spreading of the kinetic energy of atoms and electrons throughout the substance due to collisions among these particles.

Substances that conduct heat efficiently are known as **good conductors** and substances that do not conduct heat efficiently are known as **insulators**.

Examples: good conductors – silver, copper, iron, mercury, aluminium
Insulators – wood, plastic, asbestos, clay, wool

Existence of free electrons in metals make metals good conductors.

In liquids, molecules are not very tightly bound. Therefore, conduction of current through liquids is very weak. Water is a very poor thermal conductor.

This Robbin has fluffed out its feathers to trap a layer of air. Air is a poor conductor of heat and so the bird manages to keep warm even in cold weather.

Figure 9.26 - Robbin bird

Seals, spend all of their lives in cold water. They are protected from losing heat by conduction by a very thick layer of fat (blubber) which surrounds their body.

• Conduction through a metal rod

The Figure 9.27 illustrates how heat is conducted through a metal rod that is heated from one end.

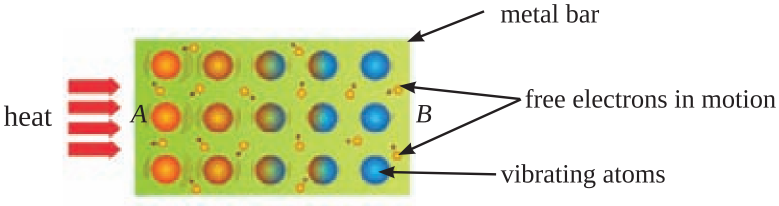


Figure 9.27 – Metal rod heated at one end

Suppose that the metallic rod shown in figure 9.27 is heated by a flame at the end *A*.

Then the atoms at that end begin to vibrate with a large amplitude by receiving thermal energy (heat) from the flame. In addition to this, the free electrons in random motion at that end gain kinetic energy from the flame. As a result of the increased kinetic energy, these atoms collide with adjacent atoms. Due to the collisions, energy transfers to one atom from another increasing the amplitude of vibrations. This process continues through the atoms in the rod from *A* to *B* in succession, transferring thermal energy along the rod. Thermal energy is also transferred by the free electrons in random motion in the rod by receiving thermal energy from the flame.

9.5.2 Convection

Figure 9.28

The water is heated just under the purple crystal - the crystal colours the water as it dissolves. The heated water expands and becomes less dense than the colder surrounding water, so it floats up to the top of the beaker. Colder water sinks to take its place, and is then heated too.

When heat is supplied to liquids or gases they expand and decrease in density and move upwards. In order to fill these gaps, liquids or gases with lower temperatures move downwards. Due to this process, heat flows upwards from the region where heat is supplied. This is known as **convection**.

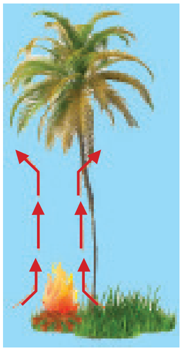


Figure 9.29

When a fire is lighted underneath a tree, branches and leaves above the fire tend to swing about and burn as a result of the upward motion of heated up air particles.

Upward motion of heated up particle streams is known as **convection currents**.

Consider the figures below showing an immersion heater used to heat up water.

Figure 9.30 - An immersion heater used to heat up water

Figure 9.30(a) shows a heater partially immersed in water. Here the water near the bottom of the jug warms up slowly but the water near the top warms up fast. This happens since convection currents do not flow downwards.

The immersion heater in Figure 9.30(b) is fully immersed inside the vessel. Then water warms up from bottom to top. Heated up water particles become lighter and move upwards and the water particles that are not heated up move down as their density is higher. When heated up they too move upwards. This process takes place continually heating up the whole jug of water.

• Formation of Sea breeze and Land breeze

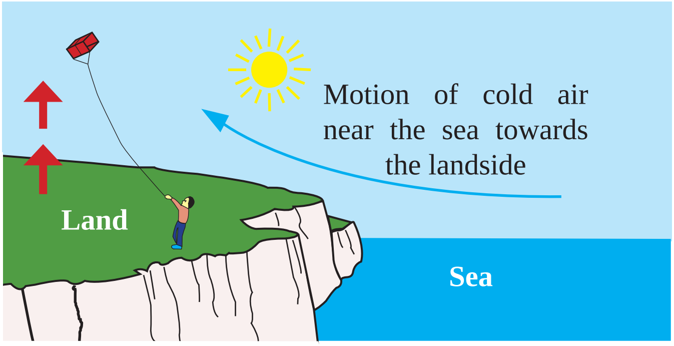


Figure 9.31 - Sea breeze

Specific heat capacity of the earth's surface in the land side is smaller than that of the sea water. Therefore during day time the land surface heats up faster from the sun's heat than the sea water. Then the air near the land surface warms up which decreases the density and the air moves upwards. This reduces the pressure near the ground. Then an air mass flows from the sea to the land side. This is known as **sea breeze.**

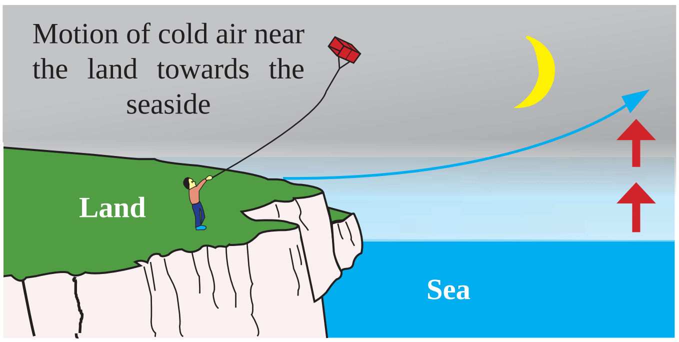


Figure 9.32 - Land breeze

During night time both the land and the sea cool down. The sea cools down slowly while the land cools down fast. Air near the sea water surface is warm while that above is cold. Therefore the air near the sea water moves upwards giving rise to a low pressure region just above the sea. Then wind blows from the land side towards the sea in order to equalize the pressure difference. This is known as **land breeze.**

Think……..
How does a warm cup of tea cool down upon blowing on it?

9.5.3 Thermal Radiation

You will be able understand that it is not due to either conduction or convection that you feel the warmth near a burning fire. Then it must be through another means that heat has transferred. We feel the warmth when thermal rays travel through space in the form of rays (waves) from the flame and reach our bodies.

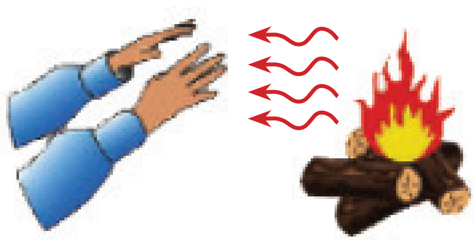


Figure 9.33

The propagation of heat in the form of electromagnetic radiation from a warm body without the aid of matter is known as **thermal radiation**. For heat transfer by radiation, a material medium is not required. However, for heat transfer by conduction or convection, particles of a medium are essential.

Heat from the sun reach the earth through a vacuum of about 150 million kilometres as thermal radiation. Any heated body emits heat as radiation.

• Absorption and Reflection of Thermal Radiation

When thermal radiation is incident on an object, part of the radiation is absorbed by the object while another part is reflected. The surface roughness or the smoothness and the colour of the surface of the object are the factors affecting the amount of thermal radiation absorbed or reflected.

Absorption of thermal radiation is high from darker surfaces and rough surfaces.

Reflection of thermal radiation is high from shining surfaces.

Reflection of heat radiation by polished surfaces and by white surfaces are very high.

Black surfaces absorb a high amount of heat while they reflect a very low amount of heat.

Assignment 9.6

Design an experiment to find out from which out of dark, white and shining surfaces that thermal radiation is most effectively absorbed. Write down the conclusions you can draw based on your observations.

• Situations where thermal radiation is important

When cricketers dress in white during the day time in the presence of sunlight, the absorption of thermal radiation is very low. Then warming up of the body is controlled.

Wearing dark colors inside homes by people in cold climates increase the absorption of thermal radiation. This helps to maintain the body temperature.

If the cooking utensils placed on cookers are black in color, they can absorb thermal radiation efficiently and transfer heat to the vessels fast.

The inner surfaces of thermos flasks are silvered to make them highly reflective. These surfaces reflect heat radiated by the contents inside the bottle or heat radiation coming from outside.

Summary

- Temperature is a measure of the mean kinetic energy of the atoms forming an object.
- The instrument that is used to measure temperature is the thermometer.
- The units used to measure temperature are degrees Celsius (^{o}C), degrees Fahrenheit (^{o}F) and Kelvin (K).
- The international unit of measuring temperature is the Kelvin.
- Heat is the energy transferred from one object to another object due to the temperature difference between them.
- If energy is absorbed by an object where no change of state occurs, then its temperature will definitely rise.
- If energy is released by an object where no change of state occurs, then its temperature will definitely drop.
- Heat capacity (C) of an object is the amount of heat required to increase its temperature by one temperature unit.
- Units of heat capacity are J K^{-1} or J $^{o}C^{-1}$.
- Specific heat capacity (c) of an object is the amount of heat required (or released) to increase (or decrease) the temperature of a unit mass of the object by one temperature unit.
- Units for measuring the specific heat capacity are J kg^{-1} K^{-1} or J kg^{-1} $^{o}C^{-1}$.
- Heat capacity $C = mc$
- Quantity of heat $Q = mc\theta$
- Latent heat is the amount of heat absorbed or released in a change of state of a substance without changing its temperature.
- Specific latent heat capacity of fusion is the heat required to convert a unit mass of a solid at its melting point into a liquid at the same temperature.

- Specific latent heat capacity of vaporization is the heat required to convert a unit mass of a liquid at its boiling point into a vapor at the same temperature.
- The unit of specific latent heat capacity is J kg^{-1}.
- The increase in length, area or volume taking place when an object is heated up is known as thermal expansion.
- Heat transfer is the flow of heat from a point at a higher temperature to a point at a lower temperature.
- The three methods of heat transfer are conduction, convection and radiation.
- Conduction is the forward flow of heat through any material by heating up of the constituent particles one by one in succession.
- Convection is the flow of heat by the upward motion of particles by decreasing the density when liquids or gases are heated up.
- Radiation is the flow of heat from a heated body in the form of electromagnetic waves without the aid of a material medium.

Exercise 9.3

(1) Fill in the blanks of the sentences given below.

(i) The international unit used to measure temperature is …………………… and the international unit used to measure the amount of heat is …………………………

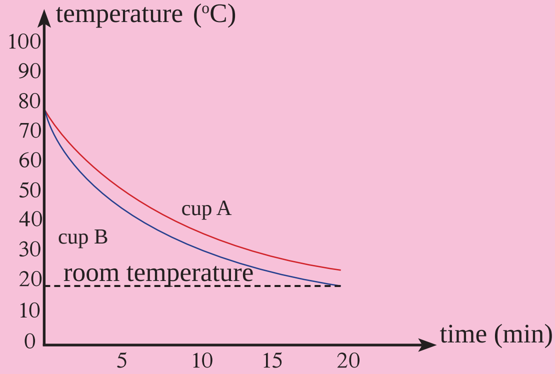
(ii) The absolute zero is equal to …………………… Celsius.

(iii) The ……………………… does not change when absorbing latent heat while the ……………………………….. changes.

(iv) The method of transferring heat without the influence of a medium is …………………………………..

(v) Bodies having low specific heat capacities increase their temperature …………….., bodies with high specific heat capacities increase their temperature …………………..

(2) Two cups of the same size and shape made out of two different materials are filled with equal amounts of hot tea and are allowed to cool down. Cooling curves plotted by measuring the temperatures of the two cups at definite time intervals are shown below.



(i) What is the temperature of the tea in cup *A* after five minutes?
(ii) What is the time taken for the temperature of the tea in cup *B* to drop by 30 °C?
(iii) What is the difference in the temperatures of the tea in the two cups after 15 minutes?
(iv) Which cup is made out of the material with the lower heat conductivity?
(v) What is the reason for your answer above?
(vi) What is the ultimate temperature of the tea in the two cups?

(3) The figure below shows the cross-section of a thermos flask.

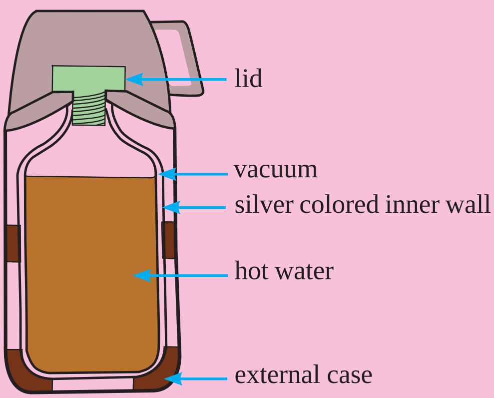


Figure 9.34

(i) There are two situations that a thermos flask can be used. What are they?
(ii) There are 500 ml of water at a temperature of 100 °C inside the flask. In order to keep the water at this temperature, heat loss has to be prevented. What are the techniques used here for this purpose?

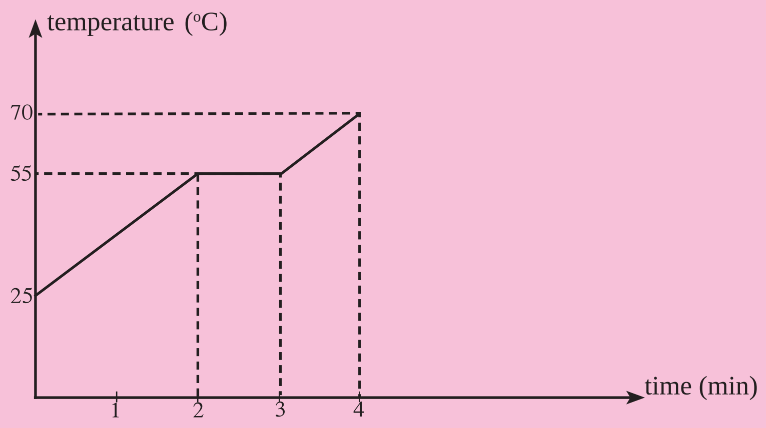
(iii) Calculate the amount of heat loss occurring when 500 ml of water at 100 °C cools down to the room temperature of 25 °C. (Specific heat capacity of water is 4200 J kg^{-1} K^{-1})

(iv) It is not appropriate to remove the hot water from a flask and fill it with cold water immediately. What is the reason for this?

(4) (i) Find the heat released in cooling 10 g of water at 100 °C down to 25 °C.

(ii) A burn caused by steam at 100 °C is more harmful than a burn caused by boiling water at 100 °C. Explain this.

(5) A piece of paraffin is at room temperature. Investigate the changes occurring in it when the temperature is gradually increased and temperature measurements were plotted against time, the following graph was obtained. Answer the questions given below using the graph.



(i) What is the room temperature?

(ii) What is the melting point of paraffin?

(iii) How long after commencing the experiment did the paraffin begin to melt?

(iv) What is the reason for the temperature to remain constant in the time interval between 2 min to 3 min?

(v) If supplying heat to paraffin was stopped at time 4 min, give a rough sketch to show the variation of the temperature of paraffin with time thereafter.

Technical terms

Temperature	- උෂ්ණත්වය	- வெப்பநிலை
Glass-mercury Thermometer	- වීදුරු රසදිය උෂ්ණත්වමානය	- கண்ணாடி இரச வெப்பமானி
Glass-Alcohol Thermometer	- වීදුරු මද්‍යසාර උෂ්ණත්වමානය	- கண்ணாடி அற்ககோல் வெப்பமானி
Heat Capacity	- තාප ධාරිතාව	- வெப்பக் கொள்ளளவு
Specific Heat Capacity	- විශිෂ්ට තාප ධාරිතාව	- தன்வெப்பக் கொள்ளளவு
Melting Point	- ද්‍රවාංකය	- உருகுநிலை
Freezing Point	- හිමාංකය	- உறைநிலை
Boiling Point	- තාපාංකය	- கொதிநிலை
Latent Heat	- ගුප්ත තාපය	- மறை வெப்பம்
Latent heat of fusion	- විලයනයේ ගුප්ත තාපය	- உருகலின் தன்மறை வெப்பம்
Latent heat of vaporization	- වාෂ්පීකරණයේ ගුප්ත තාපය	- ஆவியாதலின் தன்மறை வெப்பம்
Vaporization	- වාෂ්පීකරණය	- கொதித்து ஆவியாதல்
Evaporation	- වාෂ්පීභවනය	- ஆவியாதல்
Thermal Expansion	- තාප ප්‍රසාරණය	- வெப்பவிரிவு

Physics

10 Power and Energy of Electric Appliances

We use electric energy to do various jobs in our daily lives conveniently. On all these occasions we convert electric energy into another form of energy to suit our requirements. This energy conversion takes place in various electric appliances. The instruments used for these energy conversions are known as electric appliances. The main forms of energy conversions that take place in some electric appliances used in daily life are given in the Figure 10.1.

Figure 10.1 - The main form of energy conversion in some electric appliances

For extra knowledge

In some electric appliances, after the first energy conversion, another energy conversion also takes place and we use that energy. As an example, in a filament bulb, electric energy is initially converted into heat which increases the temperature of the filament resulting in the emission of light. In fluorescent lights electric energy is first converted into ultraviolet radiation which is next converted into visible light.

10.1 Power output of an electric appliance

We know that power is the work done in a unit time.

Just like in mechanical work, power is the rate of doing work in work done by electricity too. **That is, power is the work done in a unit time or the energy consumed in a unit time**.

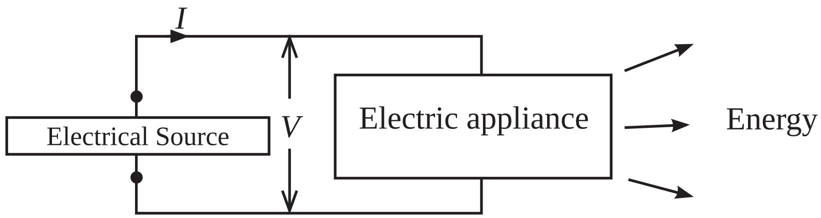


Figure 10.2 - An electric appliance operating with a potential difference *V* and drawing a current *I*

Therefore the rate of energy consumption P by an electric appliance operated with a voltage V and drawing a current I is given by the following equation.

$$\text{Power} = \text{voltage} \times \text{current}$$
$$P = VI$$

When the voltage, V is measured in Volts (V) and the current, I in Amperes (A) the power, P is given in Watts (W).

Example 1

When a filament bulb is connected across a voltage difference of 12 V, a current of 2 A flows through it. What is the power of the bulb?

$$\text{Power} \quad P = VI$$
$$= 12 \times 2 \text{ W}$$
$$P = 24 \text{ W}$$

Power of the bulb is 24 W.

Example 2

An electric oven operates under a 230 V power supply. If it has a power output of 2000 W, find the current drawn when the oven is working.

$$P = VI$$
$$\therefore 2000 = 230 \times I$$
$$\therefore I = \frac{2000}{230} = 8.69 \text{ A}$$

The current drawn by the oven is 8.69 A.

In the heating coils (heating element) of electric ovens, the energy consumed is converted only into heat. In some other appliances, part of the electric energy is converted into heat due to their internal resistance, while the remaining part is converted into other forms of energy.

10.2 Electric energy consumed by electric appliances

Power is the rate of consumption of energy or the energy consumed in a unit time by an electric appliance. Therefore, the total energy consumed by an electric appliance depends on the time duration that it operates.

If the energy consumed during a unit time interval is P, the total amount of electric energy consumed in a time t is Pt. If the total energy consumed is E,

$$E = Pt$$

When P is measured in Watts (W) and the time t in seconds (s), the electrical energy E is given in Joules (J).

Since $P = VI$, substituting VI for P,

$$E = Pt = VIt$$

$$\text{Total Energy} = \text{voltage} \times \text{current} \times \text{time}$$
$$E = VIt$$

In order to find the energy consumed by an electric appliance, the relation $E = VIt$ can also be used.

Example 1

The power of the head light of a motor car is 50 W. Find the energy consumed when this lamp is operated for $1\frac{1}{2}$ hours.

$$E = Pt$$
$$E = 50 \times 1.5 \times 60 \times 60 \text{ J}$$
$$E = 270\,000 \text{ J}$$

The amount of energy consumed is 270 000 J.

Example 2

A 6 V bicycle electric bulb draws a current 0.6 A. What is the power consumed in lighting this bulb for five minutes?

$$E = VIt$$
$$E = 6 \times 0.6 \times 5 \times 60$$
$$E = 1080 \text{ J}$$

Total electric energy consumed is 1080 J.

10.3 Efficiency of electric appliances and conserving power

In many instances, the same purpose can be achieved using various different appliances. In order to get illumination we can use filament bulbs, LED bulbs, fluorescent light tubes or CFL lights (compact fluorescent lights). Choosing a more efficient appliance helps us to save energy. A few different types of bulbs giving the same illumination, their power output and life times are given in Table 10.1 below.

Table 10.1 – Power and life times of various types of bulbs

Light source	Power	Life time
Filament bulbs	60 W	1200 h
Fluorescent tubes	22 W	3000 h
CFL bulbs	11 ~ 13 W	8000 h
LED lights	6 ~ 8 W	50 000 h

According to Table 10.1, it is advantageous to use LED bulbs as light sources. However, the use of LED bulbs in Sri Lanka is limited due to their high initial cost.

Similarly, the efficiencies of cookers used to prepare food are different from one to another due to varying amounts of heat wastage. Old cookers that use heating coils are the lowest in efficiency. Emersion heater is highly efficient for heating water. The reason is that, all the heat generated in the heater is transferred to water when using it. Heaters which contains hot plates such as rice cooker is more efficient because heat loss is less from them. Although microwave ovens cannot be used to cook all types of food, they are very efficient since they produce heat inside the food items. In addition to these, induction cookers with high efficiencies are now available in the market. In these devices, the variable magnetic field emitted by the cooker generates heat only at the bottom of the cooking utensil.

For extra knowledge

The power consumption of television sets that use LCD screens is lower than that of the old televisions that use cathode ray tubes. LCD television sets that use LED lights to illuminate the screen have a very low power consumption and are known as LED televisions in the market.

Similarly, it is more efficient to use table fans to cool houses than ceiling fans. Using the most efficient device suitable for a particular purpose whenever possible would help to minimize the future energy crisis.

If 40% of the energy supplied to a certain electric appliance is lost as heat, then only 60% of the energy would be used for the expected purpose. This means that the efficiency of the electric appliance is 60%. We should try to minimize the loss of electric energy as heat and get the maximum out of the electric energy supplied for a particular purpose. Ironing all clothes required for a week in one occasion is more efficient because it saves electricity used in the initial heating of the iron. All the unwanted lights of the home should be switched off. Also, you have to use more efficient bulbs such as CFL and LED bulbs.

Assignment 10.1

Prepare a list of electric devices used in households and indicate their power usage against them (You may use the specification labels pasted on the device or the instruction sheet provided with the device to do this. Get assistance from an adult when this is not possible.)

10.4 Home Electric Circuits

Electric energy required to operate home electric appliances is obtained from the national electric grid. Electric energy generated by electric power stations are raised to high voltages such as 132 kV or 220 kV using step-up transformers and distributed throughout the island. In distribution sub-centres, these high voltages are lowered to voltages such as 33 kV or 11 kV and ultimately they are lowered down to 230 V before supplying to households. Electricity provided to houses is in the form of an alternating current with a frequency of 50 Hz.

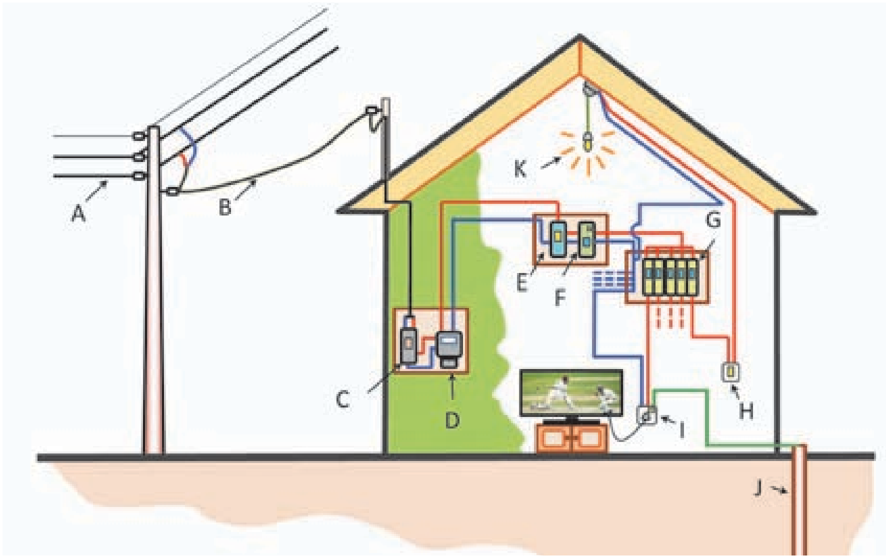


Figure 10.3 – A house connected to the electric grid

A – Distribution wire
B – Supply cable
C – Overload circuit breaker (or Service fuse)
D – Electric meter
E – Isolator (or Main fuse with main switch)
F – Residual current circuit breaker or trip switch (RCCB)
G – miniature circuit breakers or fuses (MCB)
H – Switch
I – plug socket
J – Earth wire
K – Light bulb

Electricity is supplied to houses using a service cable consisting of two wires known as the live wire and the neutral wire. The current flowing through these two wires is provided to the electric appliances through a circuit inside the house.

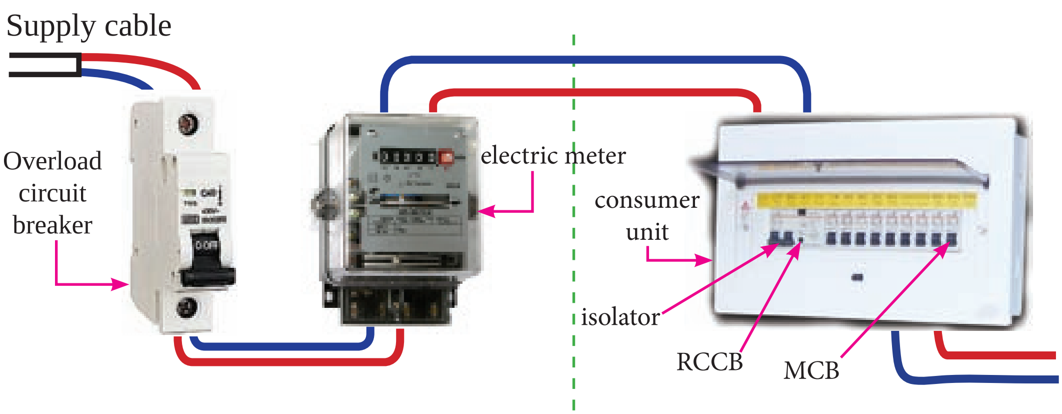


Figure 10.4

Figure 10.5 shows a diagram of a domestic electric circuit.

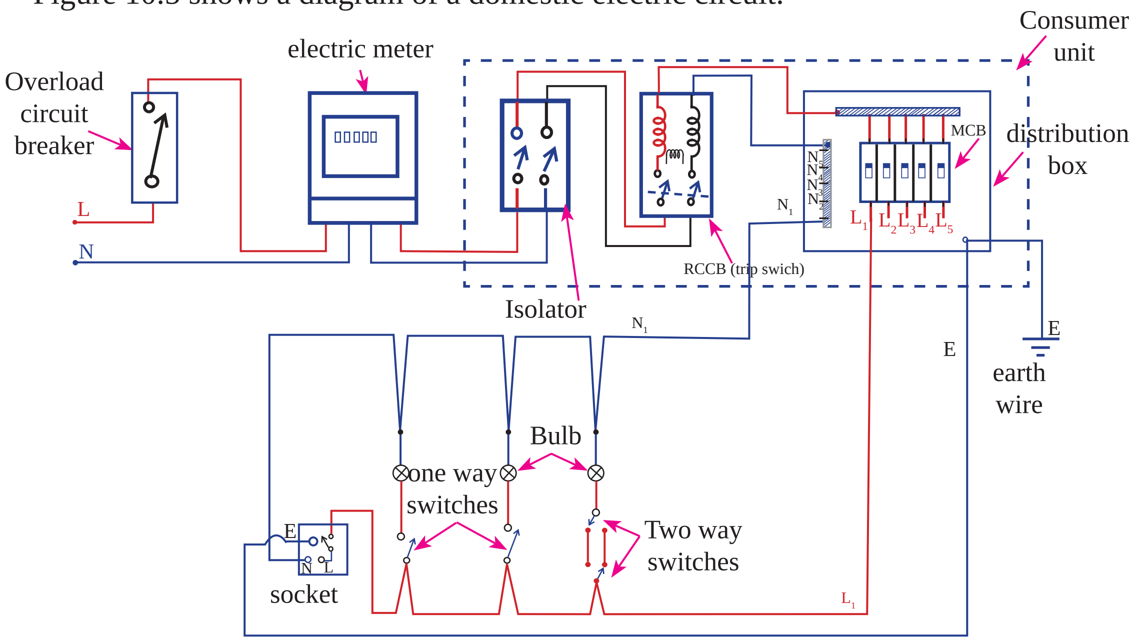


Figure 10.5 – Arrangement of a domestic electric circuit

10.4.1 Components of a Domestic Electric Circuit

- ### Overload circuit breaker (or Service fuse)

Electricity supplied to household first passes through a fuse connected to the live cable. This fuse is arranged to allow the passage of a maximum current of about 40 A. If a larger current passes through it, the circuit breaker disconnects power to the house. When that happens, the power can be reconnected by moving the lever up, manually. In older houses, a fuse, is used instead of a circuit breaker. When a current above the limit passes through the fuse wire which is made of an alloy consisting of lead and tin, it heats up and melts disconnecting the power supply. The fuse wire is inserted in a ceramic tube or a ceramic mount.

Only the live wire is disconnected by the overload circuit breaker or the service fuse. Figure 10.6(a) shows a overload circuit breaker and Figure 10.6(b) shows a service fuse.

(a) (b)

Figure 10.6 - (a) Overload circuit breaker (b) Service fuse

- ## Electricity Meter

Consumers are billed according to the amount of electricity they consume. The meter records the electric energy in kilowatt hours (kW h). The live and neutral wires coming through the over load circuit breaker or service fuse are next connected to the electricity meter. These two wires coming from the electricity meter are next connected to the main switch. An electricity meter is shown in Figure 10.7.

Figure 10.7 - An electricity meter

Overload circuit breaker and the electricity meter are properties belonging to the service provider (electricity board or electricity company) and any problem with these items should be solved by informing the service provider.

- ## Isolator (or Main Switch with Main Fuse)

All items in the domestic circuit beyond the isolator belong to the consumer. After passing through the electric meter, the live wire passes through an isolator that allows the passage of a maximum current of 30 A. Isolator acts as a 30 A high current circuit breaker too. In any instance, by the lowering of the switch levers, it can be disconnected the home hold circuit from power mains (L and N).

In older domestic electrical circuits, a main switch consisting of a 30 A fuse and a dipole switch was used in place of the isolator. The isolator is capable of disconnecting both the live and the neutral wires. Such switches are known as **dual pole switches**. Disconnecting the domestic circuit for any repair purpose can be done by turning off the isolator. Figure 10.8(a) shows the outward appearance of an isolator and Figure 10.8(b) shows the circuit diagram of a main switch.

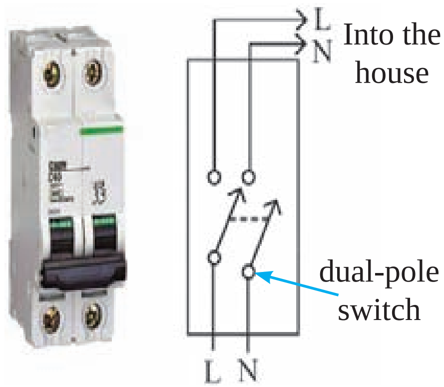


Figure 10.8 (a) - The external view of an isolator and circuit diagram of a isolator

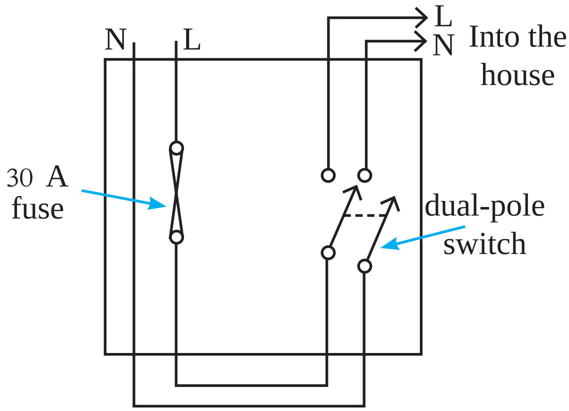
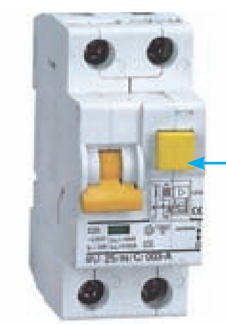


Figure 10.8 (b) - circuit diagram of a main switch

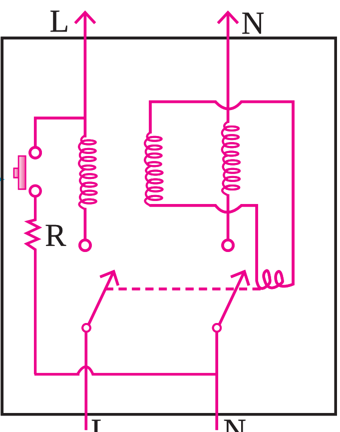
• Residual Current Circuit Breaker - RCCB (or Trip Switch)

After the isolator, the live wire and the neutral wire are connected to a RCCB or a tripped switch. The purpose of connecting to a RCCB is to protect the residents from electric shocks. When there is a current leak to the metal caring of an appliance or to the ground the circuit is automatically disconnect by the RCCB. The RCCB too is a dual pole switch. Outward appearance of a RCCB is shown in Figure 10.9(a) and circuit diagram of a RCCB is shown in Figure 10.9(b).



(a)

Test button



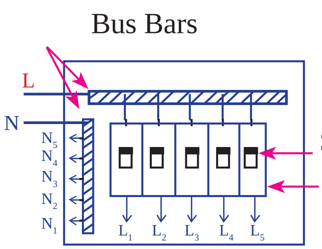
(b)

Figure 10.9 – (a) Outward appearance of a RCCB (b) circuit diagram of a RCCB

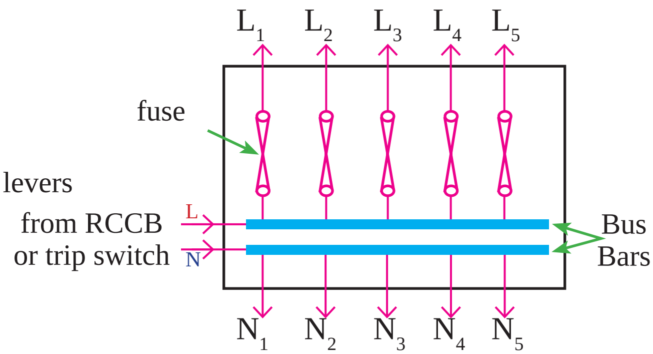
In a normal switch the switch is on when the lever is turned down. But in this switch it become on when the lever arm is raised.

Distribution Box

Electricity is distributed for consumption in the household through the distribution box. Electricity is distributed inside the house through lighting circuits and plug circuits. Adequate current to light bulbs in ordinary rooms is supplied by lighting circuits. The maximum current supplied to a lighting circuit is limited to 6 A. Plug circuits are connected to places such as the kitchen that have devices like electric heaters and electric ovens that consume a large amount of electricity. Plug circuits allow the consumption of current upto about 13 A.



(a)



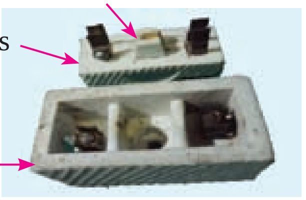
(b)

Figure 10.10 – (a) Circuit diagram of a distribution box with MCBs
(b) Circuit diagram of a distribution box with fuses

Miniature circuit breakers (MCB) and fuses

Miniature circuit breakers (MCB) supplying electricity are connected to each circuit inside the distribution box. When a current larger than the maximum current that can pass through the circuit is drawn, miniature circuit breakers automatically get disconnected and the lever shifts down to the off position. Because of this, the electricity supply gets disconnected only in these circuits and not to the whole household. For lamp circuits, MCBs which can conduct a current of 6 A are used. For socket circuits, MCBs which can conduct a current of 13 A are used.

While bulbs and two 6 A plugs can be connected to a lighting circuit, only plugs can be connected to plug circuits. Figure 10.11 shows the outward appearance of a fuse mount and a miniature circuit breaker.



(a) A fuse

(b) An MCB

Figure 10.11 – Outward appearance of a fuse and an MCB

MCBs can be mounted in specially designed distribution boxes. MCBs provide protection against electric shorts and resulting fires due to heated cables only. Since the fuse or the MCB does not operate when a person gets an electric shock, they do not provide any protection to people.

In older domestic circuits, fuses were used instead of MCB. In lighting circuits, 5 A fuses were used instead of 6 A MCBs. Instead of 13 A MCBs, 15 A fuses were used. The use of fuses has declined because replacing fuse wires of blown fuses is inconvenient. When MCBs or fuses are connected, they must always be connected to the live wire.

In modern domestic circuit, isolator, RCCB and the distribution box are included in the same units called **consumer units**. A consumer unit is shown in figure 10.12.

Figure 10.12 - A consumer unit

For extra knowledge

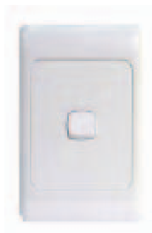
One of the two cables providing electricity to households is earthed near the step down transformer that distributes electricity to the house. Then a potential difference of 230 V is established between the other cable and the earth. Earthed cable maintains a zero potential (Earth is assumed to be at a zero potential).

Now if a person standing on the ground touches the cable that is not grounded, he would receive an electric shock due to the 230 V potential difference across his body (An electric shock is the damage caused to the body by passing an electric current through the body). A 50 mA current passing through the body is considered a major electric shock while a 100 mA current can cause death. Since touching the ungrounded cable causes electric shocks, this cable is known as the "live" cable. Since touching the grounded cable from the ground does not give rise to a potential difference across the body, this cable is known as the neutral cable.

One cable is made to be a live cable in this manner since it is essential for the operation of the RCCB that protects the household from accidents related to electric shocks. If the live wire gets grounded anywhere inside the house, the RCCB automatically disconnects the electricity supply to the house by detecting the large current passing through it. The RCCB operates from electromagnetic induction and if a current of about 35 mA passes through the switch to ground, it automatically turns off. In addition to this, a flow of about 30 A into the house (short circuit) the RCCB operates and disconnects the electricity supply to the house. Although the RCCB sometimes disconnects the electricity supply when there is lightning activity, its protection from lightning damage is not assured.

• Switches and Plug sockets

Switches used to turn on or off power to electric bulbs are major components in domestic circuits. Switches are available as single units or as units consisting of several switches on the same board. Switches are connected to the circuit so as to enable the turning on or off of each bulb separately.



A single switch

Four switches

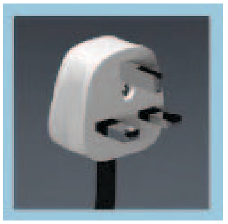
Figure 10. 13 – Switches

Another important component in a domestic circuit is the plug socket. The live cable, the neutral cable and the separately grounded earth cable are connected to these circuit elements. The larger terminal of a three-pin plug socket is connected to the external metal cover of an electric appliance and it connects to the earth wire in the domestic circuit when plugged on. This connection is essential in order to get protection from electric shocks by turning off the trip switch. For some of the modern

Figure 10.14 – A plug socket with switch

electric equipment having a plastic cover that does not leak electricity, two-pin plugs can be used. Two-pin plug sockets are not connected to the earth wire.

Two pin plugs



A three pin plug

Figure 10.15 – Plugs and plug sockets

- ## Connecting Wires

Copper wires with suitable cross-sectional areas are used as connecting wires for carrying currents. Single cables with a 1 mm^2 cross-sectional area (1.13 mm diameter) are used in order to carry 5 A or 6 A currents while cables consisting of seven wires with a 1.5 mm^2 effective cross-sectional area are used for 15 A or 13 A plug circuits.

A brown PVC cover is used to identify the live wire while a blue PVC cover is used to identify the neutral wire. Previously red and black covers were used to identify live and neutral wires respectively. Green covers are used for the earth wire.

10.4.2 Domestic Electric Circuit

Each bulb and each plug in a domestic circuit is connected in parallel to one another. All switches should be connected to the live wire. Therefore touching a bulb circuit when the switch is in the off position does not cause electric shocks.

Plug circuits are connected using cables that can withstand a current of 13 A. Only plugs are connected in these circuits and this type of circuits are often used in kitchens.

Sometimes plug circuits are connected as ring circuits. Such a ring circuit is shown in Figure 10.16. Cables with smaller diameters can be used in such circuits since each plug receives current through two wires.

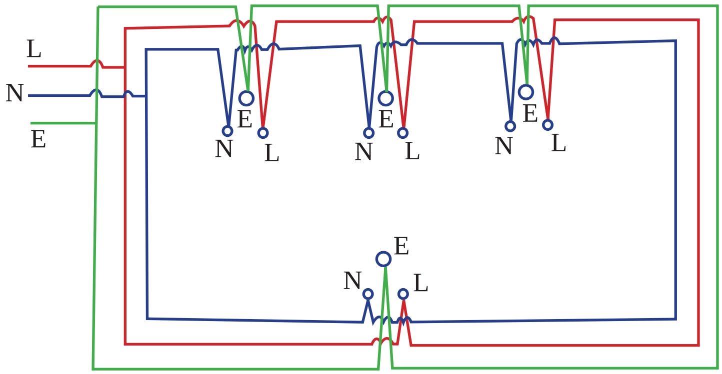


Figure 10.16 – A loop circuit

10.4.3 Protective Measures in Domestic Circuits

Basically there are two protective measures in domestic electric circuits. These are the residual current circuit breaker and the fuse or MCB's.

- **Residual current circuit breaker - RCCB (or Trip Switch)**

In case of a current leakage in the electric appliances or an electric shock, the RCCB disconnects the power supply to the whole house hold. In addition to this, the RCCB also disconnects power if a current greater than 30 A flows through the circuit. This prevents fire arising from over- heated main cables.

- **Fuses or MCB's**

These electrical components prevent large currents flowing through domestic circuits. Fuses or MCB's do not provide protection from accidents due to current leaks or electric shocks.

If there is a power disconnection due to any of the above reasons, the overload circuit breaker should be opened (turned OFF) first. Next, the lever of the RCCB or that of the MCB should be turned upwards (to the ON position) and then close (turn ON) the overload circuit breaker again. If the power supply gets disconnected again, the circuit should be repaired by an electrician.

Further to the above, it is very important to follow the following precautionary measures for safety.

- Only fuses appropriate for 6 A and 13 A currents should be used.
- Many electric appliances that draw a total current exceeding the capacity of the plug socket should not be connected to the plug socket through a multi-plug.
- Only plugs suitable for a plug socket should be inserted into a plug socket. Wires should not be inserted into a plug socket.

- When using an electric iron for ironing clothes, rubber slippers or a rubber carpet underneath the feet should be used. It is good to use a mat in front of a refrigerator for safety.
- Tasks such as changing burnt bulbs in bathrooms should not be done without turning off the overload circuit breaker or the main switch.
- When electric appliances are not in use, their plugs should be disconnected from the socket.
- If there are strong lightning strikes, radio receivers and television sets should be unplugged as much as possible. In such cases it is advisable to refrain from using any unessential electric devices. (RCCBs do not protect the domestic circuit from thunder).
- Electric devices should not be used when the body is wet. Electric switches must not be turned on or off with wet hands.
- During a power failure, switches of electric appliances should not be turned on.
- In case of a fire, the domestic power supply should be disconnected using the overload circuit breaker.
- All maintenance work and installing power extensions should be done by a trained electrician.
- The functioning of the RCCB should be checked every few days by pressing the test button.

10.5 Measuring Electric Energy in kilowatt hours

- **Commercial unit of measuring electric energy**

Electric energy is measured in kilowatt hours by the domestic electricity meter. One kilowatt hour is the amount of electric energy consumed during one hour by an electric appliance with a power consumption of 1 kW. Although energy is usually measured in Joules, when the consumption is high, energy in Joules gives a large numerical value. Because of this, kilowatt hours (kW h) is used as the measuring unit of electricity. The energy consumed in a second by a device with a 1 Watt power is equal to one Watt second (W s) or one Joule (J).

$$\therefore\ 1\ \text{kW h} = 1\ \text{kW} \times 1\ \text{h}$$
$$= 1000\ \text{W} \times 1 \times 60 \times 60\ \text{s}$$

$$\mathbf{1\ kW\ h = 3\ 600\ 000\ J = 3.6 \times 10^6\ J}$$

This shows that 1 kW h has a large numerical value in Joules.

When the power of domestic electric appliances and the number of hours they are used are known, the amount of electricity consumed by these devices can be easily calculated.

$$\text{Number of kW h} = \frac{\text{number of Watts}}{1000} \times \text{number of hours}$$

Example 1

If four bulbs, each having a power of 100 W are used for 3 hours and 5 bulbs, each with a power of 60 W are used for 4 hours daily, find the electricity consumption during a month.

Energy consumed by 4 bulbs of 100 W power } $= 100 \times 4 \times 3$ W h

Energy consumed by 5 bulbs of 60 W power } $= 60 \times 5 \times 4$ W h

Total energy consumed by all bulbs in a month $= (100 \times 12 + 60 \times 20) \times 30$ W h

Total energy consumed during a month $= (1200 + 1200) \times 30$ W h

$= \dfrac{2400 \times 30}{1000}$ kW h

Total electricity consumed during a month $= 72$ kWh

Therefore, a total of 72 kW h of electricity is consumed during a month.

Summary

- The power of an electric appliance is the amount of electric energy consumed by it in a unit time.
- When a current I passes through an electric device due to a potential difference V, its power P is given by $P = VI$
- Electric energy E consumed by an electric device over a time period t is given by $E = VIt$
- Domestic electricity meter measures electric energy in kilowatt hours (kW h).
- One kilowatt hour is the energy consumed during one hour by an electric device that has a power of one kW.

  1 kW h = 3 600 000 J

Exercise 10.1

(1) The power of an electric water pump is 750 W.

(a) Calculate the current drawn by the motor, if it is connected to a 230 V supply.

(b) State one type of energy, other than the kinetic energy, generated when the motor is operating.

(2) Specifications of a flash light bulb are given as 2.5 V and 0.3 A.

(a) What is the power of this bulb?

(b) If the efficiency of emitting light from this bulbs is 42% what will happen to the remaining 58%?

(3) The power of the two head lamps of a motor vehicle is 50 W each. There are other two lamps in the rear with 10 W each. If all these bulbs are lighted up for 1/2 h, calculate the quantity of electrical energy spent.

(4) The current flowing through a motor cycle bulb when it is connected to 12 V battery is 2 A. How much electrical energy is spent if this current is flowing for 15 minutes?

(5) (a) Name two instruments that are used in a domestic circuit for the protection of residents.

(b) Mention what is the type of protection provided by each of them.

(c) Explain what is to be done to protect electric equipment in a house when lightning occurs.

(6) (a) Consumers are charged money for the electricity used in houses. What is the unit of electrical energy which is used to make electric bills?

(b) Calculate the amount of energy in Joules equivalent to one commercial unit of electricity.

(c) If the first 60 units are charged at a rate of Rs. 7.50 per unit and the next 30 units are charged Rs. 10.00 per unit, how much will be the electricity bill of a house where the electricity usage is 75 units in a month?

(7) (a) The power of a water heater in a home is 1500 W. This is used for half an hour daily. Three 40 W bulbs are used for 3 hours daily. Two bulbs of 60 W are lighted for 2 hours daily. Calculate the number of units used up in one day.

(b) If electricity is charged according to the above rates given in the question 6 (c), what should be the monthly electricity bill.

(8) (a) A hot plate or immersion heater can be used to heat water. Which one is more efficient out of these two?
(b) Give the reason for this.
(c) What is the reason for using three pin plugs instead of two pin plugs for immersion heaters?
(d) When an electrical appliance is switched on the electrical circuit was disconnected. Give two reasons due to which this can happen.

Technical terms

Power	- ක්ෂමතාව	- வலு
Efficiency	- කාර්යක්ෂමතාව	- திறன்
Hot plate	- තාපන ඵලක	- வெப்பத் தட்டு
Immersion heater	- ගිල්ලුම තාපකය	- அமிழ்ப்பு வெப்பமாக்கி
Microwave oven	- ක්ෂුද්‍ර තරංග උදුන	- நுணுக்கலைக் கனலி
Induction cooker	- ප්‍රේරක උදුන	- தூண்டற் சமைகலன்
Live	- සජීවී	- உயிர்
Neutral	- උදාසීන	- நொதுமல்
Fuse	- විලායකය	- உருகி
Residual current circuit breaker (RCCB) or Trip Switch	- ශේෂ ධරා පරිපථ බිඳිනය හෝ පැන්නුම් ස්විච්චය	- இடறு ஆளி / எச்சமான மின் சுற்றுடைப்பான்
Distribution box	- විබෙදුම් පෙට්ටිය	- பரப்பற் பெட்டி
Miniature circuit breaker (MCB)	- සිඟිති පරිපථ බිඳිනය	- சிறு சுற்றுடைப்பான்
Plug socket	- කෙවෙනිය	- குதை
Plug	- පේනුව	- செருகி
Overload circuit breaker	- අධිධාරා පරිපථ බිඳිනය	- பளு சுற்றுடைப்பான்
Isolator	- වෙන්කරණය	- பிரதான ஆளியும் பிரதான உருகியும்

Physics

11

Electronics

11.1 Introduction

Electronics has made a huge impact on our daily lives. We use many electronic devices in our day to day activities. Mobile phone, computers, televisions and radios are some examples for such electronic devices.

Figure 11.1

Materials that conduct electricity are known as electrical **conductors**. Conductors (copper, aluminium, iron, lead etc.) and mixed conductors (brass, nychrome, manganin) are examples of these. Materials that do not conduct electricity (ebonite, polythene, plastic, dry wood, asbestos, glass etc) are known as electrical **insulators**.

The reason behind the ability to conduct electricity is the ability of some of the electrons in the atoms of such materials to move freely within the conductor. Electrons in the outer shells of conductors act in this manner since they are not tightly bound to the nucleus. Since inter-atomic bonds (covalent bonds) between the atoms of insulators are strong, there are very few electrons that are free to move.

Meanwhile, some materials conduct a small amount of electricity. Such materials are known as **semiconductors**. Materials such as silicon (Si) and germanium (Ge) in their crystalline form show such properties. These elements belong to the fourth group in the periodic table and have four electrons in their outermost shell. Such elements form crystal lattice structures by sharing the four electrons in their outermost shell to make covalent bonds with four nearby atoms and thereby acquiring a stable electronic configuration having eight electrons in the outermost shell.

However, these bonds are rather weak and can be broken from the thermal energy available even at room temperature, releasing electrons.

Figure 11.2 shows the covalent bonds of the silicon lattice at 0 K. All the bonds are complete at this temperature. Figure 11.3 shows that some bonds have been broken releasing some free electrons at a temperature higher than 0 K. An electron deficiency can be observed at the positions that the free electrons occupied previously. Such positions with an electron deficiency are known as **holes**. Due to the positively charged protons in the nucleus, a hole gives rise to a positive charge that has not been neutralized (In a neutral atom, the number of protons in the nucleus is equal to the number of and electrons). Therefore a hole is equivalent to a positive charge.

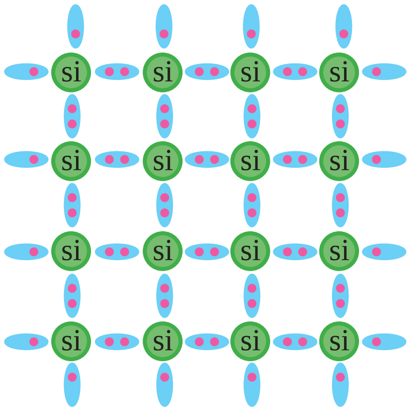


Figure 11.2 - A silicon lattice at 0 K

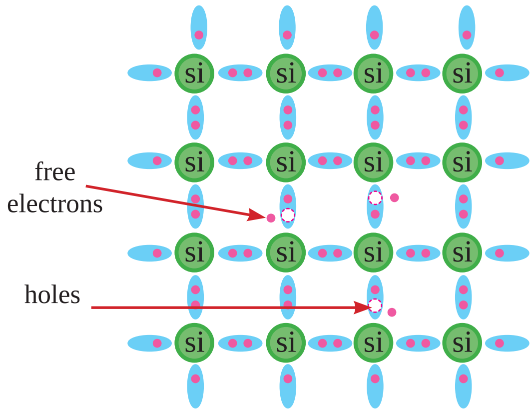


Figure 11.3 - A silicon lattice at temperature above 0 K

In semiconductors, not only electrons contribute to the conduction of electricity. When an electron in an adjacent atom jumps to an atom with a hole having a positive charge, the position of the hole can change. By changing the position of a hole from one atom to another in this manner, holes can move around in the lattice and contribute in conducting a current. Electrons act as negative charge carriers while holes act as positive charge carriers.

Therefore, when an electric potential difference is applied across a semiconductor, holes move from the positive to the negative potential while electrons move from the negative to the positive potential and the (conventional) current flows from the positive to the negative potential.

- In metallic conductors, the charge carriers that conduct electricity are the negatively charged electrons.
- In semiconductors, the negatively charged electrons as well as the positively charged holes act as the charge carriers that contribute in the conduction of electricity.
- Since a hole is generated in the breaking of a bond to release an electron, the number of carrier electrons present in a semiconductor is equal to the number of holes.
- Therefore the semiconductor lattice is electrically neutral.

11.1.1 Intrinsic Semiconductors

Pure semiconductor materials such as silicon (Si) and germanium (Ge) that exist in crystaline form as mentioned above are known as **intrinsic semiconductors**.

• Effect of Temperature on the Conduction of Electricity

Since the random motion of free electrons increases as the temperature is increased, a rise in the temperature inhibits the current flow. Therefore, a temperature rise in conductors causes a decrease in the conductivity (increase in the resistivity). However in semiconductors, a rise in temperature breaks bonds generating more holes and free electrons causing an increase in the conductivity (decrease in the resistivity).

11.1.2 Extrinsic Semiconductors

Let us consider what happens when a minute amount of the element phosphorous (P) is mixed (doped) to an intrinsic semiconductor such as Si. Phosphorous is an element in group V of the periodic table and has five electrons in the outermost shell. A phosphorous atom makes the number of electrons in its outermost shell eight by acquiring four electrons from four nearby silicon atoms around it. In the process, one of the five electrons is left behind without taking part in forming a bond. This electron has the opportunity to move about freely in the lattice.

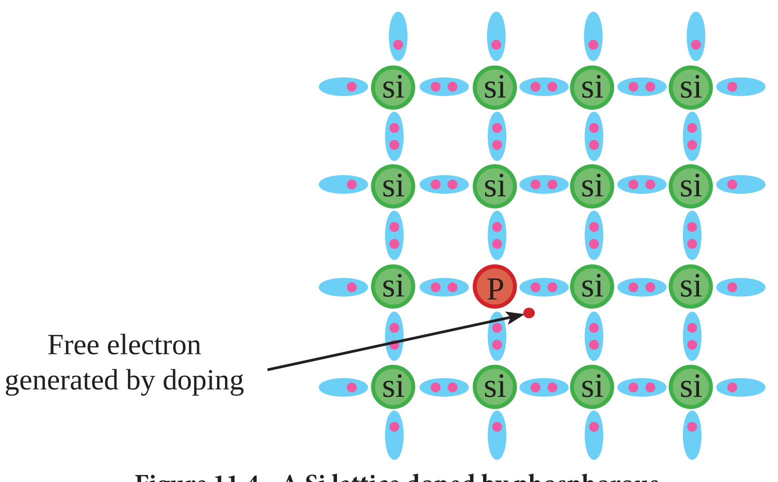


Figure 11.4 - A Si lattice doped by phosphorous

Figure 11.4 shows how a phosphorous atom forms bonds with silicon atoms. The electron left behind increases the conductivity of the lattice. Since negatively charged electrons are introduced to the lattice as charge carriers, the semiconductor is known as a negative type or n-type semiconductor. Semiconductors whose carriers have been increased by doping it with another element are known as **extrinsic semiconductors**. By doping an intrinsic semiconductor with other elements in group V such as arsenic (As) and antimony (Sb) also, n-type extrinsic semiconductors can be formed. Since electrons are donated to the lattice by group V elements, they are known as **donor atoms**.

If Si which is an intrinsic semiconductor is doped with an element in group III such as boron (B), the boron atom forms bonds with nearby silicon atoms. However, since there are only three electrons in the outermost shell of the boron atom, there is a deficiency of one electron in order to form four bonds. Figure 11.5 shows how the atoms and bonds are configured in this case.

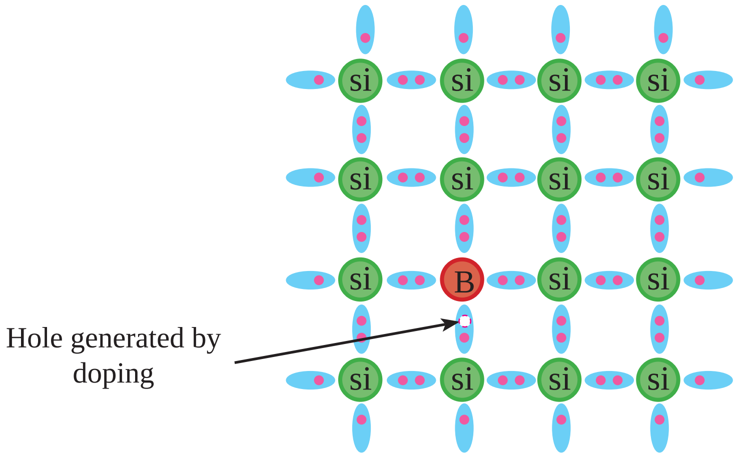


Figure 11.5 - A Si lattice doped by boron

A hole exists at the point where the electron is deficient in the boron atom to form a bond. Since holes can conduct electricity as positive charges, the conductivity of silicon increases. As a hole is equivalent to a positive charge, such extrinsic semiconductors are known as positive or p-type semiconductors. Because the hole concentration in p - type semiconductors is much greater than the electron concentration holes are called majority carriers and electrons are called minority curriers. By doping an intrinsic semiconductor with other elements in group III such as aluminium (Al), gallium (Ga) and indium (In) instead of B also p-type extrinsic semiconductors can be formed. Since holes that can receive electrons are produced by group III elements, they are known as **accepter atoms**.

11.2 p – n Junction

By doping one side of an intrinsic semiconductor such as silicon or germanium with a group III element to form a p-type semiconductor and the other side with a group V element to form an n-type semiconductor, a p-n junction can be formed at the centre of the semiconductor. Such a junction shows an electrical behaviour that is different from normal conductors.

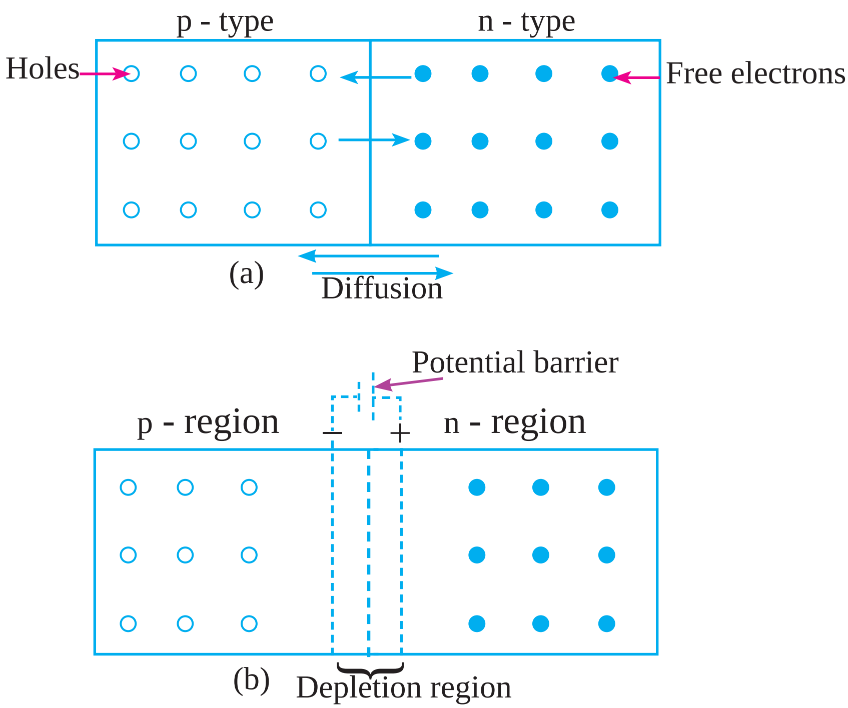


Figure 11.6 – p – n junction

As shown in Figure 11.6(a) as soon as the p–n junction is formed, the free electrons in the n-region diffuse across the junction towards the p-region and the holes in the p-region diffuse towards the n-region. Due to this diffusion, electrons and holes recombine forming a region devoid of charges near the junction. This region is known as the depletion layer or depletion region. As shown in Figure 11.6(b), extra electrons have entered the p-side of the depletion region giving it a negative charge while extra holes have entered the n-side of the depletion region giving it a positive charge generating a voltage difference across the junction. This potential difference repels the charge carriers impeding the diffusion of charge carriers across the junction. Therefore this potential difference is known as a “potential barrier”. This potential barrier is represented in the above figure as a hypothetical battery.

The magnitude of the potential barrier in a p-n junction formed by Si is about 0.7 V while that formed by Ge is about 0.3 V.

11.2.1 Biasing a p-n Junction

Applying a potential difference across the p-n junction using an external electric source is known as biasing. Depending on the direction of the bias voltage across the junction, it behaves in one of two ways. Let us engage in activity 11.1 to demonstrate this.

Activity 11.1

Apparatus required : IN 4001 diode, A 2.5 V torch bulb, Two 1.5 V dry cell batteries, A switch, A circuit board, Connecting wires

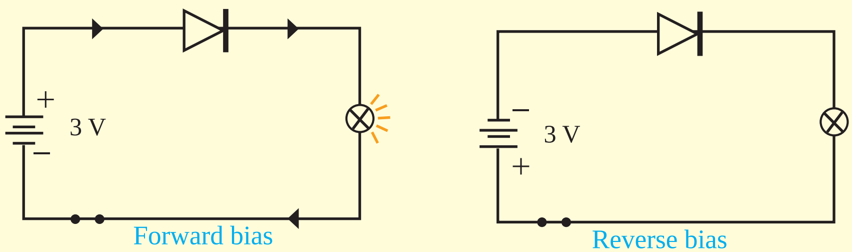


Figure 11.7(a) **Figure 11.7(b)**

- Connect the circuit on the circuit board (a project board/ bread board is better for this purpose) as shown in the Figure 11.7.
- Turn on the switch and observe the bulb.
- Next, disconnect only the battery and reconnect the battery as shown in Figure 11.8.
- Turn on the switch again. Observe the bulb.

Determine which of the above biasing methods allows a current to pass through the diode. You will observe that the bulb turns on only when the diode is connected as shown in Figure 11.7. According to this, you can use the junction diode when you need the current to flow only in a desired direction in a circuit.

For extra knowledge

- In order for the p-n junction to be forward biased and allow a current to pass through it, a positive potential should be connected to the anode and the potential difference applied should be sufficient to overcome the potential barrier across the junction. (For Si diodes this value should be greater than 0.7 V and for Ge diodes greater than 0.3 V).

- **Reverse biased p-n junction**

Let us consider what happens when a battery is connected to the junction with its negative terminal connected to the p-type semiconductor and its positive terminal connected to the n-type semiconductor.

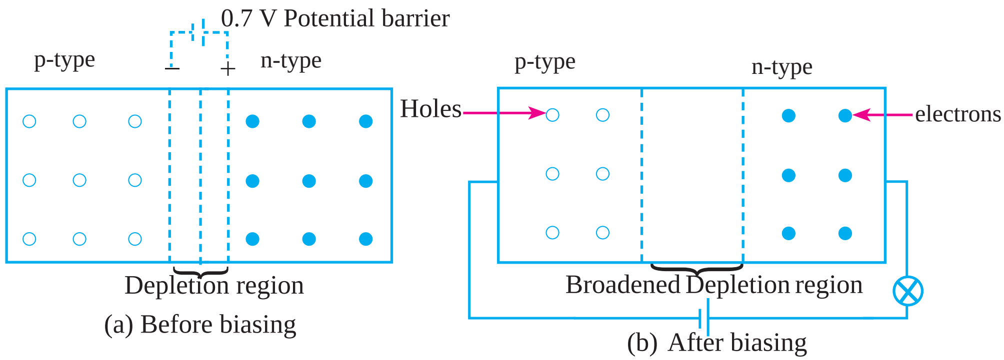


Figure 11.8 – Reverse biased p-n junction

In this case, the free electrons in the n-region are attracted towards the positive potential while the holes are attracted towards the negative potential, broadening the depletion layer. There is no carrier (charge) flow across the junction. Only the depletion region broadens depending on the potential difference of the external source. Since there is no charge flow, connecting the external potential in this manner is known as **reverse bias**. Figure 11.8(a) and (b) shows how the depletion layer behaves when it is reverse biased.

• Forward biased p-n junction

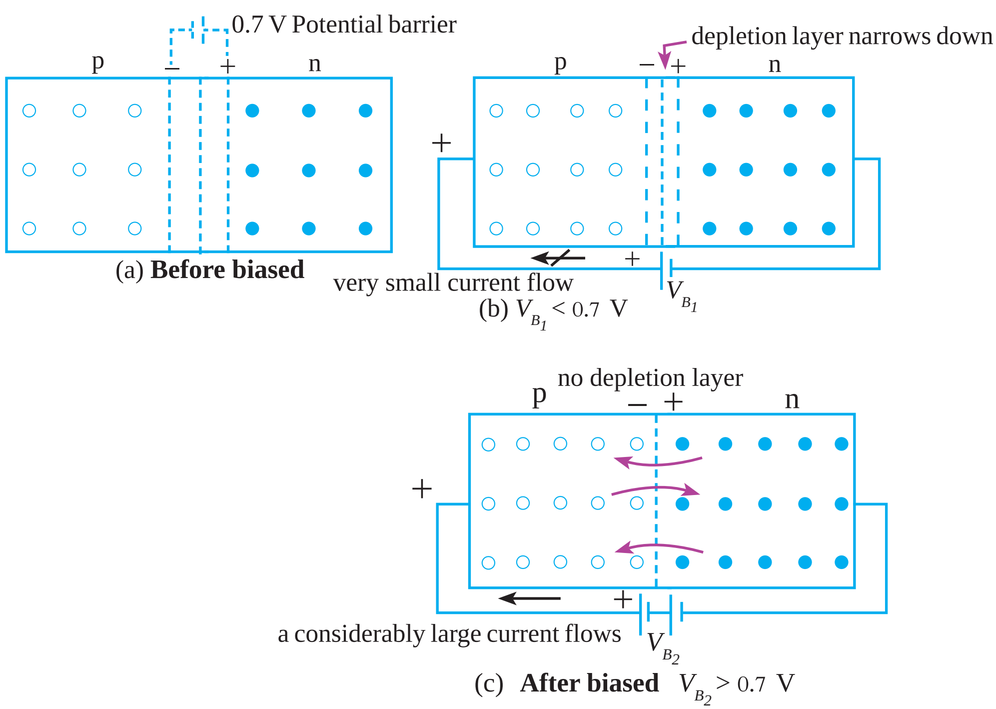


Figure 11.9 – Forward biasing of a p-n junction

In this case the external potential source is connected with the positive potential connected to the p-region and the negative potential connected to the n-region. While the holes in the p-region are repelled by the positive potential towards the junction, electrons in the n-region are repelled by the negative potential towards the junction. The depletion region narrows down due to this and if the externally supplied potential difference exceeds the potential barrier across the junction, carriers flow across the junction. When a high potential than 0.7 V is applied depletion layer is very small and a current is flowing through the p-n junction. Then a current flows across the junction. Therefore, connecting the external voltage in this manner is known as **forward basing**.

11.3 p-n Junction Diode

Now you know that a current flows across a p-n junction only if it is forward biased in the manner described above. A component consisting only of such a p-n junction is known as a junction diode. The arrangement of p and n semiconductors inside a junction diode is illustrated in Figure 11.10(a) and the symbol used for a diode is shown in Figure 11.10(b). Terminal A is known as the anode and terminal K is known as the cathode. Electricity is conducted through the junction only when the anode A is connected to the positive terminal of an external voltage supply and the direction of current through the junction is shown with an arrow head in Figure 11.10(c).

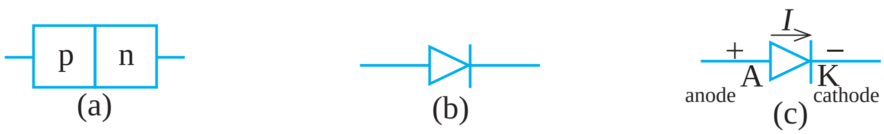


Figure 11.10 – Junction diode

Figure 11.11 - General outward appearance of a junction diode

The general outward appearance of a junction diode is shown in Figure 11.11. It has a cylindrical shape and a black color. The white or silver colored ring shows the terminal of the cathode. There are large numbers of various different types of diodes and a number is printed on the cylinder in order to identify them. But it should be remembered that the external appearance of a diode can vary widely.

11.4 Rectification of Alternating Currents

We know that an alternating current is a current that alternates or changes its direction of flow in a circuit. A direct current is a current that flows only in one direction. The variation of the current or the voltage with time for direct currents and alternating currents are shown in Figure 11.12. Usually, dynamos produce electricity as alternating currents. However, for operating some electronic devices, direct currents are required. Junction diodes that allow the current to flow in one direction can be used for converting an alternating current to a direct current. The task of converting an alternating current into a direct current that flows only in one direction is known as "**rectification**".

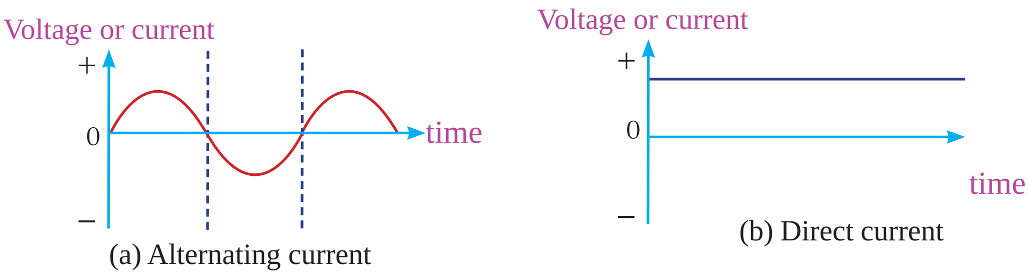


Figure 11.12 – Graphical representation of alternating and direct currents

11.4.1 Half Wave Rectification

Figure 11.13 shows a circuit used for half wave rectification. The main power supply is used to obtain the alternating current.

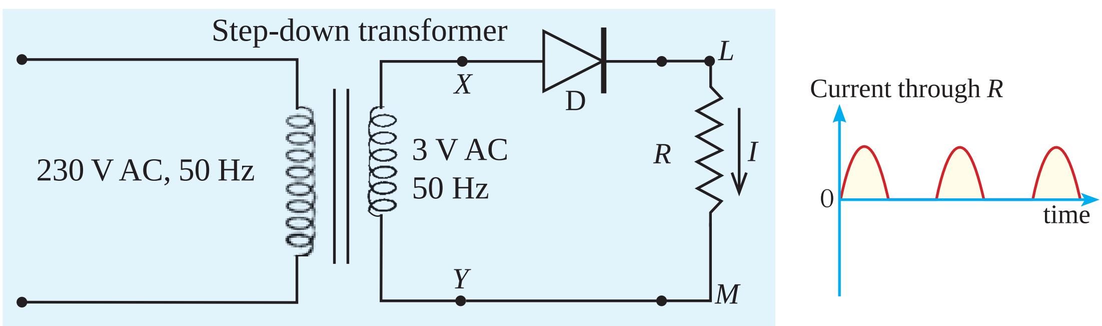


Figure 11.13 – Half wave rectification

First the voltage is lowered to a desired value using the step-down transformer. The lowered alternating potential difference is obtained from the *X*, *Y* terminals of the transformer.

Since the current flow through the diode takes place only in the direction *XL*, the current through the resistance *R* flows only during the positive half cycle of the alternating current. During the negative half cycle, the current through the resistance is zero (Compare this with the way the diode behaved when the batteries were connected in activity 11.1).

Since the output always consists only of half a cycle of the current, this is known as **half wave rectification**.

Exercise 11.1

Plot the current obtained through R when only the terminals of the diode in figure 11.13 are changed (so that X is connected to the cathode) while all other parts of the circuit remain intact.

11.4.2 Full Wave Rectification

Activity 11.2

Apparatus required : A bicycle dynamo or an alternating current generator available in the laboratory, Four 1N 4001 diodes, A centre zero galvanometer, A 100 Ω rheostat, Lead solder and a soldering iron, Connecting wires

- Solder the four diodes in the form of a bridge so that the anodes and cathodes are correctly connected.
- Connect the rheostat and the centre zero galvanometer as shown in the figure.
- Now connect the terminals of the bicycle dynamo or the alternating power source to the terminals X and Y and rotate the generator slowly.

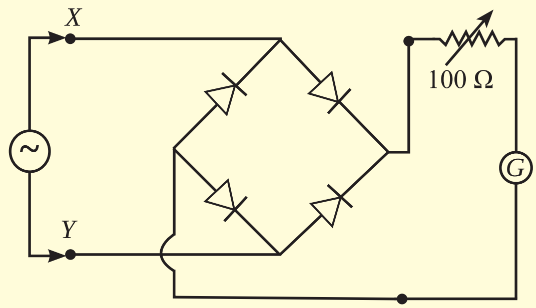


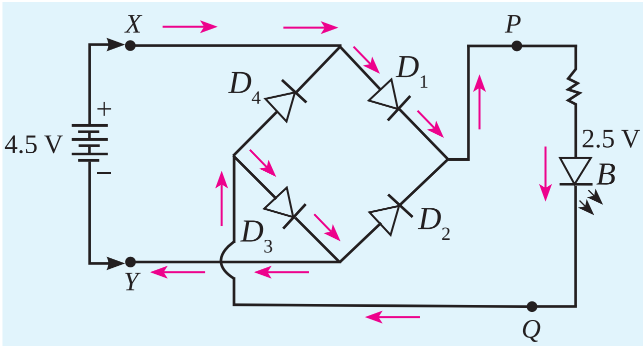
Figure 11.14

- Observe the deflection of the galvanometer. If the deflection is too large adjust the rheostat to lower it.

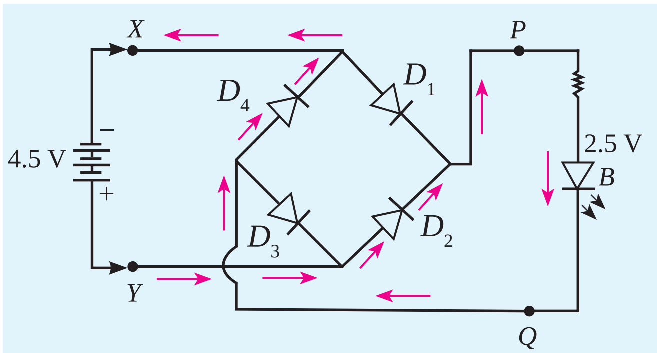
In this activity, you will observe that the deflection in the galvanometers is only in one direction. That means that the current has been converted to a direct current.

If four diodes are used in the form of a bridge in an appropriate manner and an alternating current is passed through it instead of the single diode used earlier, both half cycles of the alternating current can be made to flow in the same direction. Figure 11.15 illustrates such a bridge circuit.

When a 4.5 V battery and a LED bulb is connected as shown in Figure 11.15(a) the bulb lights up with its normal brightness. Here, the LED is used on a lamp that is turned on when the current is flowing in one direction only. When point X is positive relative to point Y, diodes D_2 and D_4 are reverse biased while diodes D_1 and D_3 are forward biased. Then the current flowing through D_1 passes through the bulb and reaches the negative terminal of the battery after passing through diode D_3.



(a)



(b)

Figure 11.15 - bridge circuit

Now if the circuit is reconnected with the negative terminal of the battery connected to point X and the positive terminal connected to point Y as shown in Figure 11.15 (b), the bulb would light up with the same brightness. In this case, the diodes D_2 and D_4 are forward biased and D_1 and D_3 are reverse biased. Therefore the current coming from the positive terminal of the battery passes through diode D_2, the bulb and diode D_4 and flows to the negative terminal of the battery. In both cases, the current through the bulb flows in the same direction.

For extra knowledge

In figure 11.15, a 4.5 V battery is used to light a 2.5 V bulb because the current in each case flows through two diodes producing a $2 \times 0.7 = 1.4$ V voltage drop. Due to this drop across the diodes, the available voltage for the bulb is $4.5 - 1.4 = 3.1$ V. If a 3V battery is used instead of the 4.5 V battery, the remaining voltage of $3 - 1.4 = 1.6$ V will not be sufficient to light the bulb.

Now if an alternating voltage is connected to the circuit in place of the battery, the current flows through the bulb in the same direction (from P to Q).

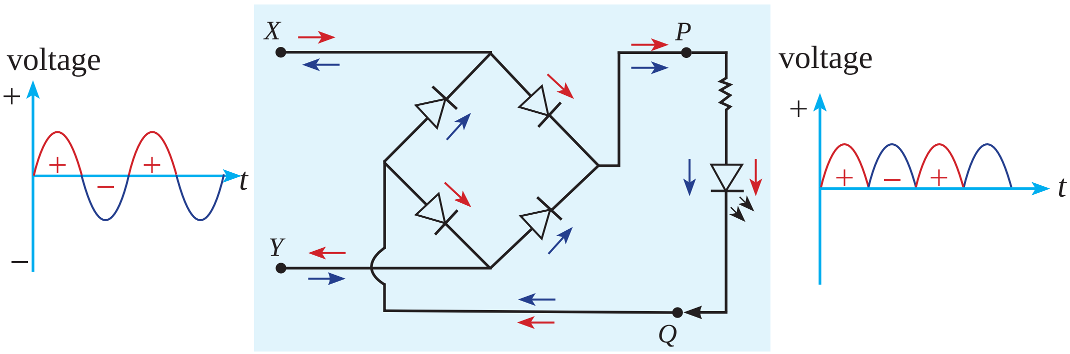


Figure 11.16 – Full wave rectification using a bridge circuit

Figure 11.16 shows the direction of current flow through the diodes in the two half cycles, positive and negative of the input. Since both cycles of the alternating current through the bulb is made to flow in the same direction in the output, this process is known as **full wave rectification**.

Exercise 11.2

Explain the reasons for your observations on the galvanometer in the two instances in activity 11.2 and show the variations of the current with time graphically for the two cases.

11.4.3 Smoothing

A half wave or full wave rectification circuit gives out a current flowing in one direction. However its magnitude (voltage or current) varies between zero and a maximum value.

Time variations of the voltage outputs from a battery, the half wave rectified output and the full wave rectified output from an alternating current are shown in Figure 11.17. For the operation of most electronic devices, a constant voltage similar to that obtained from a battery or a constant direct current is more suitable.

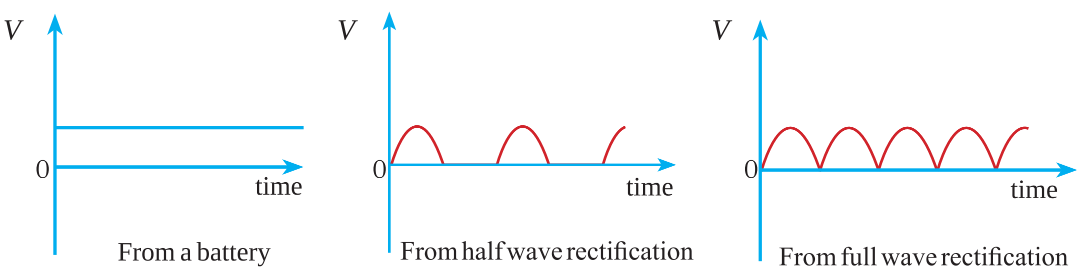
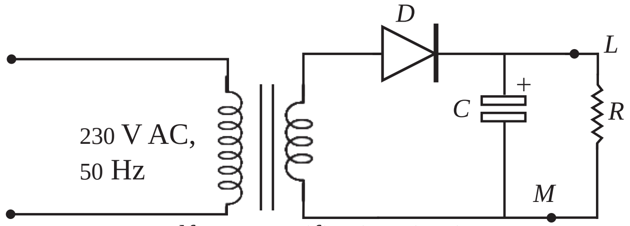
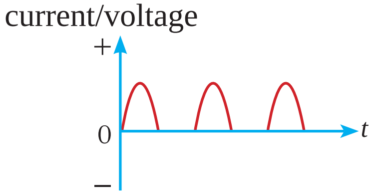


Figure 11.17 – Difference between voltage outputs from a battery and rectification

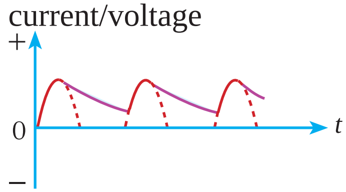
By connecting a capacitor with a large capacitance in parallel to the output terminals of the rectifier circuit, the variation in rectified voltage can be reduced. This process is known as **smoothing**. Figure 11.18 shows the output of a half wave rectified after smoothing it using a capacitor. Rectifier circuit is shown in the figure (a) and output without the capacitor is shown in (b). The figure (c) shows the output with the capacitor.



(a) Half wave rectification circuit



(b) Output before smoothing

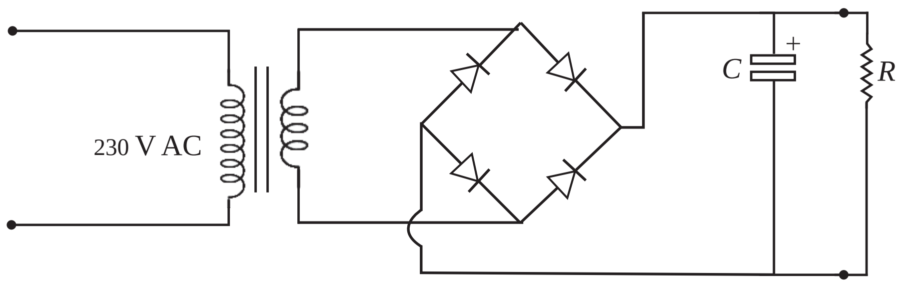


(c) Output after smoothing

Figure 11.18 – Smoothing of a half wave rectified

When the voltage supplied by the diode gradually increases from zero, the capacitor gets charged. When the voltage drops back after reaching a maximum value, the charge stored in the capacitor is released. Therefore despite the voltage supplied through the diode being zero, the voltage across the capacitor does not drop down to zero although a small reduction takes place. In addition, because the current across the diode is always in one direction only, the discharge current of the capacitor does not flow through the diode. The time variation of the smoothed output voltage is shown in Figure 11.18(c).

The output from full wave rectification too can be smoothed in the same manner. Figure 11.19 shows the circuit diagram and the time variation of the output voltage for such a rectification.



(a) Circuit diagram of full wave rectification

(b) Before smoothing (without capacitor) **(c) After smoothingq (with capacitor)**

Figure 11.19 – Smoothing of a full wave rectification output

Here the current is even smoother than in a half wave rectification. Capacitors with large capacitances such as 1000 μF, 2000 μF are used for smoothing. Smoothing becomes better with increasing capacitance.

- **Use of a diode in order to prevent the damage caused to a direct current appliance by supplying power with inverted terminals**

A rectifier diode can be used to prevent the damage caused to a direct current appliance by supplying power from the positive and negative terminals incorrectly connected.

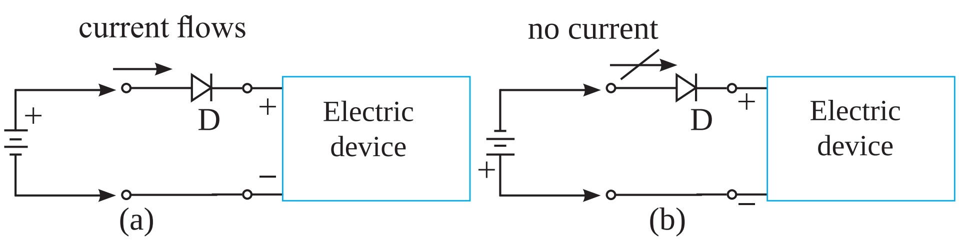


Figure 11.20 - Protecting a device from damage due to incorrectly connected terminals

Figure 11.20(a) shows the circuit with a diode as a circuit protector and the battery connected correctly. Figure 11.20(b) shows the circuit with the battery connected incorrectly. Since the diode is reverse biased in this case there is no current passing through the device. Therefore no damage is caused to the device and it operates only if it is correctly connected to the battery.

For extra knowledge

Try to construct a bridge type rectifier circuit that supplies the voltage correctly to an electronic appliance regardless of how the battery is connected to the circuit.

11.4.5 Light Emitting Diode (LED)

When a p-n junction formed with a semiconductor material such as gallium arsenide (GaAs) is forward biased, light is emitted at the junction. Such diodes that are capable of emitting light are known as **light emitting diodes (LED)**.

Figure 11.21

Various types of diodes are available in the market and Figure 11.22 shows the outward appearance, the symbol and how to identify the terminals of one of the most popular types, the 5 mm LED. The longer terminal of a diode is its anode. Similarly, if the base of the LED is pointed towards us, the terminal near the cut is its cathode. There are also LED's that emit red, yellow, green, blue colors as well as infrared (IR) and ultraviolet (UV) rays in the market.

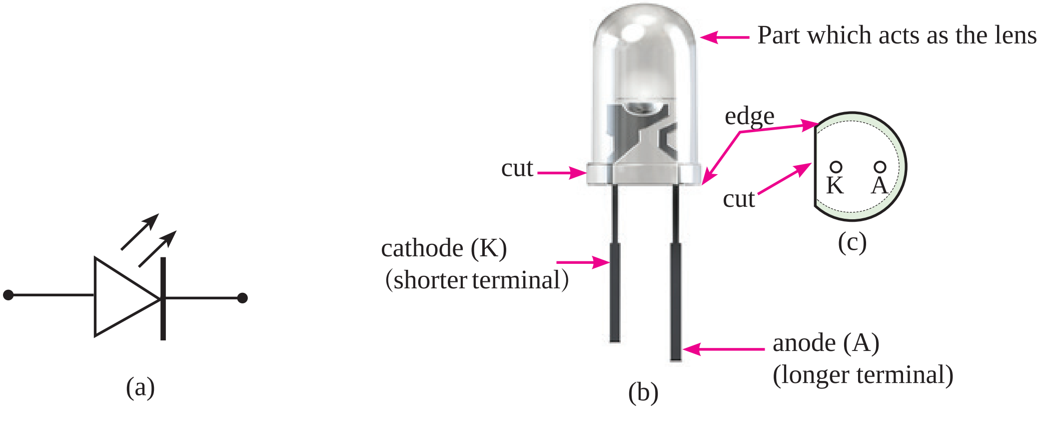


Figure 11.22 – (a) The symbol (b) Outward appearance of a light emitting diode (c) Base diagram cathode (-) is situated at the side with the cut

In the early stages light emitting diodes were mostly used as indicators. At present, light emitting diodes are also used in the construction of large television screens. With the invention of white light LED's, their use is becoming increasingly popular for lighting up homes, streets and in the construction of torches. The very low power consumption, and the long life times of about 50,000 hours are the reasons for the wide usage of light emitting diodes.

For extra knowledge

- Minimum potential required for colour LEDs vary. Minimum potential required for some of them are given below. Current flowing through these is 10 – 20 mA.

Colour	Semiconductor material	Minimum bias voltage
Red	Ga As	1.8 V
Orange	Ga As P	2 V
yellow	Al In Ga P	1.8 V
Green	Ga P	2.2 V
Blue	Ga N	5 V

- Only one colour is given by a LED. The cover is coloured to make it possible to identify its colour when it is not lighted.
- When the current passing through a light emitting diode is increased its brightness also increases. However, the life time decreases with brightness.

11.4.6 Solar Cells

Solar cells are also constructed using p-n junctions. Therefore solar cells are also diodes. They are constructed in such a manner so as to allow light to fall on the junction. When sunlight is incident on these silicon p-n junctions, a small electro motive force (voltage) is generated across the junction. Since such a p-n junction can be used as a source of an electro motive force, they are known as **solar cells**.

By arranging a number of such cells in series and parallel, voltages such as 12 V or 15 V with large currents can be obtained. Such an arrangement is known as a **solar panel**.

Originally such solar panels were developed for the use satellites. They were used instead of batteries to generate electricity. Their cost at that time was very high. Since they can now be produced at a low cost with the development of technology, solar panels are used to light up homes at present.

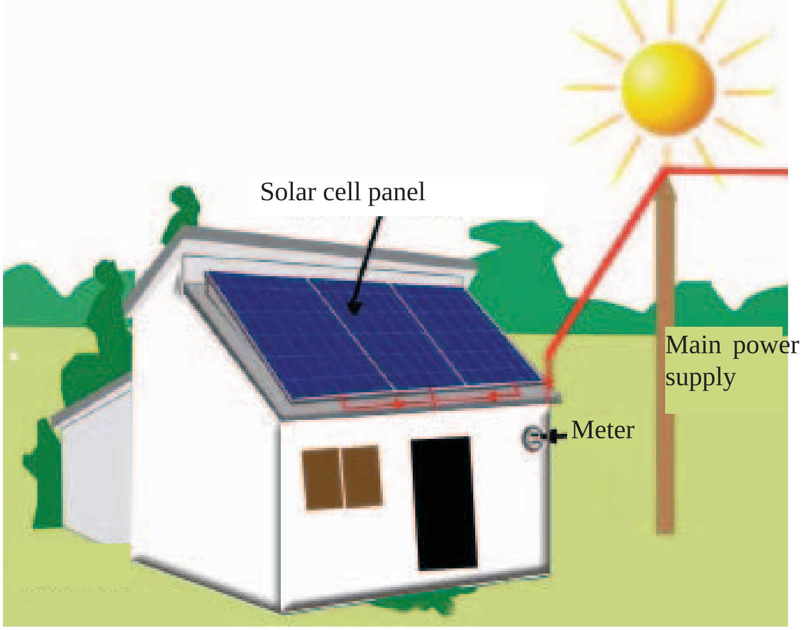


Figure 11.23 - A house with solar panels connected to the mains power supply

Solar cells are considered to be a solution to the future power and energy crisis as they operate with the solar radiation we receive at no cost, as they do not emit any substance that is harmful to the environment and as they have a long lifetime (the solar cells produced initially are still in operation).

Solar cells are presently used to operate clocks and calculators and they are also used in solar powered motor vehicles.

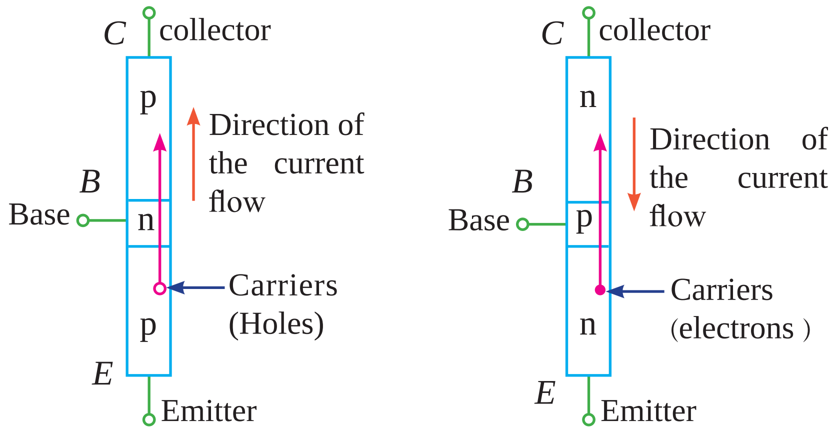
11.5 Transistors

The transistor which is responsible for vast developments in electronics is constructed using two p-n junctions. Three semiconductor regions of type p and n are connected together to form a transistor. There are only two ways in which the three semiconductor regions can be connected in order to form two p-n junctions. Figure 11.24 shows these two ways. They are known as npn and pnp transistors

Figure 11.24 – (a) structure of pnp transistor (b) structure of npn transistor

Three terminals, one from each of the three semiconductor regions protrude from the transistor. When the transistor is operating, carriers (electrons or holes) are emitted from one of the semiconductor regions at the two ends while the other one collects the carriers. Therefore, the two terminals at the ends are known as the **emitter** and the **collector**. The terminal at the middle can control the carriers flowing from the emitter to the collector and it is known as the **base**.

In figures, the three first letters of the three words *E*, *C* and *B* are used to indicate the respective terminals. Structure of a transistor direction of carries and the direction of current are shown in the figure 11.25(a). The standard symbols used to represent transistors are given in the figure 11.25(b)



(a) Layout of semiconductors

(b) Standard symbols

Figure 11.25 - Layout of semiconductors and symbols of transistors

- An arrow head is used to identify the emitter (*E*).
- The arrow head indicates the direction of current flow from the emitter to the collector of the transistor.

For extra knowledge

- Carriers always flow from the emitter to the collector.
- Since the carriers of a p-type semiconductor are holes (corresponding to a + charge) the current flow in a pnp transistor is from the emitter to the collector (arrow head towards the interior).
- Since the carriers of an n-type semiconductor are electrons, the current flow in an npn transistor is from the collector to the emitter (arrow head towards the exterior).

When using a transistor in a circuit, appropriate voltages must be provided to the terminals. This is known as **biasing a transistor**. The emitter – base junction should be forward biased while the base collector junction should be reverse biased with a higher voltage.

For this a voltage should be supplied to the terminals *C* and *E* in the direction of current shown by the arrow head.

Accordingly, in a npn transistor, *C* should be connected to the positive (+) terminal and *E* should the connected to the negative (–) terminal because current always flow from positive to negative. In a pnp transistor *E* should be connected to the positive terminal while the *C* should be connected to the negative (–) terminal. *B* should be supplied a potential difference in the same direction as *C* but with a smaller magnitude. Then, the base (B) - collector (C) junction becomes reverse biased.

For extra knowledge

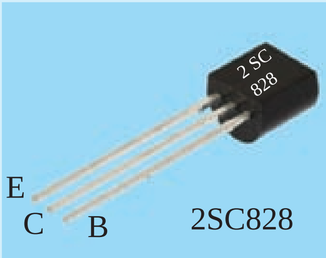
- In all the circuits we discuss in the ordinary level syllabus, we use only npn transistors.

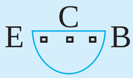
There are a large number of various types of transistors in the market and they are constructed with various different outward appearances. In order to identify these transistors they are coded with numbers.

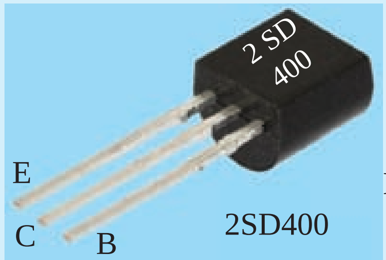
Example – 2SC828 (C828), 2SD400 (D400), 2SC1061 (C1061), 2SD313 (D313)

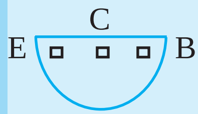
For extra knowledge

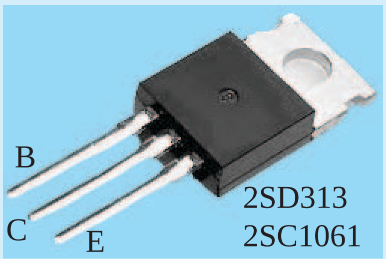
There is no common or standard method of identifing the terminals of a transistor by viewing it externally. Some transistors used in the experiments of the ordinary level syllabus are shown below.

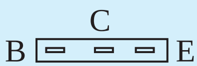












(All these are silicon npn transistors).

As given in data books, when we turn the terminals towards ourselves and view the transistor, the terminals can be identified as shown above (two dimensional figure).

11.5.1 Amplifying Process of a Transistor

- **Current Amplifier**

Basically a transistor is used as a current amplifier. When a small (DC) current is supplied as the input of a current amplifying transistor circuit, a large current can be obtained as the output of the amplifier.

Activity 11.3

Apparatus required : A 2SD400 (D400) transistor, Two 2.5 V torch bulbs, Two 3 V battery covers, six 1.5 V dry cells, Two switches (button switches are more suitable), A 10 kΩ volume controller, A circuit board

- Construct the circuit given in the figure on the circuit board.
- Attach a pair of dry cells to each of the battery covers before connecting them to the circuit. Terminals of the volume controller (variable resistance) and the transistor are indicated in the circuit.

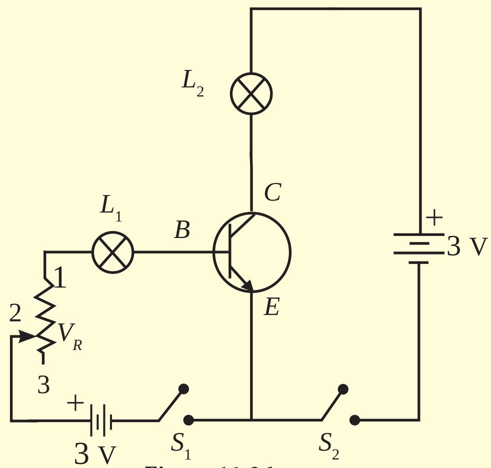


Figure 11.26

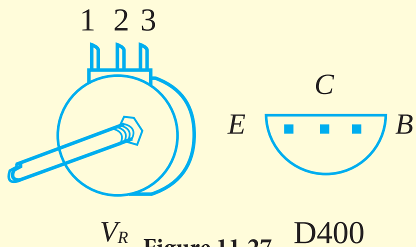


Figure 11.27

Switch S_1, the 3 V battery, the volume controller V_R, and the bulb L_1 are in the input circuit while the second 6 V battery, switch S_2, and the bulb L_2 are in the output circuit. The batteries should be correctly connected while the switches S_1 and S_2 are in the off positions.

- First turn S_1 on (close) and adjust the resistance of V_R until the bulb L_1 just begins to light up. Now turn off (open) switch S_1.
- Open and close the switches S_1 and S_2 as indicated in the table below and observe the brightness of the bulbs and fill in the table.

S_1	S_2	Bulb L_1		Bulb L_2	
		Lighting up	Brightness	Lighting up	Brightness
off	off	×	–	×	–
on	off	✓	less	×	–
off	on				
on	on				

(In order to clarify how to record your observations in the table, the first and second columns have been filled with the expected observations). You may assume that the current flow is small if the brightness of the bulbs are low and that the current flow is large if the brightness of the bulbs are high.

We can draw the following conclusions from the activity above.

- A current flows in the output circuit only when a current flows in the input circuit.
- Even when a voltage is given to the output circuit, a current does not flow in the output circuit unless there is a current flowing in the input circuit.
- When a small current flows in the input (when L_1 lights up with a low brightness) a large current flows in the output (L_2 lights up with a higher brightness). (The input current is known as the base current I_B and the output current is known as the collector current I_C).
- A small current I_B in the input can be amplified into a large current I_C in the output using a transistor. This is the process known as current amplification.

Signal Amplifier

The transistor is frequently used not only as a current amplifier but also as a signal amplifier. How a transistor can be used to amplify an audio frequency signal is illustrated in the activity 11.4.

Activity 11.4

Apparatus required : A 2SD400 transistor, A 22 kΩ carbon resistor, A 8Ω speaker, A 0.1 μF capacitor, A 3 V battery cover, Two 1.5 V dry cells, A circuit board and connecting wires, Audio frequency generator (found in the laboratory)

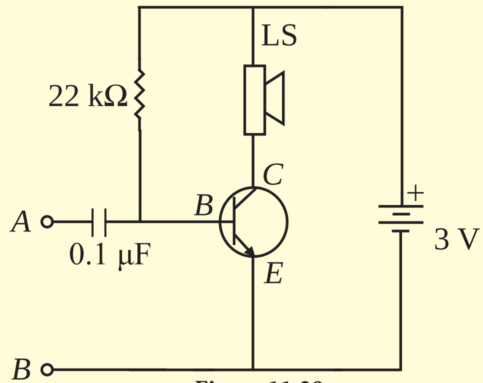


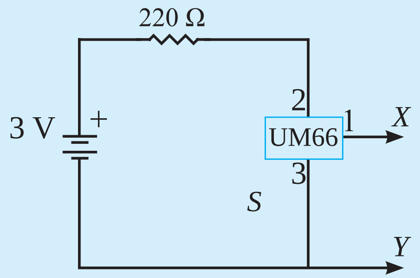
Figure 11.28

- Construct the circuit shown in the figure on the circuit board.
- First connect only the AF signal generator to the speaker and adjust the output so that a sound could be just heard.
- Connect a small signal from an audio frequency (AF) signal generator to the points *A* and *B*.
- Now you will hear an amplified output of the sound generated by the audio frequency generator.
- 0.1 μF capacitor has been connected to give only the alternating signal to the base. Base needs a forward biasing voltage of 0.7 V. This is supplied through the 22 kΩ resistor.

For extra knowledge

Apparatus required : A UM66 integrated circuit, 220 Ω carbon resistor, A 3 V battery cover, Two 1.5V dry cells, A circuit board and connecting wires

A circuit that can produce a "musical" audio frequency wave using an integrated circuit is shown below. This circuit can be constructed on the circuit board to produce a signal for the audio frequency amplifier above.



1 - signal
2 - positive supply
3 - negative supply

The signal can be given to the amplifier by connecting the X, Y terminals to the points A and B of the amplifier circuit.

11.5.2 Switching action of a transistor

Instead of a mechanical switch, the transistor can be used as an electronic switch that operates according to a certain sensation.

In electronics, when digital circuits are constructed, the transistor is often used as a switch.

Activity 11.5

Apparatus required : A 2SD313 transistor, A multimeter, A 2.5 V bulb, A 3 V battery cover, Two 1.5 dry cells, A 10 kΩ volume controller (V_R), A 10 kΩ resistor, A circuit board, A switch (S)

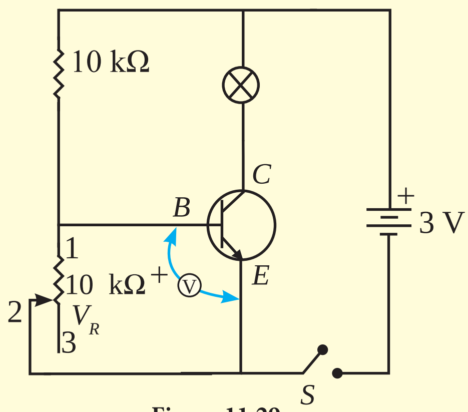


Figure 11.29

- Construct the above circuit on the circuit board. Rotate the volume controller to the extreme right so as to have the minimum resistance.
- Connect batteries while keeping switch *S* in the off position.
- Select the multimeter range 2.5 V (DC) and connect it between the base and emitter of the transistor. (Its positive probe must be connected to the base.)
- Now open switch S. Observe the voltmeter reading and the lighting up and brightness of the bulb.
- Turn the volume controller gradually to the left so as to increase the resistance while observing the voltmeter reading and the bulb.
- Observe that the bulb begins to light up when the voltmeter reading is about 0.7 V and the bulb has the maximum brightness when the voltage is about 0.8 V.

We can draw the following conclusions from the above activity.

- When the voltage difference between the emitter and the base is less than 0.7 V, there is no collector current Ic.
- When the voltage difference between the emitter and the base is about 0.7 V, the collector current begins to flow.
- When the voltage difference between the emitter and the base exceeds 0.7 V, (about 0.8 V), the collector current reaches a maximum.
- Therefore, when the voltage difference between *B-E* terminals is less than 0.7 V, the transistor acts as an open switch (off) and the voltage difference between the *B-E* terminals exceeds 0.7 V, it acts as a closed switch (on).

Let us engage in activity 11.6 to demonstrate how to design a switch circuit that automatically lights up when darkness falls using the above principle.

Here we will use a light dependent resistor (LDR) as the light sensor. When light is incident on its front surface, its resistance becomes very low (of the order of 1 Ω) while in the dark it has a very high resistance (of the order of 100 kΩ).

Activity 11.6

Apparatus required : A D400 transistor, An LDR, A 10 kΩ volume controller (V_R), A 2.5 V bulb, A 3 V battery cover, Circuit board and connecting wires

- Cover the top surface of the LDR (from light) with your finger tip and adjust the resistance of the V_R until the bulb lights up.
- Remove your finger tip and allow light to fall on the LDR.

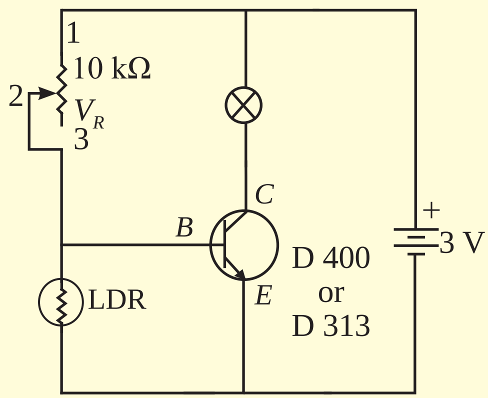
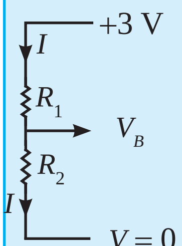


Figure 11.30

Then the light will go out (Adjust the V_R until the bulb lights up upon reducing the amount of incident light).

For extra knowledge

- In the activity 11.6, the V_R acts as a variable resistor and the LDR as a potential divider. (In the activity 11.5, 10 kΩ resistor and 10 kΩ variable resistor).
- The total potential drop across the two resistors is 3 V.



$V = IR$ from Ohm's law

$3 = I\,(R_1 + R_2)$

$\therefore\ I = \dfrac{3}{R_1 + R_2}$

If the potential at B is V_B, the potential difference across R_2 is V_B.

$V_B = R_2 I$

$V_B = R_2 \times \dfrac{3}{R_1 + R_2}$

- By keeping R_1 constant and varying R_2, any potential from 0 to 3 V can be given to that point.
- If $R = 10$ kΩ, the value of R_2 in order that $V = 0.7$ V:

$$0.7 = \frac{3 \times R_2}{10{,}000 + R_2}$$

$$7000 + 0.7\,R_2 = 3 \times R_2$$

$$7000 = 3 \times R_2 - 0.7\,R_2 = 2.3\,R_2$$

$$\therefore\ R_2 = \frac{7000}{2.3} = 3043\ \Omega$$

Therefore when R_2 is 3043 Ω, the potential at B becomes 0.7 V.

- When the resistance of the LDR increases upto 3043 Ω by decreasing the light incident on it, the bulb dimly lights up and when the light is further decreased, the potential increases upto 0.7 V and the current I_c increases to a maximum (Switch opens).

Summary

- The charge carriers that conduct electricity in metallic conductors are the negatively charged electrons.
- In semiconductors, both electrons and holes (corresponding to a positive charge) act as carriers that conduct electricity.
- Since a hole is formed in a semiconductor when a bond breaks releasing an electron, the number of free carrier electrons in the semiconductor is equal the number of holes in it.
- Therefore when a potential difference is applied across a semiconductor, holes move from the positive to the negative potential while the electrons move from the negative to the positive potential and the (standard) current flows from the positive to the negative potential.
- An n-type extrinsic semiconductor can be formed by doping an intrinsic semiconductor with a group V element.
- A p-type extrinsic semiconductor can be formed by doping an intrinsic semiconductor with a group III element.
- When an external potential difference is applied across a p-n junction so as to make the p region negative, the depletion region broadens and no current flows across the junction. This is known as "reverse bias".
- When an external potential difference is applied across a p-n junction so as to make the p region positive, the depletion region thins down if the external potential difference is sufficiently large to mate the potential barrier, then a current flows across the junction. This is known as "forward bias".
- Diodes can be used for the rectification of an alternating current.
- The potential barrier across a p-n junction for a Si junction is about 0.7 V and for a Ge junction about 0.3 V.
- Since charge carriers in a p-type semiconductor are holes (corresponding to a positive charge), in a pnp transistor, the current flows from the emitter to the collector (inward arrow head).
- Since charge carriers in a n-type semiconductor are electrons, in a npn transistor, the current flows from the collector to the emitter (outward arrow head).
- Always, carriers flow from the emitter to the collector.
- A transistor can be used as a simple current amplifier, signal (ac) amplifier and a switch.

Exercise 11.1

(1) (i) Explain briefly, how metals and semiconductors conduct electricity.
(ii) How does the increase of temperature affects the conduction of electricity?

(2) (i) A LED is not lighted up by one dry cell, but it is lighted when two dry cells are used. Explain why.
(ii) Give examples for three instances where we use LEDs in day to day life.
(iii) The use of LEDs which give white light, instead of filament bulls is increasing now. Give reasons for this.

(3) It has been stated in the activity, 11.6 that a transistor can be used as a switch to light a bull in the dark. A student plans to modify the above circuit to open the garage door automatically when the head lights of a car falls on it.

Design a circuit for building a small model of this system for the school exhibition. Draw the circuit and Name all the components. The student hopes to use a 3 V motor to open the door. And also, indicate to which place that this motor is connected.

(4) The following figure shows a circuit made to study about the rectifier bridge in a school exhibition. All the diodes need in the circuit are 1.8V LEDs.

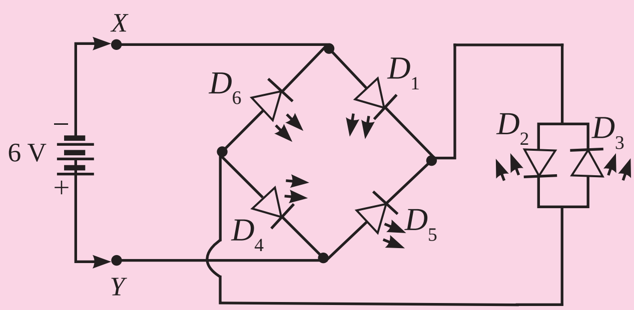


Figure 11.31

(i) Which LEDs are lighted – up, when a 6 V battery is connected to the terminal X and Y?
(ii) Mark the direction of current drawing arrows near the LEDs.
(iii) What will happen if the battery is connected to X and Y in the opposite direction?
(iv) What would happen if a 3 V battery is used to supply current instead of a 6 V battery? Give reasons for the above.

Technical terms

Semiconductors	- අර්ධ සන්නායක	- குறை கடத்திகள்
Intrinsic Semiconductors	- නිසග අර්ධ සන්නායක	- உள்ளீட்டு
Extrinsic Semiconductors	- බාහ්‍ය අර්ධ සන්නායක	- வெளியீட்டு
Charge carriers	- ආරෝපණ වාහක	- ஏற்றக்காவிகள்
Holes	- කුහර	- துளை
Doping	- මාත්‍රණය	- மாசூட்டல்
Donor atom	- දායක පරමාණුව	- தாளி அணு
Acceptor atom	- ප්‍රතිග්‍රාහක පරමාණුව	- ஏற்பான் அணு
Depletion layer	- හායිත පෙදෙස (හීන ස්ථරය)	- வறிதாக்கல் பகுதி
Rectifier diode	- ඍජුකාරක ඩයෝඩය	- சீராக்கும் இருவாயி
Bridge Rectifier	- ඍජුකාරක සේතුව	- பால சீராக்கம்
Light Emitting Diode	- ආලෝක විමෝචක ඩයෝඩය	- ஒளிகாலும் இருவாயி
Transistor	- ට්‍රාන්සිස්ටරය	- திரான்சிற்றர்
Collector	- සංග්‍රාහකය	- சேகரிப்பான்
Emitter	- විමෝචකය	- காவி
Base	- පාදම	- அடி
Current amplifier	- ධාරා වර්ධකය	- ஓட்ட விரியலாக்கி
Signal amplifier	- සංඥා වර්ධකය	- அறிகுறி விரியலாக்கி
Forward bias	- පෙර නැඹුරුව	- முன்முககோடல்
Reverse bias	- පසු නැඹුරුව	- பின்முக கோடல்

Electrochemistry

Chemistry 12

12.1 Electrochemical cells

In our everyday life, we frequently use equipment powered by domestic electricity as well as appliances operated by electrochemical cells or batteries. Toy cars, electric torches, calculators, computers and mobile phones are a few examples for equipment that are powered by electrochemical cells.


A toy car powered by batteries


An electric torch


A mobile phone


A calculator


A computer

Figure 12.1.1 - Equipment powered by electrochemical cells

The electrochemical cells or batteries used in the examples given above are small in size. A battery used to start a car is large in size. Such a battery is a collection of several electrochemical cells.

Figure 12.1.2 - Different types of cells and batteries

In your former grades you have learnt about electrochemical cells. In those cells, the chemical energy stored in the chemicals they contain is converted to electrical energy. In this section, we study further the reactions occurring in electrochemical cells and the action of those cells.

For this, let us do the activity 12.1.1 described below.

Activity 12.1.1

Materials required :- A small beaker, dilute sulphuric acid, a zinc metal sheet

Method :-

- Add dilute sulphuric acid to the small beaker. Place a strip of zinc metal sheet in the beaker so that a part of it dips in the sulphuric acid solution as shown in the figure 12.1.3 Record your observations.

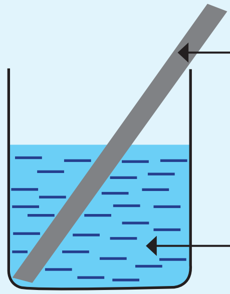


Figure 12.1.3

Here, it can be observed that, gas bubbles are liberated near the zinc strip and the zinc strip dissolves gradually. Let us find the reasons for those observations.

Zinc atoms (Zn) go into the solution as zinc ions (Zn^{2+}) leaving electrons on the metal. Electrons get accumulated on the zinc strip. This process can be shown as follows using chemical symbols.

$$Zn\,(s) \longrightarrow Zn^{2+}(aq) + 2e \;\ldots\ldots \; (1)$$

Sulphuric acid dissociates into hydrogen ions (H^+) and sulphate ions (SO_4^{2-}) in water. This can be illustrated as follows.

$$H_2SO_4\,(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

The H^+ ions in the solution are attracted towards the zinc strip to capture the electrons on it. Hydrogen ions, after receiving the electrons become hydrogen gas (H_2). Using chemical symbols, this can be written as follows.

$$2H^+(aq) + 2e \longrightarrow H_2\,(g) \ldots\ldots \; (2)$$

The reactions written as (1) and (2) above, depicting the conversion of one chemical species into another, either by removing or accepting electrons, are called 'half reactions'. By adding two half reactions appropriately, the balanced ionic equation can be obtained.

$$Zn(s) \longrightarrow Zn^{2+}\,(aq) + 2e \quad — (1)$$
$$2H^+(aq) + 2e \longrightarrow H_2(g) \quad — (2)$$

$$(1) + (2) \qquad Zn(s) + 2H^+\,(aq) + \cancel{2e} \longrightarrow Zn^{2+}(aq) + \cancel{2e} + H_2\,(g)$$

$$Zn(s) + 2H^{+} (aq) \longrightarrow Zn^{2+} (aq) + H_2 (g)$$

Next, let us consider how this reaction can be represented by a balanced chemical equation. The hydrogen ions (H^+) were added to the solution by the dissociation of sulphuric acid (H_2SO_4). When sulphuric acid dissociates sulphate ions (SO_4^{2-}) are also added to the medium in addition to H^+ ions. But sulphate ions do not undergo any change during the reaction. So, we add SO^{2-}_4 to both sides.

$$Zn(s) + \underbrace{2H^{+}(aq) + SO_4^{2-} (aq)}_{H_2SO_4} \longrightarrow \underbrace{Zn^{2+}(aq) + SO_4^{2-} (aq)}_{ZnSO4} + H_2 (g)$$

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

Given above is the complete reaction for which zinc metal reacts with dilute sulphuric acid. If the exchange of electrons taking place between the zinc metal and H^+ ions during the above process occurs through an external conductor, we can produce an electric current.

Let us do the following activity to see whether this can be done.

Activity 12.1.2

Materials required :- A beaker, zinc and copper strips, dilute sulphuric acid, connecting wire, Ammeter.

Method :- • Connect the zinc strip and the copper strip to the Ammeter using connecting wires as shown in the Figure 12.1.4. Then immerse the two metal strips in the beaker containing dilute sulphuric acid. Record your observations.

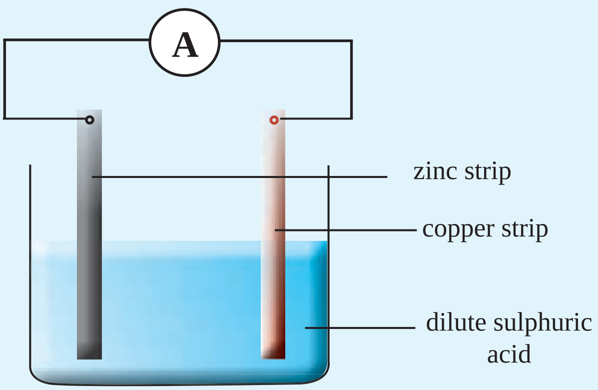


Figure 12.1.4

In this, it can be observed that the Ammeter pointer is deflected, zinc strip is dissolved and gas bubbles are evolved at the copper strip.

Let us explore the reasons for these observations.

Here too, zinc atoms become zinc ions (Zn^{2+}) leaving electrons on the metal. Therefore, the zinc strip dissolves.

The electrons accumulated on the zinc strip, flow towards the copper strip through an external wire. This flow of electrons is considered an electric current. Deflection of the Ammeter shows that an electric current flows through the circuit. Hence in this set up, H^+ ions in the solution move toward the copper strip and receive electrons from it. Therefore, hydrogen gas bubbles are liberated at the copper strip.

Reaction at the zinc strip

$$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e \ldots\ldots \textcircled{1}$$

Reaction at the copper strip

$$2H^+(aq) + 2e \longrightarrow H_2(g) \ldots\ldots \textcircled{2}$$

In the above reaction it was confirmed that an electron current flows from zinc to copper in the external wire. A current of electrons means an electric current. In this, a chemical reaction has generated an electric current. A set up of this kind used to generate electricity by a chemical reaction is known as an electrochemical cell. The conducting substances dipped in the electrolyte here are called electrodes.

In the above cell, zinc strip and copper strip act as electrodes. The balanced ionic equation obtained by adding the half reactions (1) and (2) above is the electrochemical reaction taking place in the cell.

$$\textcircled{1} + \textcircled{2} \qquad Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$$

Let us further consider the reaction occurring at the zinc electrode in the above cell.

$$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e \ldots\ldots \textcircled{1}$$

Loss of electrons from a given species (atoms, molecules or ions) is referred to as oxidation. Therefore, what is happening at the zinc strip is **oxidation**. If oxidation occurs at a certain electrode, that electrode is defined as the **anode**. Accordingly, the zinc strip is the anode of the above cell. Equation (1) represents the **oxidation half reaction** taking place at the anode. Since zinc atoms dissolve into the solution leaving electrons on the zinc plate, the zinc plate gets negatively charged relative to the copper plate. Therefore, zinc electrode is the **negative terminal** of the cell.

Next let us consider the reaction occurring at the copper strip.

$$2H^+(aq) + 2e \longrightarrow H_2(g) \ldots\ldots \textcircled{2}$$

The hydrogen ions (H^+) gaining electrons turn into hydrogen gas molecules (H_2). Gaining electrons by a given species (atoms, molecules, ions) is described as a **reduction**. Since gaining of electrons or a reduction occurs at the copper electrode, reaction (2) is the **reduction half reaction.**

If reduction occurs at a certain electrode, it is defined as the **cathode**. Therefore, copper strip is the cathode of the cell. Since electrons flow to the copper strip, it is positively charged relative to the zinc strip. Therefore, copper electrode is the positive terminal of the cell.

The electrochemical reaction of the cell can be obtained by adding the reactions (1) and (2).

At the zinc electrode/negative terminal:

$$Zn\,(s) \longrightarrow Zn^{2+}(aq) + 2e \quad \text{— (1) Anodic reaction}$$

At the copper electrode/positive terminal:

$$2\,H^{+}(aq) + 2e \longrightarrow H_2(g) \quad \text{— (2) Cathodic reaction}$$

(1) + (2)

$$Zn(s) + 2H^{+}(aq) \longrightarrow Zn^{2+}(aq) + H_2\,(g) \quad \text{Overall cell reaction}$$

The following comparisons would be important for you to identify the anode and cathode of a given electrochemical cell.

- The metal placed higher in the activity series acts as the anode and the metal placed lower in the activity series acts as the cathode.
- Oxidation occurs at the anode and reduction occurs at the cathode.
- Anode becomes the negative terminal of the cell while cathode becomes the positive terminal of the cell.

Note

In a cell, electrons flow from the negative terminal to the positive terminal. But, according to the conventions in physics, the conventional current is marked as flowing from the positive terminal to the negative terminal.

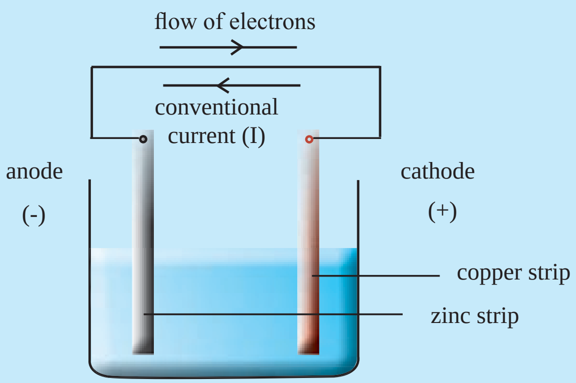


Figure 12.1.5

Next, let us consider a cell constructed using iron and copper electrodes.

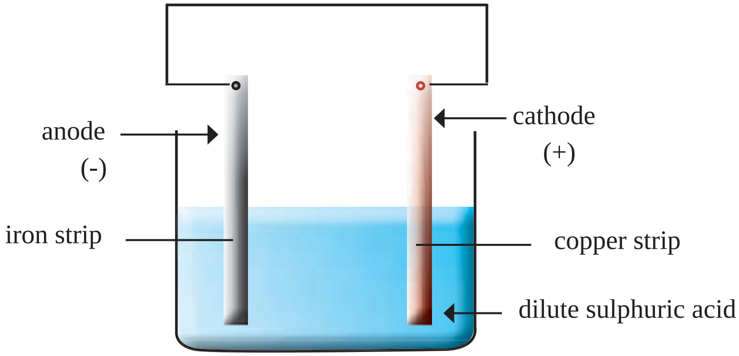


Figure 12.1.6

In the activity series, iron lies above copper. Therefore, what is subjected to **oxidation** and acts as the **anode** is the more reactive metal, iron.

$$Fe\,(s) \longrightarrow Fe^{2+}(aq) + 2e \;\ldots\ldots \; (4)$$

Since iron atoms dissolve into the solution leaving electrons on the iron strip, it is negatively charged relative to copper. Thus, iron electrode is the **negative terminal** of the cell.

In this cell also, the following reduction half reaction occurs at the less reactive copper metal. Therefore, copper electrode acts as the cathode of this cell.

$$2H^{+}\,(aq) + 2e \longrightarrow H_2\,(g) \;\ldots\ldots \; (5)$$

Electrons flow to the copper electrode across the external wire. Therefore, copper electrode is the **positive terminal** of the cell.

The overall ionic reaction of the cell can be obtained by adding the two half reactions (4) and (5) .

$$Fe\,(s) + 2H^{+}(aq) \longrightarrow Fe^{2+}(aq) + H_2\,(g)$$

When a current is drawn from this cell it can be observed that the iron electrode dissolves and gas bubbles evolve at the copper electrode.

Consider the following cell constructed using zinc and iron electrodes.

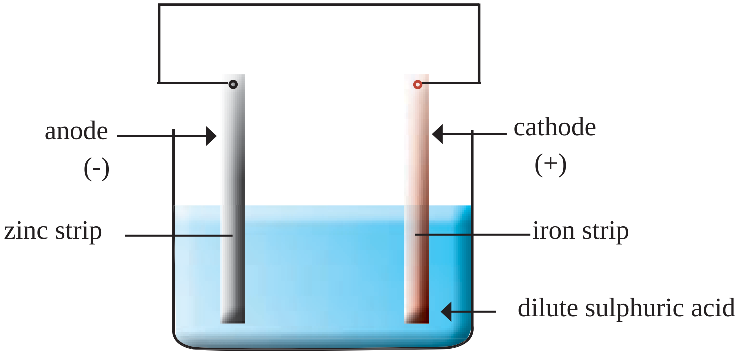


Figure 12.1.7

In the activity series, zinc metal is placed above iron. Therefore, zinc which is the more reactive metal, undergoes oxidation and acts as the anode.

Reaction at the zinc electrode/anode

$$Zn\,(s) \longrightarrow Zn^{2+}(aq) + 2e \quad \ldots\ldots \textcircled{6}$$

Here too, as the zinc atoms dissolve into the solution leaving electrons on the zinc electrode, zinc becomes negatively charged relative to iron. For this reason, zinc electrode becomes the **negative terminal** of the cell.

Reaction at the iron electrode/cathode

$$2H^+(aq) + 2e \longrightarrow H_2(g) \quad \ldots\ldots \textcircled{7}$$

Because reduction occurs at iron, it acts as the **cathode**.

Electrons flow towards the iron electrode along the connecting wire. Hence iron electrode is the **positive terminal** of the cell.

The overall ionic reaction of the cell can be obtained by adding the reactions (6) and (7).

$$Zn\,(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$$

When this cell operates, we will be able to see that the zinc electrode dissolves and gas bubbles evolve at the iron electrode.

12.2 Electrolysis

You would have seen the goldsmiths burnishing gold/silver jewellery near the jewellery shops in town.

If you have not seen such a person, make it a point to observe well the equipment he has, when you meet such a person next time. You may be able to see a battery supplying electricity, wires connected to it and a vessel filled with a certain solution. He uses a narrow gold foil as one electrode and the piece of jewellery that needs to be polished as the other electrode. What he does with these equipment is the application of gold on the piece of jewellery.

Using the above process, he deposits gold on various jewellery. He lets an electric current to pass through the solution.

The chemical changes brought about by passing electricity through a solution/liquid which conduct electricity are called electrolytic processes. This chapter discusses about electrolysis. For this, let us first do the following activity to find out about the liquids/solutions which conduct electricity.

Activity 12.2.1

Materials required :-

Carbon electrodes, two torch cells (1.5v), connecting wires, a ammeter, beakers, coconut oil, kerosene, distilled water, acidified water, salt solution, ethanol

Method :-

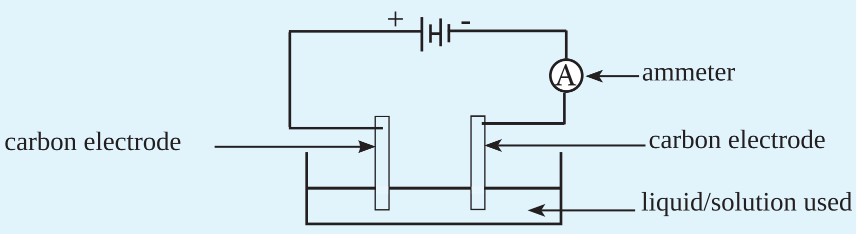


Figure 12.2.1

- Dip the carbon electrodes in the above liquids/solutions and see whether there is a deflection in the Ammeter.
- Record your observations.

A deflection in the ammeter could be observed only when acidified water and the salt solution are used in the above set up. That means, those solutions conduct electricity.

- The liquids/solutions conducting electricity are referred to as electrolytes. Some examples for electrolytes are given below.

» Aqueous solutions of ionic compounds
e.g. aqueous sodium chloride, aqueous copper sulphate

» Molten (fused) liquids of ionic compounds
e.g. fused sodium chloride

» Solutions of acids
e.g. aqueous hydrochloric acid, aqueous sulphuric acid

» Solutions of bases
e.g. aqueous sodium hydroxide

- The liquids/solutions that are not conducting electricity are non-electrolytes. Some examples for non-electrolytes are:
  - » Pure water (distilled water)
  - » Organic liquids
    e.g. petrol, kerosene, paraffin, hexane

For your memory file

The solid ionic crystals formed by the oppositely charged ions do not contain mobile ions. Therefore they cannot conduct electricity. But, when they are dissolved in water or fused (heated till the solid melts) its ions become mobile. For this reason, aqueous solutions or molten liquids of ionic compounds conduct electricity. The hydrocarbons such as petrol, kerosene and paraffin are compounds with covalent bonds, so they do not conduct electricity. Pure water is also covalent and there are almost no ions. Therefore, pure water does not conduct electricity. In aqueous solution, the covalent bonds in acids such as hydroiodic acid (HI), hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) break to form ions. Therefore the solutions of acids such as these conduct electricity.

$$HCl \xrightarrow{\text{water}} H^+(aq) + Cl^-(aq)$$

$$H_2SO_4 \xrightarrow{\text{water}} 2H^+(aq) + SO_4^{2-}(aq)$$

An apparatus set up to conduct electricity through an electrolyte is shown in the following figure. A set up such as this is called an electrolytic cell. An electrolytic cell comprises of a source of electricity, an electrolyte, two electrodes and connecting wires.

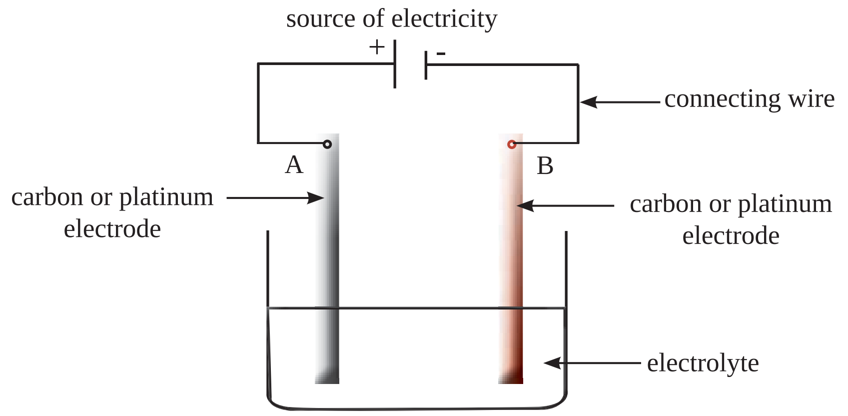


Figure 12.2.2 - An electrolytic cell.

Let us consider the supply of electricity to an electrolytic cell containing an aqueous solution of sodium chloride as the electrolyte. Liberation of gas bubbles can be seen at the carbon electrodes. This indicates that a chemical change has taken place in the aqueous solution.

Bringing about a generally non-spontaneous chemical reaction such as the one given above by supplying electricity is known as electrolysis.

- ## Conventions adopted in electrolysis

(1) The electrode connected to the positive terminal of the external electrical supply (battery) is the positive electrode whereas the electrode connected to the negative terminal is the negative electrode.

(2) The positive ions in the solution/liquid migrate towards the negative electrode while the negative ions are attracted by the positive electrode.

(3) The positive ions moving towards the negative electrode receive electrons and undergo reduction. If there are several positive ions in the solution, generally, the cations (positive ions) formed by the elements further down in the activity series has a higher tendency to undergo reduction.

For example, if there are Na^+ and H^+ ions in the solution, the H^+ ions formed by hydrogen which is below sodium in the activity series receive electrons and get reduced.

If there are Cu^{2+} and H^+ ions in the solution electrons are gained by the Cu^{2+} ions formed by copper which is placed below hydrogen in the activity series.

(4) Since a **reduction half reaction** occurs at the negative electrode, negative electrode is the **cathode**.

(5) The anions (negative ions) in the solution move towards the positive electrode and lose electrons. That means, they undergo oxidation.

For example, the Cl^- ions in the solution become Cl_2 molecules releasing electrons.

$$2Cl^- (aq) \longrightarrow Cl_2 (g) + 2e$$

(When there are several negative ions in the solution, which ion oxidizes first is decided by several factors. Since these facts are beyond the scope of your subject they are not discussed here).

(6) **Oxidation** occurs at the positive electrode, so positive electrode is the **anode**.

(7) If a metal (except platinum) is used as the anode, metal atoms get oxidized losing electrons instead of the oxidation of negative ions.

For example, if the anode is a silver rod, the oxidation reaction $Ag (s) \longrightarrow Ag^+ (aq) + e$ takes place at the positive electrode.

Based on the above conventions, let us predict the reactions taking place during the following electrolysis reactions.

- Electrolysis of fused sodium chloride using carbon electrodes

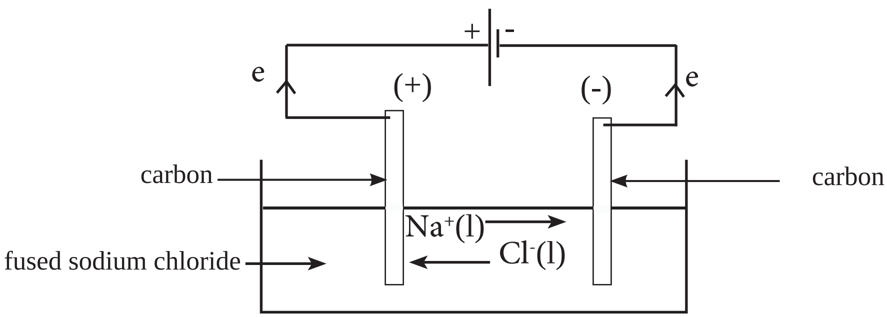


Figure 12.2.3

- **Reaction occurring at the negative electrode**

The only positive ions present in the fused (molten) liquid, Na^+ ions, are attracted by the negative electrode. At this electrode Na^+ ions receive electrons and become sodium atoms (Na).

$$Na^+ (l) + e \longrightarrow Na (l) \quad \text{...........} (1)$$

Since Na^+ ions are reduced by gaining electrons, this is the cathodic reaction. Accordingly, the negative electrode is the cathode.

- **Reaction occurring at the positive electrode**

Chloride ions (Cl^-), the only negative ions present in the liquid, migrate towards the positive electrode. At this electrode, Cl^- ions get converted to chlorine molecules (Cl_2) by removing electrons.

$$2Cl^-(l) \longrightarrow Cl_2(g) + 2e \quad \ldots\ldots\ldots\ldots (2)$$

Since chloride ions are oxidized by losing electrons, this is the anodic reaction. Hence, positive electrode is the anode.

The overall electrolytic reaction can be obtained by adding the half reactions (1) and (2) appropriately.

$$(1) \times 2, \qquad 2Na^+(l) + 2e \longrightarrow 2Na(l) \quad \ldots\ldots\ldots\ldots (3)$$

$$(2) + (3) \qquad \cancel{2e} + 2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(l) + Cl_2(g) + \cancel{2e}$$

$$2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(l) + Cl_2(g)$$

The electrolytic reaction discussed above is the reaction happening in the Downs cell to extract sodium metal industrially. This method, you will study later in more detail. Later you will study this method in more detail.

- Electrolysis of aqueous solutions

Now let us engage in the following activities to study the changes taking place during the electrolysis of aqueous solutions.

- Electrolysis of aqueous sodium chloride

Activity 12.2.2

Materials required :- A solution of sodium chloride, carbon rods, conducting wires, a 9 V battery

Method :- ● Connect the two carbon rods to the terminals of the battery using wires. Then immerse those two electrodes in the aqueous sodium chloride solution and observe. Record the observations.

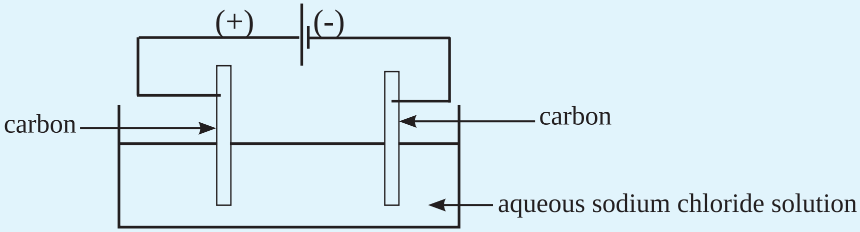


Figure 12.2.4

Liberation of gas bubbles can be observed at the electrodes. In order to explain these observations, let us understand the reactions occurring in the above experiment.

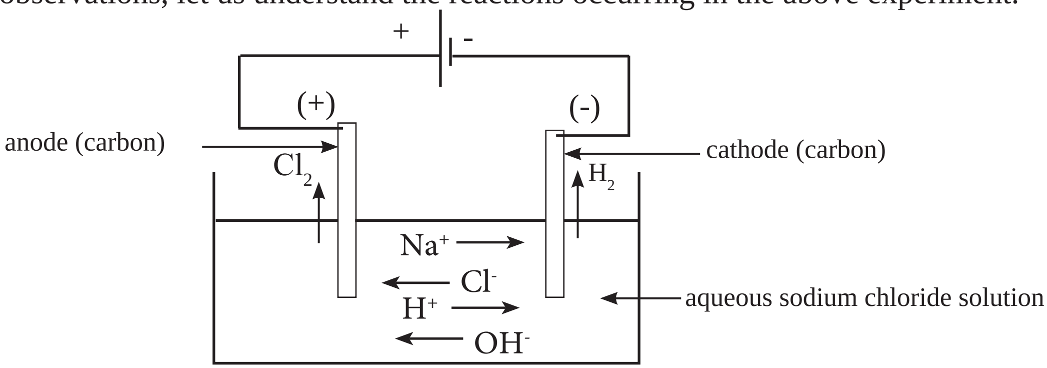


Figure 12.2.5

The solution mainly contains Na^+ and Cl^- ions. In addition to these, there is a small amount of H^+ and OH^- ions formed by the poor ionization of water molecules.

For your memory file

Water is a molecule with covalent bonds. But even in pure water it has been found that a very small amount of water molecules dissociate into H^+ and OH^- ions. In pure water, H^+ and OH^- concentrations at 25 ^{0}C are 1.0 x 10^{-7} mol dm^{-3}.

- **Reaction at the negative electrode (cathodic reaction)**

Na^+ and H^+ ions in the solution migrate towards the negative electrode.
As hydrogen is below sodium in the activity series, it is the H^+ ions that are reduced here.

$$2H^+ (aq) + 2e \longrightarrow H_2 (g) \quad ....\text{(1)}$$

As this is a reduction occurring with the gain of electrons, the negative electrode is the cathode.
Therefore reaction (1) is the cathodic reaction. Hence gas bubbles of hydrogen (H_2) are evolved at the negative terminal.

- **Reaction at the positive electrode (anodic reaction)**

The positive terminal attract Cl^- and OH^- ions in the solution. Of them, Cl^- ions have a greater tendency to oxidize.

$$2Cl^- (aq) \longrightarrow Cl_2 (g) + 2e \quad ....\text{(2)}$$

As this is an oxidation (because it involves loss of electrons) reaction (2) is the anodic reaction.
Hence chlorine gas bubbles (Cl_2) evolve at the positive electrode.
The overall electrolytic reaction can be obtained from the reactions (1) and (2)

(1) + (2) $\quad \cancel{2e} + 2H^+ (aq) + 2Cl^- (aq) \longrightarrow H_2 (g) + Cl_2 (g) + \cancel{2e}$

$$2 H^+ (aq) + 2Cl^- (aq) \longrightarrow H_2 (g) + Cl_2 (g)$$

Initially the ions Na^+, H^+, Cl^- and OH^- were present in the solution. Of these, the ions H^+ and Cl^- are removed by the conversion into H_2 and Cl_2 molecules. Hence Na^+ and OH^- ions are left in the solution. Because of this you may understand that this reaction can be used to produce sodium hydroxide (NaOH).

- Electrolysis of an aqueous copper sulphate solution

Activity 12.2.3

Materials required :- An aqueous solution of copper sulphate, carbon rods, connecting wires, a 9V battery

Method :- • Connect the electrodes to the battery as follows. Then, dip the two electrodes in the copper sulphate solution and observe. Record your observations.

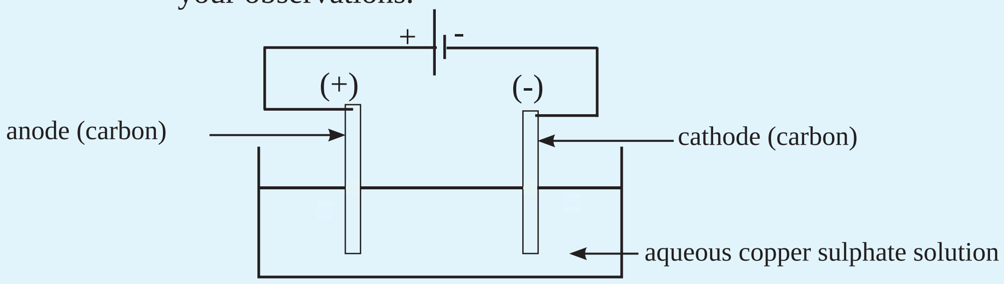


Figure 12.2.6

In this activity, it can be observed that gas bubbles evolve at the positive terminal (anode) and copper gets deposited on the negative terminal (cathode). The blue colour of the solution gradually diminishes.

In order to understand these observations, let us consider the reactions involved in here.

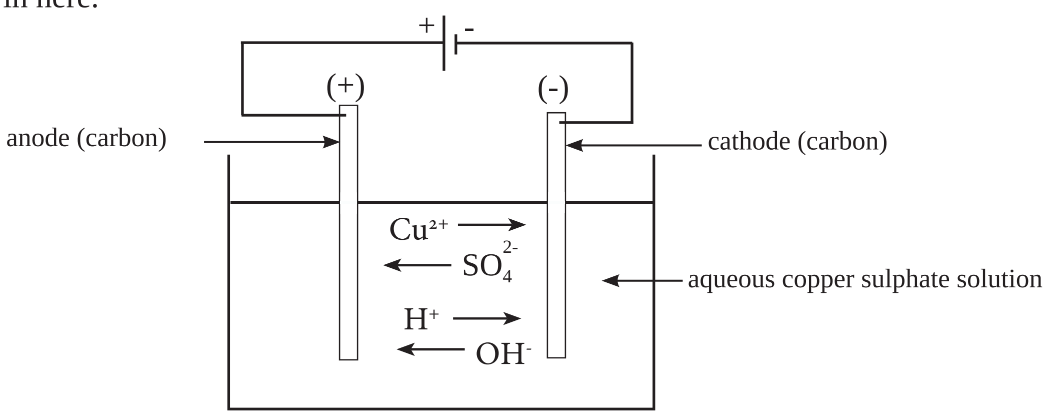


Figure 12.2.7

The solution mainly contains Cu^{2+} and SO_4^{2-} ions formed by the ionization of copper sulphate. In addition to these, a very small amount of H^+ and OH^- ions formed by the slight ionization of water molecules are also present.

- **Reaction at the negative electrode**

(cathodic reaction)

Both Cu^{2+} and H^+ ions migrate towards the negative electrode. As copper lies below hydrogen in the activity series, Cu^{2+} ions have a greater tendency to get reduced.

$$Cu^{2+}(aq) + 2e \longrightarrow Cu(s) \quad \cdots\cdots\cdots \text{①}$$

Hence, copper is deposited on the cathode. As this is a reduction, reaction ① is the cathodic reaction. Thus, negative electrode is the cathode. As Cu^{2+} ions responsible for the blue colour of the solution are removed from the solution, the intensity of the blue colour of the solution decreases.

- **Reaction at the positive electrode**

(anodic reaction)

SO_4^{2-} and OH^- ions in the solution are attracted towards the positive electrode. Of these, OH^- ions have a greater tendency to be oxidized.

$$4\,OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4\,e \quad \cdots\cdots\cdots \text{②}$$

Therefore, oxygen gas bubbles evolve at the anode.

Reaction ② is an oxidation, so it is the anodic reaction. Hence, positive electrode is the anode.

For your memory file

- Since the amount of H^+ ions in water is negligible, sometimes the reaction

  $2H_2O(l) + 2e \longrightarrow 2OH^-(aq) + H_2(g)$

  is considered the more fitting cathodic reaction than

  $2H^+(aq) + 2e \longrightarrow H_2(g)$
- Similarly the anodic reaction $2H_2O(l) \longrightarrow O_2(g) + 4H^+(aq) + 4e$ is more appropriately used in place of $4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e$

• Electrolysis of acidulated water

Now let us pay attention to the electrolysis of acidulated water using carbon electrodes.

Activity 12.2.4

Materials required :- Distilled water to which a little dilute sulphuric acid is added, carbon rods, a 9 V battery, connecting wires, a plastic cup

Method :-
- Pierce the bottom of the plastic cup and fix the carbon rods as shown in the figure. Seal any spaces around the rods with a substance such as molten wax or PVC so that water does not leak (silicone sealer may also be used). Add acidulated water to the cup. Introduce the two carbon rods into two inverted test tubes filled with water as shown in the figure 12.2. Supply electricity to the two carbon electrodes
- Record you observations.

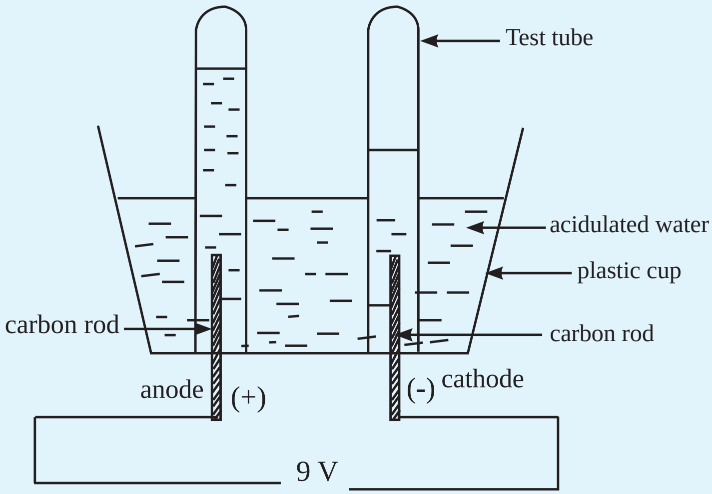


Figure 12.2.8

Here, we will be able to see gases collecting in the test tubes. Also, we can observe that the volume of gas liberated by the cathode is greater than that liberated by the anode. Let us investigate into the reactions taking place in this set up.

Acidulated water contains H^+ and SO_4^{2-} ions provided by the ionization of dilute sulphuric acid and H^+ and OH^- given by the dissociation of water.

- **Reaction at the negative electrode**

(cathodic reaction)

Which ions in the solution migrate towards the negative electrode? The positively charged H^+ ions in the solution migrate towards the negative electrode and get reduced receiving electrons.

$$2\,H^+(aq) + 2e \longrightarrow H_2\,(g) \;\ldots\ldots\ldots\; (1)$$

As this is a reduction, this is the cathodic reaction.

Hence hydrogen is liberated at the cathode.

- **Reaction at the positive electrode**

(anodic reaction)

The positive terminal attracts SO_4^{2-} and OH^- ions in the solution. Of these, the OH^- ions tend to undergo oxidation preferentially.

$$4OH^-(aq) \longrightarrow O_2\,(g) + 2H_2O\,(g) + 4e \;\ldots\ldots\ldots\; (2)$$

Because this is an oxidation, reaction (2) is the anodic reaction. Thus positive electrode is the anode.

Oxygen gas bubbles are liberated at the anode.

Electrolysis of water, on the whole can be represented by the following equation.

$$2H_2O\,(l) \longrightarrow 2H_2\,(g) + O_2\,(g)$$

Industrial applications of electrolysis

Electrolysis process is frequently used in the manufacturing of various industrial products. Some examples are given below.

(1) Extraction of metals

Example :- (i) Extracting sodium metal by electrolysing fused sodium chloride

(ii) Extracting aluminium metal from bauxite

(2) Metal refining

Example :- When copper is produced from the copper ores, the copper obtained first is impure. It is purified by an electrolytic process.

(3) Electroplating (coating an object with a metal)

Example :- (i) Applying gold on silver jewellery

(ii) Applying nickel or chromium on steel

(4) Industrial production of sodium hydroxide (Diaphragm cell method)

• Industrial production of sodium metal

We have already studied the electrode reactions occurring when fused sodium chloride is electrolyzed using carbon electrodes. The following reaction occurs at the cathode, in this process.

$$Na^+ (l) + e \longrightarrow Na (l) \quad .... (1)$$

The reaction occurring at the anode is as follows.

$$2Cl^- (l) \longrightarrow Cl_2 (g) + 2e \quad .... (2)$$

The overall reaction is:

(1) × 2 + (2) ;

$$2Na^+ (l) + 2Cl^- (l) \longrightarrow 2Na (s) + Cl_2 (g)$$

The above reaction is used to produce sodium metal industrially on large scale. For this a special type of electrolytic cell illustrated below is used. This is named the Downs cell.

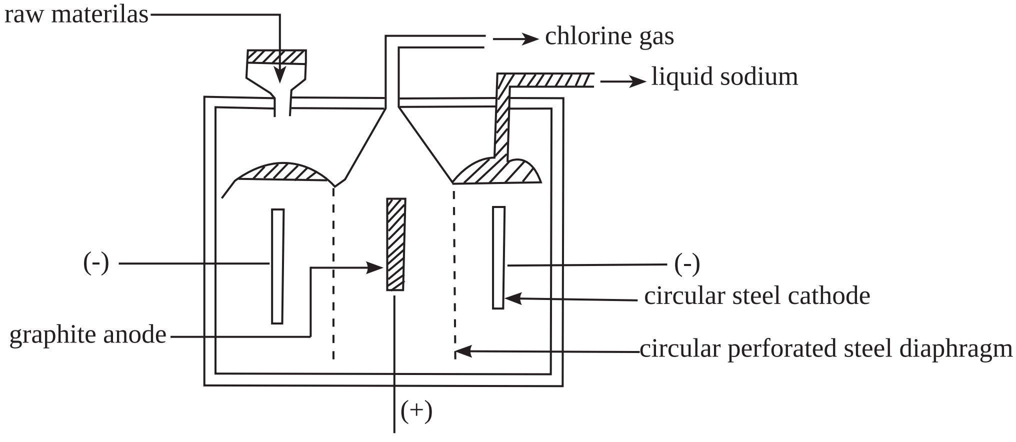


Figure 12.2.9 Downs cell

Fused sodium chloride is used as the raw material. The melting temperature of solid sodium chloride is as high as 840 ^{0}C. By adding about 40% calcium chloride to sodium chloride, the meling temperature of the mixture is decreased to about 600 ^{0}C.

What will happen is chlorine gas produced at the anode comes into contact with the sodium discharged at the cathode. Sodium and chlorine would react giving sodium chloride again. To prevent this, the anode and cathode are separated by a steel mesh diaphragm. It prevents the reaction between sodium and chlorine to form sodium chloride.

In this production process, chlorine gas is obtained as a by - product. Chlorine gas can also be used as a raw material for various products.

Uses of sodium

- Used in sodium vapour lamps which emit a yellow light.
- Used as a coolant in nuclear reactors in power houses producing nuclear energy
- It is a requirement for laboratory experiments

Uses of chlorine

- Chlorine is bubbled through water to destroy bacteria in potable water.
- Used to bleach (decolourise) paper, pulp, and cloth
- Production of hydrochloric acid by reacting with hydrogen
- Used to produce plastics such as PVC

• Electroplating

At the beginning of this lesson, it was stated that electroplating is used to coat jewellery with gold. In addition to that, think about the ornamental objects used to decorate houses. In many items such as vases, trays and door locks that shine with golden or silvery colour, the metallic lustre is given by a metal coating deposited on them.

Applying a thin metallic layer on a given surface using electrolysis is referred to as electroplating.

Generally the coating is a less reactive metal such as tin, copper, silver or chromium. The metal that is plated needs to have a certain special property which is absent for the surface that is plated. Resistance for rusting, attractive colour, chemical inertness and lustrous nature are some of such properties.

When electroplating objects, it is important to know the following.

- The object to be plated should be used as the cathode.
- A solution of a salt of the metal that is used for plating should be used as the electrolyte.
- The anode should be a plate/ rod made of the metal that is plated.
- In order to have a plating of high quality, the concentration of the electrolyte should be low. Then, the rate of the reaction decreases, so the plating is effected better.

Suppose you need to coat an iron spoon with copper. What do you use as the anode and cathode of the electrolytic cell which you construct for this? What is the electrolyte you employ?

The object to be plated, that is the iron spoon has to be used as the cathode. A copper rod can be used as the anode. A solution of copper sulphate can be used as the electrolyte.

Activity 12.2.5

Materials required :- An iron spoon, a copper plate, connecting wires, an aqueous solution of copper sulphate, a 9 V battery

Method :-
- Connect the iron spoon and the copper plate to the cell by connecting wires and immerse them at once in the copper sulphate solution.
- Record the observations.

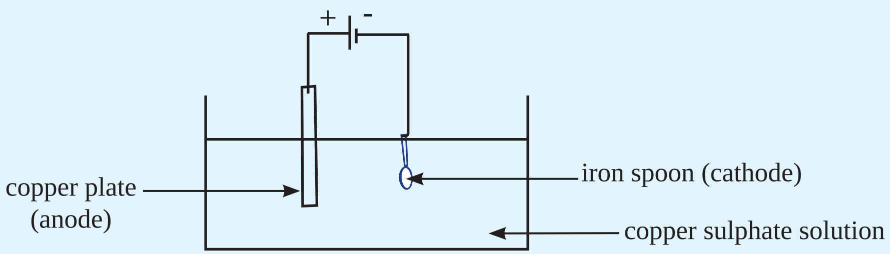


Figure 12.2.10

- **Anodic (positive electrode) reaction**

SO_4^{2-} and OH^- ions in the solution migrate towards the anode. Of them OH^- ions preferentially tend to undergo oxidation. Therefore, it can be anticipated that the reaction $4\,OH^-(aq) \longrightarrow 2H_2O\,(l) + O_2\,(g) + 4e$ occurs at the anode. However, it does not occur at the anode. As the anode is a metal, oxidation of metal atoms into metal ions is more feasible. Hence, the anodic reaction is

$$Cu\,(s) \longrightarrow Cu^{2+}(aq) + 2e$$

That means, the anode dissolves gradually.

- **Cathodic (negative electrode) reaction**

The solution contains Cu^{2+} ions and a little amount of H^+ ions produced by the dissociation of water. Of these, Cu^{2+} ion which is less in reactivity shows a greater tendency to be reduced. Therefore, the cathodic reaction is the following.

$$Cu^{2+}(aq) + 2e \longrightarrow Cu\,(s)$$

As a result, the cathode (iron spoon) gets coated with copper.

12.3 Corrosion of metals

Think about various metal objects that are used at home. With time, most of them are subjected to changes such as tarnishing, surface turning ditted and colour change. Subjecting metals to changes such as these when exposed to air is known as **corrosion** of metals.

Try to remind an instance where you relocated a lost item such as a knife or a mammoty blade after a long time in the garden. You would have observed that they are discoloured and decayed. Such objects are made of iron or steel. Corrosion of iron or steel exposed to air is specifically known as **rusting**.

12.3.1 Rusting of iron

Iron is the metal mostly used by humans. Therefore, it is the metal produced in the largest quantity. Iron manufactured is largley used to produce steel. Iron and steel are used to make vehicles, ships, bridges, machinery and many other products. Hence, rusting of iron is an economically disadvantageous process.

What kind of a process occurs when iron rusts ?

Why do the equipment made up of iron rust more easily outdoors rather than when they are indoors? Do the following activity to investigate into this

• Finding out whether air is essential for rusting

Activity 12.3.1

Materials required :- Two boiling tubes, ordinary cold water, coconut oil, two iron nails, burner, dilute hydrochloric acid

Method :-

- The iron nails available in the market has a zinc coating on them. To remove this, keep the two nails immersed in dilute hydrochloric acid for about 10 minutes and then wash with water. (Always use this procedure for experiment used the iron nail)
- Add cold water about half the height of the two boiling tubes.
- Boil the water in one of the boiling tube for about five minutes. Immerse the cleaned nails one each in the two boiling tubes. Add a little amount of coconut oil to the boiling tube with hot water to prevent the entry of atmospheric air. Allow the boiling tubes to stand for about two days and observe. Note down the observations.

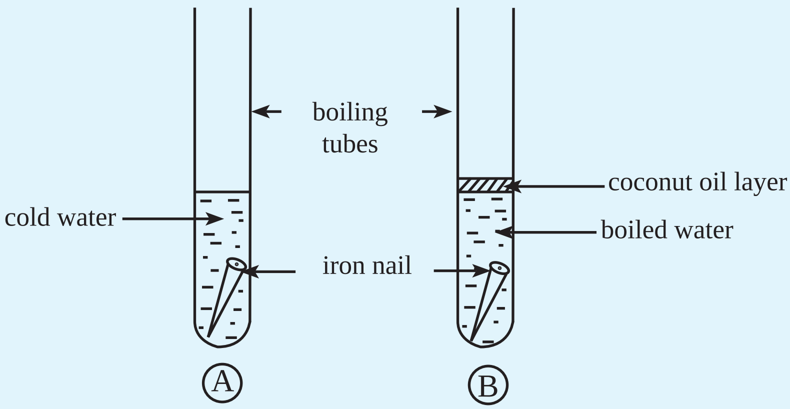


Figure 12.3.1

The nails in the above two tubes are in contact with water. But, as the water in the tube Ⓑ is boiled, air dissolved in it has been removed. Because of the coconut oil layer, water in tube Ⓑ does not come into contact with air, so the nail in Ⓑ doesn't receive air. The nail in tube Ⓐ received air (dissolved in water). All the other factors are common to the two settings.

It can be observed that the nail in tube Ⓐ has rusted but the nail in tube Ⓑ has not rusted. This confirms that air is essential for rusting.

Next, let us investigate which components in air are essential for rusting.

• Examining which components in air are essential for rusting

Activity 12.3.2

Materials required :- Two boiling tubes, iron wool, a basin of water

Method :-

- In one of the boiling tubes, trap a lump of iron wool and keep it inverted in the basin of water as shown in the figure.
- Keep the other empty tube also inverted in the basin of water.
- Observe after a few days.

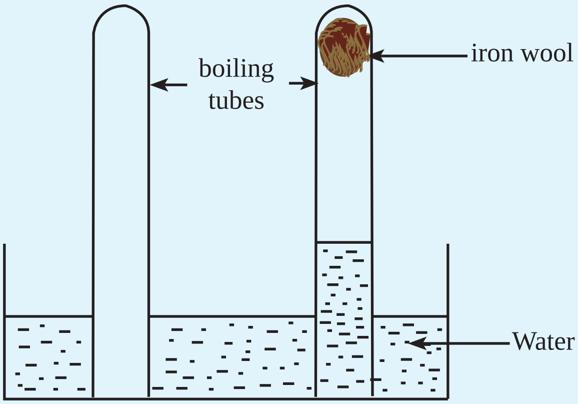


Figure 12.3.2

You can notice that the water level in the tube with iron wool has risen approximately up to 1/5th of the total volume of air inside the tube. Hence a part of air has been used for rusting. By composition, 1/5th of the volume of air is oxygen. Thus it can be concluded that it is the oxygen gas in air that is required for rusting. The gas required for rusting is oxygen.

• Examining whether water is essential for rusting

Activity 12.3.3

Materials required :- Four cleaned iron nails, two boiling tubes and two stoppers, anhydrous calcium chloride ($CaCl_2$) or silica gel

Method :-

- Fix two cleaned iron nails to each of the rubber stopper as shown in the figure.
- Fix one of the stoppers with nails to an empty boiling tube and the other to a boiling tube with anhydrous calcium chloride or silica gel
- Observe after a few days. Record your observations.

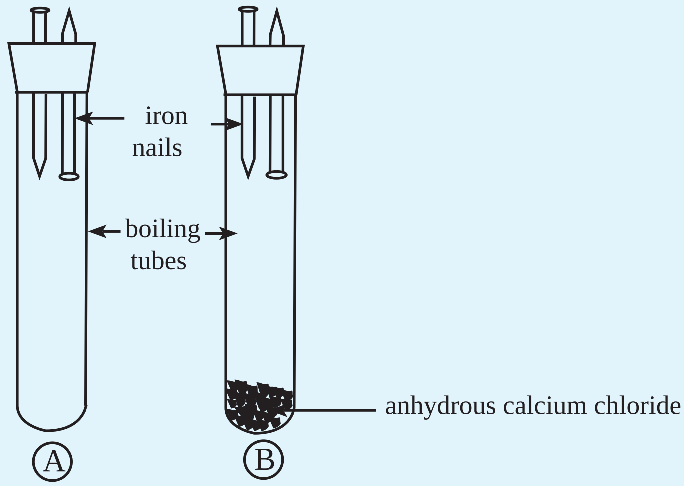


Figure 12.3.3

anhydrous calcium chloride can absorb water vapour in air.

In the above experiment, it can be observed that in the two nails in tube Ⓐ, the parts inside and outside the tube have rusted. However, in the case of Ⓑ, in the two nails, only the parts of the nails which are outside the tube have undergone rusting. As regards the tubes Ⓐ and Ⓑ are compared we note that tube Ⓑ does not have water vapour in it. Other factors are common to both tubes. This shows that water is a requirement for rusting.

Next let us get on to the process taking place during rusting.

Iron atoms form positive ions by losing electrons. This means that they get oxidised. It can be represented by an equation as follows.

$$Fe\ (s) \longrightarrow Fe^{2+}(aq) + 2e$$

Metal atoms oxidise as above only when there is another species which can accept electrons.

When oxygen gas in the atmosphere and water/ water vapour are together, they get reduced accepting electrons as indicated below.

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq)$$

Accordingly, the half reactions occuring when iron rusts can be given as follows.

$$Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2e \quad \text{..........} ①$$

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq) \quad \text{..........} ②$$

The number of electrons lost by reactions ① should be balanced by the number of electrons gained in reaction ②.

$$① \times 2\,;\ 2Fe\,(s) \longrightarrow 2Fe^{2+}\,(aq) + 4e \quad \text{..........} ③$$

$$② + ③\,;\ 2H_2O\,(l) + O_2\,(g) + 2Fe\,(s) \longrightarrow \underbrace{2Fe^{2+}\,(aq)\ \ 4OH^-\,(aq)}_{2\,Fe(OH)_2}$$

Therefore, it is clear that what occurs in rusting also is an electrochemical process similar to what you studied in the sub-unit 2.6. It can be stated that reaction ① is the anodic reaction (because oxidation occurs) and reaction ② is cathodic reaction (because reduction occurs).

$Fe(OH)_2$, formed above further reacts with air to form hydrated ferric oxide ($Fe_2O_3 \,.\, H_2O$)

$$4Fe\,(OH)_2\,(s) + O_2\,(g) \longrightarrow 2(Fe_2O_3 \,.\, H_2O)\,(s) + 2H_2O\,(l)$$

Hydrated ferric oxide is reddish brown in colour. As the number of water molecules combining with ferric oxide during hydration may vary, the formula of rust can be more appropriately given as $Fe_2O_3 \,.\, xH_2O$.

Perhaps you would have observed that if a knife used to cut a lime was left unwashed for about a day, the part of the blade smeared with lime juice becomes rusty. Let us do the following activity to find out how acidity affects rusting.

• Examining how acids affect rusting

Activity 12.3.4

Materials required :- Three boiling tubes, water, lime juice,dilute hydrochloric acid (HCl)

Method :-

- Put an iron nail each to three boiling tubes.
- Add ordinary cold water to the first boiling tube, water mixed with lime juice to the second and water mixed with dilute hydrochloric acid to the third.
- Allow to stand for about one day and observe. Record your observations.

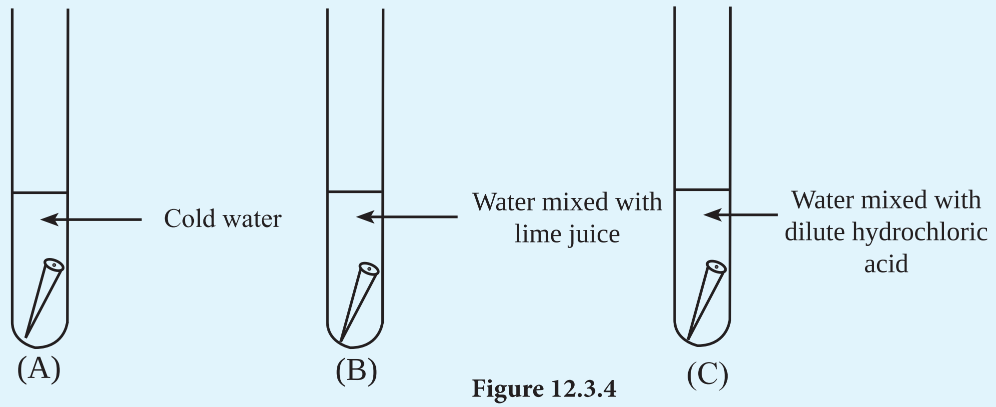


Figure 12.3.4

It can be observed that the nails in the tubes B and C have rusted more than the nail in tube A.

From this, it can be inferred that **acidity is a factor that accelerates rusting.**

Have you heard that the items made from iron used in houses in coastal areas rust faster compared to the iron objects used in other areas? In order to investigate into this, let us do the following activity.

Investigating the effect of salt (sodium chloride) on rusting

Activity 12.3.5

Materials required :- Cleaned iron nails, boiling tubes, solid sodium chloride

Method :-

- Clean two new iron nails.
- Put the two nails separately to the two boiling tubes and into one of them add water mixed with some sodium chloride and to the other tube, add ordinary cold water.
- Allow to stand for about a day and observe. Record your observations

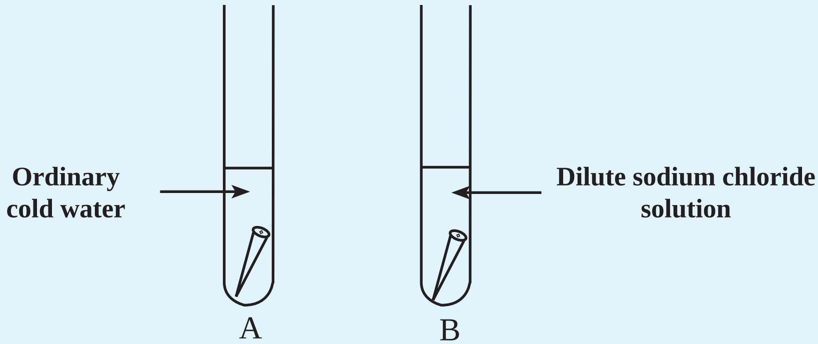


Figure 12.3.5

The nail in tube B rusts more than that in tube A. This indicates that sodium chloride has accelerated the rusting of iron. Sodium chloride is a salt. Many salts accelerate rusting. The salt concentration in coastal areas is high. Therefore, the iron objects used in those areas rust relatively faster.

We learnt that acids accelerate rusting. Next, let us do the following activity to explore how bases affect rusting.

- **Examining how bases affect rusting**

Activity 12.3.6

Materials required :- Two boiling tubes, two cleaned iron nails, sodium hydroxide (NaOH) solution

Method :-

- Put the two cleaned nails to the two boiling tubes seperately. Add equal volumes of ordinary cold water to one tube and sodium hydroxide solution to the other tube.
- Allow to stand for about a day and observe.

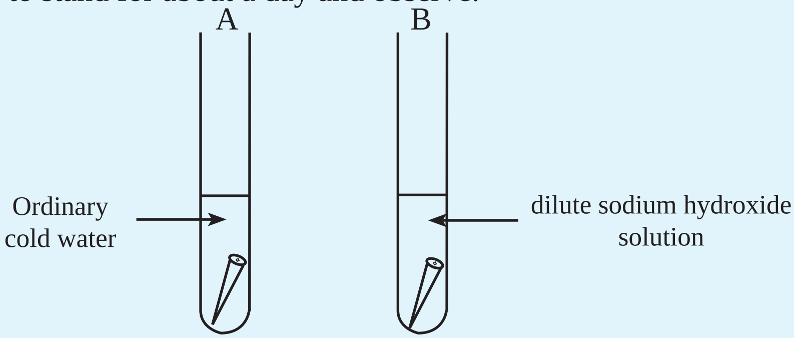


Figure 12.3.6

It can be observed that the nail in the tube with ordinary water has rusted and relative to this, the nail in sodium hydroxide solution has not rusted much. This confirms that bases decrease the speed of rusting.

The speedy corrosion of iron which is a very useful metal is a disadvantage. Therefore, steps must be taken to control the corrosion of objects made of iron.

12.3.2 Control of rusting of iron

What are the methods you suggest to prevent the corrosion of iron? In order to protect iron from corrosion you may propose that it is appropriate to prevent iron from coming into contact with the essential factors for rusting. In fact, if oxygen and water are kept away from iron, rusting can be prevented.

For this, following measures can be adopted.

1) Applying paint, grease or oil on iron

This prevents iron from coming into contact with oxygen and water (moisture)

2) Coating iron with tin

This too prevents impinging of oxygen and water (moisture) on iron.

In both instances above, the coating acts as a protective film.

Let us do the following activity to inquire into the effect of other metals on corrosion of iron.

- **Effect of other metals on corrosion of iron**

Activity 12.3.7

You will need :- Five cleaned iron nails, agar jelly, sodium chloride, phenolpthalein indicator, potassium ferricyanide, petri dishes, strips of magnesium, Zinc, copper and lead, water.

Method:-

- To approximately 250 cm^3 of water add a small amount a few of sodium chloride, phenolphthalein and potassium ferricyanide. Boil the solution and add about one tea spoonful of agar jelly to it and stir well.

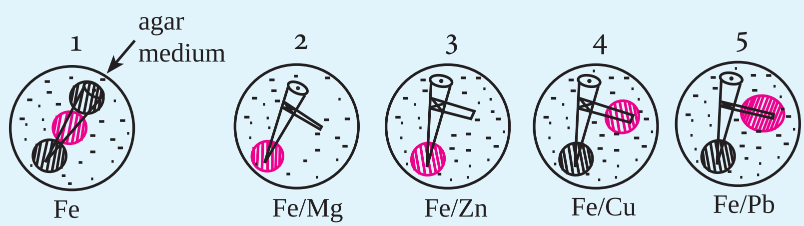


Figure 12.3.7

- Take five petri dishes. Place only an iron nail into the first petri dash. Keep the strips of magnesium, zinc, copper and lead in good contact with the other four nails. In each of the other four petri dishes, as shown in the figure. Then add the hot gel medium to all the five dishes so that the nail in each is fully covered. Allow to cool and observe after about one hour. Record the observations.

★ In the presence of OH^- ions, phenolphthalein indicator turns pink.

★ Fe^{2+} ions indicate a blue colour with potassium ferricyanide.

In the petri dishes 2 and 3 above pink colour is seen around the iron nails. That means, OH^- ions are formed near the iron nail. Absence of blue colour show that Fe^{2+} ions have not formed. In the petri dishes 2 and 3, the iron nails are in contact with magnesium and zinc which are more reactive than iron. Hence, cathodic reaction has occured at the iron nails.

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4OH^-\,(aq)$$

Here, the metals of higher reactivity, magnesium and zinc, act as the anode. At these metals oxidation occurs.

$$Mg\,(s) \longrightarrow Mg^{2+}\,(aq) + 2e$$

$$Zn\,(s) \longrightarrow Zn^{2+}\,(aq) + 2e$$

The Mg^{2+} and Zn^{2+} ions formed do not give a colour with potassium ferricyanide in the medium.

Appearnce of blue colour around the iron nails in the petri dishes 4 and 5 indicates the formation of Fe^{2+} ions. This shows that the iron nails in them have corroded. In these set ups, iron acts as the anode and is subjected to oxidation as follows.

$$Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2e$$

Copper and lead are placed below iron in the activity series. When iron is in contact with such a metal, iron rusts faster. Areas around copper and lead strips turning pink indicates the formation of OH^- ions closer to them. Therefore, the following reaction should have occured at copper or lead.

$$2H_2O\,(l) + O_2\,(g) + 4e \longrightarrow 4\,OH^-\,(aq)$$

According to the above observations it would be clear to you that in order to protect iron from corrosion, a metal above iron in the activity series can be kept in contact with iron. Then, iron acts as the cathode and is protected from corrosion. Protecting iron by making it the cathode of an electrochemical cell is known as the cathodic protection or sacrificial protection.

Instances where cathode protection is used:

- Coating iron objects with zinc (galvanizing)- buckets, barbed wire, roofing sheets, GI pipes
- Welding blocks of magnesium and zinc to the hulls of the ships sailing in the sea (These blocks of magnesium and zinc should be replaced from time to time)

Summary

- Electrochemical cells are used to convert chemical energy to electrical energy.
- A simple cell can be made by connecting two different metal rods by conducting wires and immersing them in an acid solution.
- In a simple electrochemical cell, the more reactive metal acts as the anode and the less reactive metal acts as the cathode.
- An oxidation half reaction occurs at the anode while a reduction half reaction occurs at the cathode.
- Anode is the negative terminal and cathode is the positive terminal of an electrochemical cell.
- Along the external wire, electrons flow from the anode to cathode.
- The conventional current is considered to flow from the positive terminal (cathode) to negative terminal (anode).
- Electrolysis causes chemical changes in matter by passing an electric current through a solution or a liquid.
- In electrolysis, electricity is passed through the solution or a liquid by immersing two carbon or metal electrodes in it, to which an external electrical supply is connected.
- The solution /liquid through which electricity is passed is called the electrolyte. To conduct electricity there should be mobile ions in the electrolyte.
- Since the positive terminal of the electrolytic cell acts as the anode, an oxidation half reaction occurs at the positive terminal.
- Manufacturing of useful substances from the products discharged at the electrodes is an industrial application of electrolysis.
- Industrially, sodium metal is obtained by the electrolysis of fused sodium chloride. Hydrogen and chlorine gases obtained as by-products of this are also useful chemicals.
- Subjecting the surface of a metal to chemcial changes when it is exposed to atomsphere and moisture is known as the corrosion of the metal.
- Subjecting iron and steel to corrosion as above is specifically known as rusting.
- Oxygen gas and moisture are indispensable for the rusting of iron.
- Corrosion of iron is an electrochemical process.
- The anodic reaction of this process is

$$Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2e$$

- The cathodic reaction is
  $2\,H_2O\,(l) + O_2\,(g) + 4\,e \longrightarrow 4\,OH^-\,(aq)$
- The overall corrosion reaction can be obtained by the above anodic and cathodic reactions.
  $2\,H_2O\,(l) + O_2\,(g) + 2\,Fe\,(S) \longrightarrow 2\,Fe\,(OH)_2\,(s)$
- By further oxidation of $Fe(OH)_2$, hydrated ferric oxide ($Fe_2O_3 .\, x\, H_2O$) or rust is formed.
- Salts such as sodium chloride and acids speed up rusting.
- Bases decrease the rate of rusting.
- Rusting can be prevented by keeping iron without coming into contact with oxygen and moisture, the essential conditions for rusting.
- For this, iron can be coated with a protective layer of paint, grease or tin metal.
- When a metal more reactive than iron is in contact with iron, rusting is reduced because the reactive metal acts as the anode and iron acts as the cathode. This is called sacrificial protection or cathodic protection.
- Galvanizing iron is an example for sacrifical protection.

Exercises

Multiple choice questions

1. Consider a cell constructed using a zinc metal plate, an iron metal plate and dilute sulphuric acid. Which of the following statement is true about it?
   1. The conventional current of the cell flows from zinc to iron through the wire.
   2. Gas bubbles evolve at the iron electrode.
   3. Iron electrode decays.
   4. Iron electrode is the negative terminal of the cell.

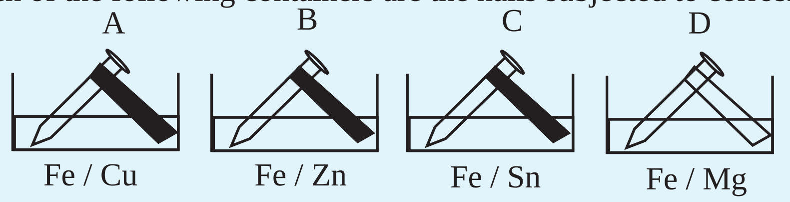
2. Consider the cell constructed by immersing iron and copper electrodes in dilute sulphuric acid. Which of the following is the anodic reaction of this cell?

   1. $Cu\,(s) \longrightarrow Cu^{2+}\,(aq) + 2\,e$
   2. $Fe^{2+}\,(aq) + 2\,e \longrightarrow Fe\,(s)$
   3. $Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2\,e$
   4. $2\,H^+\,(aq) + 2\,e \longrightarrow H_2\,(g)$

3. Which of the following is an essential factor for corrosion of iron?
    1. water 2. atomospheric carbon dioxide gas
    3. acids 4. bases

4. Which of the following is a factor that accelerates corrosion of iron?
    1. atmospheric moisture
    2. atmospheric carbon dioxide gas
    3. limewater
    4. grease

5. In which of the following containers are the nails subjected to corrosion?



    1. A and B 2. B and C
    3. A and C 4. B and C

6. Which of the following statements is not true?
    1. In an iron spoon the part smeared with vinegar rusts more.
    2. Galvanized wire rusts when the coating is scratched.
    3. A tin-coated vessel rusts when the coating is scratched.
    4. Rusting of iron can be prevented by coating it with magnesium.

7. When an aqueous solution of sodium chloride is electrolysed using carbon electrodes
    1. hydrogen gas is liberated at the positive terminal.
    2. sodium hydroxide is formed in the solution.
    3. chlorine gas is liberated at the cathode.
    4. anode dissolves.

8. When a solution of copper sulphate is electrolysed using carbon electrodes
    1. copper is deposited on the cathode.
    2. copper is deposited on the anode.
    3. oxygen gas bubbles are formed at the negative electrode.
    4. the blue colour of the solution remains unchanged.

9. Which of the following is not a conductor of electricity?
    1. aqueous sodium hydroxide
    2. acidified water
    3. solid sodium chloride
    4. aqueous sodium chloride

10. During the electrolysis of acidulated water using carbon electrodes
    1. hydrogen gas is evolved at the anode.
    2. oxygen gas is evolved at the cathode.
    3. hydroxide ions are genarated at the anode.
    4. anode dissolves.

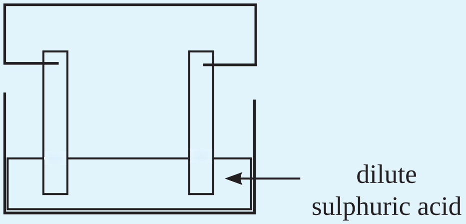
11. Which of the following is an occasion where electrolysis is not used industrially?
    1. coating an iron spoon with nickel.
    2. extraction of aluminium metal.
    3. galvanizing iron nails.
    4. extraction of sodium from fused sodium chloride.

Essay questions

1.Write balanced half equations for the following chemical processes. State whether the half reactions you write are oxidation or reduction.

i. magnesium metal (Mg) turning into magnesium ions (Mg^{2+})
ii. aluminium metal (Al) turning into aluminium ions (Al^{3+})
iii. sodium metal (Na) turning into sodium ions (Na^{+})
iv. hydrogen ions (H^{+}) turning into hydrogen molecules (H_2)

2. Consider the following electrochemical cell constructed using zinc and lead metals.



i. Name the anode and cathode of this cell.
ii. Name the positive terminal and negative terminal of this cell.
iii. Write the anodic and cathodic reactions of this cell.
iv. Name the electrode reactions corresponding to oxidation and reduction.
v. Write the overall cell reaction.
vi Write the changes that can be observed at the electrodes.

Technical terms

Electrolysis	-	විද්‍යුත්විච්ඡේදනය	-	மின்பகுப்பு
Electrolyte	-	විද්‍යුත් විච්ඡේද්‍යය	-	மின்பகுபொருள்
Non-electrolyte	-	විද්‍යුත් අවිච්ඡේද්‍යය	-	மின்பகாப்பொருள்
Electrolytic cell	-	විද්‍යුත් - විච්ඡේදන කෝෂය	-	மின்பகுப்புக் கலம்
Spontaneous	-	ස්වයංසිද්ධ	-	சுயாதீனமான
Activity series	-	සක්‍රියතා ශ්‍රේණිය	-	தாக்கவீதத் தொடர்
Bleaching	-	විරංජනය	-	வெளிற்றல்
Electroplating	-	විද්‍යුත් ලෝහාලේපනය	-	மின் உலோக முலாமிடல்
Anode	-	ඇනෝඩය	-	அனோட்டு
Cathode	-	කැතෝඩය	-	கதோட்டு
Electrochemical cell	-	විද්‍යුත් - රසායනික කෝෂය	-	மின் இரசாயன கலம்
Electrode	-	ඉලෙක්ට්‍රෝඩ	-	மின்வாய்
Half reactions	-	අර්ධ ප්‍රතික්‍රියා	-	அரை அயன் தாக்கம்
Flow of electrons	-	ඉලෙක්ට්‍රෝන ධාරාව	-	இலத்திரன் பாய்ச்சல்
conventional current	-	සම්මත ධාරාව	-	நியம மின்னோட்டம்
Galvanometer	-	ගැල්වනෝමීටරය	-	கல்வனோமானி
Oxidation	-	ඔක්සිකරණය	-	ஒட்சியேற்றம்
Reduction	-	ඔක්සිහරණය	-	தாழ்த்தல்
Negative terminal	-	සෘණ අග්‍රය	-	மறை முனை
Positive terminal	-	ධන අග්‍රය	-	நேர் முனை
Oxidation half reaction	-	ඔක්සිකරණ අර්ධ ප්‍රතික්‍රියාව	-	ஒட்சியேற்ற அரை அயன் தாக்கம்
Reduction half reaction	-	ඔක්සිහරණ අර්ධ ප්‍රතික්‍රියාව	-	தாழ்த்தல் அரை அயன் தாக்கம்
Anodic reaction	-	ඇනෝඩ ප්‍රතික්‍රියාව	-	அனோட்டுத் தாக்கம்
Cathodic reaction	-	කැතෝඩ ප්‍රතික්‍රියාව	-	கதோட்டுத் தாக்கம்
Cell reaction	-	කෝෂ ප්‍රතික්‍රියාව	-	கலத் தாக்கம்
Corrosion	-	ලෝහ විඛාදනය	-	உலோக அரிப்பு
Rusting	-	මල බැඳීම	-	துருப்பித்தல்
Bimetal effect	-	ද්වි ලෝහ ආවරණය	-	ஈருலோகச் சட்டம்
Sacrificial protection	-	කැප කිරීමේ ආරක්ෂණ ක්‍රමය	-	தியாகப் பாதுகாப்பு முறை
Cathodic protection	-	කැතෝඩීය ආරක්ෂණ ක්‍රමය	-	கதோட்டுப் பாதுகாப்பு முறை

Electromagnetism and Electromagnetic Induction

Physics

13

13.1 Magnetism

Figure 13.1 shows the use of a large electromagnet to lift and remove scrap iron and steel. Since iron and steel pieces are attracted towards this strong electromagnet, it is easy to move them using this method.

Figure 13.1 – Use of an electromagnet to remove scrap iron and steel

There are two main types of magnets known as **electromagnets** and **permanent magnets**. In electromagnets, magnetism exists only while a current is passing through the coil of the electromagnet. In permanent magnets, magnetism is a characteristic of the material of the magnet and it remains in the magnet permanently.

Both types of magnets are used in many instruments for various purposes. Magnets are used in controlling most domestic appliances and robots by electric motors, in applications involving magnetic cards, in medical equipment such as MRI machines and in various other scientific and technological instruments. Therefore, it is useful to have a good knowledge about the behaviour, operation and applications of magnets.

Figure 13.2

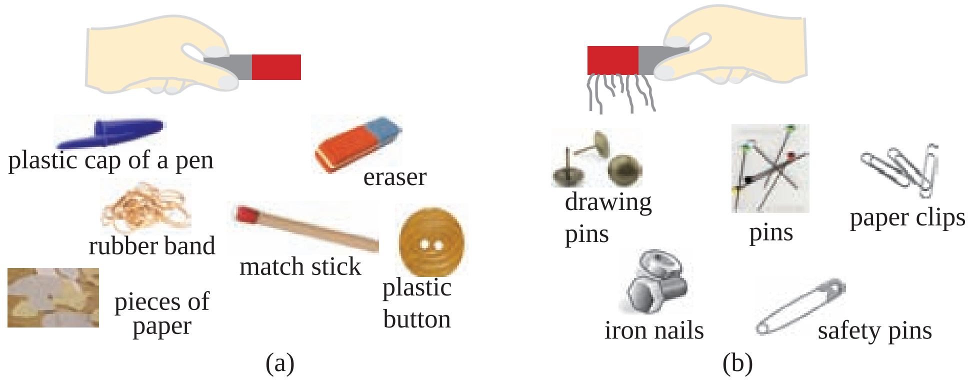


Figure 13.3 (a) - Objects which are not attracted (b) - attracted by magnets

Objects made of magnetic materials such as iron, steel, nickel are attracted by magnets. Objects made of materials such as plastic, wood, paper and rubber are not attracted by magnets.

13.1.1 Magnetic Field

Around any magnet, there is a region within which the magnet has an influence. This region is known as the **magnetic field**. A magnetic field is not perceptible to the eye. Therefore we cannot see a magnetic field. However, it can influence another magnet or a moving charge. It has been found that some animals such as birds use the earth's magnetic field for navigation.

One way of determining whether there is a magnetic field in a certain region is to use a compass. A compass is a small light-weight magnet mounted on a pivot in such way that it could rotate freely around the pivot. In the absence of any magnetic influence other than the earth's magnetic field, a compass aligns along the north-south direction. Let us engage in activity 13.1 to investigate the field near to a bar magnet.

Activity 13.1

Apparatus required: A compass, a piece of glass, A piece of iron, A magnet, A piece of plastic, a piece of brass

- Place the compass on a table and observe the deflection of its indicator by bringing close to it, a piece of glass, a piece of iron, a magnet, a piece of plastic and a piece of brass one at a time.

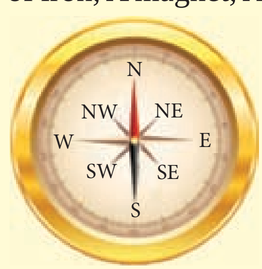


Figure 13.4

You will observe that the indicator of the compass deflects only when a magnet is brought close to it. From this we can conclude that the magnet gives rise to a magnetic field in its vicinity.

For extra knowledge

Naturally occurring magnets have been known to man as far back as thousands of years. The compass was invented by Chinese in the eleventh century AD.

When a compass is placed at a point in a region where a magnetic field exists, the direction of the compass needle shows the direction of the magnetic field at that point. This direction can vary from point to point. In addition, the strength of the magnetic field can also vary from point to point. Therefore, a magnetic field is a physical quantity with a magnitude and a direction.

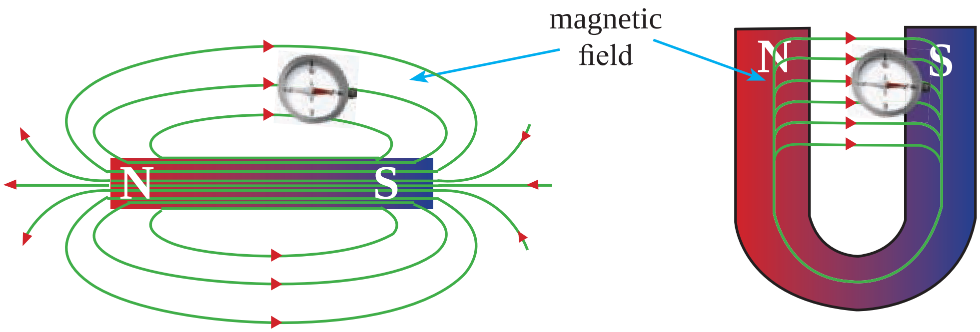


Figure 13.5 – Finding the direction of a magnetic field using a compass

13.2 Magnetic Effect of a Current

When an electric current flows through an electric conductor, a magnetic field is created in the vicinity of the conductor. Danish scientist Hans Christine Oersted was the first to observe a magnetic effect in the vicinity of a current carrying conductor.

Figure 13.6 - Hans Christine Oersted

Let us now engage in activity 13.2 to observe a magnetic effect (field) due to a straight conductor carrying a current.

Activity 13.2

Apparatus required: a compass, a straight copper wire, a few batteries, connecting wires and a switch

- Place the compass on the table with its indicator along the north-south direction and next place the copper wire *AB* above the compass and along the north-south direction.

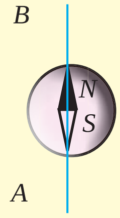


Figure 13.7

- Connect a battery and a switch to *AB* using connecting wires.
- Close the switch S and allow a current to pass through *AB*. The compass indicator will show a deflection towards the left hand sides.
- Stop the current flow by opening switch S and observe the compass needle. You will observe that the indicator returns to its original position.

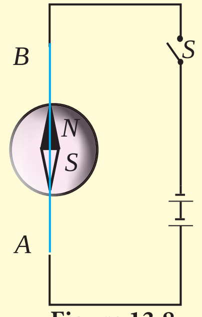


Figure 13.8

- Now place the compass horizontally above the wire *AB* and observe what happens when a current flows through *AB*. You will observe that the indicator deflects in the opposite direction.
- Now change the terminals of the battery and allow a current to flow in the opposite direction (*BA*). Place the compass below the wire *AB*. You will observe that the compass needle deflects towards the right hand side.
- Now place the compass above the wire and allow the current to pass in the direction *BA*. You will be able to observe that the compass indicator deflects in the opposite direction.

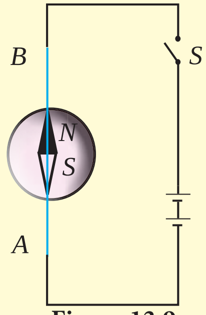


Figure 13.9

The indicator deflects only when it is subjected to the influence of a magnetic effect. That is, in the presence of a magnetic field. This activity would show you that a magnetic field is created when a current flows through a conductor.

It will be clear to you from the above activity that the direction of the magnetic field in the vicinity of a current carrying conductor depends on the direction of the current flow.

13.2.1 Direction of the Magnetic Field due to a Current through a Straight Conductor

Let us now investigate about two rules that could be used to find the direction of the magnetic field due to a current flowing through a straight conductor.

- **Maxwell's corkscrew rule**

Maxwell's corkscrew rule can be used to find the direction of the magnetic field due to a current flowing through a conductor.

When a corkscrew is rotated in such a way that its tip moves in the direction of current flow, then the magnetic field lines produced by the current are in the direction of rotation of the corkscrew.

A corkscrew is an instrument used to open bottles with cork lids. Normal screws show the same behavior as corkscrews.

(a) According to Figure 13.10 (a), when a current flows from *A* to *B*, the direction of the resulting magnetic field is anti-clockwise.

(b) According to Figure 13.10 (b), when a current flows from *B* to *A*, the direction of the resulting magnetic field is clockwise.

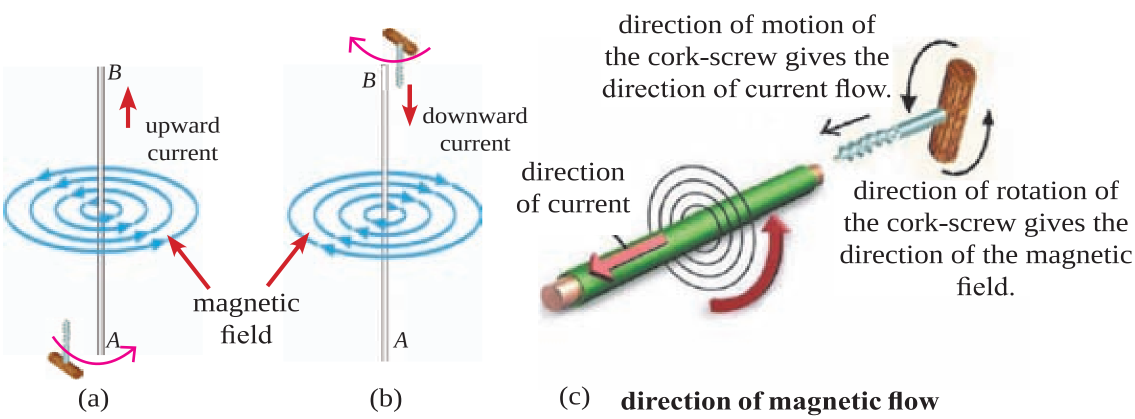


Figure 13.10 – Magnetic field around a current carrying conductor

- **Right hand grip rule**

Right hand grip rule is another simple rule for finding the direction of the magnetic field due to a current carrying conductor.

If the conductor is held with the right hand in such a way that the thumb is directed towards the direction of current flow, then the direction of the other four fingers around the conductor indicates the direction of the magnetic field.

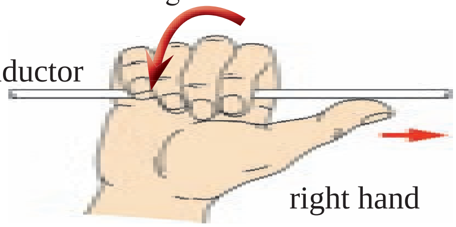


Figure 13.11 – Finding the direction of magnetic field from the direction of current flow

Figure 13.12 shows how the direction of the magnetic field due to a current carrying conductor is marked in a diagram.

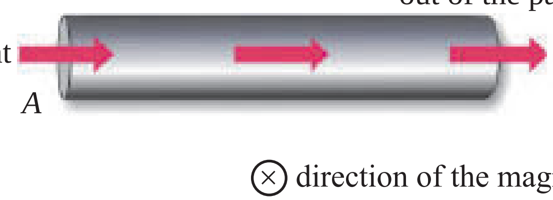


Figure 13.12 – Indicating the magnetic fields perpendicular to the plane of the page directed into and directed out of the page in a diagram

Suppose that a current flows through the conductor in Figure 13.12 along the direction *AB*. Then, according to the right hand rule, the magnetic field is directed towards you (from the page) in the region above the conductor while it is directed away from you (into the page) in the region below the conductor. A dot inside a circle (⊙) is used to indicate a magnetic field coming out of the page while a cross inside a circle (⊗) is used to indicate a magnetic field going into the page.

13.2.2 Force Acting on a Current Carrying Conductor Placed in a Magnetic Field

You have learnt that a magnetic field is established in the vicinity of a conductor that carries a current. Let us now engage in Activity 13.3 in order to find out whether a force acts on a current carrying conductor placed in a magnetic field.

Activity 13.3

Apparatus required: A U-magnet, a piece of conductor, two brass or some other conducting rods, two dry cells

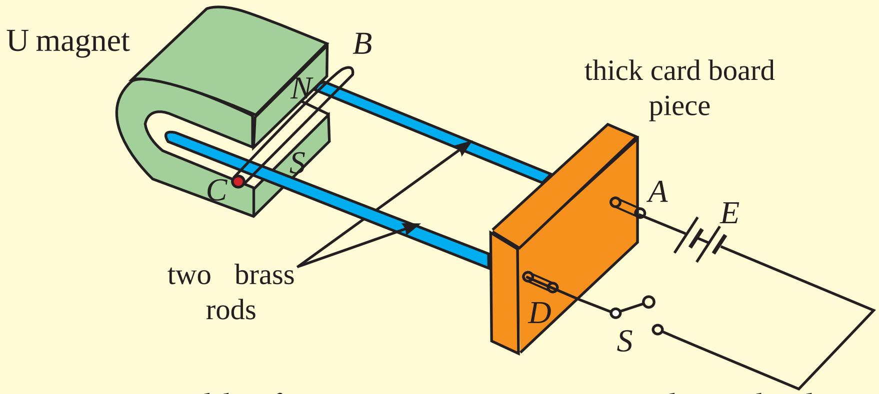


Figure 13.13 - modeling force acts on a current carrying conductor placed in a magnetic field

- Place the U-magnet on a table and place the two brass rods as shown in the figure by inserting them through two holes pierced in the thick card board. Connect the two dry cells and the switch *S* to the ends *A* and *D* of the brass rods.
- Next place the conductor *BC* on the two brass rods between the north and south poles of the magnet.
- Allow a current to flow by closing the switch *S*. Then a current flows from the cells through the brass rods along the direction *AB* and through the conductor in the direction *BC* and reaches the cell from the direction *CD*.
- When the current flows, you will observe that the conductor *BC* moves along the brass rods away from the magnet (to the right hand side).
- Now repeat the above step by changing the cell terminals to change the direction of the current. Now you will observe that the conductor *BC* moves along the brass rods towards the magnet (to the left hand side).
- Repeat the above step after changing the top and bottom poles of the magnet. You will observe that the direction of motion of the conductor *BC* is opposite to that of the above steps.

A conductor placed in a magnetic field moves when a current flows through the conductor as a result of a force acting on it. The direction of the force is indicated by the direction of motion of the conductor.

In the activity above, the direction of the magnetic field and the direction of the current through the conductor have been arranged to be perpendicular to each other.

You will be able to observe that the motion of the conductor takes place in a direction perpendicular to both of the above directions.

The magnitude of the resulting force depends on the following three factors.

- The magnitude of the current through the conductor
- The length of the conductor between the rods
- The strength of the magnetic field

The force increases as the above three factors are increased and it decreases when the above three factors are decreased. That is, the force is directly proportional to the three factors given above.

• Fleming's left hand rule

Fleming's left hand rule can be used to find the direction of the force acting on a conductor placed in a magnetic field when a current flows through the conductor.

Keep the thumb, index finger and the middle finger of the left hand perpendicular to one another and point the middle finger in the direction of the current flow and the index finger along the direction of the magnetic field. Then the direction pointed by the thumb will be the direction of the force acting on the conductor.

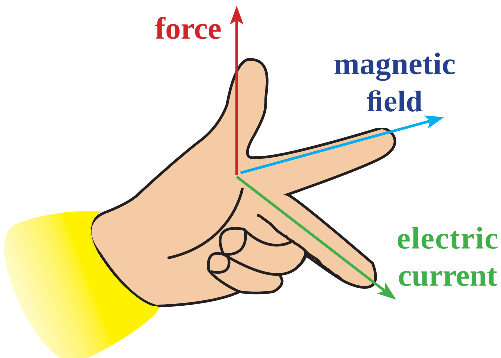
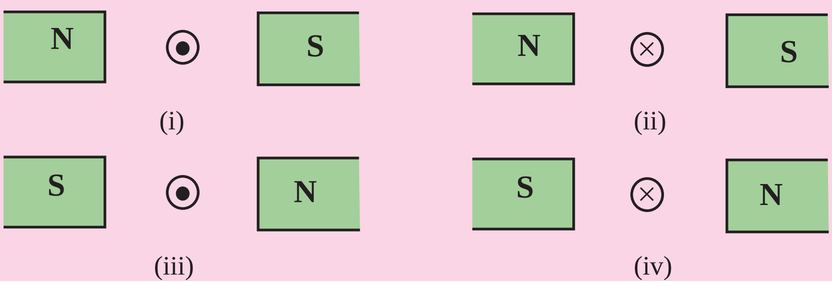


Figure 13.14 – Finding the direction of the force on the conductor based on the directions of the current and the magnetic field

Exercise 13.1

(1) Find and mark the direction of the force acting on the conductor using Fleming's left hand rule in each of the figures given below for the magnetic fields and currents indicated.



The action of a force on a current carrying conductor placed in a magnetic field is a very useful phenomenon in our daily lives. Electric motors, loud speakers, galvanometers, voltmeters and ammeters (analog) are some of the instruments constructed based on this phenomenon.

13.2.3 Loud Speaker

Figure 13.15 shows the outward appearance and the cross section of a loud speaker. A loud speaker generates a sound when a current that varies according to the wave form of the sound is allowed to pass through the coil in the loud speaker.

The main components of a loud speaker are a light-weight cardboard cone, a conducting coil and a ring-magnet. The end of the cone with the larger diameter and the magnet are fixed to a supporting metal frame as shown in Figure 13.15(b).

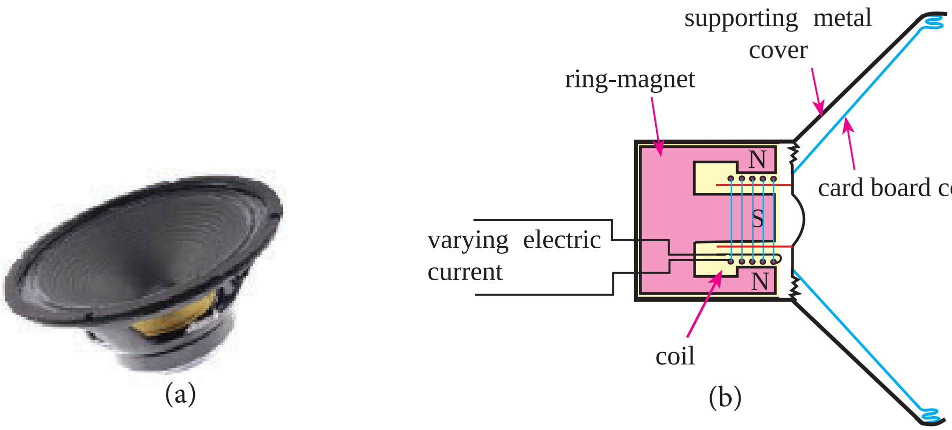


Figure 13.15 (a) – A loud speaker (b) A cross section of a loud speaker

The coil is connected to the end of the cone with the smaller diameter in such a way as to allow the coil to freely move forward and backward in the region between the poles of the magnet. When a time-varying current flows through the coil, the force exerted on the conductor by the magnet vibrates the coil forward and backward according the variation of the current and the cone too vibrates accordingly, generating sound waves.

13.2.4 Direct Current Motor (DC Motor)

Toy motor cars, hybrid cars, electric cars and electric trains are operated using DC motors.

A hybrid car

An electric car

An electric train

Figure 13.16

Let us engage in activity 13.4 to construct a DC motor.

Activity 13.4

Apparatus required: A dry cell, insulated copper wires, two needles with large holes, some clay, cello tape, A knife for cutting wires, A small (ring) magnet.

- First construct the magnetic coil. In order to do this, wrap about 30 windings of the copper wire around a cylindrical object such as a somewhat large pen, starting from the middle of the wire. Wind the free ends of the wire several times around the coil to prevent it from unwinding.
- Use the knife to remove the insulation of the wire as shown in figure 18 near the free ends. Removal of the insulation should only be done in about half of the wire and on the same side at each end.
- Next, pass the two ends through the needle holes and mount the coil on the needles horizontally as shown in figure 3.

- Fix the needles on to the terminals of the dry cell using cello tape as show in the figure 4.
- Use clay to fix the dry cell rigidly.
- Finally attach the circular magnet on the cell using clay.

You will be able to observe the copper wire rotating. If it does not rotate, give it a slight push with your hand. Then it will start rotating.

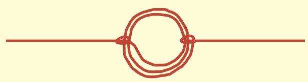


figure 1

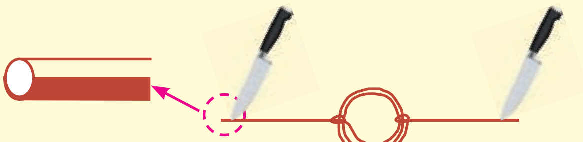


figure 2

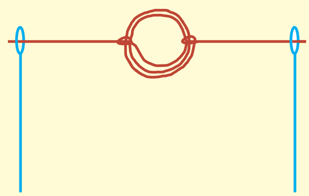


figure 3

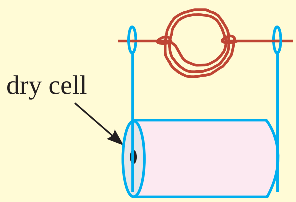


figure 4

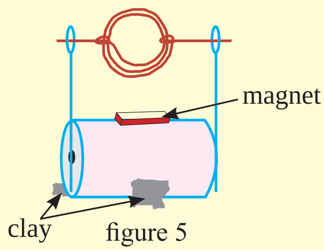


figure 5

In this case too, the magnetic field exerts a force on the conductor when a current flows through it. Since the conductor in this case is a coil, two forces act on the coil in two opposite directions (a couple) as shown in figure 6 causing it to rotate.

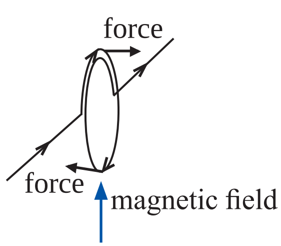


figure 6

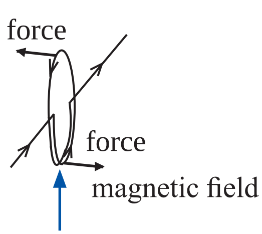


figure 7

The reason for removing the insulation in only one side of the coil at the two ends is to prevent a current from flowing through the coil in the second half a cycle (after the first half cycle). Otherwise, the couple will act in the opposite direction in the second half cycle as shown in figure 7 and the coil will tend to rotate in the opposite direction. If however the current is prevented from flowing in the second half cycle, the coil will continue to rotate in the same direction during the second half cycle too in the first half cycle.

• Main parts of the DC motor

Armature

In normal DC motors, there is a coil much like the coil you used in the previous activity. Since a motor is used to rotate some load, the coil of a DC motor must be strong enough to withstand an external load. Therefore the coil is wrapped around a steel or iron core as shown in the figure 13.17. This coil, together with the core, is known as the **armature.**

Figure 13.17 - Armature

The function of the armature is to give rise to a rotation by generating a couple when a current is passing through it.

Magnetic Poles

A magnetic field is required to exert a force on a coil when a current flows through the coil. In normal DC motors this magnetic field is obtained by poles of a permanent magnet arranged around the armature as shown in the figure 13.18.

Figure 13.18- Magnetic Poles

Commutator

In the motor you constructed, the insulation was removed only on one side of the wire near the ends. That was because the coil would rotate in two opposite directions if the insulation is completely removed. Therefore, in your motor, the current flows through the coil only in one half of each cycle. When the current flows only during half a cycle, the load that the motor can rotate is restricted. Therefore a more suitable way for the current to flow would be to let the current to flow in one direction during half of a rotation cycle and to let the current to flow in the opposite direction in the next half cycle. A **commutator** is used to alternate the direction of current flow in this manner.

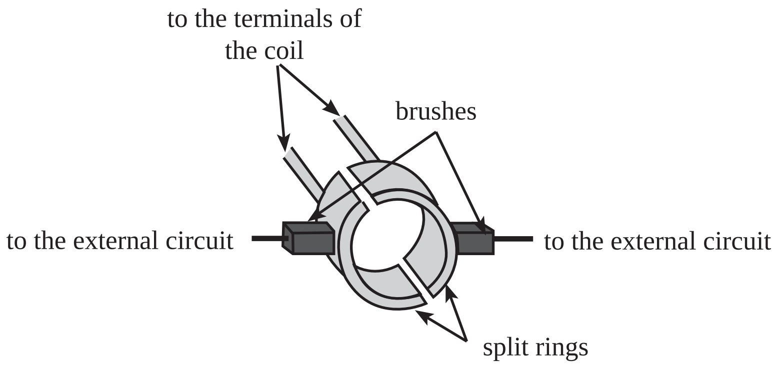


Figure 13.19 - Commutator

The commutator consists of two metallic split rings and two parts known as brushes that can be adjusted to brush against the split rings as shown in the figure 13.19. The two ends of the coil are connected to the two split rings and they rotate with the armature. The two brushes maintain contact with the split rings without rotating themselves. These two brushes are connected to the external circuit that provides current to the motor.

• Operation of a DC Motor

Figure 13.20 shows the appearance of a motor with all of the above components assembled together. Figure 13.21 shows a simplified figure that can be used to understand the operation of the motor easily. In the Figure 13.21 the coil of the motor is shown by a single loop *ABCD*. This coil is placed between two magnetic poles. The coil is connected to the split rings *X* and *Y* while the brushes *P* and *Q* are connected to the battery *S*.

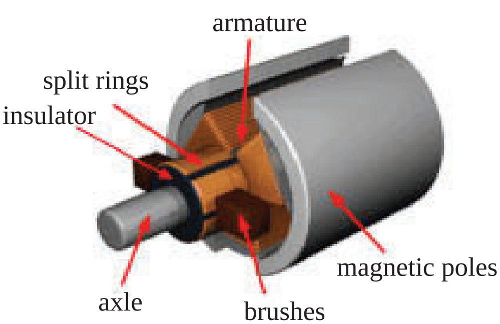


Figure 13.20 – Main parts of a dc motor

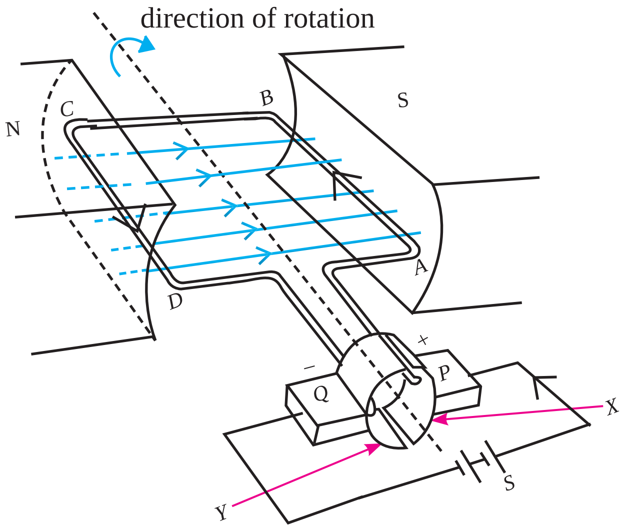


Figure 13.21 – Modeling the operation of a DC motor

- When a current is made to flow through the motor, the current enters the split ring *X* through the brush *P* and flows through the wire loop *ABCD*, reaches the split ring *Y* and passes to the external circuit through the brush *Q*.
- The current passes through the loop placed in the magnetic field along the directions *AB* and *CD*.
- Find the direction of the force acting on *AB* and *CD* by applying Fleming's left hand rule. You will find that the force on *AB* acts downwards while that on *CD* acts upwards. The armature will rotate clockwise due to the resulting couple.
- Let us now consider what happens when the coil and the two split rings have rotated by 180^{o} and their positions are inverted. This position is shown in Figure 13.22.
- At this point, brush *P* is in contact with split ring *Y* while brush *Q* is in contact with split ring *X*. Then the current enters from brush P to split ring *Y*, flows in the direction *DCBA* and reaches split ring *X* and leaves from brush *Q*.

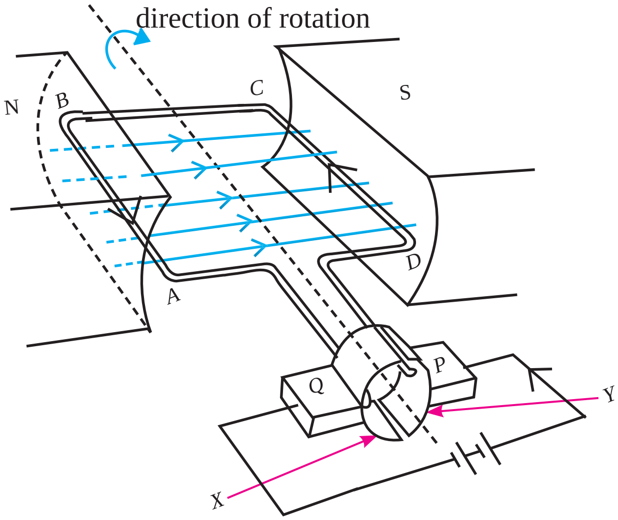


Figure 13.22 – Modeling the operation of a DC motor

- In this situation, current flows along the directions *DC* and *BA* in the coil.
- When Fleming's left hand rule is applied it will be clear that the motion of *AB* is upwards while that of *CD* is downwards. The resulting couple rotates the armature further in the clockwise direction.
- If the direction of the current is changed by changing the battery terminals, the directions of the forces also change to the opposite directions and the direction of rotation of the armature will be in the anti-clockwise direction.
- In the operation of the DC motor, the electric energy given to the motor is converted to mechanical energy.

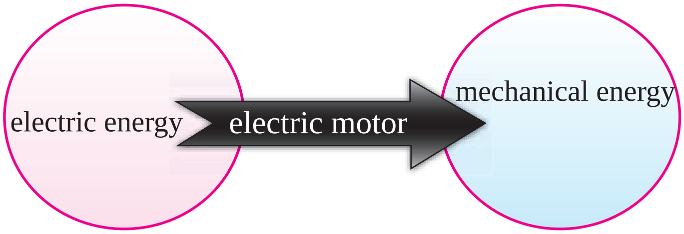
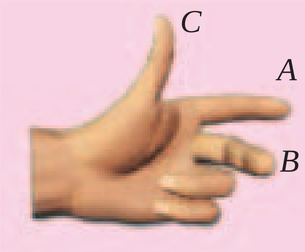


Figure 13.23 – Energy transformation in electric motor

Exercise 13.2

(1) The figure below shows how a student used his left hand in order to apply Fleming's left hand rule.

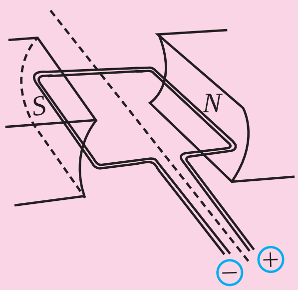


(i) For what purpose is Fleming's left hand rule used?

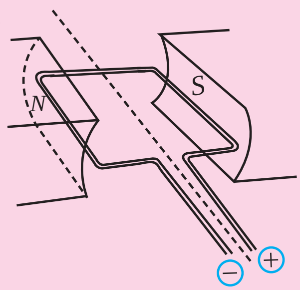
(ii) Directions of what physical quantities are represented by the fingers *A*, *B* and *C* in the above figure?

(iii) Write down what happens to the wire in the following cases using Fleming's left hand rule.

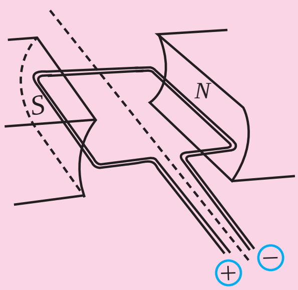
(a)



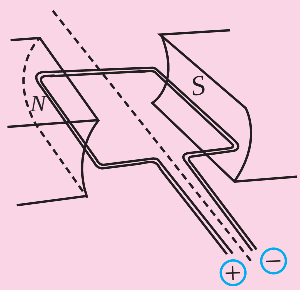
(b)



(c)



(d)



(2) The figure below shows the cross section of a loud speaker.

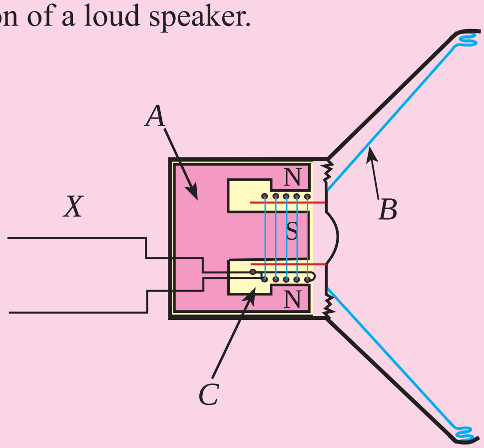
(i) Label parts *A*, *B* and *C* of the figure.

(ii) Write down a special characteristic of the current entering from the terminal *X*.

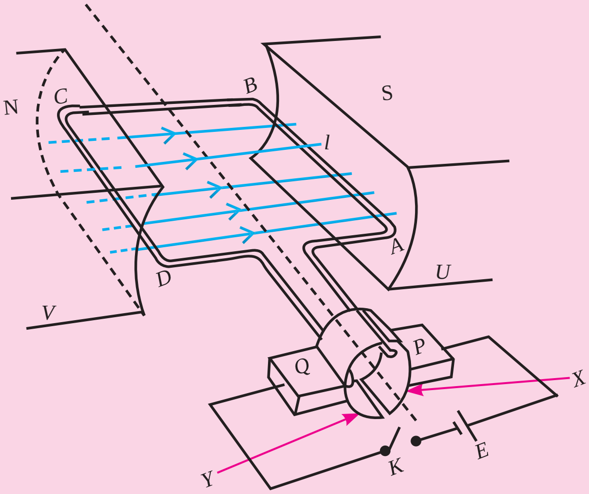
(iii) Explain the operation of the loud speaker.

(iv) Write down the energy transformation taking place in a loud speaker.

(v) Write down the functions of each of the parts *A*, *B* and *C*.



(03) The figure below shows the main parts of a DC motor.



(i) Label parts *P*, *Q* of the above figure.

(ii) What are the components labeled *X* and *Y*?

(iii) Indicate the direction of current flow in terms of the letters given when the switch *K* is closed.

(iv) What is the direction of rotation of the motor when switch *K* is closed?

(v) Write down the functions of each of the components given below in the motor above.

(a) *V* and *U* (b) *E* (c) *P* and *Q* (c) *X* and *Y*

(vi) Write down the changes that take place in the operation of the motor under each of the changes given below.

(a) Interchanging the battery terminals
(b) Increasing the strength of the magnet

13.3 Electromagnetic Induction

We studied the motion caused by electricity in the previous section. We will next focus on producing an electric current by a conductor that is moving in a magnetic field.

When there is a current flow through a conductor placed in a magnetic field, a force is exerted on the conductor causing it to move. Electromagnetic induction is the inverse of this. That is, if a conductor placed in a magnetic field is set in motion, then an electromotive force is created between the terminals of the conductor.

The generation of an electromotive force between the terminals of a conductor when the conductor is kept at rest in a changing magnetic field or when the conductor is moving in a constant magnetic field is known as **electromagnetic induction**.

Electromagnetic induction was first introduced to the world by Michael Faraday. An important law known as Faraday's law regarding this was presented by him in 1831.

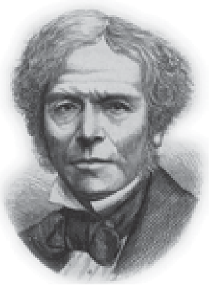


Figure 13.24 – Michael Faraday (1791 - 1867)

The phenomenon of electromagnetic induction is used in magnetic cards used to enter shops and offices by employees, and the magnetic cards (credit and debit cards) used to make payments. Electricity, essential for the daily activities of the modern world, is mainly generated by converting the energy produced from sources such as oil, coal and nuclear power into electric energy through electromagnetic induction.

Figure 13.25

Let us now demonstrate electromagnetic induction by a simple activity.

Activity 13.5

Apparatus required: A bar magnet, The inner tube from a reel of thread, About one metre length of gauge 28 copper wire, A center zero galvanometer

- Form a coil by winding the copper wire around the thread reel and connect its two ends to a center zero galvanometer.
- Now do the movements given in the table below and fill the table by observing whether there is a deflection in the galvanometer or not.
- Observe the relative magnitudes of the deflections in steps 8 and 9.

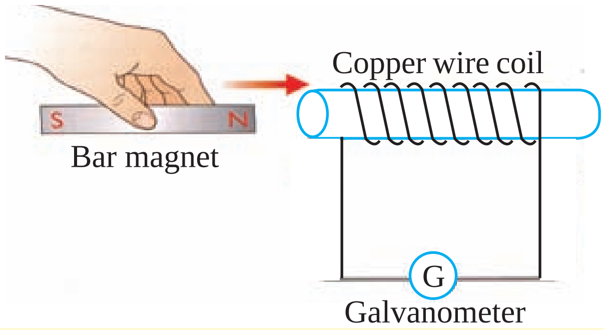


Figure 13.26 – Demonstrating electromagnetic induction

Motion of the magnet	Motion of the coil	Whether there is a deflection in the galvanometer or not
Towards the coil	Stationary	
Stationary near the coil	Stationary	
Away from the coil	Stationary	
Stationary	Towards the magnet	
Stationary	Away from the magnet	
Away from the coil	Away from the magnet	
Towards the coil	Away from the magnet (without changing gap)	
Rapidly towards the coil	Stationary	
Slowly towards the coil	Stationary	

It can be seen from the above activity that there is a deflection in the galvanometer for every motion where there is a change in the relative distance between the coil and the magnet.

- The galvanometer produces a deflection when there is a current passing through it. In order to create a current, there must be a source of electromotive force in the circuit. However there is no such source in the circuit above.
- In this case, an electromotive force has been created by the relative motion between the coil and the magnet. Such an electromotive force is known as an **induced electromotive force**.
- When the magnet and the coil get closer to each other or further away from each other, the magnetic field lines linked to the coil either increase or decrease. Since a deflection is observed in the galvanometer only at such instances, one can conclude that there must be a variation in the magnetic field lines linked to the coil in order to induce an electromotive force.

- A larger deflection is observed in the galvanometer when the magnet is moved rapidly than when it is moved slowly because the electromotive force induced in the coil is directly proportional to the rate of change of the magnetic field lines.

There are several factors affecting the magnitude of the induced electromotive force. Faraday's experiments showed these factors as,

(i) the number of turns (windings) in the coil,
(ii) strength of the magnet, and
(iii) speed of motion of the magnet or coil.

13.3.1 Direction of the current induced in a straight conductor placed in a magnetic field and connected to a closed circuit

When a straight conductor is placed in a magnetic field perpendicular to the field and moved in a direction perpendicular to both the magnetic field and the conductor, an electromotive force is induced across the ends of the conductor. If the conductor is connected to a closed circuit, a current flows through the conductor due to the induced electromotive force. The direction of current flow can be found using Fleming's right hand rule.

- **Fleming's right hand rule**

When the first three fingers of the right hand are oriented perpendicular to one another and the thumb is pointed in the direction of motion of the conductor and the index finger along the direction of the magnetic field that intersects the conductor, the middle finger shows the direction of the current flowing through the conductor.

Figure 13.27 illustrates the right hand rule.

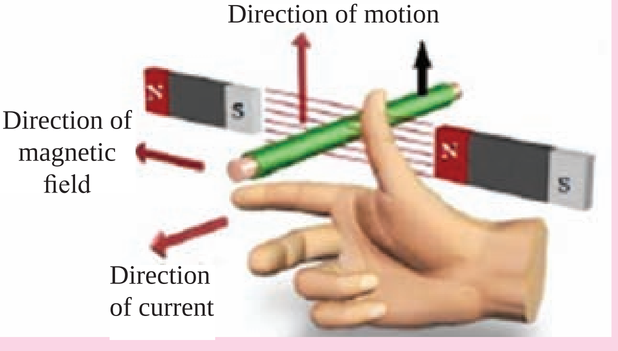
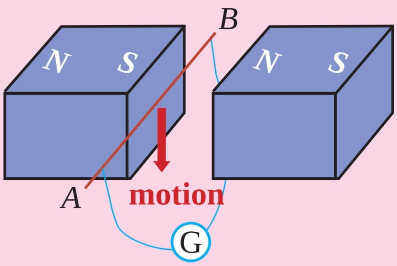


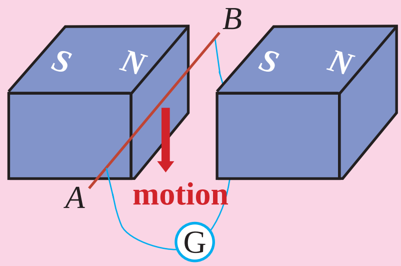
Figure 13.27 – Illustrating Fleming's right hand rule

Exercise 13.3

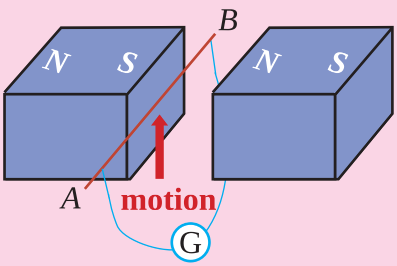
(01) Find and mark the direction of induced current flow using Fleming's right hand rule in each of the instances given below.



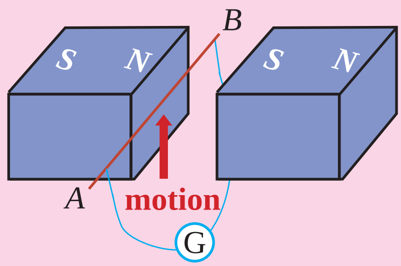
(i)



(ii)



(iii)



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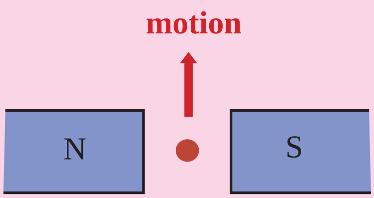

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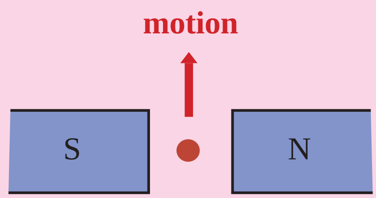

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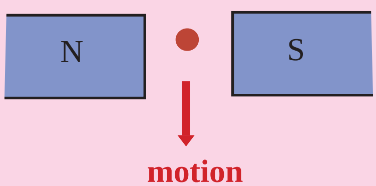

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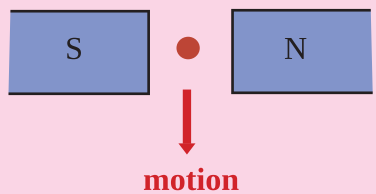


(viii)

13.3.2 Applications of Electromagnetic Induction

- **Alternating current dynamo**

Figure 13.28 shows an alternating current dynamo. A rectangular coil *ABCD* consisting of a number of turns of an insulated copper wire wound around it is connected to an axle that can be rotated around its axis. A strong magnetic field is applied across the coil using a north and a south pole placed on either side of the coil as shown in the figure. Terminal *A* of the coil *ABCD* is fixed to a coaxial copper ring *P* and the other terminal *D* is fixed to another identical copper ring *Q*. *P* and *Q* are known as brushing rings.

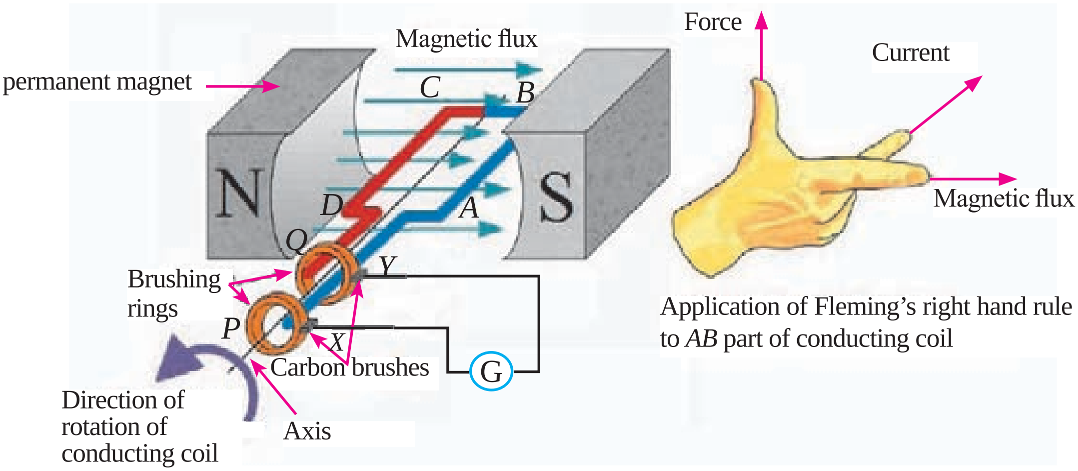


Figure 13.28 – Induced current in a conducting loop rotating in a magnetic field

Two brushes *X* and *Y* made of carbon are mounted in such a way that they brush against the brushing rings. The coil is connected to the external circuit which consists of a center zero galvanometer through the brushes *X* and *Y*. The part consisting of the coil *ABCD*, brushing rings and the axle is known as **the armature**.

Since the arms *AB* and *CD* of the coil intersect the magnetic field across the coil when the coil is rotating, an electromotive force is induced across these arms. Since the circuit is closed, a current passes through the arms *AB* and *CD* of the circuit and the direction of this induced current can be found using Fleming's right hand rule. If the coil is rotated in an anticlockwise direction as shown in the figure, according to Fleming's right hand rule the induced current flows from *A* to *B* since the arm *AB* is moving up and from *C* to *D* since the arm *CD* is moving down. Since both currents through the arms *AB* and *CD* are induced in the same cyclic direction, a current flows through the coil in the direction *ABCD*. The current flow across the galvanometer in the external circuit is from *Y* to *X*. Then the galvanometer indicator deflects to the left.

Figure 13.29 shows how the induced voltage in the coil varies with time when the *ABCD* coil shown in Figure 13.28 is rotated anti-clockwise in the magnetic field.

The upper part of the figure 13.29 shows how the coil (armature) rotates in the magnetic field.

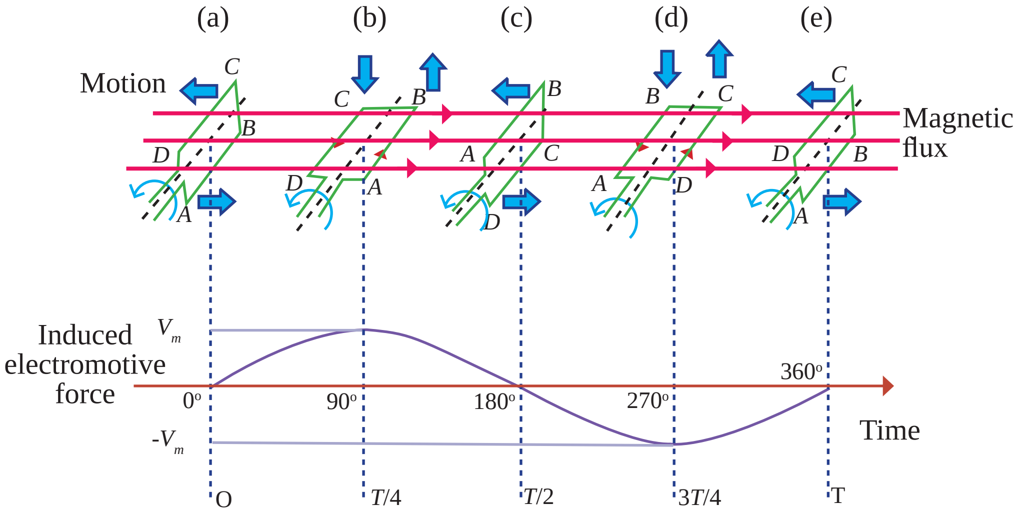


Figure 13.29 – Production of an alternating current

- Since the arms *AB* and *CD* are moving parallel to the magnetic field when the rotating coil is in position (a), the conductors do not intersect the magnetic field lines. Therefore an electromotive force is not induced in the arms *AB* and *CD*. Therefore the galvanometer does not show a deflection.
- While the coil is rotating from position (a) to position (b), the rate at which the field lines are intersected by the coil increases. Therefore, the galvanometer deflection increases accordingly.
- Position (b) is the position of the coil after the coil has rotated by 90° from position (a). At this position, the field lines are intersected perpendicularly by the coil in the upward motion of *AB* and downward motion of *CD*. Then a current flows in the direction *ABCD* as described above causing a deflection to the left of the galvanometer.
- While the coil is moving from position (b) to position (c), the coil is rotating from 90° to 180° and the electromotive force during this period keeps decreasing and becomes zero at position (c). When the coil rotates from position (c) to (d), the coil is rotating from 180° to 270°. During this time *AB* moves down and *CD* moves up intersecting the field lines. Using Fleming's right hand rule one can find that the induced currents flow from *D* to *C* and *B* to *A*. Therefore, the induced current flows through the coil in the direction *DCBA*. This causes a deflection to the right hand side of the galvanometer in the external circuit.

Since the induced electromotive force becomes maximum in the horizontal positions of the coil when the field lines are intersected perpendicularly (in positions (b) and (d) when plane *ABCD* of the coil is parallel to the magnetic field), the current flow becomes maximum at those positions. The induced electromotive force becomes zero for vertical positions of the coil (positions (a), (c) and (e)).

When the coil rotates continuously in this manner, it can be seen that the current flow in the external circuit alternates its direction. We can see that the direction of current flow oscillates periodically since the galvanometer deflects to the left in (b), becomes zero in (a), (c) and (e) and deflects to the right in (d) repetitively. That is, the current changes its direction in each half cycle during one complete cycle of rotation of the coil. The variation of this alternating current or the induced electromotive force with time can be represented by a sinusoidal wave as shown in Figure 13.28.

When the plane of the coil is parallel to magnetic field, the EMF becomes a maximum in + or – direction. when the plane of the coil is perpendicular to the magnetic field, EMF becomes zero.

• Moving coil magnetic microphone

Figure 13.30 shows a diagram of a moving coil magnetic microphone. When a sound reaches the diaphragm of the microphone, the diaphragm vibrates in and out. Then the light coil attached to it also vibrates accordingly. Since the coil vibrates in a magnetic field, the magnetic flux linked to the coil changes inducing an electromotive force in the coil. Since the coil moves in both directions, the direction of the electromotive force alternates. This generates a small alternating current (flowing in both directions) in the microphone that varies corresponding to the variations of the sound reaching the diaphragm.

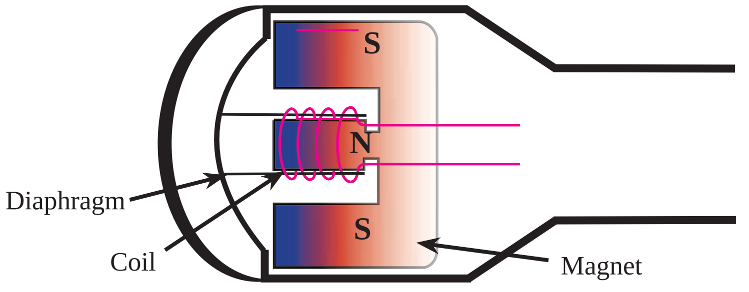


Figure 13.30 – Cross section of a moving coil microphone

• Bicycle Dynamo

Figure 13.31 shows the internal components of a bicycle dynamo. When its rough head is arranged to touch a tire of a bicycle, it rotates fast when the tire is rotating.

Then the cylindrical magnet connected to the rough head also rotates. Since the magnetic field linked to the coil wound around the soft iron changes now, an electromotive force is induced in the coil.

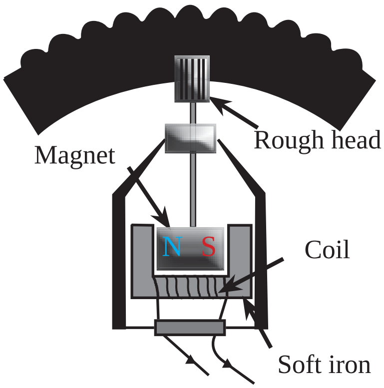


Figure 13.31 – A bicycle dynamo

As a result of winding the dynamo coil around a soft iron it is possible to link most of the magnetic field lines through the coil which increases the induced electromotive force.

Since the direction of the magnetic field alternates when the magnet rotates, the direction of the induced current also alternates its direction. Therefore the output from a bicycle dynamo is an alternating current.

When the bicycle is ridden fast, the speed of the wheels increases. Then the head of the dynamo which is in contact with the tire also rotates fast increasing the rotation speed of the magnet. The increased rate of change of the magnetic field linked to the coil increases the induced electromotive force which gives rise to a larger current. Therefore, the brightness of the bicycle lamp increase with the speed of the bicycle.

An energy transformation takes place in a dynamo. In order to generate electricity, the dynamo has to be rotated. Therefore in a dynamo, the energy is converted from mechanical energy to electric energy.

13.3.3 Direct Currents and Alternating Currents

Figure 13.32(a) shows a circuit connecting a battery, a resistor and a center-zero galvanometer in series. (The resistor prevents a large current from passing through the galvanometer). The constant deflection of the galvanometer will show that the current in the circuit is constant. When the current is plotted against time, a straight line can be obtained as shown in figure 13.32(b).

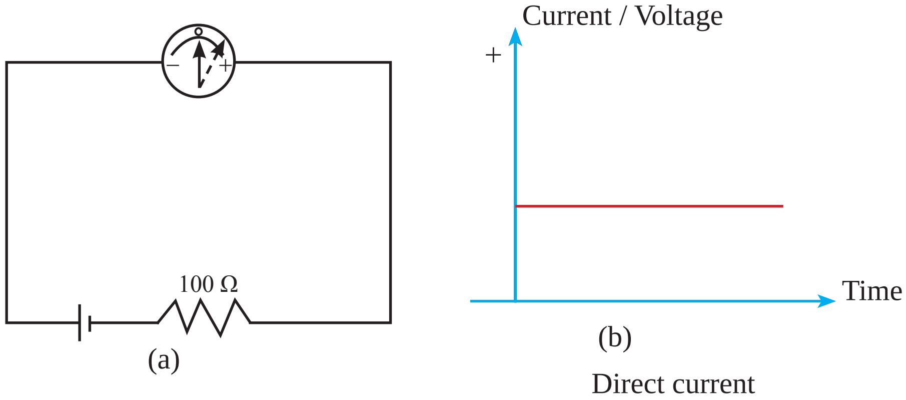


Figure 13.32 – A DC current circuit

If we connect a resistor and a center zero galvanometer in series to the alternating current dynamo discussed above as shown in Figure 13.33(a) and slowly rotate the armature of the dynamo, you will observe that the galvanometer indicator would oscillate in the positive and negative directions around the zero. Therefore when the current (or voltage) is plotted against time, a curve such as that shown in Figure 13.33(b) will be obtained.

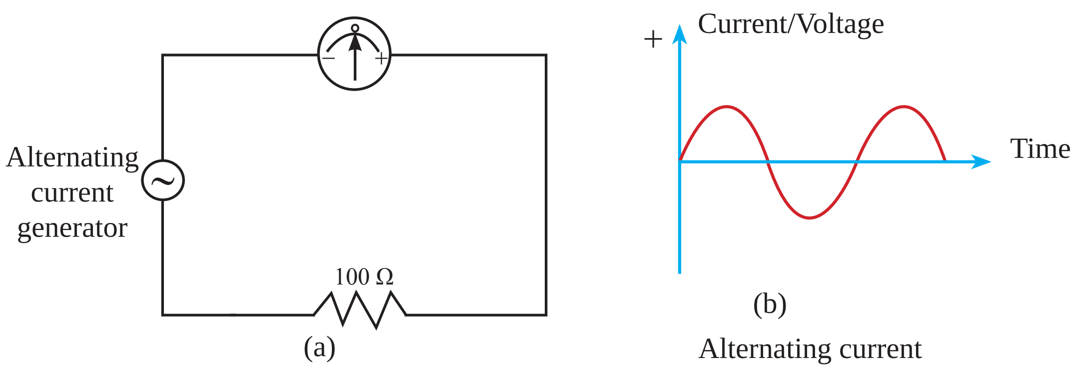


Figure 13.33 – An alternating current circuit arrangement

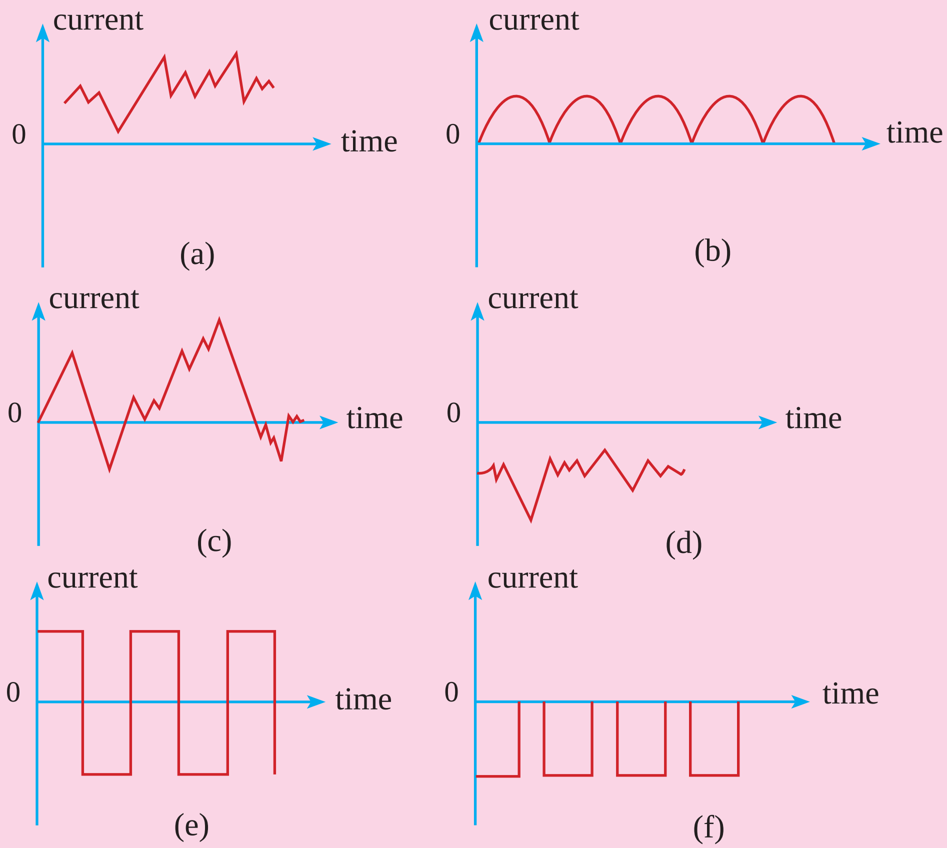
In the first case (Figure 13.39) the direction of current flow does not vary with time. Such currents whose direction does not vary with time are known as **direct currents**.

In the second case (Figure 13.33) the direction of current flow varies with time and such currents whose direction varies with time are known as **alternating currents**.

Exercise 13.4

(1) Write down some instances where alternating currents and direct currents are used.

(2) Several graphs showing the variation of current with time are given below. Indicate which type of current is represented by each of them giving reasons for your answer.



13.3.4 Transformers

Transformers are useful because they allow you to change the voltage of a supply. Transformers are used in power packs and in electric appliances such as computers and radios.

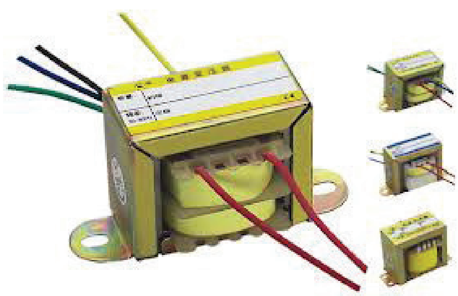


Figure 13.34

Activity 13.6

Apparatus required: about two meters of copper wire of gauge 28, a bundle of soft iron wires, two dry cells, a center zero galvanometer, a switch

- Wrap about 100 turns of insulated copper wire around the bundle of soft iron wires in order to form a coil as shown in the figure.
- Now form another similar coil on the same soft iron wire rope at about a distance of one centimeter from the first.

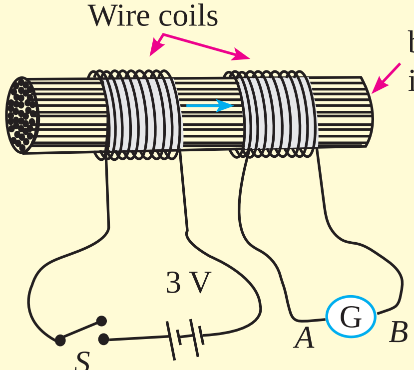


Figure 13.35

- Connect a switch and two 1.5 V dry cells in series to one of the two coils above. Connect the other coil to a center zero galvanometer.
- Now observe the deflection of the galvanometer by turning the switch *S* on and off and fill the table given below by crossing off the incorrect words.

Switch *S*	Galvanometer deflection	Conclusion
Turned on	Deflects to the right/left	A current flows in the second circuit from A to B/B to A.
Turned on continuously	There is a/no deflection	A current flows/does not flow.
Turned off	Deflects in the opposite direction (to the left/ right)	A current flows/does not flow in the opposite direction.
Turned off continuously	There is a/no deflection	A current flows/does not flow.

You will be able to draw the following conclusions from the above activity.

- A current is induced in the second circuit at the instant that a current starts to flow in the first circuit.

- When the current in the first circuit is flowing continuously, the current in the second circuit ceases to flow.
- At the instant that the current flow through the first circuit is turned off, a current is induced in the second circuit in a direction opposite to the direction of current flow before.
- When the current flow in the first circuit ceases, the induced current in the second circuit becomes zero.

In this activity there is no magnetic field through the coils before a current passes through the first coil. A magnetic field is generated when a current begins to flow through the first coil. This magnetic field also passes across the second coil through the soft iron wires. As a result of this change in the magnetic field through the second coil, an electromotive force is induced in it which causes a current to flow through the galvanometer giving rise to a deflection in the galvanometer.

When a current is continuously flowing through the first circuit, the magnetic field remains constant and there is no variation in the magnetic field through the second coil. Therefore an electromotive force is not induced in it. Then the galvanometer deflection is zero.

When the switch in the first circuit is opened, the current flow is terminated. The magnetic field caused by the current too diminishes together with the current. As a result of the diminished magnetic field, the magnetic field through the second coil changes and therefore an electromotive force is induced in the second coil. This induced electromotive force has a direction opposite to that of the previous occasion. Therefore the galvanometer deflection occurs in the opposite direction.

When there is no current flow through the first coil, an electromotive force is not induced in the second coil as there is no variation in the magnetic field. Therefore the galvanometer deflection is zero. Therefore we can conclude that an electromotive force is induced in the second coil whenever there is a “change” caused by the first coil in the magnetic field through the second coil.

If we connect an alternating voltage to the first coil, instead of a battery, then as the magnetic field varies continuously, a similar alternating voltage difference is induced in the second coil too. Such a combination of coils linked by a magnetic field is known as a **transformer**. Transformers only work with ac currents and ac voltages. They will not work with dc currents and dc voltages. Transformers work with alternating currents or voltages and with changing direct currents only. They do not work with cons that direct currents.

The figure below shows the symbol used to represent a transformer in circuit diagrams.

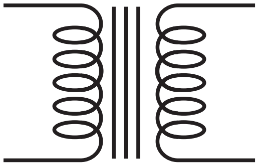


Figure 13.36

The straight lines between the two coils represent the soft iron core.

• Construction of a Transformer

Figure 13.37 shows a simple arrangement of a transformer. It has two insulated copper coils wrapped around a soft iron ring.

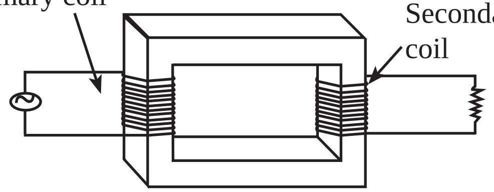


Figure 13.37 – A Simple transformer

Primary coil	Secondary coil
Number of turns N_P	Number of turns N_S
Electromotive force V_P	Induced electromotive force V_S

Normally one coil of a transformer is connected to an alternating power supply while the other is connected to a load (a resistor or an electric appliance operated with an alternating power supply). The first coil that supplies power to the transformer is known as the primary coil or the "**input**". The second coil from which power is taken out of the transformer is known as the **secondary coil** or the "**output**". The voltage supplied to the primary is denoted by V_P and the voltage given out by the secondary is denoted by V_S.

The alternating voltage V_P applied to the primary gives rise to an alternating current flow in the primary circuit which in turn gives rise to an alternating magnetic field. This alternating magnetic field is linked to the secondary coil by the soft iron core and this varying magnetic field induces an alternating voltage V_S in the secondary coil.

The relation between the voltages and the number of turns of a transformer can be expressed as follows.

$$\frac{\text{Number of turns in the primary}}{\text{Number of turns in the secondary}} = \frac{\text{Voltage difference in the primary coil}}{\text{Voltage difference in the secondary coil}}$$

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

According to this relationship, by varying the ratio between the number of turns N_P in the primary and the number of turns N_S in the secondary, an output voltage larger than or smaller than the input voltage can be obtained.

- **Step-up Transformers and Step-down Transformers**

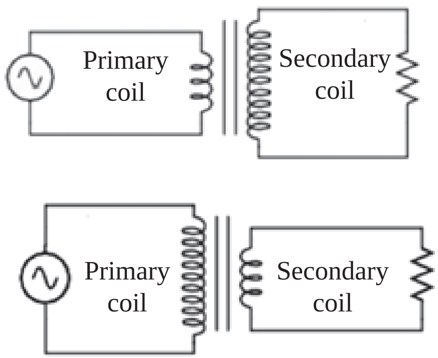


Figure 13.38

Transformers that give an output voltage larger than the input voltage are called **step-up transformers**. They have a larger number of turns in the secondary coil than that in the primary coil.

Transformers that give an output voltage smaller than the input voltage are called **step-down transformers**. They have a smaller number of turns in the secondary coil than that in the primary coil.

- **Applications of transformers**

- Alternating current electricity generated in electric power stations are stepped up to high voltages such as 132 000 V (132 kV) or 220 000 V (220 kV) using step-up transformers before supplying to the national power grid.
- Step-down transformers are used in power substations that distribute power obtained from main power transmission stations to homes.

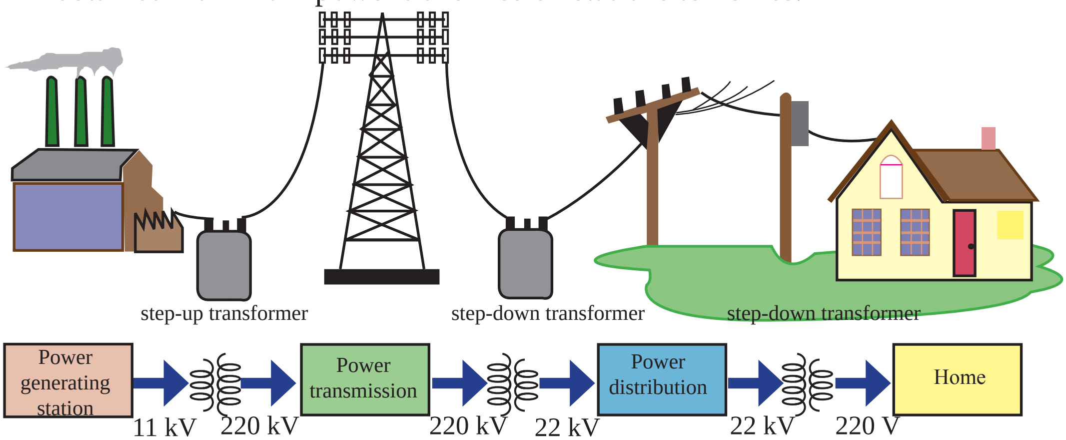


Figure 13.39

- In order to obtain high voltages used in microwave ovens and X ray tubes, step-up transformers are used.
- They are also used in power packs and in electric appliances such as computers and radios.

- **Energy Relation in a Transformer**

The efficiency of any instrument is not 100% as they produce other forms of energy (such as heat) apart from what they are intended for. In transformers too, all the energy supplied to the primary cannot be obtained from the secondary. However we will assume here that there is no energy loss in the transformer. Then according the law of energy conservation, efficiency will be 100%. Then the power of the primary coil is equal to the power of the secondary coil.

Power = **Potential difference** × **Current**

Therefore following relationship is obtained.

Energy supplied to the primary = Energy obtained from the secondary

In this equation,

$$\therefore V_P I_P = V_S I_S$$

I_p = current in the primary coil
I_s = current in the secondary coil
V_p = Voltage in the primary coil
V_s = Voltage in the secondary coil.

Example

A certain transformer has 500 turns in its primary coil and 5000 turns in its secondary coil. A voltage difference of 12 V is supplied to the primary coil.

(i) Find the voltage difference of the secondary coil.
(ii) If a 2 A current passes through the primary. calculate the current in the secondary coil.
(iii) Which type of a transformer is this?

(i) $N_p = 500,\ N_s = 5000,\ V_p = 12\text{ V},\ V_s = ?$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{V_p N_s}{N_p}$$

$$V_s = \frac{12\text{ V} \times 5000}{500}$$

$$V_s = 120\text{ V}$$

(ii) $V_p = 12\text{ V},\ V_s = 120\text{ V},$
$I_p = 2\text{ A},\ I_s = ?$

From $V_p I_p = V_s I_s$

$$I_s = \frac{V_p\ I_p}{V_s}$$

$$I_s = \frac{12\text{ V} \times 2}{120\text{ V}}\text{A}$$

$$I_s = \frac{2}{10}\text{ A}$$

$$I_s = 0.2\text{ A}$$

(iii) This is a step-up transformer.

Summary

- The direction of the magnetic field existing in the vicinity of a current carrying conductor can be found using the corkscrew rule.
- When a corkscrew is rotated in such way that it moves in the direction of current flow, then the direction of rotation gives the direction of the magnetic field lines.
- A force acts on a current carrying conductor placed in a magnetic field.
- This force is directly proportional to three factors; current flowing through the conductor, length of the conductor and the strength of the magnetic field.
- Fleming's left hand rule can be used to find the direction of the force acting on the conductor.
- According to Fleming's left hand rule, when the thumb, index finger and the middle finger of the left hand are oriented perpendicular to one another so that the middle finger points in the direction of current flow and the index finger is pointed in the direction of the magnetic field, the thumb is pointed in the direction of the force acting on the conductor.
- The operation of instruments such as the DC motor and the loud speaker are based on the force acting on a current carrying conductor placed in a magnetic field.
- In the operation of a motor, electric energy is converted into mechanical energy.
- The generation of an electromotive force in a closed circuit due to a variable magnetic field is known as electromagnetic induction.
- The magnitude of the induced electromotive force depends on the number of turns in the coil, the strength of the magnetic field and the speed of the moving magnet.
- In order to find the direction of current flow due to the induced electromotive force in a straight conductor, Fleming's right hand rule can be used.
- According to Fleming's right hand rule, when the thumb, index finger and the middle finger of the right hand are oriented perpendicular to one another so that the index finger is pointed in the direction of the magnetic field, the thumb is pointed in the direction of motion, then the middle finger points in the direction of current flow through the conductor.
- Bicycle dynamo, moving coil microphone and the transformer are instruments whose operations are based on electromagnetic induction.

- A current whose direction does not depend on time is a direct current.
- A current whose direction depends on time is an alternating current.
- Dry cells and solar cells produce direct currents while the alternating current dynamo produces an alternating current.
- Using a transformer, an alternating voltage can be changed from one value to another value.
- Relations between the primary and secondary coils of a transformer is given by

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \qquad V_p I_p = V_s I_s$$

Exercise 13.5

(1) The primary coil of a transformer has 1000 turns while its secondary coil has 100 turns. An alternating current with a voltage difference of 230 V is supplied to the primary coil. Find the following, assuming that there is no energy loss in the transformer.

(i) The maximum voltage that can be obtained from the secondary.
(ii) Current output of the secondary if the current input of the primary is 5 A.

(2) In a certain transformer the number of turns in the primary coil is 5000 and that in the secondary coil is 500. A voltage difference of 230 V is supplied to the primary coil. If the efficiency of the transformer is 100%,

(i) Find the output voltage of the secondary.
(ii) Find the current input of the primary if the current output of the secondary is 10 A.

(3) The ratio between the number of turns in the primary coil and the secondary coil in a certain transformer is 1:10. An alternating current with a voltage difference of 6 V is supplied to the primary coil. An output current of 20 A is required from the secondary. Find the following assuming that the efficiency of the transformer is 100%.

(i) Voltage output of the secondary.
(ii) Current input to the primary.
(iii) Ratio between the primary voltage and the secondary voltage.
(iv) Ratio between the primary current and the secondary current.

(4) There are many useful applications for electromagnetic induction. The following figure shows a set up used to model the phenomenon of electromagnetic induction.

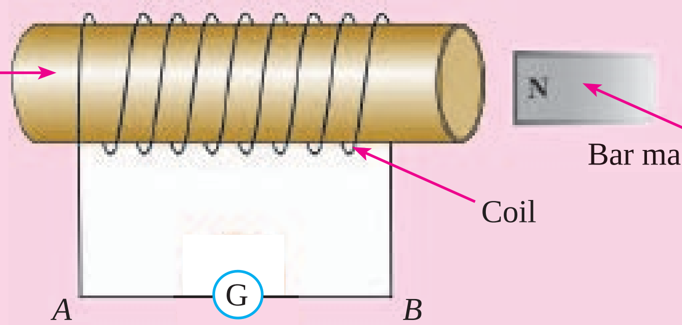


Figure 13.40

(i) Describe electromagnetic induction in a simple manner.

(ii) When the north pole of the bar magnet was brought towards the coil rapidly, a deflection was observed to the right hand side in the center zero galvanometer (G). Is the current flowing through the galvanometer from *A* to *B* or *B* to *A*?

(iii) What is the direction of deflection of the galvanometer when the bar magnet is moved away from the coil?

(iv) What is the direction of deflection of the galvanometer if the South pole of the bar magnet is moved towards the coil?

(v) Write down three factors that the strength of the current flowing through the galvanometer depends on.

(5) The internal components of a bicycle dynamo are shown in the figure below.

(i) Label the parts *A*, *B*, *C* and *D*.

(ii) What is the principle that the operation of a dynamo is based on?

(iii) Describe the operation of the dynamo.

(iv) Is the current output of a dynamo a direct current or an alternating current?

(v) Draw a rough sketch to show the variation of the voltage output of this current with time.

(vi) The brightness of a bicycle lamp depends on the speed at which the bicycle is being ridden. Explain how this happens.

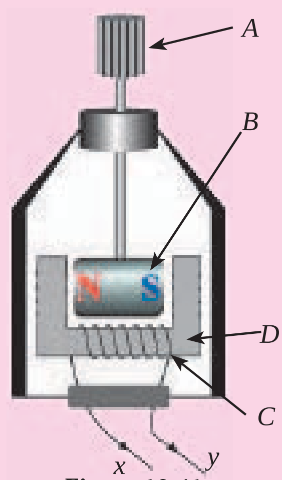


Figure 13.41

(vii) Write down the energy transformation that takes place when a bicycle lamp is lit up using the bicycle dynamo.

(6) The figure below shows a moving coil galvanometer. Name the components labeled as *A*, *B*, *C* and *D* and describe the function of each of them.

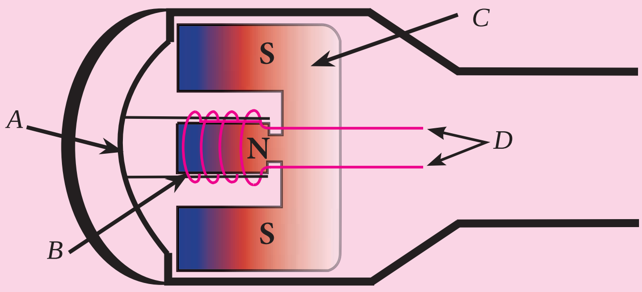


Figure 13.42

Technical terms

Magnetic field	- චුම්බක ක්ෂේත්‍රය	- காந்தப்புலம்
Step - up transformer	- අධිකර පරිණාමකය	- படிகூட்டு நிலைமாற்றி
Step - down transformer	- අවකර පරිණාමකය	- படி குறை நிலைமாற்றி
Magnet	- චුම්බකය	- காந்தம்
Power	- ජවය	- வலு
Coil	- දඟරය	- சுருள்
Transformer	- පරිණාමකය	- விரியலாக்கி
Alternating current	- ප්‍රත්‍යාවර්තක ධාරාව	- ஆடலோட்டம்
Electro magnetic induction	- විද්‍යුත් චුම්බක ප්‍රේරණය	- மின்காந்த தூண்டல்
Induced current	- ප්‍රේරිත ධාරාව	- தூண்டல் மின்னோட்டம்
Electromotive force	- විද්‍යුත්ගාමක බලය	- மின்னியக்கவிசை

Hydrocarbons and Their Derivatives

Chemistry 14

14.1 Hydrocarbons

Figure 14.1 shows some items that we use in our day to day life.


Plastic goods


Food items


Tyres


Clothes


Paints


Cosmetics


Agro-chemicals

Figure 14.1

When considering the composition of all of the above materials, presence of carbon as a component element seems to be a common feature. Carbon is also abundant in the plants and animals that we find in our environment and all the materials obtained from those sources.

Elements combine with one another in different ways to create a very large number of compounds. Quite a majority of them are compounds formed by the combination of carbon with other elements.

Because of the abundance of carbon containing compounds and the special chemical characteristics shown by those compounds, carbon chemistry (organic chemistry) is studied as a separate section under chemistry.

The compounds contaning carbon are commonly referred to as organic compounds [But, the oxides of carbon, namely carbon dioxide (CO_2) and carbon monoxide (CO) and carbonates and bicarbonates such as sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) are not considered organic]. Organic compounds necessarily contain carbon and in addition, they may contain elements like hydrogen, oxygen, nitrogen, halogen, phosphorus and sulphur.

For the convenience of study, organic compounds are classified in various ways. One method is classifying on the basis of the component elements in the organic compound. On this basis, the simplest group of organic compounds are hydrocarbons which contain carbon and hydrogen only.

Assignment 14.1

List several types of fuels that are used in day to day life. Investigate into the chemical composition (the elements they contain) of those fuels.

Compare the list you prepared with the following table.

Table 14.1

Fuel	Elements present
Wax	C, H
Petrol	C, H
Methane	C, H
L.P. gas	C, H
Kerosene	C, H
Diesel	C, H
Firewood	C, H O, N

It is seen that every fuel in the above table contain carbon and hydrogen.

Let us do the following activity to examine whether wax contains carbon and hydrogen.

Activity 14.1

Confirming the pressure of carbon and hydrogen in candle wax

Materials required :- connecting tubes, beaker, aspirator, Lime water, copper sulphate, U - tube, test tube.

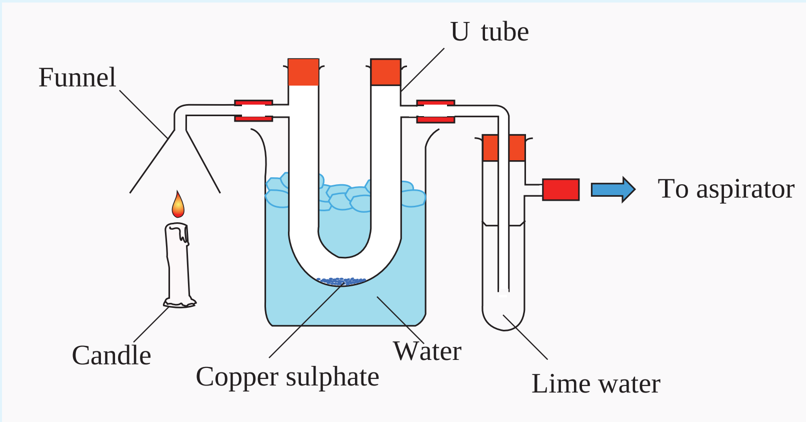


Figure 14.2

Set the apparatus as shown in figure 14.2, light the candle, connect the apparatus to the aspirator and make air pass through.

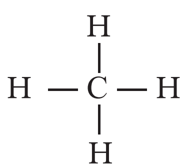
It will be seen that, the anhydrous copper sulphate contained in the U tube turns from white to blue. This change in colour was brought about by the water produced during the burning of the candle. Hydrogen required to produce that water was supplied by candle wax. This verifies the presence of hydrogen in wax.

Also, it can be observed that the limewater contained in the test tube on the right hand side turns milky. Therefore, carbon dioxide gas has been produced during the burning of the candle. The source of carbon in that carbon dioxide is wax.

This confirms the presence of carbon (C) and hydrogen (H) in candle wax.

All the countries in the world meets their energy requirements by using petroleum fuels produced by the distillation of crude oil. All compounds in those fuels are hydrocarbons. Based on the structure, hydrocarbons are classified as alkanes, alkenes and alkynes.

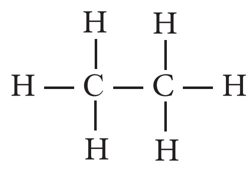
- ## Alkanes



Have you heard that bio gas produced using the waste disposed from poultry farms is used as a fuel? The main component of it which is important as a fuel is methane gas. This gas is also present in the marsh gas produced when organic matter decays in marshes.

This is the simplest hydrocarbon and has the formula CH_4. Its structure is shown in the figure.

During the mining of mineral oils, the gas ethane comes out from oil wells. Ethane is also a hydrocarbon. Its formula is C_2H_6. The structure corresponding to this formula is as follows.



Consider the methane and ethane molecules described above. Bonds between carbon atoms and hydrogen atoms (only) are present in the methane molecule. But in the ethane molecule there are bonds between carbon and carbon atoms. The hydrocarbons which have only single bonds between carbon atoms are referred to as alkanes.

Alkanes are a series of compounds. This series has several common characteristics. One of those is that all the compounds in that series can be represented by a common formula.

The common formula of the alkane set is C_nH_{2n+2}. In this, 'n' is the number of carbon atoms in a molecule of the compound. According to the above formula, the formula of the simplest alkane methane can be obtained as follows.

For methane n = 1. Hence the formula of methane is,

$$C_1H_{1 \times 2 + 2} = CH_4$$

In ethane ⟶ n = 2. Hence the formula of ethane is

$$C_2H_{2 \times 2 + 2} = C_2H_6$$

Assignment 14.2

Using the common formula, derive the formulae of alkanes that contain carbon atoms from 1 to 5.

Listed in Table 14.2 are the formulae and names of the alkanes of which the number of carbon atoms varies from 1 to 5.

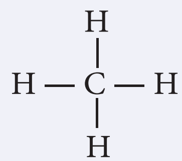
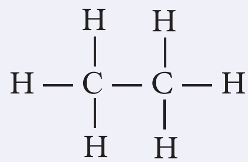
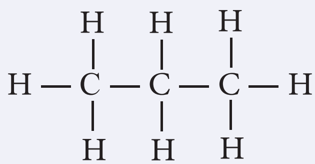
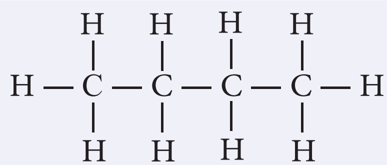
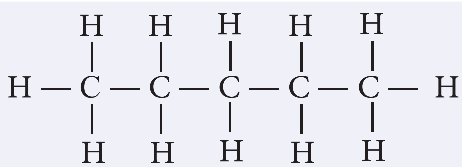
The fuel petrol (gasoline) is a mixture of alkanes. The most abundant alkane in it is octane represented by the formula C_8H_{18}. L.P. gas, another mixture of alkanes/ mainly contain alkanes propane (C_3H_8) and butane (C_4H_{10}).

Table 14.3 presents the molecular formulae and structural formulae of the alkanes with carbon atoms 1 - 5.

Table 14.2

Molecular formula	Name of the alkane
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
C_5H_{12}	Pentane

Table 14.3

Molecular formula	Structural formula
CH_4	
C_2H_6	
C_3H_8	
C_4H_{10}	
C_5H_{12}	

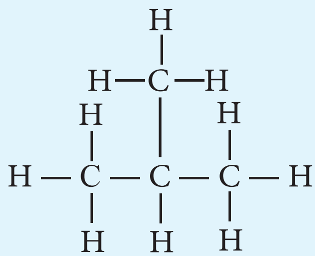
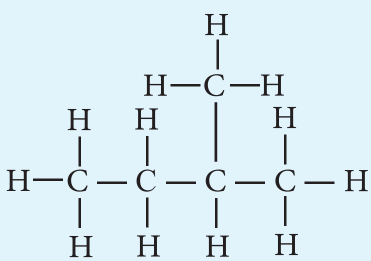
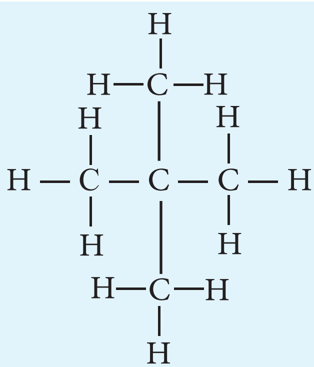
Activity 14.2

Make models of the alkanes with carbon atoms 1 - 5 with the help of your teacher, using suitable materials.

Extra knowledge

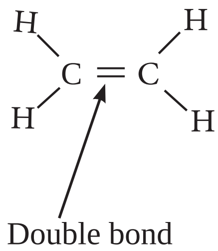
For C_4H_{10} and C_5H_{12}, the following structures are also correct in addition to the structures given in Table 14.3

Table 14.4

Molecular formula	Structural formula
C_4H_{10}	
C_5H_{12}	 

• Alkenes

In alkanes there are only single bonds between carbon - carbon atoms. Also, there are hydrocarbons having double bonds between carbon - carbon atoms. The hydrocarbons of this type with one or more double bonds between carbon - carbon atoms are classified as alkenes. The molecular formula of the simplest alkene ethene is C_2H_4. Its structural formula is given below.

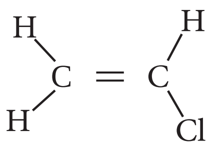


Due to the presence of double bonds between the carbon atoms, alkenes are more reactive than alkanes.

14.2 Derivatives of ethene

- ### Chloroethene

The compound derived by the displacement of a hydrogen atom in ethene by a chlorine atom is called chloroethene. The formula of chloroethene is C_2H_3Cl and its structure is given below.



- ### Tetrafluoroethene

The compound derived by the displacement of the four hydrogen atoms in ethene by four fluorine (F) atoms is known as tetrafluoroethene. Its formula is C_2F_4 and the structure is as follows.

C_2F_4

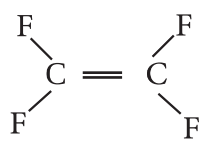
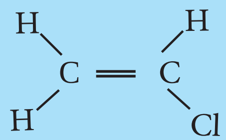
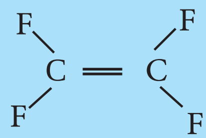


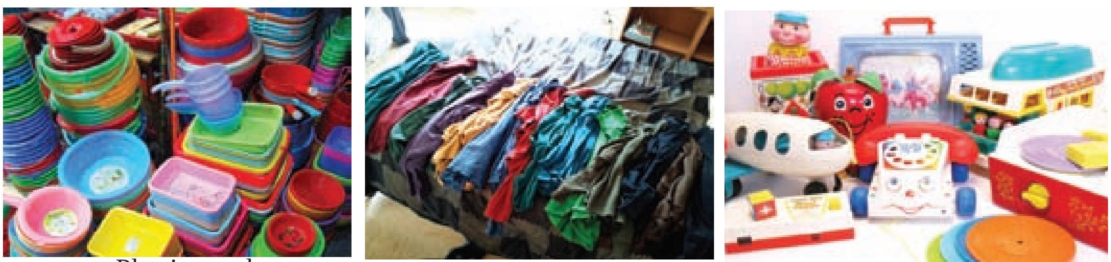
Table 14.4 - Derivatives of ethene

Chloroethene C_2H_3Cl	
Tetrafluoroethene C_2F_4	

Ethene and derivatives of ethene are used to produce the polymers that we use in our day to day life such as polythene, styrofoam and teflon

14.3 Polymers

Pay your attention to the following pictures.



Plastic goods Clothes Toys

Figure 14.3

Let us inquire into the chemical nature of the materials shown in the above pictures that we use frequently in our daily life.

At molecular level, they all have a common special feature. That is, they all are made up of large molecules arranged in the form of long chains. Another speciality is that most of those long chain molecules are composed of repeating small molecular units. Thus, the molecules from which they are made are called polymers. In this lesson, let us discuss about polymers.

Large molecules formed by the joining of a large number of small molecules with one another are known as polymers.

The process of forming polymers is called polymerization. The small molecules forming polymers are known as monomers and the large molecules formed by the polymerization of monomers are referred to as polymers. Pay your attention to the chain formed by joining some paper clips together.

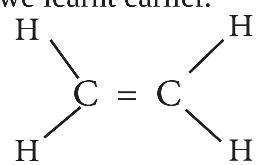
Figure 14.4

The single paper clips used to form the above chain are analogous to monomers and the chain of clips is equivalent to the polymer. The basic structural units contained in the chain after the formation of the polymer are referred to as repeating units. The molecular mass of monomers is relatively low. However, the relative molecular mass of polymers formed by the polymerization of a large numbers of monomers has a very high value.

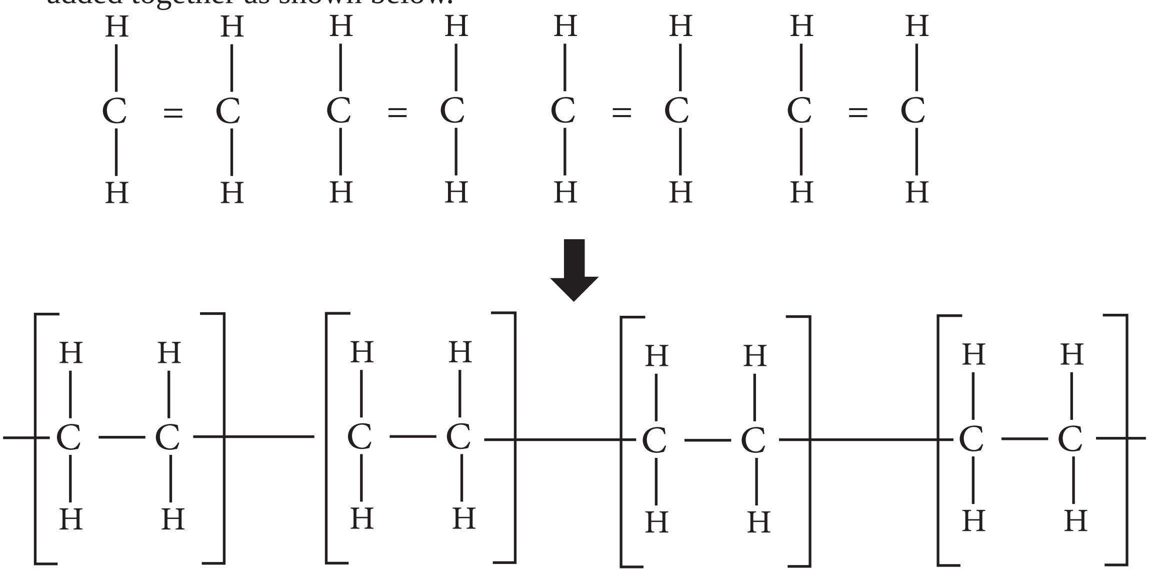
Now, let us investigate into some common polymers.

- **Polythene (Polyethene)**

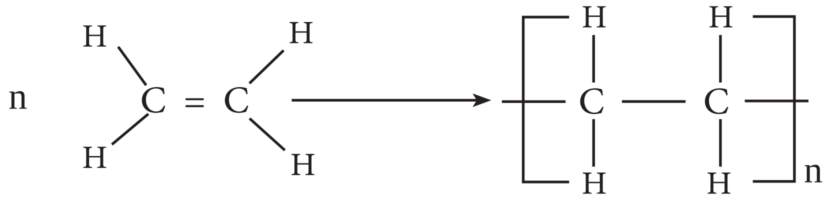
Consider the ethene molecule we learnt earlier.



Polythene is produced by the polymerization of ethene molecules. What happens here? Of the double bond, one bond breaks and thousands of ethene molecules are added together as shown below.



The above polymerization process may be summarized and indicated as follows.

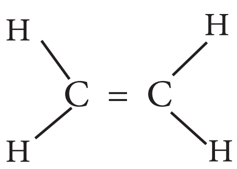


This means that 'n' number of ethene molecules link with one another and create a polythene molecule with 'n' number of $-CH_2-CH_2-$ repeating units.

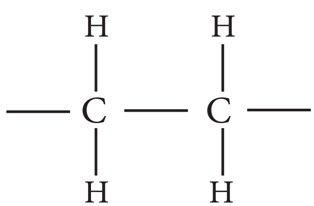
Assignment 14.3

Make a polythene polymer molecule linking appropriately the models of the ethane molecules you have made in assignment 14.2.

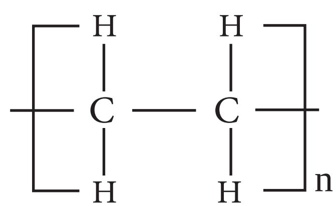
Hence, it may be clear to you that polythene is a macromolecule formed by the linking of a large number of ethene molecules in a specific pattern.
The polymer, monomer and the repeating unit of polythene are given below.



Monomer



Repeating unit

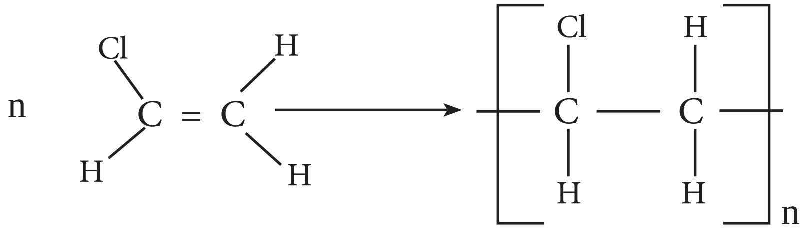


Polymer

Polymers - Very large molecules formed from linking together, a large number of small molecules are named polymers.
Monomers - Small molecules contributing to form polymers are called monomers.
Repeating unit - The basic structural units contained in a polymer are known as repeating units.

- **Polychloroethene (Polyvinyl chloride)**

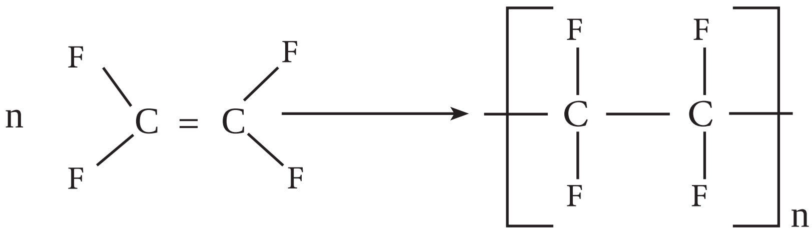
Polymerization of chloroethene gives polychloroethene. This can be summarized as follows.



Try to identify the monomer, repeating unit and the polymer of polychloroethene.

- **Polytetrafluoroethene (Teflon)**

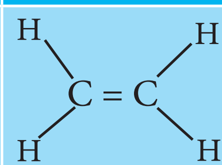
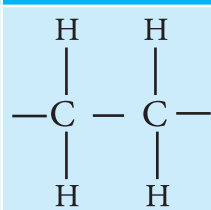
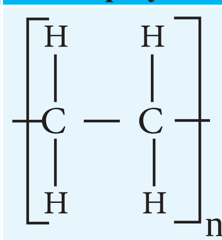
Polytetrafluoroethene is formed by the polymerization of tetrafluroethene. This can be illustrated as follows.

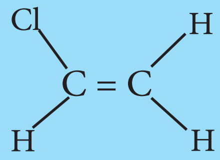
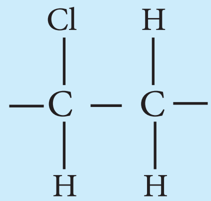
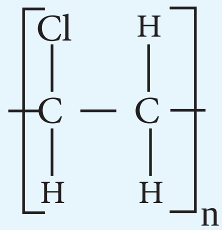
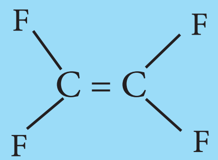
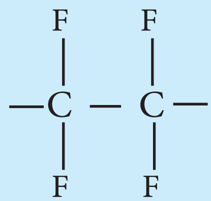
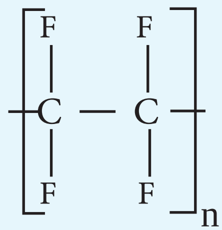


Identify the monomer, repeating unit and the polymer of tetrafluoroethene.

A summary of the polymers you studied is present in Table 14.6

Table 14.6

Polymer	Monomer	Repeating unit	Representation of the polymer
Polythene			

Polychloroethene (PVC)			
Polytetrafluoroethene			

Given in Table 14.6 are the special properties and uses of the polymers which we discussed above.

Table 14.7

Polymer	Special properties	Uses
Polyethene	Electrical insulator, impervious to water and air, light and can withstand tensions, durable	Making plastic bottles, toys, polythene tissues, polythene bags, garbage bins, hard plastic fibers
Polychloroethene (Polyvinyl chloride PVC)	Resistant to fire, electrical insulator, impervious to water, light	Making gutters, water pipes, conduits and flexible pipes
Polytetrafluoroethene (TEFLON)	resistant to heat, electrical insulator	Making non - stick cooking pans, snow shoes

• Classification of polymers based on origin

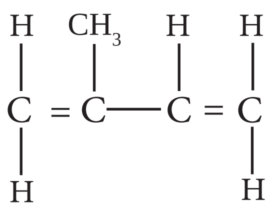
Recall the polymers you studied earlier. All of them are artificially synthesized polymers. Have you heard about natural polymers Pay attention to the bio - molecules you learnt in grade 10. Molecules like proteins, starch, cellulose and DNA are polymers. They belong to the category of natural polymers. Therefore, by origin, polymers can be classified into two types as natural and artificial. Rubber which is frequently used for technical purposes is also a natural polymer. Table 14.7 lists some examples of natural and artificial polymers.

Table 14.8

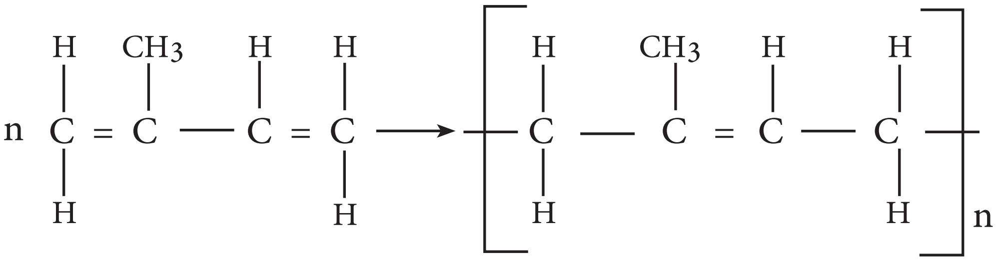
Natural polymers	Artificial polymers
Rubber	Polythene
Protein	Polychloroethene
DNA	Teflon
Starch	Polyester
Cellulose	Nylon
RNA	Terylene
	polystyrene
	Bakelite

- ## Rubber

Rubber is a natural polymer formed by the polymerization of a monomer called isoprene. The structure of an isoprene molecule is given below.



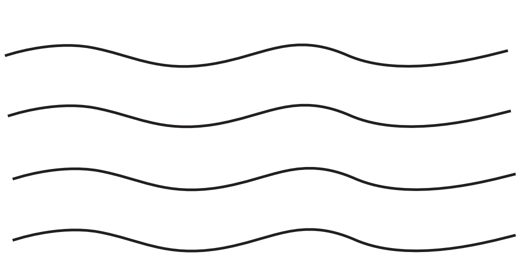
The process leading to the formation of the polymer can be illustrated as follows.



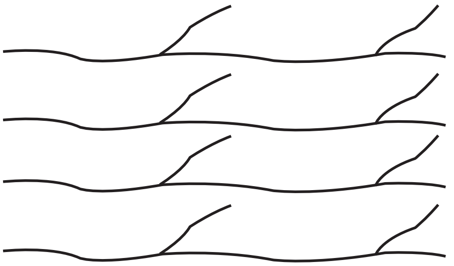
- ## Classification of polymers based on structure

All the polymers so far discussed are made of linear chains. However, all polymers are structurally not linear polymers. By joining polymer molecules laterally to the principle chain of the linear polymers of the type described above, branched polymers are produced.

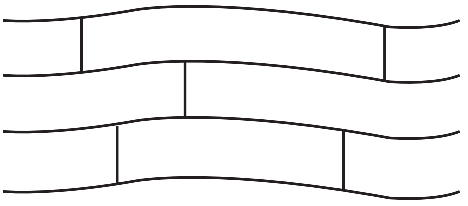
The polymers in which the linear chains are cross-linked are known as cross-linked polymers. Therefore, the polymers can be classified as follows according to the structure.



Linear polymers
Figure 14.5

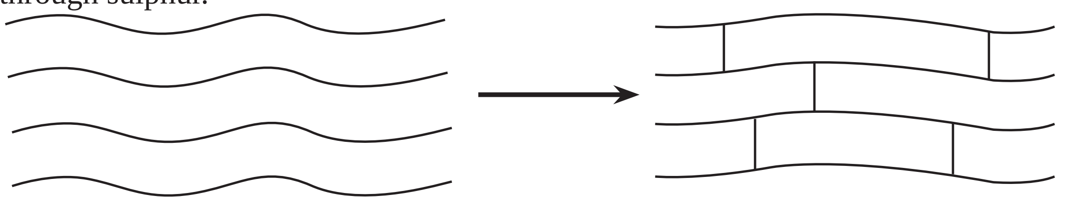


Polymers with side chains
Figure 14.6



Polymers with cross links
Figure 14.7

Have you heard about vulcanized rubber? Because of the elastic property of rubber, it is difficult to be used in some applications. By vulcanization, rubber can be made harder while decreasing its elasticity. During vulcanization natural rubber is reacted with sulphur. Then, cross links are formed among the linear chains of rubber through sulphur.



Rubber
Figure 14.8

Vulcanized rubber
Figure 14.9

Vulcanized rubber is used to make tyres, tubes and battery cases.

• Importance of polymers

When taking lunch away from home, natural materials such as a banana leaf or a "Kolapatha" was used for wrapping in the past. But today, what we use for this purpose is a type of polythene which is a synthetic polymer. Like this, at present, artificial polymers are being used as substitutes for materials. Properties such as the ability to synthesize with required characteristics, ease of usage, ability to produce in various shapes, ability to make colourful with any required colour and cheapness have made the items produced with polymers popular.

Assignment 14.4

List the products made of polymers that are of domestic use.

Most of the artificial polymers are not subjected to biodegradation. That is, they do not decay through biological process. Therefore they get collected in the environment. This is a big environmental problem. Since the combustion of artificial polymers release poisonous gases, burning is not suitable. Chemists are making attempts to find a solution for this problem by producing degradable polymers. At present, production of biodegradable and photodegradable polymers and water-soluble polymers are underway.

The clothes produced with artificial polymers such as nylon, terylene and polyester do not absorb sweat and cause discomfort to the body. This can be minimized by mixing natural polymers such as cotton and wool with artificial polymers.

Summary

- Organic compounds only made up of carbon and hydrogen are called hydrocarbons.
- In some hydrocarbon molecules, carbon atoms are bound only by single covalent bonds. Such hydrocarbons are named alkanes.
- Crude oil is a mixture of alkanes. The common formula of the alkane family is $C_n H_{2n+2}$.
- In addition to alkanes, there are hydrocarbons in nature with double or triple bonds between carbon atoms.
- Joining of other atoms or atomic groups in place of hydrogen atoms in hydrocarbons gives rise to other organic compounds.
- The macromolecules formed by linking together of a large number of simple molecules are known as polymers.
- The polymers present in natural animal parts or plant parts are called natural polymers. The artificially synthesized polymers are artificial polymers.
- Artificial polymers are generally referred to as plastics.
- The shape of some polymers can be changed by heat whereas in some the shape cannot be changed by heat.
- Since artificial polymers do not decay, there are both advantages and disadvantages in them.
- If the management of plastic wastes is not carried out properly, many environmental problems may arise

Exercises

01. L.P. gas is a mixture of propane and butane.

i. Write the molecular formulae of propane and butane.

ii. Draw the structures of propane and butane.

iii. If only carbon dioxide and water are formed during the combustion of the above compounds, write balanced chemical equations for their combustion separately.

iv. Is the use of L.P. gas as a fuel more environment friendly than using firewood? Present your ideas.

02. Octane is the most abundant alkane contained in petrol

i. What would be released if petrol completely burns in a combustion engine?

ii. State two unfavorable substances released to the environment during the incomplete combustion of petrol.

iii. How do you know that the L.P gases burn incompletely in the gas cooker used at home?

03. Polythene is a commonly used artificial polymer.

i) What is the chemical name of polythene?

ii) Draw the structure of the monomer that forms polythene and write its name

iii) State two advantages and two disadvantages of polythene.

04. It is more suitable to use PVC pipes as water pipes rather than iron pipes.

i) Give three reasons to support this statement.

What is the name of the monomer that is used to make the polymer PVC?

ii) Draw the structure of that monomer.

05. Name three natural polymers of your choice.

Technical terms

Organic compound	-	කාබනික සංයෝග	-	சேதன சேர்வைகள்
Hydrocarbon	-	හයිඩ්රොකාබන	-	ஐதரோகாபன்
Alkanes	-	ඇල්කේන	-	அற்கேன்
Alkenes	-	ඇල්කීන	-	அற்கீன்
Polymers	-	බහුඅවයවක	-	பல்பகுதியம்
Monomer	-	ඒකඅවයවකය	-	ஒருபகுதியம்
Repeating unit	-	පුනරාවර්තන ඒකකය	-	மீண்டுவரும் அலகு

Biosphere 15

15.1 Organizational levels and interactions of biosphere

15.1.1 Environmental equilibrium/Ecological balance

The physical and the biological components in which interactions take place for the existence of organisms is environment. Soil, water and air come under the physical component and all the organisms that is plants, animals and micro organisms are included in the biological component or the biotic component. Other than that temperature, rainfall, humidity and sunlight come under environmental conditions.

The organisms and the physical environment have a balanced relationship. This favourable relationship is referred to as the **environmental equilibrium.** Even a small change in the environment can affect its existence. Then it has an ability to restore its conditions. But today this equilibrium is affected due to complicated human activities.

15.1.2 Organizational levels in the biosphere

Biosphere is organized from the simplest level to complex level. This organization can be shown in the following flow chart.

Individual → Population → Community → Ecosystem → Biosphere

Observe the organizational levels of the biosphere in the diagram given below.

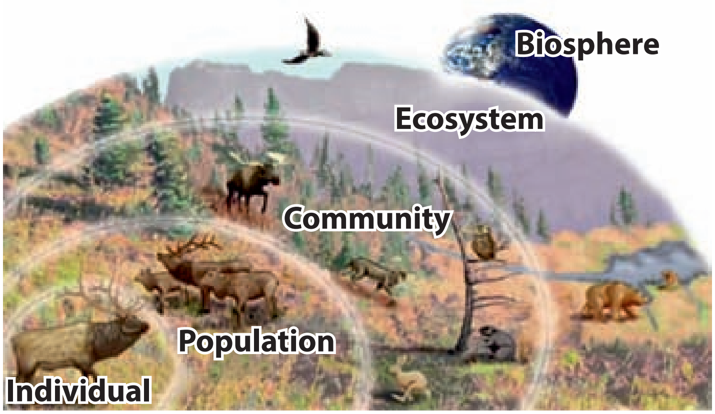


Figure 15.1 - Organizational levels in biosphere

- **Individual**

A single organism belongs to a particular species and lives in the environment is referred to as an individual.

E.g. - Coconut plant, Elephant

A species is a group of similar organisms who can interbreed naturally to produce fertile offsprings.

Assignment 15.1

Name different species found in a particular location of your home garden or school premises.

- **Population**

A group of organisms belong to the same species in a particular geographical location during a specific time period is called a population.

E.g. - The number of elephants lived in Yala national park in year 2011 is 5,879
Human population in Sri Lanka in year 2014 is 21,899,445

- **Community**

A group of different populations, interact with each other in a particular area is reffered to as community

E.g. - Animal community in Yala national park
Mangrove plant community in Negombo lagoon area

- **Ecosystem**

All the communities and the non living component with which they interact in a particular area is called an ecosystem.

E.g. - A pond, A decaying log, A forest
A beach with rocks and cliffs

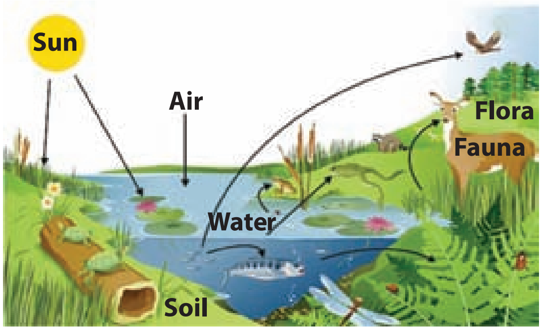


Figure 15.2 shows the interactions of the living organisms with the non living component in a pond eco system.

Figure 15.2 - Interactions in a pond ecosystem

- **Biosphere**

The part of the earth and its atmosphere that is inhabited by living things is called biosphere. The biosphere is composed of three components.

- Lithosphere - The crust and the upper mantle of the earth.
- Hydrosphere - The region that includes all the oceans and fresh water bodies. 70% of the earth surface is covered with water.
- Atmosphere - The region that contains air around the earth.

15.1.3 Growth of population and growth curves

The number of organisms of a species, living in a unit area of a selected habitat is called the population density.

E.g. - Human population density of Sri Lanka in year 2014 is 329.12 km^{-2}

The size of a natural population varies with time. There are four factors that affect the population density.

- Births (Number of new born organisms added to the population)
- Deaths (Number of organisms die in the population)
- Immigration (Number of organisms add to the population from outside)
- Emigration (Number of organisms leave the population)

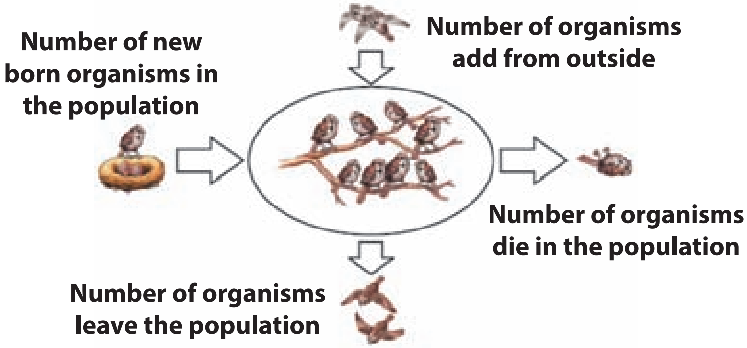


Figure 15.3 - Factors affecting population density in biosphere

Typical growth curve of population

The number of organisms in a natural population changes with time according to a particular pattern. When this pattern is expressed in a graph it will be a sigmoid shaped growth curve. There are four main phases in it.

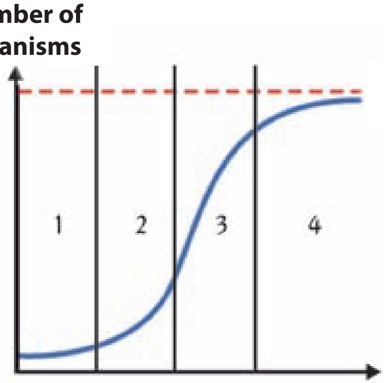


Figure 15.4 - Typical population growth curve

Phase 1 - Slow growth phase (Lag phase)

During this phase population growth increases as reproduction gets underway. Often starts slowly because intially there is a shortage of reproducing individuals which may widely dispersed.

Phase 2 - High growth phase (Exponential phase/ Log phase)

This phase represents the maximum growth rate as organisms are well adapted to the environment and the number of organisms that reproduce is high. Presence of favourable environmental conditions and abundance of food increases the growth rate of organisms rapidly. Birth rate exceeds death rate.

Phase 3 - Deceleration phase

Due to the competition for resources, food shortage, spreading of diseases, predation and parasitism, the growth rate of population decreases.

Phase 4 - Stationary phase/ Stabilizing phase

The number of organisms in a population increases till it has a population adapted to environmental conditions which the environment can bear. Once it reaches its carrying capacity the population achieves the dynamic equilibrium. During dynamic equilibrium birth and death rates balance. Hence the growth of the population is considered as zero. When it comes to this balanced situation the number of organisms in the population is called as the carrying capacity.

- **Growth curve of human population**

Although the growth curve of a natural population is **S** shaped, it takes **J** shape for human population. That means the human population is still in exponential phase.

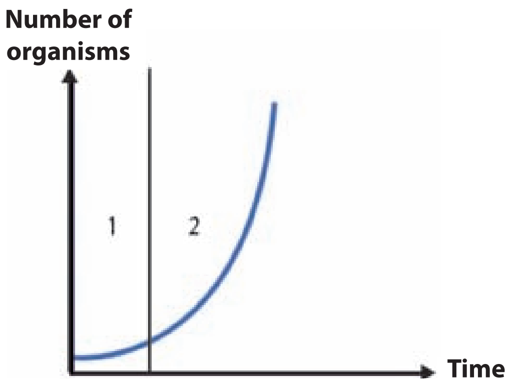


Figure 15.5 - Growth curve of human population

It has taken 300,000 years for the human population to become, one billion. But it has taken only 130 years for it to become two billions and 15 years for it to become four billions. There are two reasons for this rapid growth.

- Increase of birth rate
- Decrease of death rate

The development of technology, progress in medical field and high rate of food production are some of the reasons for high population growth.

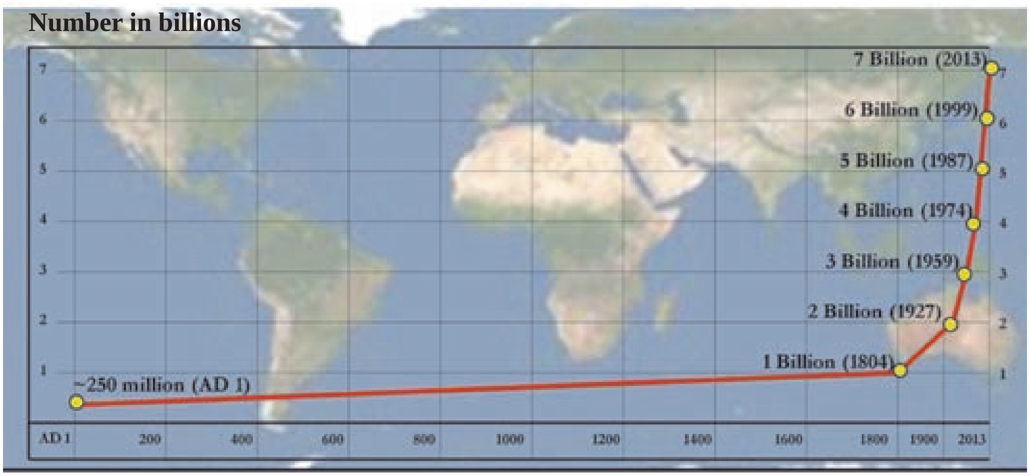


Figure 15.6 - Growth curve of human population from 1 AD to year 2013

Assignment 15.2

According to the graph, predict the time that would take for the world human population to become twice as it was in 2013.

15.2 Mechanisms involve in maintaining the equilibrium of ecosystems

15.2.1 Flow of energy and nutrients

The energy source of all ecosystems in the biosphere is the sun. Flow of energy and nutrients among ecosystms is essential for the existence of the biosphere.

- **Food web**

The mutual relationships for food among organisms is referred to as food webs. Different trophic levels of many food chains are inter-connected in a web like structure in the biosphere. Due to this relationship an organism is free to depend on different types of food. This helps to avoid bioaccumulation of organisms. An example for a food web is given in figure 15.7

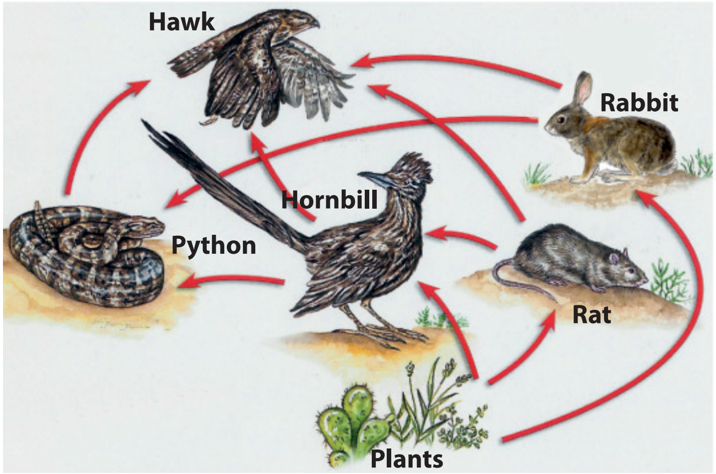


Figure 15.7 - An example for a food web

Assignment 15.3

Build up a food web in a pond ecosystem.

- **Food chains**

The sequence of energy and materials flow from producer to consumers such as primary consumer and then to the secondary consumer is referred to as a food chain. This can be shown in a linear diagram as follows.

E.g. :-

Grass ⟶ Grass hopper ⟶ Toad ⟶ Cobra ⟶ Hawk

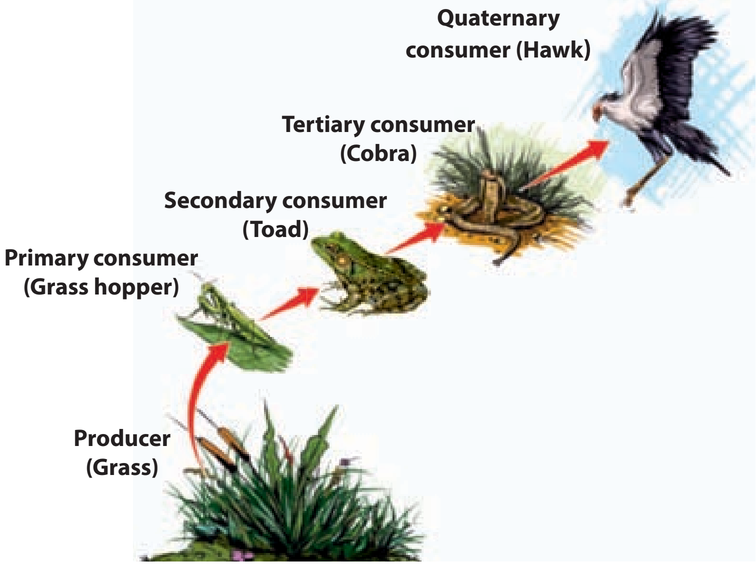


Figure 15.8 - An example for a food chain

Assignment 15.4

Observe different modes of nutrition consumed by different organisms in the environment. Write down their relationships for food.

Trophic level

Every organism belongs to a certain trophic level according to their mode of nutrition. The links of a food chain are known as trophic levels. The number of trophic levels of a food chain cannot be exactly predicted. Most often it is less than five links. Somehow the organisms belong to last trophic level would be carnivorous predators.

All organisms can be divided into three groups on the basis of their mode of nutrition.

- Autotrophs
- Heterotrophs
- Decomposers

Autotrophs

Organisms such as green plants, algae and some bacteria which can transform simple inorganic compounds into organic compounds to fulfill their nutrition requirement are called autotrophs.

According to the energy source used to produce their food, autotrophs can be divided into two groups, as photo-autotrophs and chemo-autrotrophs. Green plants are photo-autotrophs and some bacteria are chemo-autotrophs.

Heterotrophs

The animals that cannot produce their own food are known as heterotrophs. They depend on food produced by other organisms. Therefore they are known as consumers. The consumers are further divided as follows,

1. Primary consumers : They are herbivores. Feed on producers.
2. Secondary consumers : They are carnivores. They can be omnivores too. Feed on primary consumers.
3. Tertiary consumers : They are carnivores.

Decomposers

Organisms feed on bodies of dead organisms and organic waste products by converting complex organic compounds into simple compounds are known as decomposers. Saphrophytes like bacteria and fungi belong to this group. This process is called decomposition.

Figure 15.9 - Stages of decomposition process of a dead body

• Ecological pyramids

Ecological pyramids can be built up using number of organisms, biomass and energy relationships in different trophic levels of an ecosystem.

The base of the pyramid represents, producers, and the rest of the rows represent consumers in different trophic levels respectively.

There are three types of Ecological pyramids.

- Number pyramid
- Biomass pyramid
- Energy pyramid

Number pyramid

The graphical representation of number of organisms in different trophic levels is called the number pyramid. It is expressed as the number of organisms per square meter (1 m^2).

The number of organisms in a particular trophic level can be greater or lesser than the number of organisms in the upper trophic level. Therefore upright and inverted number pyramids can be seen.
An upright number pyramid is shown in Figure 15.10.

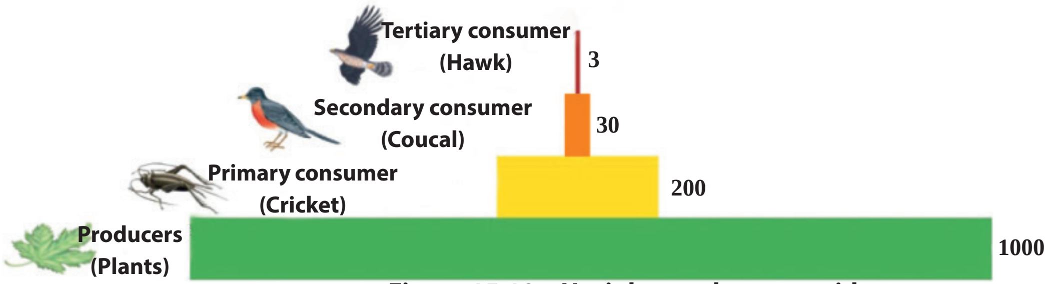


Figure 15.10 - Upright number pyramid

An inverted number pyramid is shown in figure 15.11.

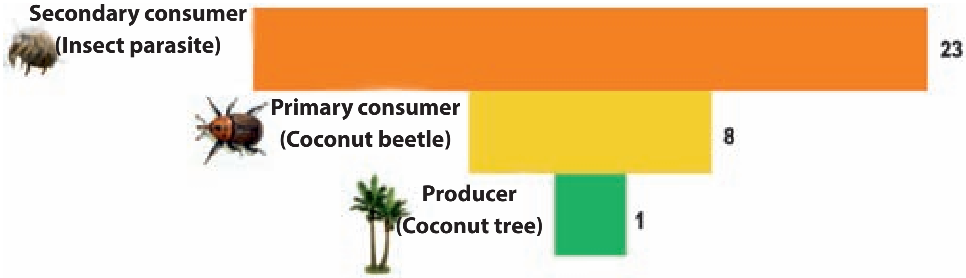


Figure 15.11 - Inverted number pyramid

Biomass pyramid

The graphical representation that shows the total amount of organic matter present in different trophic levels is called biomass pyramid. By considering the dry mass of organisms it is expressed as grammes per square meter per year (g m^{-2} yr^{-1})

Mostly the biomass of consumers is less than the producers. Therefore most of the time the biomass pyramids are upright. But rarely, the biomass of consumers in aquatic environment is greater than that of producers. Then the biomass pyramid is an inverted one.

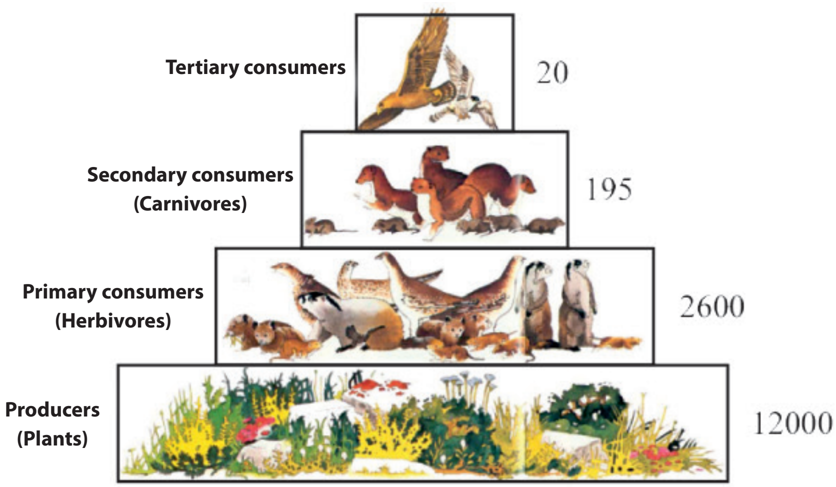


Figure 15.12 - A biomass pyramid

Energy pyramid

The graphical representation that shows the amount of energy, flows through different trophic levels is called the energy pyramid. It is expressed as kilo joules per square meters per year (kJ m^{-2} yr^{-1}).

Only 10% of energy in a trophic level passes to the upper trophic level. 90% of the energy is dissipated to the environment. Therefore the energy in the upper trophic levels is less than the lower trophic levels. So the energy pyramids are always upright. The number of links in a food chain is less than five levels due to this loss of energy.

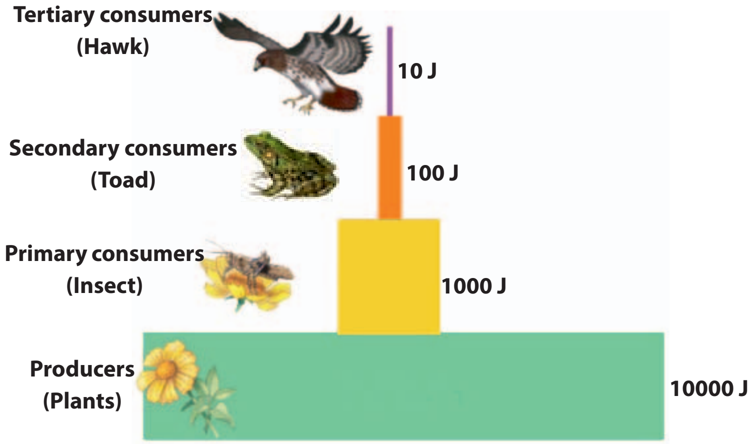


Figure 15.13 - An energy pyramid

- ## Flow of energy through ecosystem

The main energy source of the biosphere is the sun. Green plants absorb sunlight, and use CO_2 and water as raw materials to produce glucose. This process of fixing energy of sunlight is called photosynthesis.

The energy fixed by producers passes from organism to organism along trophic levels. Only 10% of the energy of lower trophic levels passes to the upper trophic levels. 90% of energy is lost in each trophic level as heat.

Energy dissipation

The loss of energy during transferring energy from one trophic level to the next, is called energy dissipation.

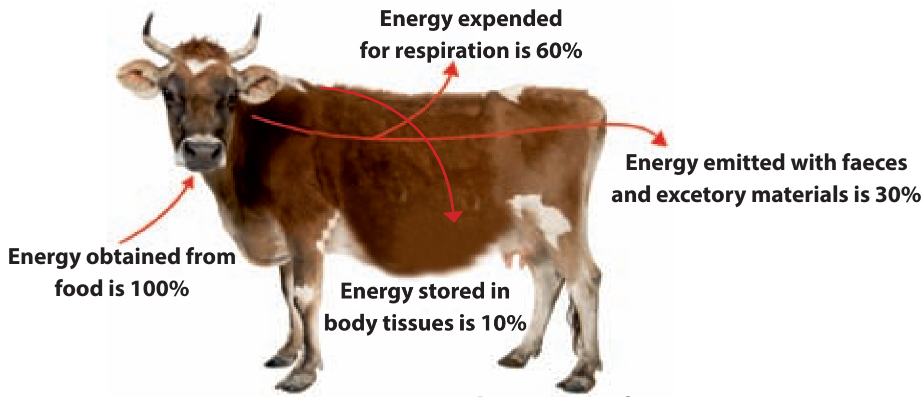


Figure 15.14 - Energy dissipation of a cattle

As a considerable amount of energy is lost during the flow of energy from one trophic level to the next, the shorter food chains are efficient than longer food chains.

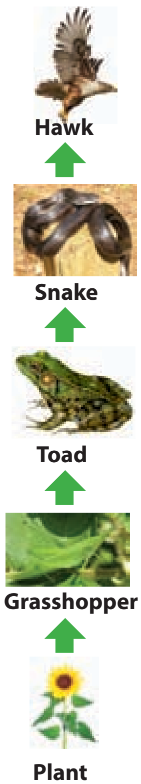


Figure 15.15 - A long food chain

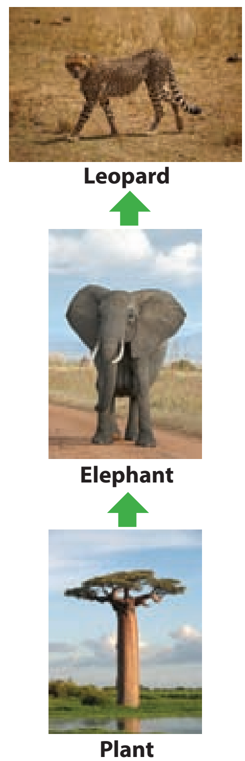


Figure 15.16 - A short food chain

15.2.2 Biogeochemical cycle

The process of cyclic circulation of essential chemical components through atmosphere, hydrosphere and lithosphere of biosphere is called Biogeochemical cycle.

Cyclic circulation of water, carbon, nitrogen, oxygen and phosphorous takes place in the biosphere. The natural environmental balance is maintained by these Biogeochemical cycles.

A few such Biogeochemical cycles are given below.

- Carbon Cycle
- Nitrogen Cycle
- Phosphorous Cycle

Among the above Biogeochemical cycles carbon and nitrogen cycles are discussed in details.

• Carbon cycle

The main method of fixing carbon in an ecosystem is photosynthesis. Animals depend on green plants and they receive carbon through those food. Decomposers obtain carbon by digesting dead organisms. All organisms release carbon as CO_2 during respiration. When decomposers are absent, carbon in dead plants and animals convert in to fossil fuels. This process needs millions of years to be completed. During combustion of fossil fuels carbon releases. Micro organisms play a major role in carbon cycle. They release carbon in dead matter rapidly to the atmosphere. Carbon cycle is represented in the diagram 15.17.

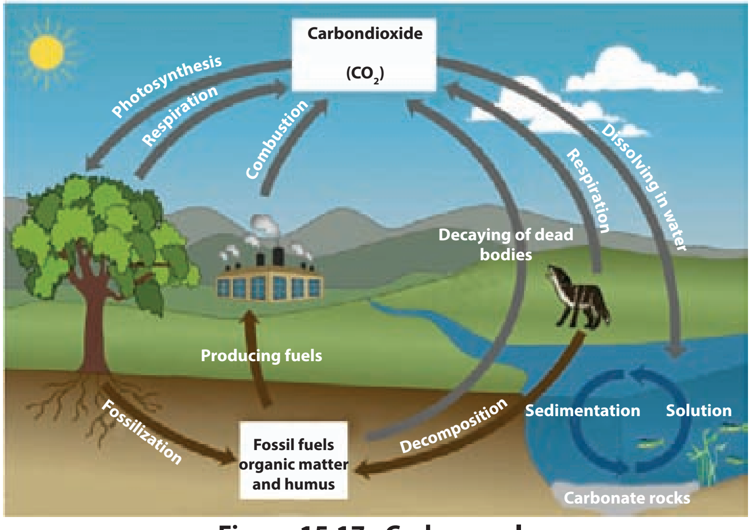


Figure 15.17 - Carbon cycle

• Nitrogen cycle

The main source of nitrogen of earth is the atmosphere.

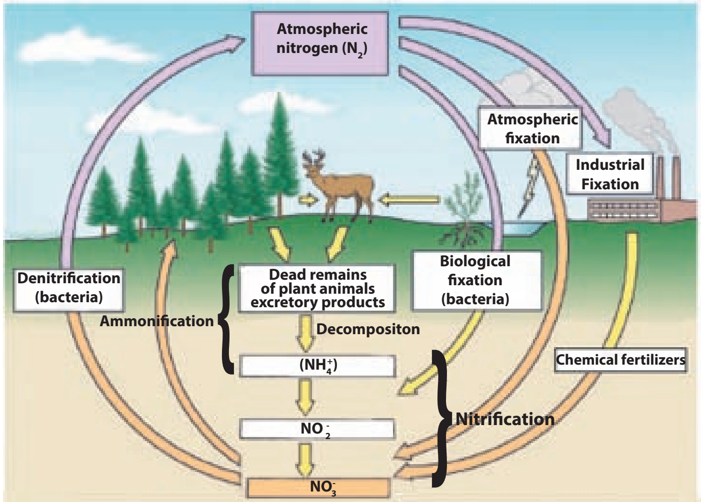


Figure 15.18 - Nitrogen cycle

The fixation of atmospheric nitrogen takes place in three main methods.

- **Biological fixation**

Free living bacteria in soil (*Azotobacter*) and symbiotic bacteria like *Rhizobium* live inside root nodules of leguminous plants that can convert atmospheric nitrogen into NH_4^+.

- **Atmospheric fixation**

During lightning atmospheric nitrogen is converted to nitric oxide and nitrogen dioxide.

- **Industrial fixation**

Atmospheric nitrogen converts to nitrate during industrial production of chemical fertilizers.

Nitrifying bacteria like *Nitrosomonas* first convert Ammonium compounds into nitrites and then *Nitrobacter* bacteria convert nitrite to nitrates. These nitrates are absorbed by plants and used to synthesise proteins. These plant proteins pass into animals through food chains.
Due to microbial activity on dead bodies of organisms, the nitrogenous compounds convert to ammonium compounds known as ammonification and collect into soil. The denitrifying bacteria like *Pseudomonas* and *Thiobacillus* convert nitrates back to atmospheric nitrogen.

Assignment 15.5

Prepare a creative exhibit board to display the nitrogen or carbon cycle.

15.3 Different environmental pollutants and their effects

Disposal of different effluents by the rapid growing population, affects the environmental balance. Let us discuss about the effects of these waste materials.

15.3.1 Environmental pollution

Discharge of pollutants, which cause deleterious effects on natural environment is called environmental pollution.
Environmental pollution are of three types.

- Soil pollution
- Water pollution
- Air pollution

15.3.2 Factors affecting environmental pollution

There are many factors which cause pollution. Let's do the activity 15.1 to identify those pollutants.

Activity 15.1

Materials required :- Different waste materials found in environment
Method :-

- Make a list of pollutants found in the school premises after a field trip.
- Classify them according to the methods given below.

Method I

Method II

- If you are asked to place different waste disposal bins in your school premises decide what type of bins to be placed mostly after analyzing the amount of different waste materials.

There are different types of waste materials involved in environmental pollution. We have to be aware of them to reduce their usage.

These different types of wastes are,
- Agro chemical waste
- Industrial waste
- Greenhouse gases
- Heavy metals
- Particulate matter
- Domestic waste
- Electronic waste
- Nuclear waste

• Excessive usage of agro chemicals

The artificially synthesised chemicals for agricultural practices are called agro chemicals. Mainly agrochemicals include chemical fertilizers, weedicides, insecticides, and fungicides. They are used to get short term benefits, but they cause many ill effects on the environment and hazardous to health.
Weedicides, insecticides and fungicides are commonly known as pesticides. The dose of a pesticide required to kill 50% of a population of a particular pest species is defined as lethal dose (LD_{50}).

Assignment 15.6

List out the agro chemicals that are used for a specific crop from its planting to harvesting. Avoid touching those agro chemicals.

The gazette announcement issued on 23rd of December 2014 by the government has banned selling and usage of chemicals such as Glyphosate, Propanil, Carbaryl, Choloropyrifos and Carbofuran.

Figure 15.19 - Different types of chemical substances sold at market

• Discharge of industrial effluents to the environment

The waste materials that discharge after the production process which cannot be used again are called industrial wastes. The discharge of these industrial wastes to the environment causes harmful impacts on the environment. Industrial waste are as follows.

Hydrocarbons

The compounds formed by combination of carbon and hydrogen only in different ratio are called hydrocarbons.

Methods of releasing hydrocarbons to the environment

- Release of CH_4 (methane the simplest hydrocarbon) due to bacterial activity on garbage and dead plant and animal matter in marshy lands.
- During usage of liquid petroleum (LP gas), petrol, diesel, kerosene as fuel that are obtained by fractional distillation of crude oil.
- During usage of lubrication oil and greese which are products of fractional distillation of crude oil.

Emission of greenhouse gases

The temperature of the earth is fixed by a steady state balance between the energy received from the sun and the energy radiated back by the earth. Carbondioxide, water vapour, methane, ozone and CFC absorb radiation given out from the earth and some of it re-radiates back to the earth's surface. This re-radiation helps to warm the earth and maintains a climate that will support life. This is called greenhouse effect and these gases are called greenhouse gases.

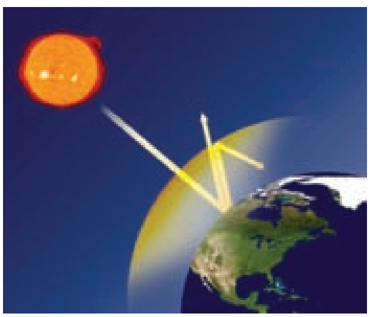


Figure 15.20 - Greenhouse effect

Types of greenhouse gases	
Carbondioxide	(CO_2)
Sulphurdioxide	(SO_2)
Oxides of Nitrogen	(NO_x)
Methane	(CH_4)
Chloro Fluoro Carbon	(CFC)
Water vapour	(H_2O)

Due to emission of greenhouse gases enormously, global warming increases.

Ways by which greenhouse gases released to the environment

- Release of CO_2 due to excessive combustion of fossil fuels.
- Sulphur dioxide is released instead of CO_2 due to combustion of fossil fuels and eruption of volcanos.
- Release of CH_4 due to anaerobic decomposition of dead plant and animal matter in marshy lands and garbage.
- CFC is released when using refrigerators and air conditioned appliances.

Accumulation of heavy metals in the environment

The metals with high density and higher relative molecular mass are called heavy metals. Discarded metal items, instruments and parts of vehicles that contain heavy metals accumulate in the environment. Some heavy metals are naturally present in the soil of some areas.

Figure 15.21 - Soil containing heavy metals

Types of heavy metals	
Mercury	(Hg)
Arsenic	(As)
Chromium	(Cr)
Cadmium	(Cd)
Lead	(Pb)
Copper	(Cu)
Manganese	(Mn)
Zinc	(Zn)

Methods by which the heavy metals released into the environment

- Release of industrial wastes, wastes of zinc mines, electro plating and cadmium (Cd) released during production of orange coloured pigments.
- Due to excessive usage of agro chemicals, arsenic (As) is released to the environment.
- Release of lead (Pb) from lead mixed petrol.
- Due to excessive usage of coal, discard of damaged thermometers, barometers, CFL bulbs, the paints used to apply on ships and industrial wastes release mercury (Hg).
- Chromium (Cr) is released by paints, cement, paper and rubber. Chromium is used as a pigment to colour them.

Assignment 15.7

- List out the materials and appliances that is utilized at home. Discuss the ill effects caused by different types of heavy metals in them.

Particulate matter

There are two types of particulate matter accumulated in air. They are solid particulate matter and liquid particulate matter.

Solid particles	Liquid particles
• Carbon particles • Heavy metal particles • Ash • Dust • Asbestoes	• Water droplets • Liquid organic particles • Mercury droplets


Figure 15.22 - Particulate matter of asbestoes

Sulphurdioxide

A colourless gas with a pungent smell. When it releases to the environment it causes a big impact on the atmosphere.

Methods of releasing SO_2 to the environment

- When using coal as a fuel
- During combustion of petroleum
- During combustion of vulcanized rubber products
- During bacterial activity on organic matter
- During eruption of volcanoes

Oxides of nitrogen (NO_x)

Oxides of nitrogen (NO, NO_2) cause a big impact on the environment once they are released to the atmosphere.

Methods of releasing oxides of nitrogen to the environment

- During lightning, the reaction between N_2 and O_2 form oxides of nitrogen.
- During combustion inside the engines of vehicle N_2 and O_2 react together to form oxides of nitrogen.

Acid rain

Naturally rain is little bit acidic due to dissolution of carbondioxide and nitrogendioxide (NO_2). The pH is about 5.6 of natural rain water. Sometimes this pH decreases, that is acidity of rain increases. The reason for the increase of acidity in rain is due to increase of sulphurdioxide, sulphurtrioxide and nitrogendioxide in the atmosphere.

Sulphurdioxide is water soluble and then it makes sulphurous acid (H_2SO_3) with water. This sulphurous acid further oxidizes to make sulphuric acid (H_2SO_4). Sulphuric acid is formed due to dissolution of sulphurtrioxide too. Nitrogendioxide helps in increasing acidic nature of rain. It forms nitric acid with water. Water mixing with above acids to form rain is known as acid rain.

Adverse effects of acid rain

Figure 15.23 - Acid rain

- Destruction of forests and crops.
- Destruction of aquatic organisms due to increase of acidity in water.
- Affect the aborption of minerals by plants.
- Dissolving of limestones and other rocks.
- Destruction of metalic buildings, statues, and other ruins.
- Some poisonous heavy metals dissolve in water and the concentration increases in reservoirs.

Activity 15.2

- Ditect the acidity of normal rain and the rain after drought period using indicators.

Domestic waste

Figure 15.24 - Domestic-waste

Food scraps, spoiled food, plastic and polythene wastes, discarded clothes, glass and porcelain items, garden wastes and human excretory matter belong to domestic wastes. These are added to the environment continuously.

Electronic waste

Figure 15.25 - Electronic waste

The electrical and electronic accessories which are stopped permenantly from reselling, and selling are called e-waste.

Electronic wastes due to the modern technology are added to the environment at a higher rate.

The materials released as e- waste

- Lead - Battery, circuit boards, cathode ray tubes of computers and televisions
- Mercury - Thermometers, florescent lamps
- Cadmium - Battery, cellular phones
- Berilium - Computers, telephone, automatic electronic apparatus
- Arsenic - Light emitting diodes (LED)
- Polyvinylchloride (PVC) - Computer casings, wires, etc.

Nuclear-waste

The radio active and high toxic materials discarded by nuclear preparation centres and nuclear weapons are known as nuclear wastes. Uranium and plutonium are the main elements used as nuclear fuels. The radioactivity of them can exist for a longer period of time. Therefore, they are deposited in deep sea or ground after covering by thick concrete or metal casing.

- ### Domestic chemical-waste

Figure 15.26 - Domestic chemical - waste

With the industrial development, the usage of chemicals for domestic purposes instead of natural materials has become popular. In present days there are many such chemicals that are used for domestic purposes. Food additives, cleaning agents, medicine, paints and cosmetics are the main chemicals that come under domestic chemical waste.

Food additives

The substances that are added to food to enhance the taste, odour, appearence nutrification and shelf - life are called food additives.

E-number

E-number is a code given by European union to indicate that the food additive is experimentally proven to assure that it is safe for human consumption. Though it is given by an E- number, reliability of some additives is not 100% assured.

Activity 15.3

Identify E-numbers of food items that is brought home. What are the substances denoted by those numbers? What is the purpose of adding such things? What are the adverse effects of them.

Activity 15.4

- Do an investigation about the substances such as colourings and flavours which are used for the fast foods. Fill the table using those information

Food type	Ingredients	Defects

Extra knowledge

Materials added and the objective	Substances contained	Adverse effects
Pigments (Attractive colour)	FDSC Blue No 1, FDSC Red No - 40 Beta carotene	Allergies, Deformities in children
Sweeteners (Enhance sweetness)	Sucrose, Glucose, Fructose	Obesity, Diabetes, Belly protrude outwards
Taste Enhancer (Enhance the taste of food)	Monosodium Glutamate (MSG)	Headache, Chest pain, Weakening of taste buds, Heart attack
Preservatives (Preserve food without spoilage)	Ascorbic acid, BHA, BHT, EDTA, Sodium Bensoate, Calcium Proponate, Sodium Nitrate ($NaNO_3$)	Allergies, Vomitting, Nausea, Stomachache, Infertility, Cancers, Mutations, Disorders in liver and kidney
Stabilizers (Enhance the texture)	Gelatine, Pectin	Diarrhoea
Leavening agent (Make porous)	Sodium bicarbonate (Baking soda) Calcium carbonate Monocalcium phosphate	Stomachache, Cancers
Bleaching agents	Sulphurdioxide SO_2	Breathing difficulties
Nutrients (Addition of nutrients that are destroyed during production)	Thyamine hydrochloride Riboflavin Folic acid Ascorbic acid	Nausea, Vomitting

Diseases caused by food additives

- Wheezing
- Kidney disorders
- Diabetes
- Cardiac diseases
- Cancers (Digestive tract, Lungs, Liver, Thyroid gland)
- Allergies (Skin diseases)
- Disorders associated with nutrition
- Diseases of nervous system
- Hyperactivity of children
- Mental disorders
- Diseases associated with digestive tract.

Cleaning agents

Soap or different types of shampoo are used to cleanse skin and hair. Soap or detergents are used to wash clothes and different types of cleaning agents are used to clean floors and walls. Cleaning agents are important to do the cleaning activities which cannot be done with water, better. The basic raw materials of soap are plant oil or animal fat and a strong base like sodium hydroxide or potassium hydroxide. Coconut oil and other plant oils are often used for this purpose.

Figure 15.27 - Detergent swans

Soap bubbles are formed less in dense water. Artificial detergents are used as a solution to this. These are produced with a mixture of artificially synthesized chemicals. When both these types are added to water, it is harmful to the aquatic organisms. Furthermore, there is a threat of coral reefs being destroyed in the marine areas near hotels and it also affects to reduce the bio diversity of fresh water sources.

The harmful effects of the excessive use of artificial detergents are detergent swans which can be seen on the surface of water systems.

Medicines

In the past, man had a sound knowledge of popular indigenous medicines and they used natural medicines. At present there are different kinds of medicines at home that are used without prescription to ease simple ailments. Examples are using anodynes for fever, using different creams for pains and itching and using antacids for gastro acidity. Moreover, when there are cuts and bruises, antiseptics like spirit is used. Antiseptics is a chemical which is applied on living tissues which destroy microorganisms or prevent their growth. When they are used, the correct dosage should be taken on the correct time. It is very dangerous to use medicine without the advice of the doctors for a long period of time. In the past, margosa, turmeric liquid and salt water were used as disinfectants and at present artificial disinfectants are used to clean the floor, kitchen, toilets and bathrooms. Disinfectants destroy microorganisms and it is not safe for them to come into contact with living tissues. Many side effects can be resulted due to their excessive use and they should be used moderately. By using disinfectants often and excessively in the toilet, the microorganisms that decompose faeces are destroyed.

The following grid contains examples for medicines, disinfectants and antiseptics that are used in homes.

Medicines	Disinfectants	Antiseptics
Magnesium carbonate	Phenol	Iodine
Aluminum hydroxide gel	Chlorine	Surgical spirit
Aqueous magnesium hydroxide (milk of magnesia)	Alcohol	Boric acid

Cosmetics

For cleanliness, beauty, health and pleasantness, people have used natural plant extracts like sandalwood, turmeric and types of clay as cosmetics for thousands of years in the history.

At present, perfumes, bleaching creams, talc, hair colourants and bleaches, deodorants and lipsticks are used as cosmetics. There are naturally or artificially synthesized oils, colourings, fragrant substances, distilled substances and preservatives contained in them. Most of them are complex carbonic substances. In perfumes and deodorants, there are alcohol, esters and distilled substances. When these are used excessively, some diseases are caused in some people. Sometimes, headaches, vomiting and breathing difficulties can occur. In most of the lipsticks, there is led and the excessive usage can cause dryness and cracks on lips.

Mercury is present in some cream. In some other creams, carbon compound that controls the formation of melanin colourant is present. This will destroy the natural protection that protects the skin from ultraviolet rays and poses the risk of skin cancer. It gets into the skin and harms the connective tissues. The use of cream for a long period of time can cause defects in skin. Sometimes, this can harm the brain, liver and kidneys. Some hair colourings and compounds with bleaches cause allergies in some people. This causes itching in the scalp, skin rashes, swelling, cancers and even death.

Paints

A material that is applied on sufaces to protect the surface having a desired colour are called paints. Paints contain three components.

- Pigment - They are produced mainly by metal oxides or metal salts. Bronze, gold, zinc and alminium metals are prepared into a fine powder and used as pigments.
- Binder or non volatile substance
- Vehicle or solvent - Volatile hydrocarbonic substance such as turpentine is used as vehicle. water is used as the vehicle for water soluble binders.

• Cumbustion of fossil fuel and waste matter

Combustion of fossil fuel enormously in factories, automobiles, petroleum power stations results in emitting a large amount of carbonmonoxide (CO), carbondioxide (CO_2) and sulphurdioxide (SO_2). Burning of plastics and polythene too emits dioxin and other gases.

• Persistent Organic Pollutants - POPs

Some toxic, hazardous organic substances have been identified as persistent organic pollutants. They are released to the environment from different sources. These pollutants have certain specific features as follows.

- Persist in the environment for a long of time period
- Accumulate in the body of organisms along food chains
- Widely dispersed in the environment
- Highly toxic

Twelve organic pollutants have been identified as dirty dozen which can pose effective threat to the earth.

Extra knowledge

Dirty dozen

Chemicals associated with factories	Industrial and cumbustive byproducts	Pesticide
Hexacholoro benzene Polychlorinated biphenyls / PCBs	Dioxin Furan	Aldrin Chlordane DDT Deildrin Endrin Heptachlor Mirex Toxaphene

Other than those, some other compounds belong to persistent organic pollutants. These POPs cause certain adverse effects as follows,

- Inborn defects
- Cancers
- Mental defects
- Weakness of the immunity and function of reproductive system.

15.3.3. Adverse effects of environmental pollution

- **Direct effects of environmental pollution**

Acid rain

It is mentioned in page 184 about acid rain. Acid rain has been described as a harmful condition caused by the industrial wastes such as oxides of nitrogen and sulphur.

Global warming

Greenhouse effect occurs in the atmosphere with the high concentration of the polyatomic molecules of greenhouse gases such as carbondioxide, methane, CFC etc. High amount of energy received from sun is refracted away from the earth when the greenhouse gases exceed their permissible level. Hence, the temperature of the atmosphere increases. This is called global warming. Changes that occur due to global warming are shown in Figure 15.28

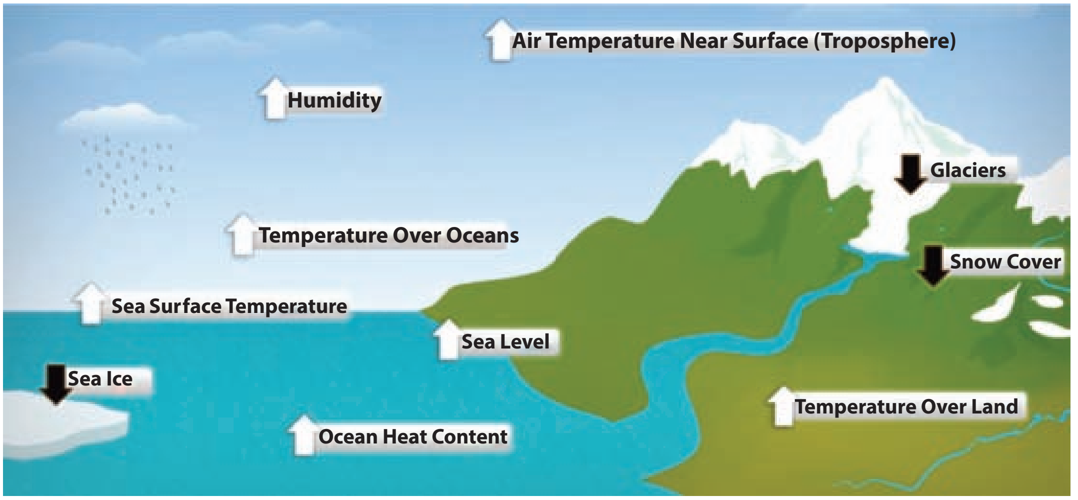


Figure 15.28 - Changes that occur due to global warming

Ill effects of greenhouse effect

- Melting of polar Glaciers due to global warming
- Rising of sea level and small islands will be submerged
- Change of global climatic patterns

Depletion of ozane layer

Ozone is a trimetric molecule of oxygen. This is a thin layer found at 25 km away from the earth surface. At higher atmosphere oxygen absorbs Ultra Violet radiation and forms atomic oxygen.This atomic oxygen is highly reactive. They react with O_2 to form O_3. This O_3 is converted back to O_2 and natural equilibrium is maintained. This ozone layer acts as a protective shield to prevent the entry of harmful UV radiation to the earth surface. But gases like CFC and nitric oxide (NO) destroy ozone layer by detaching O_2. CFC at higher atmosphere obtain solar radiation and is converted to atomic chlorine. This atomic chlorin reacts with O_3 and breaksdown ozone molecules**.** Similarly nitric oxide also reacts with ozone to destroy them.

Due to the depletion of ozone layer, holes appear in it. As a result, radiation with high energy reaches the earth surface.

Ill effects of ozone layer depletion

- Cause cataracts
- Cause mutations
- Reduce body immunity
- Affect photosynthesis and reduce crop yield

Photo chemical smog

It is a yellow coloured mist that is formed due to reaction, resulted between sunlight and the chemicals in vehicle emission, which causes eye irritation and vision impairment.

Extra knowledge

The oxides of nitrogen released due to combustion of fossil fuel and unburnt hydrocarbons transforms into ozone aldehyde, Peroxy Acetyl Nitrate (PAN), Peroxy Benzyl Nitrate (PBN) at 15^0C in the presence of sunlight. Due to these secondary pollutants, photochemical smog is formed.

Figure 15.29 - Photochemical SMOG

Adverse effects of photochemical SMOG

- Cause respiratory tract disorders like cough, wheezing etc.
- Toxic to plants. So plant growth and food production is affected.
- Vision is affected due to turbidity.
- The quality of rubber and clothes reduces due to bleaching.

Biomagnification

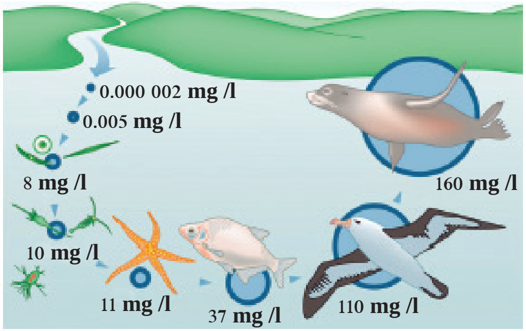


Figure 15.30 - Biomagnification

Collection of toxic chemical pollutants along with food chains from one trophic level to the other is called biomagnification.

Extra knowledge

Dichloro Diphenyl Trichloro Ethane (DDT), Poly Chlorinated Biphenyl (PCB), Mercury, Copper (heavy metals) accumulate in the body of organisms.

Features of bioaccumulated substances

- These substances do not degrade easily and retain for a longer period of time
- Can pass from one organism to the other
- Soluble in lipids
- Become active as biochemicals

These substances enter into lower trophic levels in micro amounts. But they get concentrated along higher trophic levels.

Eutrophication

Figure 15.31 - Eutrophicated reservoir

Phosphate and nitrate concentration in reservoirs increases due to waste materials from industries, agrochemicals, faecal matter and detergents. As a result algae grow excessively and form a green coloured foamy layer. This incident is known as eutrification. The over populated algae die due to competition and anaerobic bacteria act on these dead matter and emit gases such as hydrogen sulphide (H_2S) ammonia (NH_3), methane (CH_4)which result an unpleasant odour.

Ill effects of eutrofication

- Loss of transparency of water
- Unable to utilize water
- Reduction of bio diversity due to death of aquatic plants and animals
- Loss of beauty of reservoirs

Increase of radiation level

Exposure to radiation increases day by day. These radiations are released by natural sources and due to human activities. Especially destruction of ozone layer and accidents in nuclear power stations are the reasons for this situation.

E.g. :- Fukushima power station in Japan, Churnobill power station in Russia

Figure 15.32 - Accidents in nuclear power stations

• Indirect effects of environmental pollution

Loss of habitats of organisms

The natural environment where a plant or an animal lives is known as a habitat. These habitats are lost due to environmental pollution. Wild elephants tempt to destroy villages and agricultural lands due to the loss of their habitat. That is a result of environmental pollution.

Desertification

The change of the ground condition making unsuitable for the plant growth is called desertification. Deforestation, greenhouse effect, salination and natural causes such as weather changes are the reasons for desertification. Irregular monsoon rains causing droughts is a result of this.

Reduction of crop yield

When the conditions required for photosynthesis are not present in optimum levels the productivity of plants is affected. Therefore, the yield is reduced. Lands become infirtile due to their constant use for agriculture. The productivity of plants decreases through water, land and air pollution.

Constructions and degradation of natural environment

Metal statues, buildings, ruins and marble buildings are eroded by acid rains. Natural limestones also degrade due to acid rains. As temperature of the environment increases wall plasters and paintings of Taj Mahal is at a risk of deterioration.

Health issues

As environment is polluted, the infectious (contagious) and non - infectious (non-contagious) diseases spread rapidly in the environment. Due to improper disposal of garbage, diseases like Dengue spread.

Reduction of biodiversity

Reduction of number of species in a unit area of biosphere is known as reduction of biodiversity. When pruning some plants used in landscaping some parts are removed. When ornamental fish like catfish grow in size they are released to the natural water bodies. These organisms become a threat to other organisms in the natural environment and affect the biodiversity.

Introduction of invasive species

Invasive species are results of the changes in the environment. These species can tolerate the conditions and therefore invade the habitats of native species.

E.g. - Giant Mimosa, Trout, Andara, Lantana

Assignment 15.8

Prepare a report about invasive plants and animal species of Sri Lanka.

Economical losses

An extra amount of financial input and effort is needed to revise the environment and maintain it.

15.4 The factors that affect the life style of human and the problems created

15.4.1 Factors that affects the life style of human

Several factors on earth affect the life style of human. Industrialization, urbanization, commercial agriculture and irrigation systems are some of them.

- **Industrialization**

The process by which a country transforms primarily from an agricultural society to a society that produces goods and services is called industrialization. The industrialization initiated from Western Europe in AD 1800 with the technological development and insufficiency of small scale production.

- ### Urbanization

Aggregation of people in areas with abundant resources with the growth of human population is called urbanization. People migrate to cities in search for employments and comfortable life style. As a result, urbanization takes place.

Figure 15.33 - View of an urban area

- ### Commercial agriculture

Large scale agriculture which exceeds the subsistance food production and commercial intentions are called as commercial agriculture. Here, use of modified varieties to obtain productive harvest, agrochemicals and machinary are taken into consideration.

- ### Irrigation systems

Instead of depending on direct rain water, man constructed tanks, ponds, reservoirs, canals, dams and tunnels to obtain water for agricultural purposes. They are considered as irrigation systems.

- ### Utilizing materials and energy abundantly and differently

Due to technological development and complex needs of life, materials harmful to environment in a great extent are being used while minimum labour is spent whereas machinery is used consuming energy.

15.4.2 Problems that arise due to changes in life style

- ### Growth of non contagious diseases and dissabilities

Diseases which are not spread from one person to the other are called as non contagious diseases. According to data of World Health Organization (WHO) annually 38 million people die due to these type of diseases. Most comman contagious diseases are cancers, pulmonary diseases and diabetes Excessive consumption of tobacco and liquor, wrong food habits and lack of physical exercises are the causes for these diseases. Non contagious diseases have become a major problem in Sri Lanka today. Out of the deaths occured due to diseases, 60% had occured due to non contagious diseases. Out of them several diseases are given below.

Chronic Kidney Disease /CKD

Chronic Kidney Disease or renal failure is spreading gradually in agricultural areas in Sri Lanka. Gradual loss of kidney functions including the urine production is known as renal failure.There are two main forms of renal failure as follows,

1. Acute renal failure

Loss of kidney function temporarily for a few hours or days is a feature of acute renal failure. It is often reversible with immediate treatment.

2. Chronic renal failure

Chronic renal disease causes gradual loss of kidney function which is not reversible.

Other causes for renal failure are,

- Diabetes
- High blood pressure
- Constant urine infections
- Calculi in bladder
- Urinary tract Infections
- Intoxication (snake,wasp, hornet venum, agrochemicals)
- Allergies

Symptoms of renal failure

- Urinary urgancy may occur frequently at night
- Little or no urine output
- Pain in the back
- Swelling of feet and ankle
- Weakness, pale skin
- Urine contain protein
- Rashes on palm and soles

Figure 15.34 - Patches due to clinical kidney disease

Speciality of the kidney disease

- Though acute renal failure occurs due to uncontrolled diabetes or high blood pressure people might have chronic kidney disease without any prior disease.
- Most of the people who have the disease are engaged in agriculture. Tendency of people who spray the agrochemicals having the disease is high.
- The first patient was reported from Padaviya Govi Janapadaya in 1994. Though at the beginning farmers of 50-60 years of age were seen to have the disease, later people of 25-30 years of age have got the disease at present.
- Delayed symptoms keep the patient ignorant about this disease. Sometimes when the patient realizes, he is affected by the disease and 40-60% of the kidney has lost its function.
- Most of the people affected are identified to be drinking hard water

Factors that have been identified to be contrtibuting to CKD

- Toxic elements emmited by blue green algae.
- Absorption of agrochemical into body.
- Absolutely heavy metals such as Cd, Pb, As
- Drinking water with floride
- Dehydration
- Using drugs without any control
- Consumption of liquor

Measures that can be taken to avoid CKD

- Refraining from using agrochemicals, and food for which agrochemicals are used
- Maintaining a wholesome life style to control and prevent diabetes and high blood pressure
- Minimizing the frequent urine infections during childhood or which adults are affected from
- An adult drinking 3.5-4.5 litres or 5-6 bottles of clean water a day
- Receiving medical treatment for skin allergies immediately
- Refrain from improper use of pain killers
- Refrain from liquor consumption and smoking

Diabetes

Increase of blood glucose level above the normal level is known as diabetes. Normally, insuline converts the excess glucose in the blood into glycogen and allows it to store in the liver. Failing of the secretion of insulin due to dysfunction or inborn absence of beta cells in the Islets of Langerhans which is located in the pancreas, secretion of insulin fail. When diabetes is not controlled kidney weakens and gradual blindness occurs. Due to busy life style, consumption of food items made of wheat floor and polished rice which are digested instantly, abstaining from exercising and mental stress are some of the causes of diabetes.

Cancer

Cancer is a disease caused by an uncontrolled division of abnormal cells in a part of the body. With the industrialization, harmful radiation, chemical and heavy metals are abundant in the environment. Frequent exposure to radiation and intake of heavy metals to the body, increase the possibility of a cancer.

Heart diseases

Narrowed or blocked blood vessels, heart muscles, valves or rythem not functioning properly lead to heart diseases. Chest pain, heart attack, strokes, thrombosis are some forms of heart diseases. The main cause of heart diseases is the changes in the human life style. With the industrialization, activities of human have become more convenienced, lack of physical exercises, rest and mental stress cause these diseases.

Pulmonary diseases

An unhealthy condition which affects the organs or tissues which involves in the respiration such as trachea, bronchi, bronchioles, alveoli and other nerves and muscles may cause pulmonary diseases. Harmful gases emitted from vehicles and factories also contribute to this.

Wheezing

The air ways are obstructed by the mucus produced due to allergies in trachea, bronchi, bronchioles and alveoli of the respiratory system. Harmful gases and dust particles (Air pollutants and irritants) remain as causes.

Gastritis

Inflammation and swelling in the lining of the stomach due to increasing acidity is the main symptom of this disease. Not taking meals on time because of busy life style, frequent consumption of food containing excessive oil and acids, mental stress caused because of living under a competitive condition are the causes of this disease.

Cataracts

Due to the change in the nature of proteins in the lens of the eye, the transparency of the lens ceases. It is known as the cataract. Here, light does not enter the eye and the eye sight is weakened. Due to the emission of harmful gases from factories, the ozone layer becomes depleted. Thus, ultraviolet rays fall on earth. The exposure to these rays is a cause for this disease.

15.5 Sustainable development and environmental management

Sustainable development is the smart use of the natural resources by safeguarding the balance of the environment in such a manner that the future generations can use them in the future.

Environmental management is the maintenance of natural resources by using them in an environmental friendly manner to fulfill the needs of man.

15.5.1 Sustainable agricultural uses

A sustainable development could be expected by reforestation, use of traditional knowledge and technology, carbon foot print, minimizing food miles, waste management and energy management.

- **Multiple cropping**

Cultivation of different crops in one land area instead of mono cropping in large scale is called multiple cropping. Multiple cropping avoids the risk of destroying the cultivation with a disease and also reduce pests with high resistance.

Figure 15.35 - Mono cropping

Figure 15.36 - Multiple cropping

- **Biological pest control**

The biological pest control is the use of another plant, animal or a microorganism which do not harm the cultivation in order to destroy pests. Coconut catepillar *Promecotheca cumingii* was a major coconut pest which was successfully controlled, using a larval parasitoid *Dimokia javanica*.

- **Use of organic fertilizer**

It is environmental friendly to use substances made by transforming complex organic compounds found in animals and plant parts to simple compounds as fertilizers. Organic fertilizers are the decomposed plant and animal matter which help to improve, soil structure and porosity to enhance the activity of soil organisms.

Assignment 15.9

Engage in a discussion about the advantages caused to the environment by using the above mentioned agricultural uses.

- **Reforestation for environmental balance**

Environmental management is the maintenance of natural resources by using them in an environmental friendly manner to fulfill the needs of man.

As a result of changing the environment by man according to his necessity, the forest cover gradually decreased. Specially, paddy cultivation, vegetable cultivation, tea cultivation, rubber cultivation and large scale development projects were the reasons for this situation.

At present, we experience the harmful effects of the decrease of the natural forest cover. Therefore, in order to reestablish the environmental balance, it is necessary to do reforestation in suitable areas.

Figure 15.37 - Reforestation

15.5.2 Traditional knowledge and use of technology

- **Agriculture**

It is mentioned that during the rule of King Parakramabahu the Great, our country was self sufficient with rice and rice had even been exported. But, at present, we are unable to achieve such heights although machines and agricultural chemicals are excessively used. Therefore, instead of seeds and agricultural chemicals purchased from multinational companies, it is the high time to use traditional agricultural methods such as local seeds and cultivation methods.

Extra knowledge

Some important information of traditional varieties of paddy

Type of paddy	Function
'Kuruluthuda'	• Induce spermatogenesis • Make body strength • Reduce joint pain • Increase immunity • Act on excretory system readily
'Kahawanu'	• Facilitate digestion of food • Facilitate absorption of sugar • Prevent carcinogenic properties
'Rathhal'	• Activate excretory system • Make the body comfortable • Cure lung diseases and fever • Heal abdominal disorders • Clean urine and bile
'Madathawalu'	• Removal of toxic metals from body • Prevent diabetes • Avoid gene mutations • Enhance immunity • Growth and repair of tissues • Cooling of body
'Suwadal'	• Control eye diseases • Induce nerve activities and control diseases • Aids in spermatogenesis • Reduce oedema • Anti-diabetic properties
'Mavee'	• Anti-diabetic properties • Reduce burning sensation, Thridosha and prevent constipation • Improve skin condition
'Kaluheenati'	• Prevent constipation • Anti cancerous properties or carcinogenic properties • Body warming • Aids in spermatogenesis

• The technology of irrigation

Sri Lankan irrigation system is one of the unique water management systems in the world. Historical large tank can be identified as a great technical attempt with a very complex scientific knowledge.

Figure 15.38 - An ancient tank bund

The reservoir constructed across a river, canal or a branch of it with the aim of collecting sufficient water for agricultural activities is known as a tank.

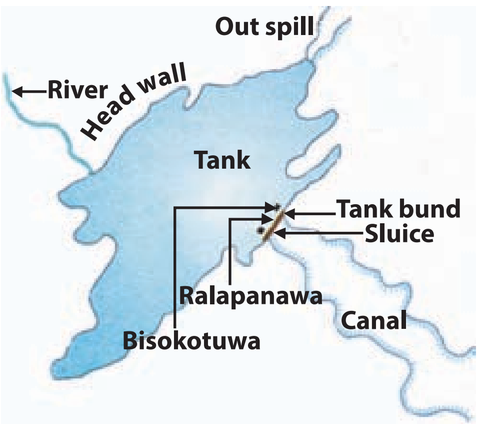


Figure 15.39 - Major parts of a tank

The large tanks distributed in the dry zone of Sri Lanka hold a huge water capacity. Major factor that should be paid attention to constructing such large scale tanks is, keeping the collected water for a long time. Also by controlling the pressure caused by its colossal capacity of collected water and controlling the power caused by its extremely destructive pressure when the water is taken out for use.

There are several functions done by tank bund, sluice, Bisokotuwa (Sluice gate), Ralapanawa and canal, which are considered as the major parts of a tank. The tank bund was built with soil connecting the hills from either side.

The robustness is essential if the stability of the tank bund and needs to be protected. To maintain this situation a systematic methodology has been applied. Tank bund had been constructed of several soil layers. It had been made of several thoroughly beaten layers such as, a layer of clay, soil, gravel and clay (Kirimeti) layer, kept one on one.

\

Figure 15.40 - A sluice gate

When water in large tanks is taken out a huge pressure is exerted and the magnitude of pressure increases with the height of water column. The sluice was built at a specific level on the tank bund using huge pieces of stones in a way that it began from the area where water is filled in the tank bund and going under the tank bund or piercing it. A slab of stone, connected to the sluice vertically was used to release water. There are more than one sluice made in tanks with a high bund.

Bisokotuwa is also a part of the sluice. It means that the rectangular space made of stones, from which water flows out from the tank. Its purpose is to take water out with less pressure level after releasing water at different pressure levels. The mud sluice is at the bottom level of a tank bund. This mud sluice was used to remove alluvial collected after a rainy season.

When a tank is filled with water, waves occur on its surface, and the waves can erode the bund. The Ralapanawa is made by keeping stones on the interior slope of the tank bund. A brink **(Isweti)** is built to avoid collecting water with eroded mud, sand and gravel, to the tank water.

The small sized water tanks built in the upper part of tank collect water first and next the large tank.

The upper part of tank that is Head wall **(Wew Ismaththa)** is the water catchment area. Clearing forest, cultivation and building of houses is strickly prohibited in this area.

The surrounding area parellel to the water level is known as **wew thawulla** and this is rich with natural habitats of flora and fauna.

Accordingly, tank is a marvellous human creation that is compatible with nature.

Assignment 15.10

Make a scientific investigation about the technology of irrigation system of Sri Lanka, and prepare a report.

• Conventional food patterns

Food comprises of a collection of nutrition, healthyness, culture, tradition, environment, creation, folk tales, literature, technology, etc. The traditional food patterns improved the quality of life of our people. But consumption of oily, starchy food, flavourings and bad food habits cause number of issues in public health. This condition has influenced the tendency of non-contagious diseases like high blood pressure and diabetes.

Important facts about natural flavourings

- The most reactive parts of a food
- Improve the colour, taste, odour and appetite of food.
- Contain bactericidal properties
- Minimize, harmful effects caused by food
- Has unique taste and quality, which cannot be obtained by artificial flavourings.

E.g. :- Cinnamon - Control the blood glucose level.
Reduce diseases caused by phlegm
Has anticancer properties

Clove - Give pleasant odour to mouth
Relieve pain
Destroy microorganism (Detergent property)

Pepper - Stimulate digestion of food
Relieve abdominal disorders

• Indegeneous medical science

This field consists of Aurveda, **Siddha, Unani** and native medicinal fields, which has history of thousands of years. Ayurveda is one of the important medical fields, descended from India. It is a perfect science with two traditions.

1. Clinical medicine (Kayachikithsa)
2. Surgical science

According to Ayurveda there are three types of reaction that take place in human body. Those three factors are known as **Va, Pith and Kapha.**

'Va' - Air

'Pith' - Bile

'Kapha' - Phlegm

Imbalance of these three factors cause diseases according to Ayurveda. Ayurveda field of medicine, use plants, or parts of plants to treat patients.

Treatments are given in three ways

1. Medicine 2. Food 3. Exercises

In Ayurvedic medicine, treatments are done to the cause or root to the disease. Body activity is not controlled artificially by giving medicine (drugs) externally. Therefore side effects are not resulted.

Food is also a significant factor to cure diseases. It should be consumed to balance Va, Pith and kapha the three factors.

Its main target is not only curing diseases, but also maintaining physically and mentally fit healthy life.

15.5.3 Carbon footprint and minimization of food mile

• Carbon footprint

The amount of carbondioxide released into the atmosphere as a result of the activities of a particular individual, organization or community is a carbon footprint. Total carbonfoot print cannot be calculated as CO_2 is naturally produced whereas it needs more data.

• Water footprint

The amount of fresh water utilized in the production or supply of the goods and services used by a particular person or group.

Figure 15.41 - Water footprints of several foods

• Food mile

The distance over which a food item is transported during the journey from producer to consumer, is known as food mile.

The food mile changes according to the quantity of food and the place it is produced.

E.g. - Food mile of some of the foods that you take for your breakfast can be calculated as follows. Suppose you are in kurunegala.

(1)

Rice	1 mile	(Taken from your paddy)
Potato curry	100 miles	(Taken from Welimada area)
Coconut	0 mile	(Taken from your coconut trees)
Eggs	10 miles	(Taken from a poultry farm of your area)
Summation	111 miles	

(2)

String hoppers made up of rice floor	85 miles	(Rice taken from Polonnaruwa)
Dhal curry	925 miles	(Taken from Misur area of India)
Coconuts	0 mile	(Taken from your home garden)
Coconut sambol	185 miles	(Taken from Jaffna)
Summation	1195 miles	

(3)

Bread		(Wheat flour taken from America)
Fish curry	9340 miles	(Taken from Negombo)
Coconuts	44 miles	(Taken from your home garden)
Coconut sambol	0 mile	(Taken from Chennai, India)
	800 miles	
Summation	10184 miles	

As long as the food mile is short, sustainability and environmental friendliness is high. Therefore we should take actions to shorten the magnitude of food mile.

15.5.4 Waste management

Consumption of substances becomes greater with the increase of human population. Eventhough natural waste materials deteriorate gradually, they get collected to the environment rapidly. Odour of such waste spreads in urban areas, rather than in villages. Non deteriorative materials such as polythene, plastic, electrical cells, electronic waste, electric bulbs and, printed coloured newspapers get collected in the environment continuously. When burning these waste materials gases such as dioxine emits. When these waste materials are burried, soil gets polluted and heavy metals get collected into soil. Public is unaware of the danger of them. It is very important to be knowledgeable that gradual disposal of the tiny piece of plastic, battery of a mobile phone CFL bulb be catostrophic. It is our responsibility to collect waste matter separately and forward it to the process of recycling.

The waste handling technique named 4R is practised in waste management

Reuse - Use as many items as possible again and again.
E.g. Polythene

Reduce - Unnecessary items should be avoided or minimized.
E.g. - Avoid taking antibiotics and vitamins unnecessarily

Replace - Use of eco friendly substances instead of incompatible materials with nature.
E.g. - Use of organic fertilizer instead of chemical fertilizer.

Recycle - Process to convert different raw materials, animal dung and dead bodies into new products to prevent waste of potentially useful materials.
E.g. - Production of bio gas using animal excretory matter, dung and dead matter.
Recyling polythene and plastic in order to produce fuel.

15.5.5 Energy management

Consumer is provided with an opportunity to utilize energy with the aim of conservation of energy and minimization of cost. Planning and monitoring of energy production and consumption is required for sustainable utilization and then fulfil the needs of the consumer. This process is referred to as energy management.

• Energy crisis and technological issues

Drastic increase of price of economically important energy resources due to their constricted supply is referred to as energy crisis. Fuel oil crisis, electiricity crisis and dearth of energy resources also indicate this problem. Energy crisis occurs as a result of the great demand for the supply of limited natural energy resources.

Reasons for energy crisis

- Drastic growth of human population
- Increase of the number of industries
- Over consumption of energy
- Wasting energy
- Non investigation of renewable energy resources
- War activities
- Political problems

Technical problems arise during the management of available energy. Technology for extraction of energy resources, methodology of purifying energy resources are some of them.

Assignment 15.11

List out the steps you follow to utilize energy with minimum wastage.

• Monitoring of daily energy consumption

It is necessary to be aware and compare the energy consumption by measuring it daily. Then wastage can be minimized.

- **Energy auditing**

The purpose of monitoring is to visit different institutions, and make recommendations and advise based on the results of the respective energy audits and make the authorities aware related to energy consumption.

In this context making the public enthusiastic on reduction of energy consumption and improving energy efficiency are ensured.

- **Energy efficiency**

Energy efficiency is defined as utilization of minimum quantity of energy for a particular service through effective management of energy consumption.

It is possible to improve energy management and control through energy efficiency. It also enables to provide an enhanced service by utilizing minimum energy. However this does not mean that the service is withheld or controlled.

Assignment 15.12

Investigate the electrical appliances at your home and record their wattage (power). Hence compare their level of energy consumption.

- **Sustainable energy use**

In sustainable use maintenance of a certain aspect at a desired status/level is expected. Due to technical reasons, utilization of most renewable energy resources still remains at a lower level.

E.g. Solor energy, Wind energy, Biomass

Importance of utilizing natural energy in architecture

In constucting a house some steps need to be taken in order to maintain good indoor air circulation. When natural sunlight incidents upon the surfaces the temperature of indoor environment increases. Hence it is not desirable to place fenestrations (windows) on East and West walls of the house. Especially since heat transfer from the western side is high, it is not done. By placing windows on North and South directions good air circulation and natural cooling can be maintained within the house. Electrical energy consumption for air conditioning can be minimized to a great extent by means of natural ventilation. Day light harvesting can be utilized for reducing electrical energy consumption due to artificial lighting. This enables a substantial reduction of operational cost of a building. Using thick curtains can also lead to reduction of heat transfer in air conditioned spaces. This considerably reduces energy consumption for air conditioning. Rain water harvesting can be applied as an energy conservation measure. In boiler systems exhaust gases discharged through the chimney stack contain high temperature waste heat which can be extracted to heat boiler feed water and as an air pre-heater. With the utilization of eco-friendly natural energy sources it is possible to minimize the adverse effects on the environment.

Different Conventions, Legislations and Acts are in function at international and national level for the management and sustainable use of the environment.

Several examples for international conventions are given below.

- Montreal protocol to control the gases which harm the ozone layer
- Kyoto protocol to minimize the emission of greenhouse gases

State institutions under the Ministry of Environment, Central Environment Authority, Marine Environment Protection Authority, Geological Survey and Mines Bureau, State Timber Corporation, National Gem and Jewellery Authority implement law, rules and regulations related to environmental management.

Assignment 15.13

Prepare a booklet on renewable energy sources.

Summary

- There is a natural balance among living organisms, physical component and the environmental conditions in the biosphere. This balanced relationship is known as the environmental equilibrium.
- The increasing human population and their activities cause the breakdown of the ecological balance.
- The simple organizational level that is individual, organize to form population, community, ecosystem and finally forms the biosphere.
- The flow of energy and natural minerals among organisms is essential to maintain the ecological balance.
- The flow of energy and nutrient among organisms occur through food chains, food webs and bio geo-chemical cycles.
- Environmental pollution is the breakdown of ecological balance due to the waste materials released to the environment by man.
- Agro chemicals, industrialized waste, greenhouse gases, heavy metals, particulate matter, food additives, cleaning agents medicine, detergents and perfumes are the main causative agents of environmental pollution.
- Man is experiencing direct and indirect effects of environmental pollution at present.
- Usage of indegenous knowledge and technology, indegenous medicines waste management and energy management are some of the effective ways for sustainable development.

Exercise

(01)

(i) What is the organizational level which includes abiotic component in the biosphere

i. Individual ii. Population iii. Community iv. Ecosystem

(ii) Select the answer with all the descriptions about the population

i. Species name, living period
ii. Species name, location
iii. Living period, locaton
iv. Species name, living period, location

(iii) Which of the following is not a causative gas for acid rain

i. Nitrogendioxide ii. Carbondioxide
iii. Sulphurdioxide iv. Sulphurtrioxide

(iv) The main gas which cause greenhouse effect is,

i. Carbondioxide ii. Methane
iii. Chloro Fluoro Carbon iv. Oxides of nitrogen

(v) The bacteria which involves in fixation of atmospheric nitrogen as ammonium is,

i. *Rhizobium* ii. *Nitrosomonas*
iii. *Nitrobacter* iv. *Pseudomonas*

(02)

(1) There are many ecosystems found in the biosphere.

1. Name two relationships present in an ecosystem.
   ----
2. Name two biological communities identified in a pond ecosystem.
   ----
3. Name two causes for the breakdown of ecological balance.
   ----
4. What is the main method of fixation of carbon in an ecosystem ?
   ----
5. The flora in Singharaja forest are naturally well-grown than the crops in an agricultural land. Justify this statement.

   ----

(3)

1. Name two applications in sustainable agriculture.

   ------------------------------------ ---------------------------

2. State two fields where indigeneous knowledge and technology can be applied.

   ------------------------------------ ---------------------------

3. What is known as **food mile** ?

   ------------------------------------ ---------------------------

4. Name two ways to shorten the food mile.

   ------------------------------------ ---------------------------

Technical terms

Biosphere	- ජෛවගෝලය	- உயிர்க்கோளம்
Bio geo - chemical cycles	- ජෛව භූ රසායනික චක්‍ර	- உயிர்ப்புவி இரசாயனச் சக்கரம்
Industrialization	- කාර්මීකරණය	- கைத்தொழில் மயமாக்கம்
Urbanization	- නාගරීකරණය	- நகரமயமாக்கம்
Non - contagious diseases	- බෝ නොවන රෝග	- தொற்றாத நோய்கள்
Food chain	- ආහාර දාමය	- உணவுச் சங்கிலி
Food web	- ආහාර ජාලය	- உணவு வலை
Energy pyramid	- ශක්ති පිරමීඩය	- சக்திக் கூம்பகம்
Number pyramid	- සංඛ්‍යා පිරමීඩය	- எண்ணிக்கைக் கூம்பகம்
Biomass	- ජෛව ස්කන්ධ	- உயிர்த்திணிவு
Sustainable development	- තිරසාර සංවර්ධනය	- தொடர்ச்சியான அபிவிருத்தி
Environmental management	- පරිසර කළමනාකරණය	- சூழலில் முகாமைத்துவம்
Energy management	- ශක්ති කළමනාකරණය	- சக்தி முகாமைத்துவம்
Waste management	- අපද්‍රව්‍ය කළමනාකරණය	- கழிவு முகாமைத்துவம்
Carbon food print	- කාබන් පියසටහන	- காபன் அடிச்சுவடு
Food mile	- ආහාර සැතපුම	- உணவின் மைல் பெறுமானம்

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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