PREFACE

Teaching higher order thinking skill is currently at the center of educational attention. In general, measures of higher order thinking include all intellectual tasks that call for more than the retrieval of information. Six fundamental higher order thinking skills have been identified in this textbook. They are problem solving skills, inquiring skills, reasoning skills, communicating skills, conceptualising skills and creative and innovative skills.

In this Grade 10 Science Textbook, students will be working with their teacher and other students to develop the basic knowledge and skills which will help them understand science more and to apply them in their daily life. They will learn how to show an interest in the creativity and innovation found in science.

After learning this course, students will develop and practise higher order thinking skills: comprehension, analysis, synthesis and evaluation. They will be able to participate actively in all lessons through the **5C's** as important 21st century skills for learning in the classroom.

Collaboration – in lessons students will be working in groups, to share ideas with their classmates and to find the solution together

Communication – students will develop verbal and non-verbal communication skills in group works

Critical Thinking and Problem Solving – students will be given interesting problems to solve – finding and explaining solutions, looking for correcting errors

Creativity and Innovation – thinking 'outside the box' is an important 21st century skill. Students will be encouraged to explore new ideas and solve problems in new ways

Citizenship - students will join the school community and develop fairness and conflict resolution skills

Grade 10 Science Curriculum covers 3 main portions: Chemistry, Physics and Biology. There are ten chapters included in this Textbook.

Science (Chemistry)

Chapter 1. Introduction to Chemistry

Chapter 2. Acids, Bases and Salts

Chapter 3. Fossil Fuels

Science (Physics)

Chapter 1. Measurement and Motion

Chapter 2. Force and Pressure

Chapter 3. Work, Energy and Heat

Chapter 4. Wave, Sound and Light

Chapter 5. Electricity and Magnetism

Science (Biology)

Chapter 1. Introduction to Biology

Chapter 2. Cell Structure and Organization

Goals of Grade 10 Science Textbook

The Grade 10 Science has been written for students who are studying social science subjects. By studying Grade 10 Science, students will be able to understand the fundamentals of chemistry, physics and biology. It is hoped that students will be able to participate successfully in 21st century learning based on the skills through the 5C's as well as to understand the benefits and hazards of the Material World through the knowledge they have learned.

CHAPTER 1

INTRODUCTION TO CHEMISTRY

Chemistry is an area of knowledge remarkable for its breadth and depth. Knowledge of chemistry is essential to improve the quality of our lives. For instance, faster electronic devices, stronger plastics, and more effective medicines and vaccines all rely on the innovations of chemists throughout the world. We cannot truly understand or even know very much about the world we live in or about our own bodies without knowing the fundamental concepts of chemistry.

Climate change, water contamination, air pollution, food shortages and other societal issues are regularly featured in the media. However, did you know that chemistry plays a crucial role in addressing these challenges? As the 'Central Science', chemistry is woven into the fabric of practically every issue that our society faces today.

Learning Outcomes

After completing this chapter, students will be able to:

- recognise the importance of chemistry in daily life;
- know the states of matter;
- differentiate between physical changes and chemical changes;
- classify the substances as elements, compounds and mixtures;
- understand the separation techniques of mixture;
- describe the solutes, solvents and solutions.

1.1 IMPORTANCE OF CHEMISTRY

Chemistry is **important** because everything you do is **chemistry**. **Chemical** reactions occur when you breathe, eat, or just sit there reading. You are surrounded by materials and substances, all chemicals. Even your body is made of chemicals. The air you are breathing is a mixture of elements like oxygen and nitrogen. The book you are reading is made from wood pulp or cellulose which has been bleached and treated with various chemicals. The clothes you are wearing are probably made from synthetic chemicals called polymers, such as nylon or terylene. The seat you are sitting on is perhaps a plastic polymer, with polyurethane; foam seat padding and metal support. The room you are in is made from cement, plastics, concrete and glass, all of which are chemicals. Chemicals provide us with luxuries and improve our leisure time.

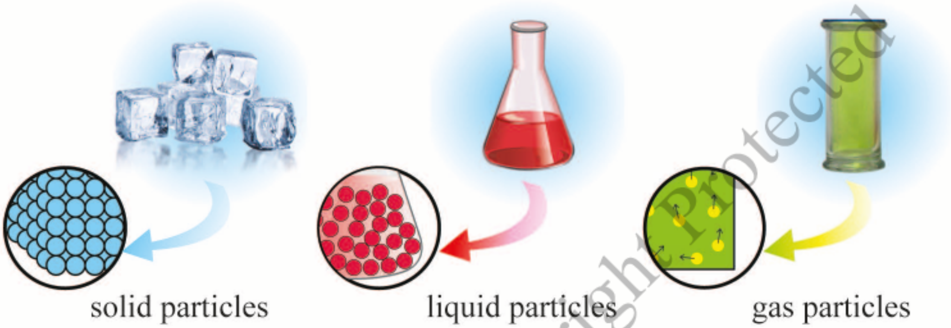
Some chemicals are toxic. Some causes cancer. Some chemicals are also beneficial. Some can save lives. Many are useful. All matter is made of chemicals, so the **importance** of chemistry is that it is the study of everything. **Chemistry deals with everything**. Perhaps a better understanding of chemistry would enable us to control the uses of chemicals so that we could maximise their benefits and minimise the risk involved in their use.

1.2 MATTER

All substances are **matter**. Matter is made up of tiny particles. These can be atoms or molecules (groups of atoms), and elements or compounds. This includes the air, the sea, the Earth, all living creatures and even the galaxies.

(a) States of Matter

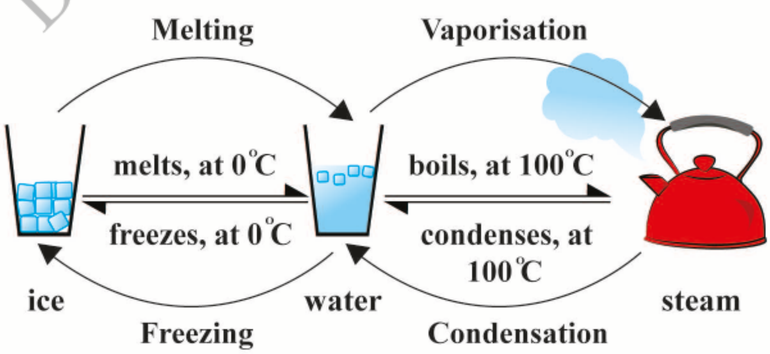
Solid, **liquid** and **gas** are the most common states of matter. Water is a substance, which exists in all three states of matter: ice (solid), water (liquid) and steam (gas). The properties of each state of matter depend on the forces of attraction between the particles which can be weak or strong.



(b) Changes in Matter

The materials around us are subject to constant change. Plants and animal materials decay, metals corrode, and land areas erode. Moreover, every substance – for example, water, sugar, salt, gold or silver – has a set characteristics or properties that distinguish it from all other substances and gives it a unique identity. One way to classify properties is based on whether or not chemical composition of an object is changed by the act of observing the property. Changes in substances can be classified as either physical or chemical.

Physical changes



A physical change is a change in which no new substances are formed. For example, when ice melts from solid to liquid, or when sand is ground to a fine powder, no new substance is formed. Melting, boiling, freezing, evaporation (liquid to gas), vaporisation (liquid to gas), condensation (gas to liquid), sublimation (solid to gas) and deposition (gas to solid) are considered as physical changes.

Chemical changes

A chemical change is a change in which one or more new substances are formed. Examples of chemical changes are cooking of rice from rice grains, green mangoes ripening, burning of a match, and burning of a candle.

Chemical changes occur via chemical reactions such as dissociation, neutralisation, precipitation, etc. For example,

- Heating of limestone or marble (dissociation or decomposition)
- Use of magnesia to treat gastric patient (neutralisation)
- Passing carbon dioxide into limewater (precipitation)

1.3 ELEMENTS, COMPOUNDS AND MIXTURES

All samples of matter can be divided into two categories: pure substances and **mixtures**. A pure substance is a form of matter that always has a definite and constant composition. Pure substances are classified as either **elements** or **compounds**. At the beginning of the 19^{th} century, John Dalton proposed the theory of matter: that all matter was composed of atoms, which were invisible and indivisible. Today, the atom is still considered as the basic unit of any element. An atom may combine chemically to form molecules; the molecules become the smallest unit of any substances that possesses the properties of that substance. Modern experimental evidence has shown that atoms are divisible to create either lighter or heavier atoms.

(a) Elements

There are 92 known elements which occur naturally, either in the free or combined state. Some elements are solids such as copper, iron, zinc, silver, gold, carbon and phosphorus. Some elements are liquids. They are mercury and bromine. Some elements are gases such as oxygen, nitrogen, hydrogen and chlorine. Substances like these, which cannot be broken down into a simpler substance by chemical means, are called elements.

(b) Compounds

Molecules exist in elements as well as compounds. A molecule of an element (molecular element) consists of atoms of the same kind. A molecule of a compound (molecular compound) consists more than one kind of atoms. The atoms of different elements in the molecule of a compound are combined in a definite ratio.

Most substances on Earth occur as compounds, e.g., carbon dioxide (CO_2), water (H_2O), marble ($CaCO_3$), glucose ($C_6H_{12}O_6$), ethanol (C_2H_5OH) and ammonia (NH_3). Although there is only small number of elements, there are millions of compounds.

(c) Mixtures

Mixtures consist of two or more different substances that are mixed physically but not chemically combined. They do not have well defined specific properties and the substances are not in fixed ratios.

The substances in a mixture may be solids, liquids or gases. For example, brass, a solid, is a mixture of the elements copper and zinc; sea water is a mixture of compounds including mainly water and sodium chloride; air is a mixture of gases containing nitrogen, oxygen, argon, carbon dioxide and water vapour. The mixtures may also be heterogeneous or homogeneous (Table 1.1). Therefore, the mixtures can be classified as two main categories: homogeneous and heterogeneous mixtures.

Table 1.1 Different Types of Mixtures

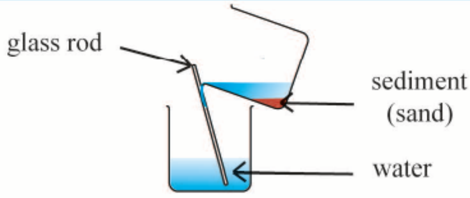
Physical state	Type of mixture	Example
solid-solid	homogeneous	stainless steel (mixture of iron and chromium)
solid-solid	heterogeneous	flour and rice powder
solid-liquid	homogeneous	sugar solution (sugar and water)
solid-liquid	heterogeneous	salt and oil
solid-gas	heterogeneous	dust in air
liquid-liquid	homogeneous	vinegar (mixture of acetic acid and water)
liquid-liquid	heterogeneous	oil and water
liquid-gas	homogeneous	soft drink (carbon dioxide gas dissolved in sterilised water at high pressure)
liquid-gas	heterogeneous	fossil fuel (mixture of crude oil and natural gas)
gas-gas	homogeneous	air (mixture of different gases)

(i) Separation of mixtures

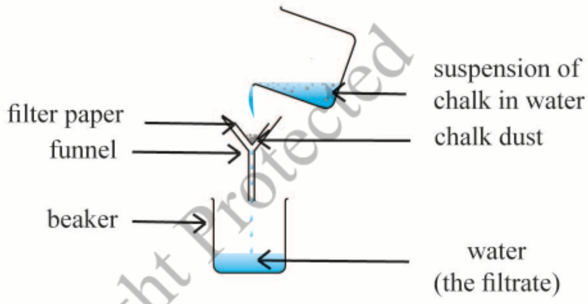
Most substances are naturally found as mixtures; therefore the separation methods shown in Table 1.2 indicate how the physical states of components in the mixture can be separated into pure substances.

Table 1.2 Some Separation Methods of Mixtures

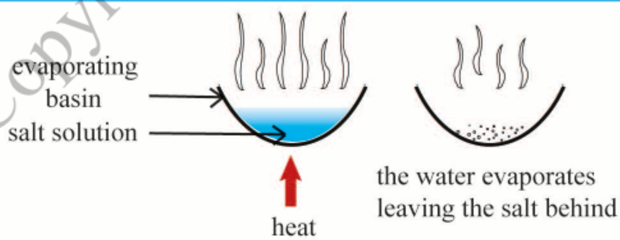
<table>
<tr><th>Types of mixtures and their separation techniques</th><th>Description</th></tr>
<tr><td>a liquid and a solid mixture such as a suspension (sand / water)

Decantation: a process to separate mixtures of solid and liquid or two immiscible liquids to settle and separate by gravity.</td><td>

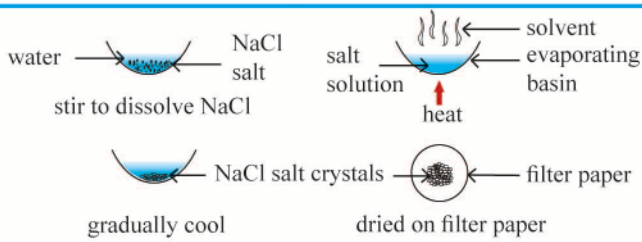
decantation</td></tr>
<tr><td>a solid from a liquid
(chalk dust from water)

Filtration: a method for separating an insoluble solid from a liquid. When a mixture of sand and water is filtered, the sand remains as residue on the filter paper and the water, which is also called filtrate, passes through the filter paper.</td><td>

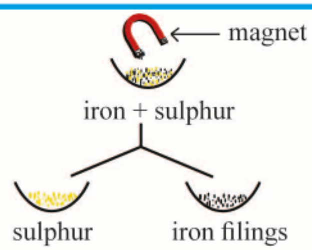
filtration</td></tr>
<tr><td>solute from its solution
(sodium chloride, NaCl salt from its solution)

Evaporation: the process of a substance in a liquid state changing to a gaseous state due to an increase in temperature and / or pressure.</td><td>

evaporation</td></tr>
<tr><td>a solute crystal from its solution
(sodium chloride, NaCl salt from its solution)

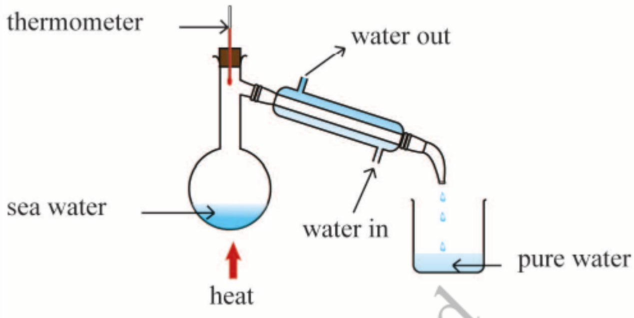
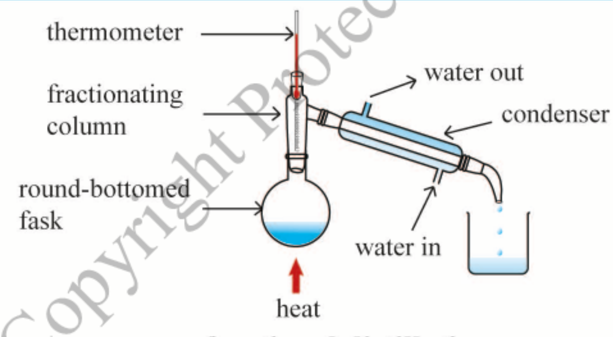
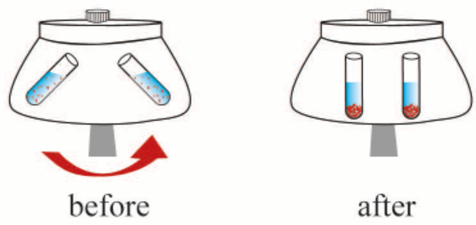
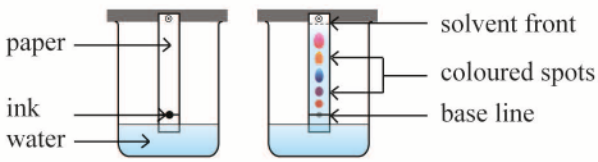
Crystallisation: a process by which a chemical is converted from a liquid solution into a solid crystalline state.</td><td>

crystallisation</td></tr>
<tr><td>to attract magnetically susceptible materials (sulphur and iron mixture)

Magnetic separation: a method used to separate the components of a mixture when at least one of them is magnetic in nature.</td><td>

magnetic separation</td></tr>
</table>

Continued from **Table 1.2**

Types of mixtures and their separation techniques	**Description**
a solvent from a solution (pure water from sea water) **Simple distillation**: a procedure by which two liquids with different boiling points can be separated. It is used to separate solvent from a solution.	 **simple distillation**
liquids from each other (separation of petroleum) **Fractional distillation**: a method for separation of a liquid mixture into fractions with different boiling points (and hence chemical composition) by means of distillation, typically using a fractionating column.	 **fractional distillation**
a solid from a liquid (milk, blood) **Centrifugation**: a technique used for the separation of particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed.	 **centrifugation**
different substances from a solution (separation of ink by paper chromatography) **Chromatography**: a separation method of the mixed substances that depends on the speed at which they move through special media, or chemical substances. It consists of a stationary phase (a solid) and a mobile phase (a liquid or a gas).	 **chromatography**

(ii) Solutions

Some solids such as copper(II) sulphate, sugar and common salt are soluble in water but some solids such as sand, charcoal and chalk are insoluble in water. Some solids such as iodine are slightly soluble in water. When you mix sugar with water, it seems to disappear. That is because its particles spread all through the water particles. The sugar dissolves in water, giving the mixture called as a **solution**. Sugar is the **solute**, and water is the **solvent**.

Sugar (solute) + Water (solvent) = Sugar solution (solution)

Some liquids can mix with one another in all proportions (miscible liquids), while some liquids do not mix (immiscible liquids). For example, ethanol, acetic acid and sulphuric acid are soluble in water but petrol and oils are insoluble in water.

Some gases such as hydrogen chloride and ammonia are very soluble in water. Some gases such as oxygen, nitrogen and hydrogen are not very soluble in water.

Solutions may be gaseous, solid, or liquid in nature. Dry air is a familiar example of a gaseous solution. Brass (copper and zinc) is an example of a solid solution. Liquid solutions may contain solid, liquid or gaseous solutes. Salt water is a familiar example of a solid dissolved within a liquid. Vinegar is a solution containing two liquids, acetic acid and water. Carbonated water contains carbon dioxide gas molecules existing between molecules of water.

Solutions having water as the solvent are referred to as aqueous solutions. Many reactions including those vital for life processes occur in aqueous solutions. Blood and saliva are some of the more familiar solutions of biological importance.

Chemistry in Daily Life

- All substances in our environment are found in three states. Some are in solid (ice, sugar, salt, iron, copper, etc.); some are in liquid (water, oil, juice, etc.); some are in gaseous (air, oxygen, carbon dioxide, etc.) states.
- Mothballs used as deodorant for toilets and bathrooms sublime directly into vapour. It is also a physical change.
- In our daily life, cooking the foods, burning the candle, iron rusting, vegetables rotting, building a fire, photosynthesis reaction, making soaps and detergents, etc. are chemical changes.

Continued from **Chemistry in Daily Life**

- Solution can be found almost everywhere on the Earth, from the ocean to the sky. Every ocean and every lake on the Earth is a solution, because the water has mixed with dirt, salt and various substances.
- Colloidal mixtures (heterogeneous mixtures) have components that tend not to settle out. Milk is a colloid of liquid butter suspended in water.

Review Questions

Section 1.1

(1) Why is chemistry important? Give some examples for your answer.

Section 1.2

(1) Distinguish among the solid, liquid and gas.

(2) Which states can you see the following matter in our environment as solid or liquid or gas?
(a) iron (b) water (c) mercury (d) argon (e) gold (f) copper (g) vinegar

(3) Classify the following changes as either physical or chemical change:

(a) boiling an egg	(b) mixing sand and water	(c) making jelly
(d) evaporating alcohol	(e) souring of milk	(f) baking a cake
(g) digesting food	(h) crushing a can	(i) breaking a glass

(4) Is dissolving glucose in water a physical change or a chemical change? Give reason for your answer.

Section 1.3

(1) When attempts are made to break down substance **A** by chemical methods, the same original substance is always formed. Is substance **A** an element or a compound?

(2) When a substance is broken down by chemical means, two substances with different properties are formed. Is the original substance an element or a compound?

(3) Give two examples for each of the following:
(a) solids that dissolve in water
(b) insoluble solids in water
(c) solvents other than water.

Key Terms

- **Matter** is made up of tiny particles, and has mass and takes up space. Three common states of matter are solid, liquid and gas.
- A **solid** is a substance which has definite volume and shape because particles in a solid are held together in a fixed position. It cannot be compressed and does not flow.

- A **liquid** is a substance which has definite volume but no definite shape because particles in a liquid are not held in a fixed position. It takes the shape of the container in which it is placed and flows in all directions. It cannot be compressed.
- A **gas** is a substance which has no definite volume and shape because particles in a gas are in a random arrangement so that they can move freely. It fills up every space; it can enter and it takes up the volume and the shape of its container; it can easily be compressed, and flows in all directions.
- A **physical change** is a change in which no new substances are formed. There may be a temporary change in colour, temperature and state of the substances but no new substances are formed in the physical change.
- A **chemical change** is a change in which one or more new substances are formed. The substances change in colour, temperature and state but they also change into a new substance or substances in the chemical change.
- An **element** is a substance that cannot be broken down into other simpler substances through chemical means. Every element is made up of its own type of atoms. Therefore, it has a unique position in the Periodic Table.
- A **molecule** is the simplest unit of the chemical substance, usually a group of two or more atoms.
- A **compound** is a substance containing two or more different elements chemically joined together in a fixed ratio.
- A **mixture** is a combination of more than one substance, where these substances are not bonded to each other. It consists of two or more substances which may be present in any proportion by weight. The constituents of the mixture do not combine chemically.
- A **heterogeneous mixture** is one that is non-uniform, and where the different components of the mixture can be seen. The components separate, and the composition varies.
- A **homogeneous mixture** is one in which the composition of its components are uniformly mixed throughout. The components cannot be seen separately on visual or microscopic examination.
- A **solute** is a substance which dissolves in a solvent to give a solution.
- A **solvent** is a substance, mostly liquid, in which another substance dissolves to give a homogeneous mixture.
- A **solution** is a clear homogeneous mixture obtained when a substance dissolves in a solvent. In a solution the solute is uniformly distributed throughout the solution.

EXERCISES

1. Write TRUE or FALSE for the following statements. If FALSE, correct it.
   (a) Melting butter is a chemical change.
   (b) Lighting of candle is a physical change.
   (c) Mixtures consist of two or more different substances that are chemically combined.
   (d) Flour and rice powder are solid-solid homogeneous mixture.

(e) Separation of sugar from tea can be done with filtration.
(f) Sea water is a mixture and not a single substance.

2. Fill in the blanks with suitable word / words given below.

   components, separation, states, compounds, mixtures

   Many _____ can contain useful substances mixed with impurities. Chemists have developed different _____ methods for separating the _____ from complex mixture. The methods depend on the properties of the _____ of the mixture and the_____ of components to be separated.

3. At room temperature and pressure, which of the substances listed below is a solid element, a liquid element, a solid compound, a liquid compound, a gas compound, a homogeneous solution, a heterogeneous solution, a gaseous mixture or a solid mixture? gold, ash, soil, carbon dioxide, air, mercury, limestone, bromine, milk, water, vinegar

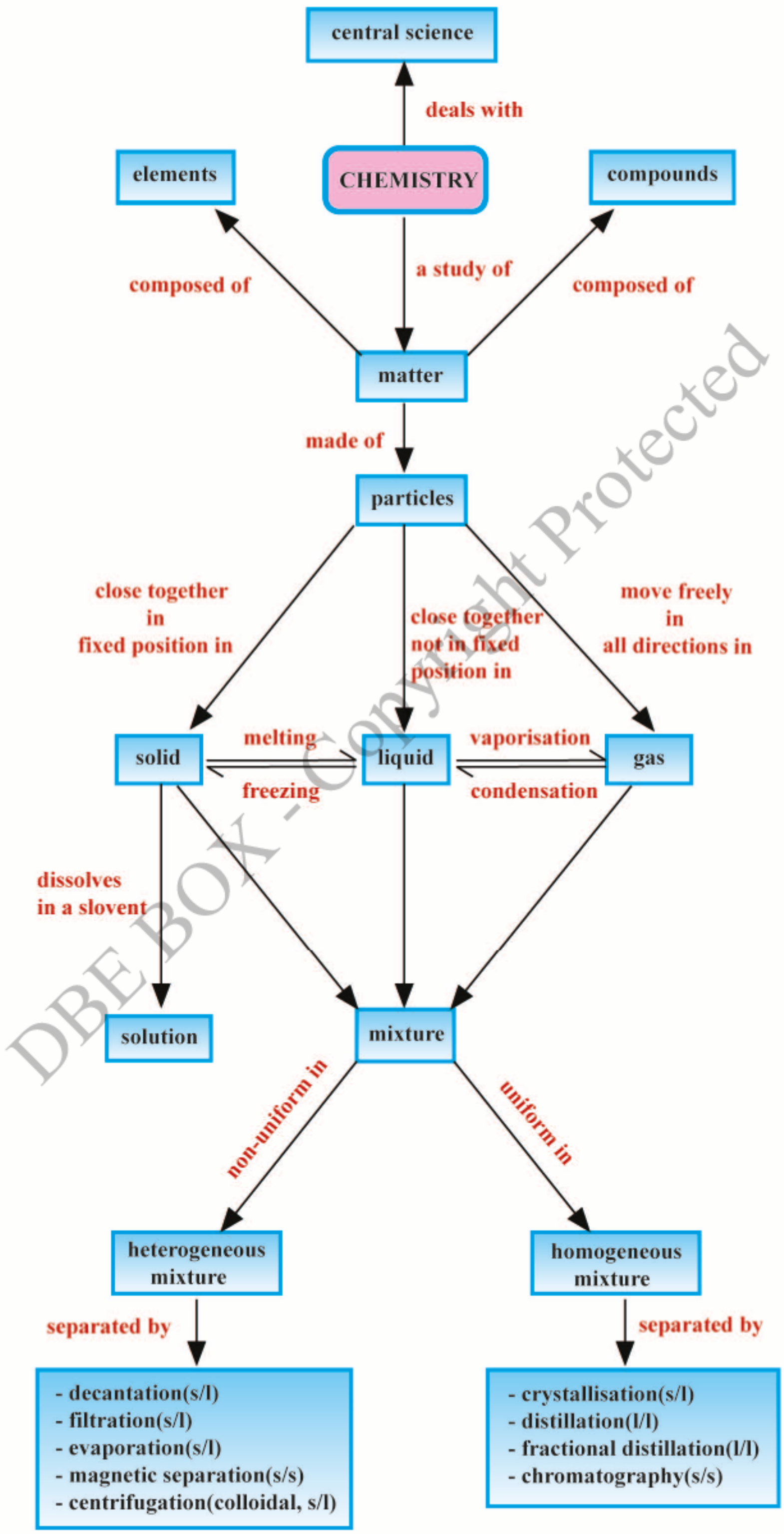
4. (a) Which of the following can be classified as a mixture?
   yogurt, table salt, smoke, iron, soap solution, silver coin

   (b) Choose one correct answer from the following:
   An element can be defined as:
   (i) A substance that cannot be separated into two or more substances by ordinary chemical (or physical) means
   (ii) A substance with constant composition
   (iii) A substance that contains two or more substances, in definite proportion by weight
   (iv) A uniform substance

5. This question is about ways to separate and purify substances. Match each term from List A with the correct description from List B.

List A	List B
(a) evaporation	(i) a solid appears as the solution cools
(b) condensing	(ii) used to separate a mixture of two liquids
(c) filtering	(iii) the solvent is removed as a gas
(d) crystallising	(iv) this method allows you to recycle a solvent
(e) distillation	(v) a gas changes to a liquid, on cooling
(f) fractional distillation	(vi) separates an insoluble substance from a liquid

CHAPTER REVIEW
(Concept Map)



CHAPTER 2

ACIDS, BASES AND SALTS

Acid-Base chemistry is important in a wide variety of everyday life. In our bodies, in our home and in our industrial society, acids, bases and salts play key roles.

In our bodies, proteins, enzymes, blood, genetic materials and other components of living matter contain both acids and bases.

The organs of human and animals also contain acids. You probably know how painful a bee sting or an ant bite can be. The pain is caused by an acid called methanoic (formic) acid. The pain we sometimes feel in our leg muscles during exercise is caused by lactic acid. Our stomach produces an acid (HCl) for food digestion.

H_2SO_4 (battery acid)	HCl	HNO_3	CH_3COOH (vinegar)	Antacid tablets	NH_4OH (glass cleaner)

Learning Outcomes

After completing this chapter, students will be able to:

- describe the physical and chemical properties of acids, bases, alkalis and salts and their uses in daily life;
- distinguish between bases and alkalis;
- relate the role of indicators and the pH scale;
- classify the salts based on acids used.

We often use salts in our home. We sprinkled sodium chloride on our food to bring out its taste. We may use bath salts to help us relax in the bath and some of the medicines we take are salts. Salts are used as a preservative in pickles and in curing meat and fish, in the manufacture of soap, keeping ice from melting and making chemicals like washing soda, baking soda, etc.

2.1 ACIDS

Acid is a substance which when dissolved in water produces hydrogen ions (H^+). In other words, an acid increases the number of H^+ ions in an aqueous solution.

Many 'acids' are corrosive, meaning they destroy body tissue and clothing, and many are also poisonous. Acids can be found in many foods we eat. Some organic acids are used in food preservative, food fermentation, salad, etc., such as ethanoic acid (acetic acid). Some organic acids are found in the food presented in Figure 2.1.

Yogurt (lactic acid) | Apples (malic acid) | Citrus fruits (citric acid) | Grapes (tartaric acid) | Gooseberries (Zee Phyu) (ascorbic acid) | Roselle plant (Chin Baung) (oxalic acid)

Figure 2.1 Occurrence of Some Organic Acids in Nature

The word 'acid' comes from the Latin word *acidus*, which means sour. Acids can be classified as mineral acids (inorganic acids) and organic acids. Acids can be strong or weak. Strong acid cannot dissociate itself without water. When a strong acid dissolves in water, it completely dissociates to produce hydrogen ions, which are protons, (H^+), and a weak acid only partially dissociates in water. Mineral acids are strong acids and organic acids are weak acids. Some acids and their strengths are described in Table 2.1.

Table 2.1 Names and Formulae of Some Acids and Their Strengths

Name of acids	Chemical formula	Strength of acids
hydrochloric acid	HCl	strong
sulphuric acid	H_2SO_4	strong
nitric acid	HNO_3	strong
ethanoic acid	CH_3COOH	weak

(**Caution**: Always add strong acid slowly to water. This is because the acid becomes very hot and splashing may happen.)

Properties

An acid is a compound which becomes a proton (H^+) donor when dissolved in water. The properties and reactions of an acid are due to these hydrogen ions.

Physical properties

(i) Acids are hazardous, irritant and corrosive.
(ii) Acids have a sour taste. **(DON'T TASTE, DON'T TOUCH.)**
(iii) Acids dissolve in water to form solutions which conduct electricity.
(iv) Acid solutions have pH values less than 7.
(v) Acids have the ability to change the colour of indicators and turn blue litmus paper (an indicator) red.

Chemical properties

(i) Acid reacts with metals to form a salt and hydrogen.

metal + acid (dil.) ⟶ salt + hydrogen

(ii) Acid reacts with carbonate to form a salt, carbon dioxide and water.

metal carbonate + acid (dil.) ⟶ salt + carbon dioxide + water

2.2 BASES AND ALKALIS

Bases and alkalis are found in many cleaning agents such as soap and many household detergents. When ashes are burnt, the product is alkaline. The word **alkali** comes from the Arabic 'al-qili' which means burnt ashes. It is used traditionally by gardeners as a good source of potash.

(a) Bases

A **base** is usually a metallic oxide or hydroxide and will react with an acid to form a salt and water only.

For example,

metal oxide + acid (dil.) ⟶ salt + water

metal hydroxide + acid (dil.) ⟶ salt + water

(b) Alkalis

An alkali is a base that is soluble in water. An example of a soluble base is sodium oxide.

sodium oxide + water ⟶ sodium hydroxide

$$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$$

Alkalis can be strong or weak. Strong alkalis dissolve in water to produce OH^- ions in solution. Sodium hydroxide and potassium hydroxide are examples of strong alkalis. Ammonium hydroxide is the most common example of a weak alkali.

Most bases are insoluble in water. MgO, CuO, Fe_2O_3, etc. are insoluble bases. They do not react with water and also not dissolve in water. Thus, it is a base and not an alkali.

(c) Properties

Physical properties

(i) Strong bases are hazardous to handle.
(ii) Bases have a bitter taste and soapy feel. **(DON'T TASTE)**
(iii) Bases cause a colour change in indicators. Litmus changes from red to blue in a basic solution.
(iv) Alkalis have pH values greater than 7.

Chemical properties

(i) Bases react with acids to neutralise each other and form a salt and water.
(ii) When alkalis are gently warmed with ammonium salt, it gives off ammonia gas.
(iii) Alkalis react with fatty acids to form soaps.

2.3 INDICATORS AND THE pH SCALE

Many brightly coloured flowers, vegetables and berries make good indicators. For example, the coloured juice extracted from red cabbage is pink in acids and green in alkalis. Hydrangea flowers are interesting natural indicators. They are blue when grown in acidic soil and pink or red when grown in alkaline soil.

(a) Indicators

Indicators are dyes, or a mixture of dyes, which change colour when they are added to acids or alkalis. Some indicators can be used to determine pH because of their colour changes somewhere along the pH scale (Figure 2.2). Litmus is red in acidic solution, purple in neutral and blue in alkaline solution.

(b) The pH Scale

A measure of the acidity or alkalinity of the solution is known as **pH**. The pH value can be measured by pH meter (Figure 2.3). It is a much more reliable and accurate method of measuring pH than the universal indicator paper.

Substances in the body have different pH values. Acidic conditions in the stomach (pH~1.5) are needed for good digestion. Usually the body maintains the pH of blood close to 7.4. The pH scale demonstrates the strength of an acid or alkali (Figure 2.2). Solutions and their pH values are described in Table 2.2.

Table 2.2 Solutions and Their pH Values

Solutions	pH value (0 to 14)
acidic	below 7
basic	above 7
neutral	equal to 7

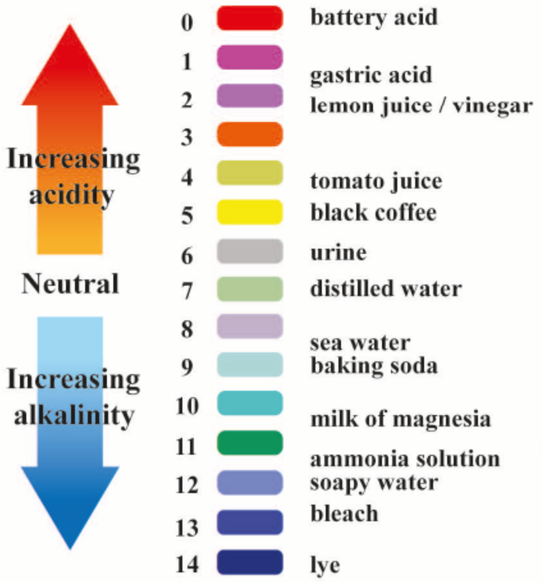


Figure 2.2 The pH Scale

(a) (b)

Figure 2.3 (a) The pH Meter
(b) Universal Indicator Paper

2.4 SALTS

Many different types of salts can be found in nature. The sea water contains many salts such as sodium chloride, potassium chloride, magnesium sulphate, magnesium chloride and magnesium bromide.

The Earth's crust is made up of minerals containing various types of salts such as calcium fluoride (fluorite), magnesium sulphate (Epsom salt), lead(II) sulphide (galena) and calcium carbonate (limestone), etc.

A salt is produced when an acid reacts with a base. The salt consists of two parts. One part comes from the base, the other from the acid. An example is sodium chloride, NaCl, produced from sodium hydroxide and hydrochloric acid.

Classification of Salts

The salts can be classified based on acids used. Some examples of salts (chloride, sulphate, nitrate, sulphite and carbonate salts) formed from different acids are shown in Table 2.3.

Some salts are soluble and some are insoluble depending on the types of metals.

Table 2.3 Some Salts Formed from Different Acids

Acids		Salts	
hydrochloric acid	HCl	**chloride salts** sodium chloride zinc chloride magnesium chloride	 NaCl $ZnCl_2$ $MgCl_2$
sulphuric acid	H_2SO_4	**sulphate salts** sodium sulphate copper(II) sulphate	 Na_2SO_4 $CuSO_4$
nitric acid	HNO_3	**nitrate salts** sodium nitrate potassium nitrate ammonium nitrate copper(II) nitrate	 $NaNO_3$ KNO_3 NH_4NO_3 $Cu(NO_3)_2$
sulphurous acid	H_2SO_3	**sulphite salts** sodium sulphite	 Na_2SO_3
carbonic acid	H_2CO_3	**carbonate salts** sodium carbonate calcium carbonate	 Na_2CO_3 $CaCO_3$
ethanoic acid	CH_3COOH	**ethanoate salt** sodium ethanoate	 CH_3COONa

Chemistry in Daily Life

Some examples of most common uses of acids in daily life are listed in the following Table:

Acids	Formula	Uses
sulphuric acid	H_2SO_4	extraction of some metals such as copper, manufacture of fertilisers, detergents, paints, rubber, paper and pulp industry, car batteries and rust removal
hydrochloric acid	HCl	to help swimming pools be free of algae, to make aqua regia for dissolving gold and platinum

Continued from **Chemistry in Daily Life**

Acids	Formula	Uses
nitric acid	HNO_3	making fertilisers and explosives, to make aqua regia (a mixture of one part of the concentrated nitric acid and three parts of the concentrated hydrochloric acid) for dissolving gold and platinum
phosphoric acid	H_3PO_4	making fertilisers and rust inhibitor
carbonic acid	H_2CO_3	in fizzy drinks
citric acid	$C_6H_8O_7$	in fruit juices, in the preparation of effervescent salts, as a food preservative
ethanoic acid	CH_3COOH	in vinegar, used in salad dressings

Some common bases and alkalis and their uses are described in the following Table:

Bases and alkalis	Formula	Uses
sodium hydroxide	$NaOH$	making soap, paper, baking soda, oven cleaners
calcium hydroxide (slaked lime)	$Ca(OH)_2$	treating acidic soil (liming), making cement, limewater, mortar, plaster
calcium oxide (quicklime)	CaO	making cement
magnesium oxide	MgO	in antacids (gastric medicine), in toothpaste
ammonia	NH_3	in many household cleaners and production of fertilisers

- The pH is important for the correct functioning of the body, for food and water and for the growth of plants.
- Many plants do not grow properly in highly acidic or highly alkaline soil. Highly acidic soil is treated by spreading quicklime (CaO), slaked lime ($Ca(OH)_2$) or calcium carbonate ($CaCO_3$) to lower its acidity.
- Highly alkaline soil is treated by adding gypsum ($CaSO_4.2H_2O$) to lower its alkalinity.

Continued from **Chemistry in Daily Life**

Salts play an important role in our society. Some salts and their uses in society are described in the following Table:

Salts	Formula	Uses
sodium chloride	$NaCl$	food additive
sodium sulphate sodium nitrite sodium citrate	Na_2SO_4 $NaNO_2$ $Na_3C_6H_5O_7$	food preservatives
ammonium sulphate ammonium nitrate ammonium phosphate	$(NH_4)_2SO_4$ NH_4NO_3 $(NH_4)_3PO_4$	fertilisers
potassium chloride	KCl	fertiliser
magnesium sulphate magnesium hydroxide	$MgSO_4.7H_2O$ $Mg(OH)_2$	medical uses (Epsom salt) medical uses (milk of magnesia, MOM)
calcium sulphate	$CaSO_4$	medical uses (Plaster of Paris , POP)

Review Questions

Section 2.1

(1) After rubbing an old copper coin with lemon juice, what visible change happens to the coin? Why?
(2) How can you detect whether a solution is acidic or not? **(Not to taste)**
(3) Ant bite is painful. Why is it so?
(4) Why can you treat bee stings with baking powder?

Section 2.2

(1) What is the difference between base and alkali?
(2) Complete the following:
  (a) All acidic solutions contain ______ ions.
  (b) A base is a usually a ______ oxide or hydroxide.
  (c) A base reacts with an acid to form a ______ and water only.
  (d) Strong alkalis dissolve in water to produce ______ ions in solution.
  (e) When alkalis are gently warmed with ammonium salt, it gives off ______ gas.

Section 2.3

(1) Which of the solutions having the following pH, are acidic or alkaline or neutral?
(a) pH 6 (b) pH 3 (c) pH 7 (d) pH 8
(2) The pH of pancreatic juice is 7.9. Is pancreatic juice acidic or basic?
(3) How do we detect whether a soil is acidic or basic?
(4) Name a common household substance with a pH (a) greater than 7 (b) less than 7 (c) almost 7.

Section 2.4

(1) How would you neutralise hydrochloric acid if you spill it on the floor of a laboratory?
(2) If the soil is too acidic, we add lime to the soil. Explain the purpose of this.
(3) Farmers treat the alkaline soil by using gypsum ($CaSO_4 . 2H_2O$). Why?
(4) We take gastric medicine when we feel stomach pain. Explain the action of this medicine.

Key Terms

- An **acid** is a compound that dissolves in water to produce hydrogen ions, H^+.
- A **base or** an **alkali** is a chemical compound that combines with an acid to form a salt and water. An **alkali** is a base which is soluble in water producing OH^- ions. All **alkalis** are bases but all bases are not alkalis.
- An **indicator** is a substance that has different colours in acidic and alkaline solutions.
- A measure of the acidity or alkalinity of a solution is known as its **pH**. Solutions with $pH < 7$ are acidic and those with $pH > 7$ are alkaline. The solutions of pH 7 are neutral. The pH of pure water is 7. The pH of a solution can be measured by using the pH meter.
- A **salt** is a substance produced from the reaction between an acid and a base or a metal. Based on the acids, salts can be classified as chlorides, sulphates, nitrates, sulphites and carbonates, etc.
- **Neutralisation** is the reaction between an acid and a base to form a salt and water only.

EXERCISES

1. Think carefully about the following statements. Are they TRUE or FALSE? If FALSE, correct it.
   (a) In general, all acid solutions contain hydrogen ions, H^+.
   (b) Copper(II) hydroxide is an alkali.
   (c) The smaller the pH value, the more acidic a solution is.
   (d) Strong acids and alkalis are harmful and corrosive.
   (e) Litmus paper can measure the range of pH of a solution.

2. Select the correct word or words given in the brackets.
   (a) Which of the following compounds can form an aqueous solution of pH >7?
   (carbon dioxide; hydrogen chloride; sodium chloride; sodium hydroxide)

Section 2.3

(1) Which of the solutions having the following pH, are acidic or alkaline or neutral?
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EXERCISES

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   (e) Litmus paper can measure the range of pH of a solution.

2. Select the correct word or words given in the brackets.
   (a) Which of the following compounds can form an aqueous solution of pH >7?
   (carbon dioxide; hydrogen chloride; sodium chloride; sodium hydroxide)

(b) Which of the following gases reacts with sulphuric acid to form a fertiliser? (ammonia; carbon dioxide; hydrogen; nitrogen)

(c) A sample of pond water has a pH value of 11. This means that the water is (weakly acidic; neutral; weakly alkaline; strongly alkaline).

(d) Which of the following substances could be used in excess to change the pH of soil from 5 to 7? (sodium chloride; calcium oxide; hydrochloric acid; sulphuric acid)

3. Fill in the blanks with a suitable word or phrase or numerical value with unit as necessary.

(a) The combination of H^+ and OH^- ions to form water is called _____.

(b) The pH of alkali solution is greater than _____.

(c) Solutions having pH values below 4.5, turn blue litmus paper _____.

(d) A measure of the acidity or alkalinity of a solution is known as _____.

(e) The salts can be classified based on _____ used.

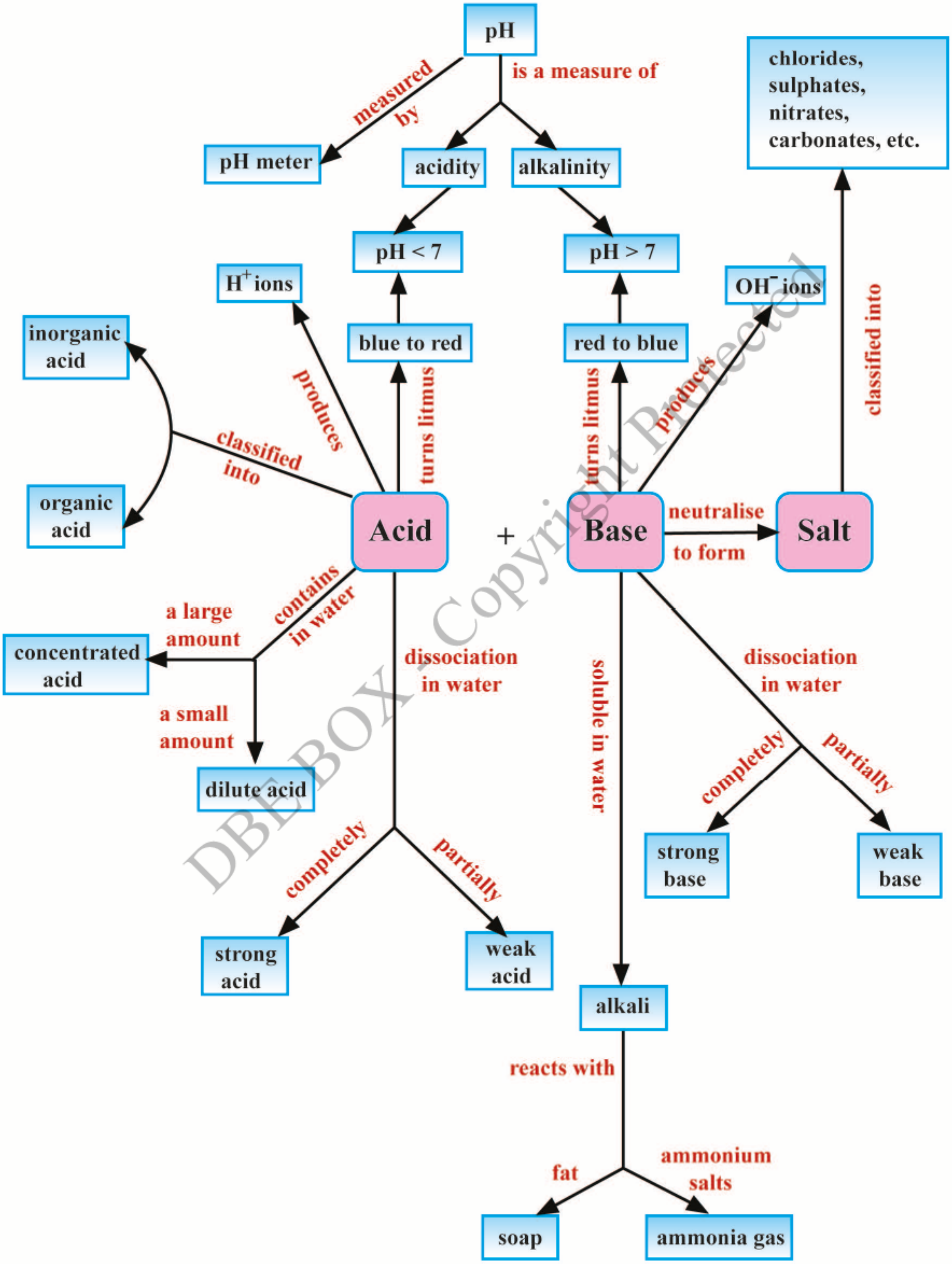
4. Complete the following sentences by using the words given below:

(a) hydroxides, hydrogen, dissolves, salt, oxides, water
An acid is a compound that _____in water to produce _____ions. Acids react with metals to form _____and hydrogen. When acids react with metal _____ or _____, a salt and _____are formed.

(b) acids, ammonia, hydroxide, salt, soluble
Alkalis are water _____ bases. Examples of alkalis are_____ and sodium _____. Alkalis react with_____ to form a _____and water.

(c) universal, alkaline, neutral, high, scale, seven, acidic
The pH_____ shows how acidic or _____a solution is. Strongly_____ solutions have a low pH, strongly alkaline solution have a _____ pH. A solution that is neither acidic nor an alkaline is called a_____ solution. It has a pH of _____. The pH of a solution can be measured using _____indicator or a pH meter.

CHAPTER REVIEW
(Concept Map)

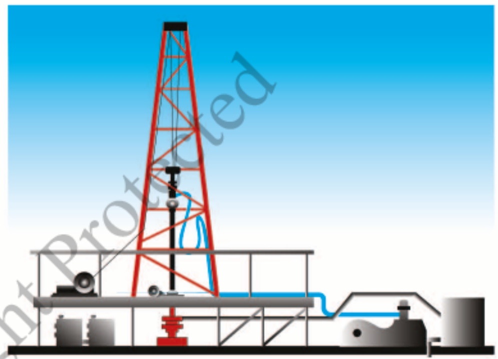


CHAPTER 3 FOSSIL FUELS

In the twenty first century society, the main energy source which is used to operate the machines, power cars and buses, daily cooking our food and lighting our homes is obtained from fossil fuels.

These fuels are classified as non-renewable and are finite (limited) resources because they take a very long time (millions of years) to form. Modern society is still using up fossil fuels reserved for heavy and soft industries, for non-stop transportation, generating electricity in power stations, and also for cooking.

There are three major fossil fuels. They are (a) coal (b) crude oil and (c) natural gas. Coal comes from fossil plant materials. Crude oil and natural gas are formed from the bodies of marine microorganisms. The formation of these fuels took place over many millions of years. That is why they are not only classified as non-renewable, but of finite (limited) reserved resources.


Oil and gas production

Learning Outcomes

After completing this chapter, students will be able to:

- identify the sources, properties and behaviours of fossil fuels;
- explain the process of fractional distillation as applied to crude oil;
- describe the cracking process used to split long chain hydrocarbon molecules into shorter ones;
- recognise the sources, compositions and uses of alternative fuels.

3.1 COAL

Coal is fossilised plant material containing mainly carbon together with hydrogen, nitrogen and sulphur. Most coal was formed during the Carboniferous period (286-360 million years ago). The action of pressure and heat through geological forces converted the plant material in stages from peat to lignite to bituminous soft coal to hard coal (anthracite). At each stage the percentage of carbon increases. Coal contains between 80 to 90 % carbon by mass. Coal is found in many countries. The United States, Russia, China and some European countries have large coal deposits. MYANMAR also has coal deposits in Shan State, Kachin State, Tanintharyi Region and Sagaing Region.

Coal is a black solid. It is mainly carbon, with small amounts of hydrogen, oxygen, nitrogen and sulphur. Coal is used in many countries to produce electricity. At a coal burning power station, coal is burnt in air to heat the water in a boiler. The steam produced turns the steam turbines to generate electricity (Figure 3.1). When coal is burnt, the main products are carbon dioxide and water.

$$\text{coal} + \text{air} \longrightarrow \text{carbon dioxide} + \text{water}$$

Quantities of soot, oxides of sulphur and nitrogen, and a solid residue called ash are also produced. Various kinds of pollutants are produced when coal is burnt.

Coal is also used to produce coke. When coal is strongly heated in the absence of air, a solid called **coke** is produced. Coke is almost pure carbon. It burns more cleanly than coal and it does not produce as much smoke. The main use of coke is as a reducing agent in the blast furnace for making iron. It is also used to produce zinc.

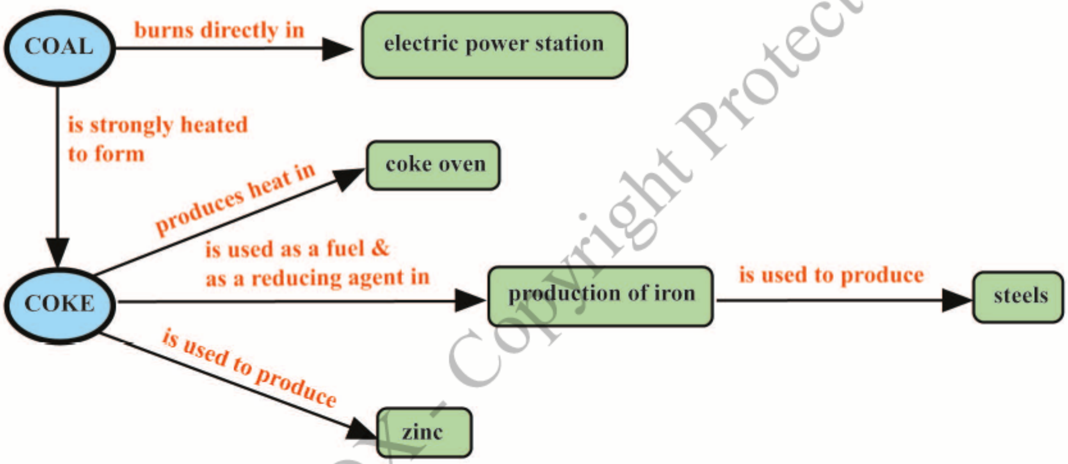


Figure 3.1 Uses of Coal and Coke

3.2 CRUDE OIL AND NATURAL GAS

The crude oil and natural gas were formed from dead animals and plants that lived in the sea a long time ago. The dead materials settled at the bottom of the sea, where it was covered with sand and other sediment. Rock then formed on top of the animal and plant remains. High pressure and temperature changed it into petroleum over millions of years. Some of it was changed into a gas - called natural gas.

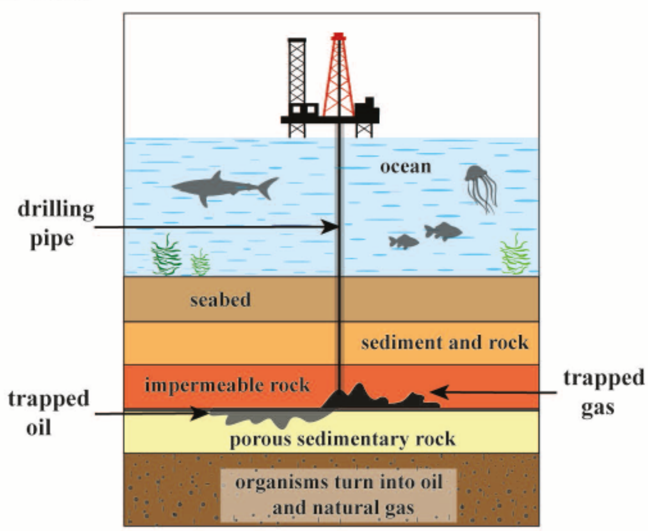


Figure 3.2 Extraction of Natural Gas and Oil from Seabed

Crude oil and **natural gas** are found together, held in between layers of non-porous rock in the ground (Figure 3.2). These fuels are extracted by a drilling pipe through the rock. These fuels are hydrocarbons. Hydrocarbons are made up of hydrogen and carbon only.

(a) Crude Oil

Crude oil (also called petroleum) is a thick black liquid. It is found together with natural gas in the Earth. Today, about 40 % of the world's energy comes from petroleum while 20 % comes from natural gas. Large amounts of petroleum are produced in the Middle East, the United States and Russia.

Myanmar is one of the world's oldest oil producers. British Burma exported its first barrel of crude oil in 1853. The London-based Burma Oil Company (BOC) was established in 1871 and began production in the Yenangyaung oil field in 1887 and the Chauk oil field in 1902.

(b) Natural Gas

Natural gas was formed at the same time as crude oil and the two are often found together, although it may occur on its own or with coal. It consists mainly of methane (85-95 %) with varying amounts of ethane, propane, butane and other gases such as carbon dioxide, nitrogen, hydrogen sulphide, etc.

3.3 FRACTIONAL DISTILLATION OF CRUDE OIL

Crude oil is a mixture of many different **hydrocarbon** molecules. These molecules have different sizes and number of carbon atoms. The small molecules have few carbon atoms and low boiling points, while the large molecules have many carbon atoms and high boiling points. Therefore, it is necessary to refine the crude oil into useful fuels and chemicals.

Separation of the crude oil takes place in a fractional distillation column, or fractionating tower into different fractions (parts) in an oil refinery.

Crude oil is heated in a furnace. Many fractions could be collected, each having a different boiling point range. The oil vaporises and passes up the fractionating column. The fractions condense and come out of the column at different heights depending on their boiling points. The petroleum gas fraction comes out first at the top of the column as its molecules have the lowest boiling points. Then, a series of fractions such as petrol, naphtha, kerosene and diesel comes out in order of increasing boiling points, number of carbon atoms and viscosity. The lubricating oil fraction comes out at the bottom because its molecules have higher boiling points, followed by fuel oil. Bitumen is the residue at the bottom of the column.

All the fractions are insoluble in water and burn in air. The properties and uses of some of the main fractions from the distillation of crude oil are given in Table 3.1.

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Table 3.1 Some Important Crude Oil Fractions

Fraction	Approximate boiling point range / °C	Approximate number of carbon atoms per molecule		Important uses
refinery gas (petroleum gases)	below room temperature < 40	1 ~ 4	Increasing boiling point and viscosity ↓	bottled gas for gas cookers and motor cars
petrol (gasoline)	35 ~ 75	5 ~ 10		petrol for motor cars
naphtha	70 ~ 170	8 ~ 12		petrochemicals
paraffin (kerosene)	170 ~ 250	10 ~ 14		fuel for jet aircraft; kerosene lamps for light and kerosene stoves for cooking
diesel oil	250 ~ 340	15 ~ 25		fuel for diesel engines of buses, lorries, trucks, steamers and trains
lubricating oil	350 ~ 500	19 ~ 35		lubricant in engines to reduce friction; also for making waxes and polishes
fuel oil	500 ~ 600	30 ~ 40		fuel for ships, factories and central heating
bitumen (residue)	> 600	> 70		a black substance used to make surface roads and roofing

Note: 'Crude oil' (UK) is the same as 'petroleum' (USA); 'petrol' (UK) is the same as 'gasoline' (USA); and 'paraffin' (UK) is the same as 'kerosene' (USA).

There is a greater demand for petrol and kerosene than other fractions. Consequently, cracking method is used to produce smaller molecules from larger hydrocarbon molecules.

3.4 CRACKING

Fuels made from oil mixtures contain large hydrocarbon molecules and are not efficient. They do not flow easily and are difficult to ignite. Crude oil often contains too many large hydrocarbon molecules and not enough small hydrocarbon molecules to meet demand. Consequently, cracking is important to convert the larger hydrocarbon molecules to smaller ones.

Cracking takes place in huge reactor. In this reactor, particles of catalyst (made of powdered minerals such as silica, alumina and zeolites) are mixed with the hydrocarbon fraction at a temperature around 500 °C and moderately low pressure. The cracked vapours produced smaller molecules. All cracking reactions give two types of products:

(i) an alkane with a shorter chain than the original and

(ii) a short-chain alkene molecule.

Both these products are useful. The shortened alkanes can be blended with the gasoline fraction to enrich the petrol. The alkenes are useful as raw materials for making several important products. Figure 3.3 shows the various uses for the ethene produced; preparation of ethanol and plastics such as polyethene, polychloroethene and polystyrene. Here in, ethene polymerises to polyethene, i.e., many ethene molecules combine to form larger molecule polyethene that contains repeating structural units. Propene polymerises to polypropene (trade name 'polypropylene'), while butene polymerises to produce synthetic rubber.

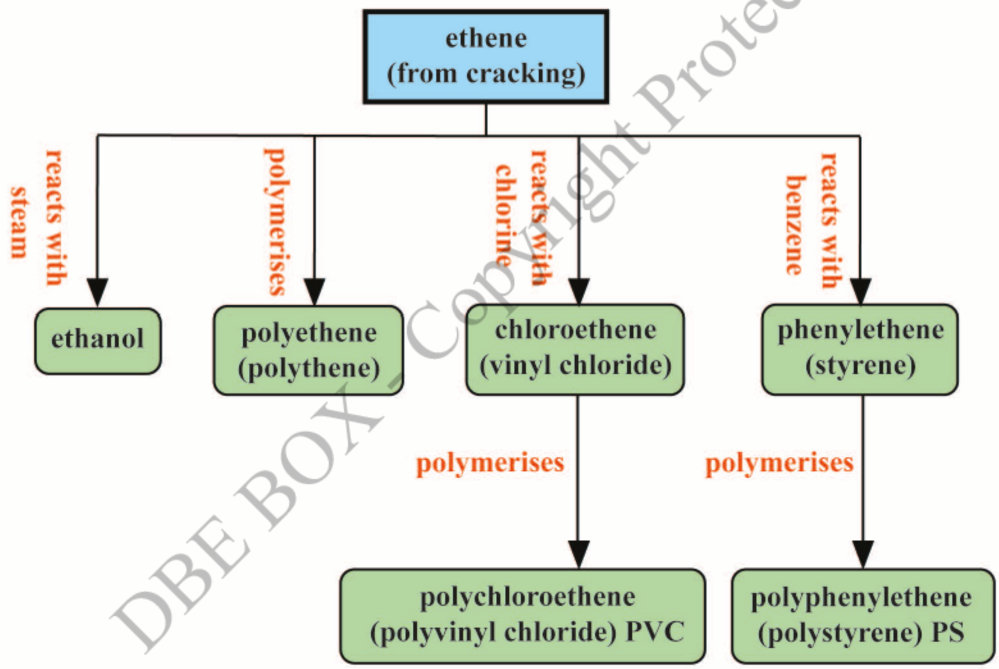

Figure 3.3 Important Products from Ethene

3.5 OTHER KINDS OF FUELS

Fossil fuels take millions of years to form. There are limited amounts in the Earth. At the present rate of consumption, petroleum and natural gas may run out within 50 years and coal will only last for a further 250 years. Therefore, scientists have tried to overcome the problem of limited crude oil supply by looking for alternative fuels to replace crude oil.

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An **alternative fuel** is an internal combustion engine fuel other than gasoline or diesel oil. Alternative fuels include natural gas (methane, compressed natural gas - CNG), propane (liquefied petroleum gas - LPG), hydrogen fuel, biomass-derived fuels, biodiesel, bio-alcohols (including ethanol and methanol), alcohol mixtures with gasoline or other fuels (gasohol) and electricity

Hydrogen fuel, biomass-derived fuels, biodiesel, bio-alcohols (including ethanol and methanol) are renewable fuels, and also known as alternative transport fuels.

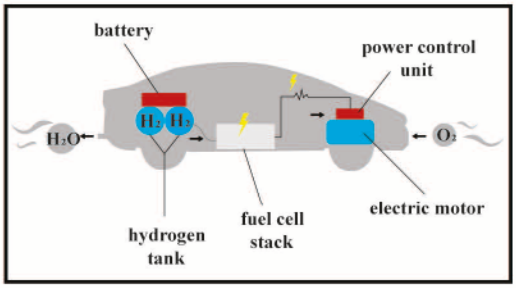
Some alternative fuels and their uses are described in Table 3.2.

Table 3.2 Some Alternative Fuels and Their Uses

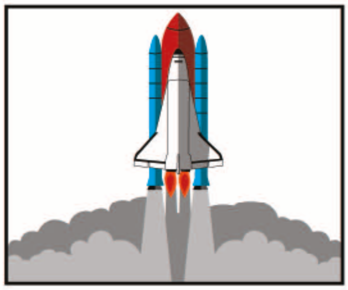
Fuels	Source	Composition	Uses
LPG (Liquefied Petroleum Gas)	petroleum gas	propane and butane	used as fuels in vehicles, cars, trucks and stationary power generation, for cooking and other heating systems
CNG (Compressed Natural Gas)	natural gas	90 % methane	used as fuels in vehicles, cars, trucks and stationary power generation
biodiesel	plant oils, animal oils	long chain esters	used in power tractor engines, petro-diesel engines and electricity generation engines
biogas	waste organic matter	methane	used for heating and cooking, and the solid residue is used as a fertiliser
hydrogen fuel	water, petrol and natural gas	hydrogen	used as fuels for cars, in space shuttles and other big rockets
gasohol	petrol and ethanol	90 % petrol + 10 % ethanol, 15 % petrol + 85 % ethanol (US)	used as fuels in vehicles

(a) Hydrogen Fuel

Most hydrogen is manufactured on a **large scale** in industry from petrol and natural gas. Hydrogen burns cleanly in air. The product is steam, which is a non-pollutant. However, hydrocarbon fuels, such as petrol and diesel, produce polluting oxides of carbon in combustion.



Hydrogen fuel cell car


Hydrogen fuel cell in space shuttle

Hydrogen produces at least twice as much heat energy per gram when burnt, than any other common fuel. This is why it is used as a fuel in space shuttles and other big rockets. Hydrogen has great possibilities as a fuel for cars, replacing petrol. Experimental hydrogen- powered cars are already being used.

(b) Biogas (Methane or Marsh gas)

Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source.

Methane is produced from organic waste (biomass) when it decays in the absence of air. This can be exploited as a source of energy. In India and China, biomass digesters are important sources of fuel for villages. Industrialised countries produce large amounts of waste, which is deposited in landfill sites. Biogas forms as the rubbish decays.

Methane gas is formed naturally under a number of different circumstances. Anaerobic bacteria help decomposition of organic matter under geological conditions to produce natural gas. Methane accumulates in coal-mines, where it can cause explosions. Marsh gas, which bubbles up through the stagnant water of marshes, swamps and paddy fields, is also methane. Methane produced in this way contributes to the **'greenhouse effect'**.

What is greenhouse effect?

The gases occurred naturally in the atmosphere that trap heat are called **greenhouse gases** (GHGs) such as water vapour, carbon dioxide, methane, nitrous oxide and ozone. Besides, man-made chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), as well as sulphur hexafluoride (SF_6) are also GHGs.

Human activities, such as burning fossil fuels and farm-lands, and excessive use of fertilisers increase the amount of greenhouse gases. This greenhouse effect is gradually increasing the Earth's surface temperature, resulting in more extreme weather, such as flooding, drought, cyclone, forest fire, landslide, heat wave, etc. Another growing concern is the melting of glaciers and Artic ice which will increase sea levels resulting in many coastal communities being flooded and no longer habitable. The average temperature of the Earth increases leading to **global warming** (Figure 3.4).

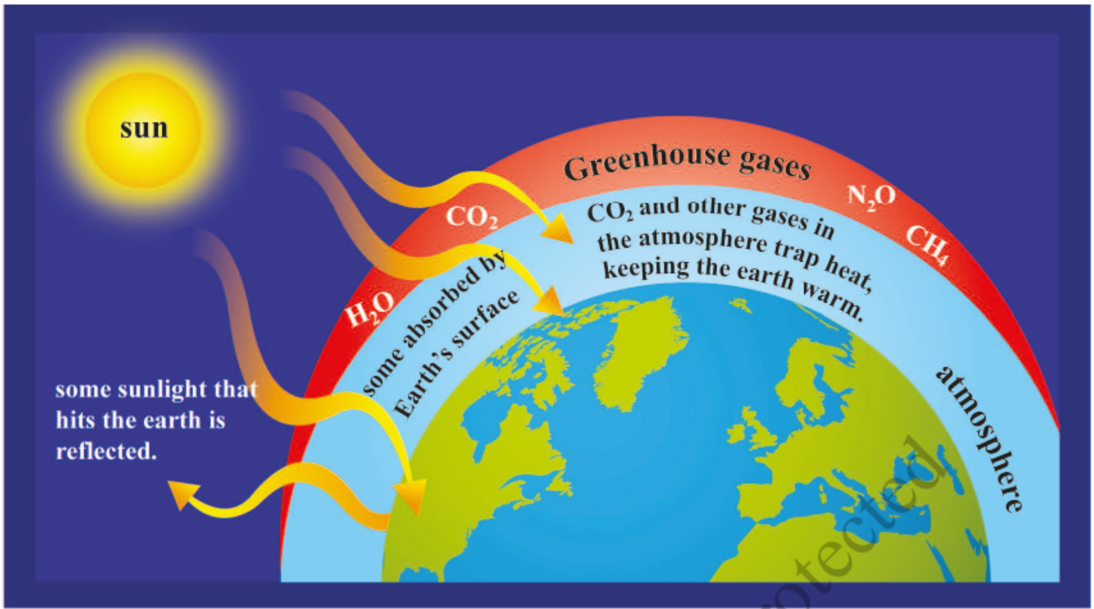


Figure 3.4 Global Warming and the Greenhouse Effect

Chemistry in Society

- The fuels that are derived from petroleum support more than half of the world's total energy production.
- The order for the main energy sources currently used in the world in terms of producing energy is:
  crude oil > coal > natural gas > hydroelectric > nuclear fission > wind > biofuels > solar > geothermal.
- Crude oil, coal and natural gas are non-renewable fossil fuels and contain stored energy from photosynthesis trapped millions of years ago.
- Plant oil, hydroelectric, wind, biofuels, solar and geothermal are all renewable energy sources.
- Fuel oil and natural gas are used to generate electricity. Petroleum products are used for the manufacture of synthetic fibers for clothing and in plastics, paints, chemicals, fertilisers, insecticides, soaps and synthetic rubber.
- Natural gas offshore projects in Myanmar are Yadana project, Yetagon project, Shwe Platform project and Zawtika project.

Natural gas offshore projects in Myanmar

Review Questions

Sections 3.1 and 3.2

(1) Why is petroleum called a fossil fuel?
(2) Describe the uses of coal.
(3) What gases are present in natural gas?

Section 3.3

(1) Name a crude oil fraction that: (a) is used for jet aircraft (b) has the smallest molecules (c) is the most viscous (d) has molecules with 19 ~ 35 carbon atoms.

(2) Consider the following petroleum fractions:
naphtha, paraffin, bitumen, diesel oil, lubricating oil
Which of the above fractions:
(a) has the lowest boiling point; (b) has the highest boiling point;
(c) is used to make waxes; (d) is used as a fuel for jet engines;
(e) contains $C_{15} \sim C_{25}$ carbon atoms per molecule?

(3) There is a limited quantity of petroleum on Earth. Describe two ways of conserving petroleum.

Section 3.4

(1) Describe the usual conditions needed for cracking a hydrocarbon in the petroleum refinery.

(2) What are always produced in a cracking reaction?

Section 3.5

(1) Name each alternative fuel that: (a) is used for cooking and heating systems (b) has the composition of long chain ester (c) is the source of waste organic matter (d) has molecules with 15 ~ 20 carbon atoms.

(2) What are the differences between diesel and gasohol?

Key Terms

- **Fossil fuels** consist of coal, petroleum and natural gas. **Natural gas** consists mainly of methane, CH_4. **Crude oil** (petroleum) is a mixture of many different hydrocarbon molecules.
- **Non-renewable fuels** are fuels which take millions of years to form and which are used up at a rapid rate.
- **Renewable fuels** are fuels produced from renewable resources. (e.g., vegetable oils, animal oils, etc.)
- **Biodiesel** refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters.
- **Biogas** is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen.

- **CNG** stands for Compressed Natural Gas (90 % methane).
- **LPG** stands for Liquefied Petroleum Gas which is composed of propane and butane.
- **Organic matter** is a substance that is made up of undecomposed and partially decomposed residue of plant and animal tissues of living and dead microorganisms.

EXERCISES

1. Write TRUE or FALSE for each of the following statements. If FALSE, correct it.
   (a) Nowadays, all fossil fuels are not used up rapidly.
   (b) There is a gradual change in the physical properties of the petroleum fractions.
   (c) Hydrogen is a good fuel because it is non-polluting when it burns.
   (d) At present, there is no alternative fuel to fossil fuels.
   (e) Polychloroethene is also known as PVC.
2. Match each of the items given in List A with the appropriate correct item shown in List B.

List A	List B
(a) coke	(i) produced from plant oil
(b) methane	(ii) formed from waste organic matter
(c) biodiesel	(iii) blended fuel from petrol and ethanol
(d) biogas	(iv) a reducing agent
(e) gasohol	(v) main constituent of natural gas

3. (a) Name the method used to separate petroleum in oil refineries. What physical property of liquids mainly depends on this separation method?
   (b) State the uses of the following components of crude oil:
   (i) Gasoline (ii) Naphtha (iii) Paraffin (iv) Bitumen.
4. Suggest the name of a petroleum fraction that would be suitable for each of the following purposes:
   (a) seal cracks in the concrete tanks
   (b) boil a beaker of water in the laboratory
   (c) protect a wooden furniture
   (d) oil the sewing machine to reduce friction.
5. How do you produce coke from coal? Describe their uses.

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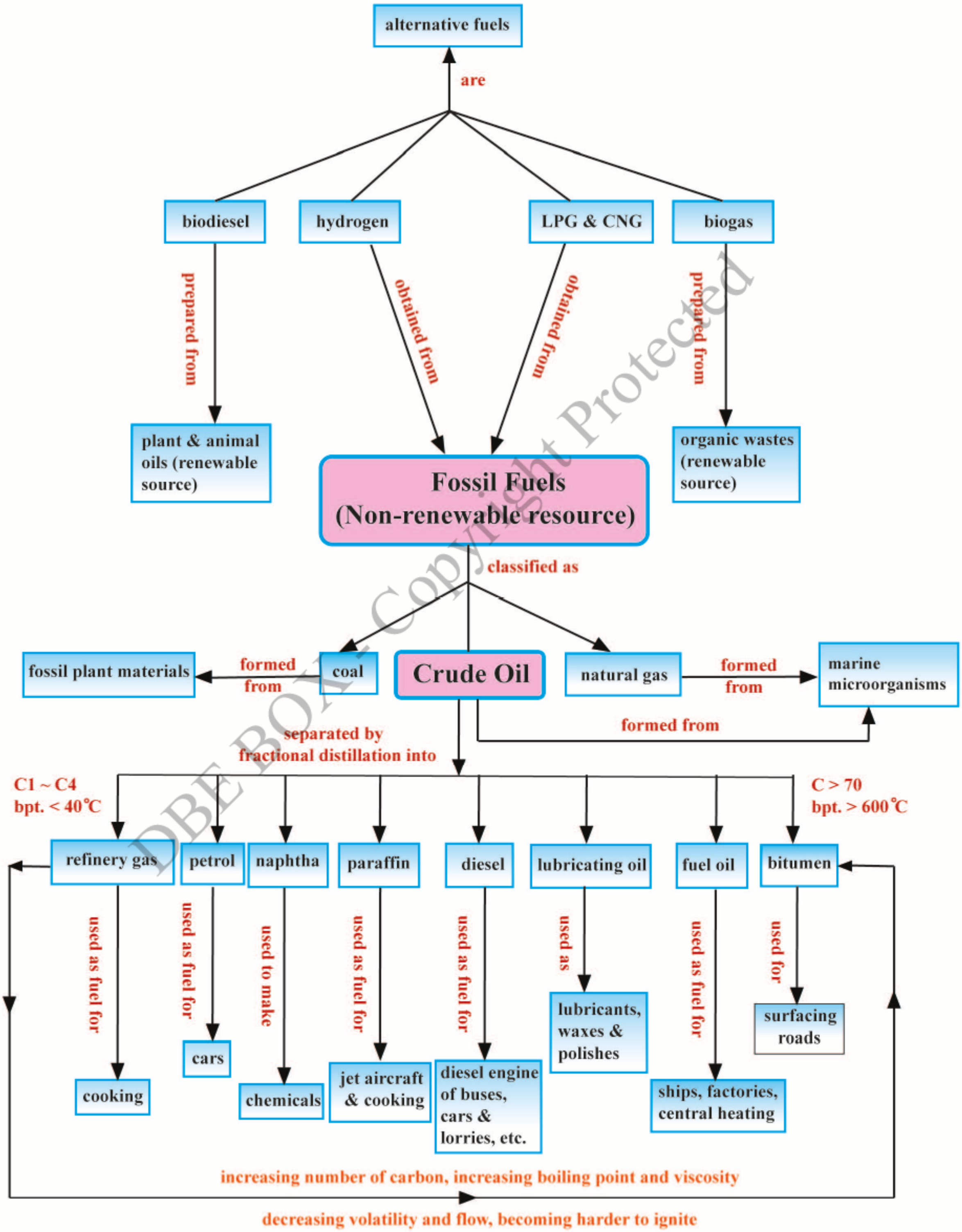
CHAPTER REVIEW
(Concept Map)



GLOSSARY

Acid a compound that dissolves in water to produce hydrogen ions, H^+
Alkali a base which is soluble in water producing OH^- ions

Base a chemical compound that combines with an acid to form a salt and water
Biodiesel a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters
Biogas the mixture of gases produced by the breakdown of organic matter in the absence of oxygen

Centrifugation a technique used for the separation of particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed
Chemical change a change in which one or more new substances are formed
Chromatography a separation method of mixed substances that depends on the speed at which they move through special media, or chemical substances
CNG Compressed Natural Gas (90 % methane)
Compound a substance containing two or more different elements chemically joined together in a fixed ratio
Crude oil a mixture of many different hydrocarbon molecules
Crystallisation a process by which a chemical is converted from a liquid solution into a solid crystalline state

Decantation a process to separate mixtures of solid and liquid or two immiscible liquid to settle and separate by gravity

Element a substance that cannot be broken down into other simpler substances through chemical means

Filtration a method for separating an insoluble solid from a liquid
Fossil fuel a fuel consisting of coal, petroleum and natural gas
Fractional distillation a method for separation of a liquid mixture into fractions with different boiling points (and hence chemical composition) by means of distillation, typically using a fractionating column

Heterogeneous mixture one that is non-uniform, and where the different components of the mixture can be seen (The components separate, and the composition varies.)
Homogeneous mixture one in which the composition of its components are uniformly mixed throughout (The components cannot be seen separately on visual or microscopic examination.)

Indicator a substance that has different colours in acidic and alkaline solutions

LPG Liquefied Petroleum Gas which is composed of propane and butane

Matter a substance made up of tiny particles, and has mass and takes up space. Three common states of matter are solid, liquid and gas

Mixture a combination of more than one substance, where these substances are not bonded to each other (It consists of two or more substances which may be present in any proportion by weight. The constituents of the mixture do not combine chemically.)

Molecule the simplest unit of a chemical substance, usually a group of two or more atoms

Neutralisation the reaction between an acid and a base to form a salt and water only

Non-renewable fuels are fuels which take millions of years to form and which are used up at a rapid rate

Organic matter a substance that is made up of undecomposed and partially decomposed residue of plant and animal tissues of living and dead microorganisms

pH a measure of the acidity or alkalinity of a solution

Physical change a change in which no new substances are formed (There may be a temporary change in colour, temperature and state of the substances but no new substances are formed.)

Renewable fuels fuels produced from renewable resources

Salt a substance produced from the reaction between an acid and a base or a metal

Simple distillation a procedure by which two liquids with different boiling points can be separated

Solute a substance which dissolves in a solvent to give a solution

Solution a clear homogeneous mixture obtained when a substance dissolves in a solvent (In a solution the solute is uniformly distributed throughout the solution.)

Solvent a substance, mostly liquid, in which another substance dissolves to give a homogeneous mixture

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CHAPTER 1

MEASUREMENT AND MOTION

Physics, like any other branch of science, is based on systematic observations and precise measurements. Experiments are an essential feature of science. Most experiments in Physics require the observations made to be quantitative rather than qualitative.

Learning Outcomes

It is expected that students will

- work accurately with basic and derived units of measurement.
- distinguish between a scalar quantity and a vector quantity.
- explain distance, displacement, speed, velocity and acceleration.

1.1 MEASUREMENT AND PHYSICAL QUANTITY

Measurement essentially is a comparison process. Quantitative measurements must be expressed in numerical comparison to certain agreed upon set of standards. A standard quantity of some kind, referred to as a unit, is first established. Standard is something (or) a reference used as a measure for length, mass and time. Unit is a quantity (or) an amount used as a standard of measurement.

A physical quantity is the quantity that can be measured. It consists of a numerical magnitude and a unit. For example, length of table is 2 metre. In this case 2 is numerical magnitude and metre is unit of length.

BASIC AND DERIVED UNITS

Physical quantities can be classified as the basic type such as length, mass, time, temperature, and the derived type such as area, volume, velocity, work, energy, etc. Their units are also called the basic units and the derived units. A derived unit is a unit of measurement formed by combining the basic (or base) units of a system.

Reviewed Exercise

1. How do you understand measurement ?
2. What is a physical quantity?

Key Words : physical quantity, unit

1.2 SYSTEM OF UNITS

In this textbook, we shall be using the following system of units:

(i) the British system

(ii) the metric system

(iii) the SI units (Systeme International d' Units)

The British system is based on foot (ft), pound (lb) and second (s) and is therefore also called the FPS system.

The metric system consists of (i) the CGS system and (ii) the MKS system.
The CGS system is based on centimetre (cm), gram (g) and second (s).
The MKS system is based on metre (m), kilogram (kg) and second (s).
The SI unit is just the modified form of the MKS system of units.

Units

System of units	MKS / SI	CGS	FPS
length	m	cm	ft
mass	kg	g	lb
time	s	s	s

Relation between basic units

1 m = 100 cm

1 kg = 1 000 g

1 ft = 0.304 8 m

1 in = 2. 54 cm

Reviewed Exercise

- What are the units of basic quantities in SI units ?

Key Words : system, unit

Example (1) Write down the value of (a) 1 564 cm in m, and (b) 1 750 g in kg.

(a) 100 cm = 1 m
1 564 cm = 15. 64 m

(b) 1 000 g = 1 kg
1 750 g = 1.75 kg

Example (2) Determine the derive units of:
(a) speed (= distance / time)
(b) volume (= length × width × height)
(c) density (= mass / volume)

$$\text{unit of speed} = \frac{\text{unit of distance}}{\text{unit of time}}$$

$$= \text{m s}^{-1}$$

$$\text{unit of volume} = (\text{unit of length})^3 = \text{m}^3$$

$$\text{unit of density} = \frac{\text{unit of mass}}{\text{unit of volume}} = \text{kg m}^{-3}$$

Example (3) The density of water is 1.0 g cm^{-3}. Calculate this value in kg m^{-3}.

$$1\,\text{g cm}^{-3} = 1\ \frac{\text{g}}{\text{cm}^3} = \frac{1}{10^3}\text{kg} \times \frac{1}{(10^{-2})^3\,\text{m}^3}$$

$$= \frac{10^6\,\text{kg}}{10^3\,\text{m}^3} = 10^3\,\text{kg m}^{-3}$$

1.3 SCALAR AND VECTOR

Some physical quantities of physics are completely described by a single number (or magnitude) with an appropriate unit. Such quantities, that have only magnitude, are called scalar quantities. For example, it is sufficient to say that the length of the ship is 30 m, the mass of the block is 500 g and the area of the blackboard is 48 ft^2.

However, some quantities have a directional quality. Not only the magnitude but also the direction is required for the complete description of such quantities. Such quantities, that have both magnitude and direction, are called vector quantities. For example, we have to say that the plane is flying with a velocity of 20 mi h^{-1} towards east, the force acting on the body is 20 N upwards and the displacement of the ship is 150 km northeast from the port.

Graphical Representation of Vectors

Using graphical method a vector may be represented by an arrow. The length of the arrow is proportional to the magnitude of the vector and the direction of the arrow gives the direction of the vector. For example, Figure 1.1 shows $\vec{A}$ = 5 units (east), $\vec{B}$ = 10 units (south), $\vec{C}$ = 15 units (west) and $\vec{D}$ = 20 units (northeast).

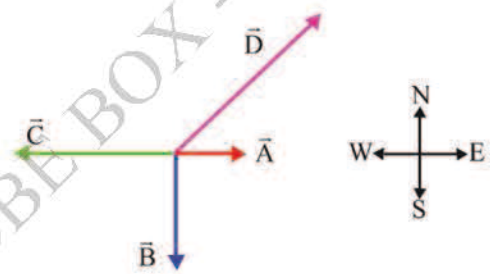


Figure 1.1 Vectors are represented by arrow

Reviewed Exercise

1. What is the difference between scalar and vector ?
2. Draw the vector diagrams (i) the magnitude is 12 units (east) (ii) the magnitude is 3 units (northeast).

Key Words : vector, scalar

1.4 DESCRIBING MOTION

Distance and Displacement

Consider that a particle moves from a starting point A to an end point B along a curved path as shown in the diagram.

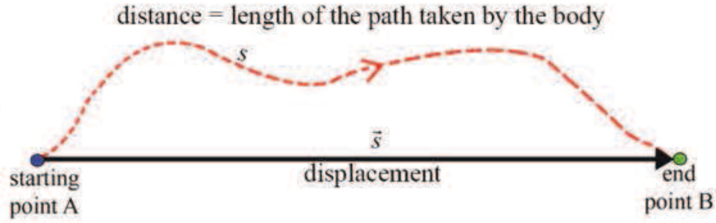


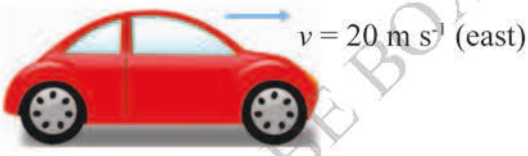
Figure 1.2 Distance and displacement of a body

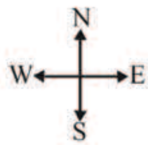
Distance (or) distance travelled by the body is the length of the path along which the body moves. However, the displacement of the body is a vector directed from the starting point to the end point, as described in the diagram.

Displacement is the distance travelled along a particular direction. Distance has no specific direction. It has only magnitude; and therefore, it is a scalar. On the other hand, displacement has a specific direction. It is always directed from the starting point to the end point. It has both magnitude and direction; and therefore, it is a vector.

Speed and Velocity

Speed is how fast a body is travelling per second. Speed is defined as the rate of change of distance travelled.
Velocity is the distance travelled per second in a specific direction.
Velocity is defined as the rate of change of displacement.
Speed is a scalar quantity and velocity is vector quantity.
If a body moves along a straight line speed is the magnitude of velocity. For example, a car is travelling at a velocity of 20 m s^{-1} towards east. Its speed is 20 m s^{-1}.





Average Speed and Average Velocity

Let us assume that, in Figure 1.2, the body moves from starting point A to end point B in a time interval t. The average speed and average velocity are defined as;

The average speed, v_{av} (or) $\overline{v}$, is the ratio of total distance s to time taken t.

$$v_{av} = \frac{s}{t} \quad \text{(or)} \quad \overline{v} = \frac{s}{t} \qquad (1.1)$$

The average velocity, $\vec{v}_{av}$ (or) $\overline{\vec{v}}$, is the ratio of total displacement $\vec{s}$ to time taken t.

$$\vec{v}_{av} = \frac{\vec{s}}{t} \quad \text{(or)} \quad \overline{\vec{v}} = \frac{\vec{s}}{t} \qquad (1.2)$$

If the body moves from B back to A along the curved path starting point and the end point are the same, the total displacement is zero. Therefore, average velocity is zero. The average speed is not zero.

Example (4) The car covers a distance of 20 km due east in 2 hours. What is its average speed and average velocity?

$s = 20\ \text{km} = 20 \times 10^3\ \text{m},\ t = 2\ \text{h} = 2 \times 3\,600\ \text{s} = 7\,200\ \text{s}$

$$\bar{v} = \frac{s}{t}$$

$$\bar{v} = \frac{20\,000}{7\,200} = 2.78\ \text{m s}^{-1}$$

Average speed is 2.78 m s^{-1} and average velocity is 2.78 m s^{-1} (east).

Acceleration

When a body is moving along a straight line with a constant speed, the velocity of the body is also constant because its magnitude and direction remains constant. For a motion with constant velocity equal displacements take place in equal intervals of time. Motion with constant velocity is known as uniform motion.

If either magnitude or direction or both magnitude and direction of the velocity changes, the body is said to have an acceleration $\vec{a}$. Motion with changing velocity is called non-uniform motion (or) accelerated motion. Acceleration is the rate of change of velocity.

If the velocity of a body changes from initial velocity $\vec{v}_0$, to final velocity $\vec{v}$, in a time interval t, the average acceleration $\vec{a}_{av}$ is defined by the equation, $\vec{a}_{av} = \dfrac{\vec{v} - \vec{v}_0}{t}$. (1.3)

Acceleration is a vector quantity.

Acceleration is said to be positive if the magnitude of velocity is increasing and negative if the magnitude of velocity is decreasing. Negative acceleration is usually called deceleration (or) retardation.

Units

Quantities \ System	MKS / SI	CGS	FPS
Distance / displacement	m	cm	ft
Speed / velocity	m s^{-1}	cm s^{-1}	ft s^{-1}
Acceleration	m s^{-2}	cm s^{-2}	ft s^{-2}

Reviewed Exercise

- If the speed of a body changes, can its velocity change?

Key Words : speed, velocity, acceleration

Example (5) In a 400 m race, the person running in the innermost lane clocked 50 s and won the gold medal. Find his average velocity. Is the magnitude of the average velocity the same as the value of the average speed? (Hint: For the innermost lane, the starting point is the same as the finishing point.)

$t = 50\text{ s}$, distance travelled = 400 m, displacement = 0

$$\text{average velocity} = \frac{\text{displacement}}{\text{time taken}} = \frac{0}{50} = 0$$

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time}} = \frac{400}{50} = 8\text{ m s}^{-1}$$

The magnitude of the average velocity is not the same as the value of the average speed.

Example (6) A car moving in a straight line with constant acceleration arrives at a certain point after travelling 5 s from the starting point. If the initial velocity is 44 m s^{-1} and the final is 66 ft s^{-1}. Find the acceleration of the car.

$v = 66\text{ ft s}^{-1}$, $v_0 = 44\text{ ft s}^{-1}$, $t = 5\text{ s}$, $a = ?$

$$a = \frac{v - v_0}{t} = \frac{66 - 44}{5} = 4.4\text{ ft s}^{-2}$$

SUMMARY

A **physical quantity** is the quantity that can be measured, and consists of a numerical magnitude and a unit.

Physical quantities can be classified as the **basic type** (length, mass, time, temperature, electric current, amount of substance, luminous intensity) and the **derived type** (area, volume, velocity, work, energy, etc.). Their units are also called the **basic units** and the **derived units**.

A **derived unit** is a unit of measurement formed by combining the basic (or base) units of a system.

Standard is something (or) a reference used as a measure for length, mass and time.

Unit is a quantity (or) an amount used as a standard of measurement.

Distance (or) distance travelled by the body is the length of the path along which the body moves.

Displacement is the distance travelled along a particular direction.

The **average speed** is the ratio of total distance to time taken.

The **average velocity** is the ratio of total displacement to time taken.

The **average acceleration** is the ratio of the change in velocity to the time taken.

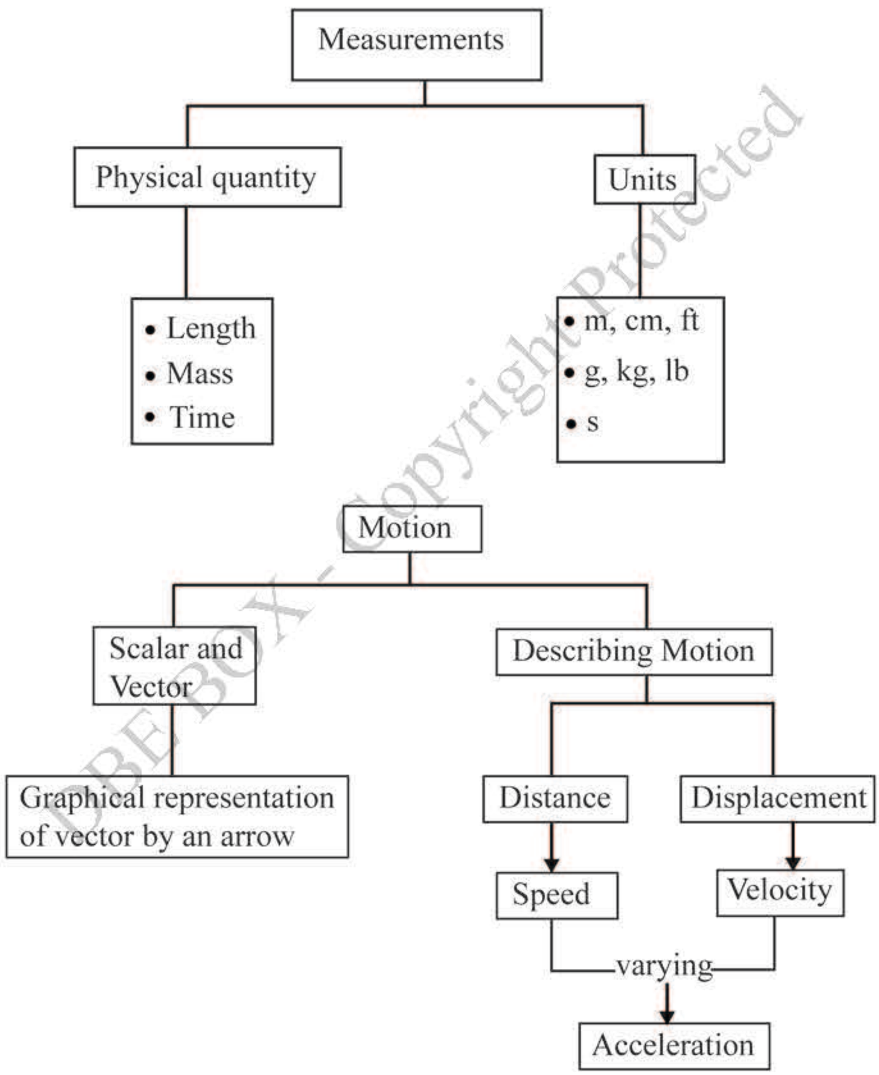
EXERCISE

1. A person goes from his house to a nearby shop at the corner of the street and returns home. Can you say that the distance travelled by him is equal to the magnitude of his displacement? Explain.

2. In a one-round-about-town walking race the starting point is the same as the finishing point. Whose magnitude of displacement is greater: the one who completes the race (or) the one who gives up half-way?

3. Check whether the following statements are true (or) not. (i) Although speed changes, there is no acceleration. (ii) If the speed does not change, but the direction changes, there will be acceleration.

CONCEPT MAP



CHAPTER 2

FORCE AND PRESSURE

Force can change the state of motion of an object. Although a force is commonly understood as a push (or) a pull, it cannot be said that this definition is sufficient and complete. Force is defined precisely by Newton's laws of motion.

Learning Outcomes

It is expected that students will

- explain force as a cause for change of state of motion.
- recognize gravitational force between two masses which obeys inverse square law.
- distinguish between mass and weight.
- explain pressure and its units of daily usage.
- distinguish between the density and the specific gravity.

2.1 NEWTON'S LAWS OF MOTION

Newton's three laws of motion will be stated in words and then expressed in mathematical forms.

First Law

Newton's first law states that:

When no net external force acts upon it, a particle at rest will remain at rest and a particle in motion at a constant velocity will continue to move with the same constant velocity.

In mathematical form:

$$\text{If } \vec{F}_{net} = 0 \text{ then } \vec{a} = 0, \vec{v} = \text{constant (or) zero} \qquad (2.1)$$

This law means that if no net external force acts on a particle, the initial state of the motion of the particle will not be changed. For example, if two equal and opposite forces act simultaneously on a particle at rest, it will remain at rest. In this case, the net force acting on the particle is zero since the two forces cancel out. Therefore, the initial state of the particle is totally unchanged.

Another statement of the first law, if there is no net external force of any kind, a particle initially in motion at a constant velocity will continue to remain in the same state of motion.

Second Law

Newton's second law predicts what will happen when a net force acts on a particle. Its velocity will change; it will accelerate. More precisely the second law states that:

The net external force acting upon a particle is equal to the product of the mass and the acceleration of particle.

In mathematical form:

$$\vec{F}_{net} = m\vec{a} \qquad (2.2)$$

In the above equations $\vec{F}_{net}$ is the net external force. The direction of the acceleration is the same as that of the net force.

The second law may also be viewed as follows:

If a net external force acts upon a particle, the force produces acceleration, and the ratio of the force to the acceleration is the mass of the particle.

Let us consider a particle. Assume that a force $\vec{F}_1$ produces an acceleration $\vec{a}_1$ when applied to the particle, and a force $\vec{F}_2$ applied to the same particle produces an acceleration $\vec{a}_2$ as shown in Figure 2.1.

Hence, according to Newton's second law we have

$$\frac{\vec{F}_1}{\vec{a}_1} = \frac{\vec{F}_2}{\vec{a}_2} = m = \text{constant} \qquad (2.3)$$

where the constant m is the mass of the particle. If $F_1 < F_2$ than $a_1 < a_2$. It means that as the magnitude of the force acting on a particle increases, the acceleration of the particle will increase accordingly. It is equivalent to say that acceleration is directly proportional to force. In symbols, $\vec{a} \propto \vec{F}$

Therefore, second law is also called law of force and acceleration.

Figure 2.1 Illustration for net force and acceleration

Third Law

Newton's third law of motion states that:

Whenever two particles interact, the force exerted by the second on the first is equal in magnitude and opposite in direction to the force exerted by the first on the second.

In other words, for every action, there is an equal and opposite reaction.

$$\vec{F}_{\text{second on first}} = -\vec{F}_{\text{first on second}} \qquad (2.4)$$

In order to discuss and explain Newton's third law the following cases will be considered. Consider a man sitting on a chair. The man exerts a force which is equal to his body weight on the chair. At the same time the chair exerts a reaction force, which is equal in magnitude and opposite in direction, on the man. If the force exerted by the man is called 'action', the force exerted by the chair should be called 'reaction' shown in Figure 2.2.

Figure 2.2 Action and reaction force for sitting on chair

Units of Force

Units of force can now be defined explicitly from $F = ma$. The newton and the dyne are particularly useful units of force. In SI units, force that is acting on 1 kg mass to give it an acceleration of 1 m s^{-2} is called 1 newton (1 N). 1 N = 1 kg m s^{-2}

Similarly, in CGS system a force that is acting on 1 g mass to give it an acceleration of 1 cm s^{-2} is called 1 dyne. 1 dyne = 1 g cm s^{-2}

In FPS system the unit of force is pound (lb).The slug is the unit of mass in British engineering system. It is defined as follows: when 1 pound force acts on a body and the acceleration of the body is 1 ft s^{-2},the mass of the body is called 1 slug. 1 lb = 1 sl ft s^{-2}

Units

System of units	MKS / SI	CGS	FPS
mass	kg	g	slug
acceleration	m s^{-2}	cm s^{-2}	ft s^{-2}
force	N	dyne	lb

Example (1)

If 10 N force acts upon a 2 kg mass , find the acceleration produced.

Since F = 10 N and m = 2 kg , using Newton's second law,

$$F = m\,a$$
$$10 = 2 \times a$$
$$a = 5 \text{ m}s^{-2}$$

Example (2)

A 12 lb force gives a body an acceleration of 4 ft s^{-2}. Find the mass of the body.

Since F = 12 lb and a = 4 ft s^{-2}, using Newton's second law,

$$F = m\,a$$
$$12 = m \times 4$$
$$m = 3 \text{ sl}$$

Reviewed Exercise

- Can action and reaction cancel each other? Why?

Key Words : net external force, action, reaction

2.2 GRAVITATIONAL FORCE AND NEWTON'S LAW OF GRAVITATION

Newton was able to point out and express precisely that all bodies in the universe are attracting one another. Gravitational force causes bodies which are above the earth's surface to fall onto the earth's surface. The gravitational force enables the moon to go round the earth and the earth to go round the sun. These are examples of the effects of gravitational force.

Newton stated the gravitational law as follows:

Everybody attracts every other body in the universe. The gravitational force between the two bodies is directly proportional to the product of the masses and inversely proportional to the square of the distance between them.

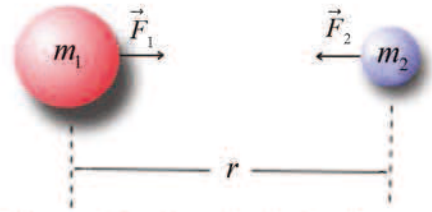


Figure 2.3 Gravitational force between two masses

In symbols, $F \propto \frac{m_1 m_2}{r^2}$

$$F = G\frac{m_1 m_2}{r^2} \qquad (2.5)$$

where F is the gravitational force between the masses m_1 and m_2 whose distance apart is r shown in Figure 2.3.
where G is a constant which is the same for all bodies in the universe.

According to experimental measurements the value of G in MKS system is found to be $6.67 \times 10^{-11} m^3\, kg^{-1}\, s^{-2}$ (or) $N\, m^2\, kg^{-2}$.

Applications of Newton's law of gravitation

(a) The attractions of the moon and the sun upon water of the earth cause tides.
(b) Satellites are kept in their circular orbit by the gravitational attraction of the earth.

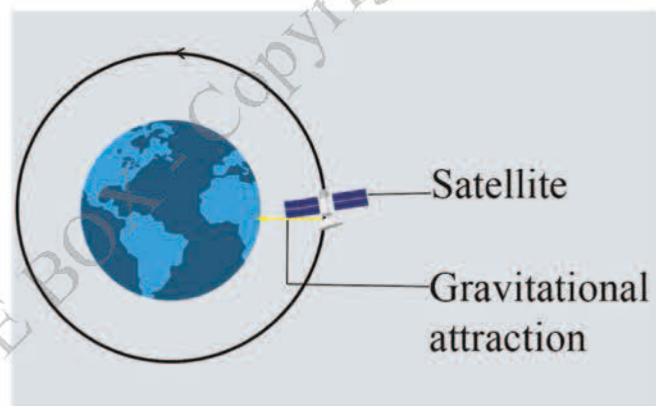


Figure 2.4 Gravitational attraction of the earth on satellite

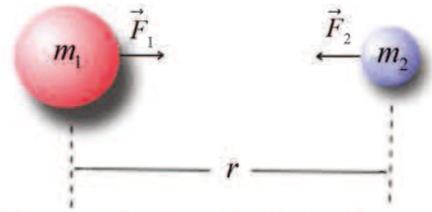
2.3 MASS AND WEIGHT

If a body is dropped from a height above the surface of the earth, it will fall onto the ground. This is due to the force of gravity. The weight of body is the force of gravity acting on it which gives it acceleration when it is falling. The acceleration due to the gravitational force is called acceleration due to gravity and it is represented by the symbol g ($9.8\ m\ s^{-2}$). The attracting force of the earth acting on a body is defined as the weight of the body. Let the mass of the body be m; and if $a = g$ is substituted in Newton's second law: $F = ma$, the gravitational force acting on the body (or) the weight of the body is found to be

$$w = mg \qquad (2.6)$$

Newton stated the gravitational law as follows:

Everybody attracts every other body in the universe. The gravitational force between the two bodies is directly proportional to the product of the masses and inversely proportional to the square of the distance between them.



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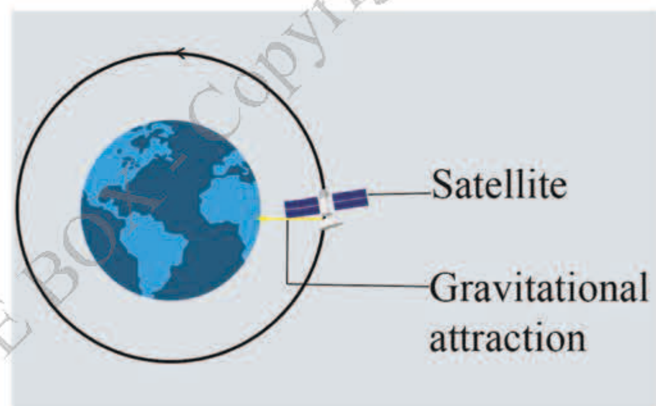

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Weight is a vector and is directed toward the center of the earth. Since weight is force, units of weight are newton, dyne and pound while the units of masses are kilogram, gram and slug.

Mass is the quantity of matter in a body. Mass is also a measure of inertia. Mass should not be confused with weight. Mass and weight are two different quantities. Mass is a scalar and always a constant. Wherever a body may be, there is no change in the value of the mass of the body. But the weight of the body can change.

Example (3) If weight of a man is 600 N , find the mass of the man.

$w = 600\ \text{N}\ ,\ g = 10\ \text{m s}^{-2}\ ,\ m = ?$

$w = mg$

$$m = \frac{w}{g} = \frac{600}{10} = 60\ \text{kg}$$

Reviewed Exercise

- The weight of a body may change when its location is changed but mass does not. Why?

Key Words : acceleration due to gravity, weight, mass

2.4 PRESSURE, DENSITY AND RELATIVE DENSITY

Pressure

Pressure is defined as the force exerted normally on unit area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}\ ,\quad p = \frac{F}{A} \qquad (2.7)$$

In SI units, pressure is measured in pascal (Pa).

$$1\ \text{Pa} = 1\ \text{N m}^{-2}$$

Pressure is a scalar quantity.

From the definition of pressure, it is obtained that pointed nails penetrate the surfaces because for a definite force and the exerted area is too small.

Similarly sharp knives can cut easily than blunt knives because of smaller cutting area. Elephants have four large flat feet so they reduce the pressure and less likely sink into the ground.

Most obvious is tractors used for ploughing has large tire areas so that they do not sink in the muddy fields.

Some applications of pressure in daily life are school bags having wider straps and buildings having wider foundation.

Density And Relative Density

Density is the ratio of mass to volume of an object.

$$\text{density} = \frac{\text{mass of substance}}{\text{volume of the substance}}$$

$$\rho = \frac{m}{V} \quad [\rho = \text{rho} = \text{Greek alphabet}] \tag{2.8}$$

Density is the scalar quantity.

In SI unit, density is expressed in kilogram per cubic metre (kg m^{-3}).

In CGS unit, it is expressed in gram per cubic centimetre (g cm^{-3}).

Relative density is how much a substance is denser than water. Relative density is also known as specific gravity. As the relative density is the ratio of two densities and so it is just a number without units.

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water at } 4\,^{\circ}\text{C}} = \frac{\rho_s}{\rho_w} \tag{2.9}$$

As the relative density is the ratio of two densities, it is just a number without a unit.

Example (4) The mass of a statue which is made of silver is 120 g. If the density of silver is 10.5 g cm^{-3}, find the volume of the statue.

mass $m = 120$ g , $\rho = 10.5$ g cm^{-3}

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

$$10.5 = \frac{120}{V}$$

$$V = 11.4 \text{ cm}^3$$

Example (5) Concrete slab 1.0 m by 0.5 m by 0.1 m has a mass of 120 kg. What is the density of concrete slab?

$$\begin{aligned} \text{Volume} &= \text{length} \times \text{breadth} \times \text{height} \\ &= 1.0 \text{ m} \times 0.5 \text{ m} \times 0.1 \text{ m} \\ &= 0.05 \text{ m}^3 \end{aligned}$$

$$\rho = \frac{m}{V} = \frac{120}{0.05} = 2\,400 \text{ kg m}^{-3}$$

Example (6) The relative density of sulphur is 2. Find the volume of 1 kg of sulphur. (density of water = 1 000 kg m^{-3})

$$m = 1 \text{ kg}$$

$$\text{Relative density} = \frac{\text{density of substance } (\rho)}{\text{density of water}}$$

$$2 = \frac{\rho}{1\,000}$$

$$\rho = 2\,000 \text{ kg m}^{-3}$$

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

$$V = \frac{m}{\rho} = \frac{1}{2\,000} = 5 \times 10^{-4} \text{ m}^3$$

Reviewed Exercise

1. A person exerts pressure on the floor when standing, sitting and lying. Explain why the pressure is different when the person is in each of these positions.
2. We say that the density of iron is 7.9 g cm^{-3}. Write this in kg m^{-3}.

Key Words : pressure, normal force, relative density.

SUMMARY

Mass is the quantity of matter in a body (or) a measure of inertia.

The attracting force of the earth acting on a body is defined as the **weight** of the body.

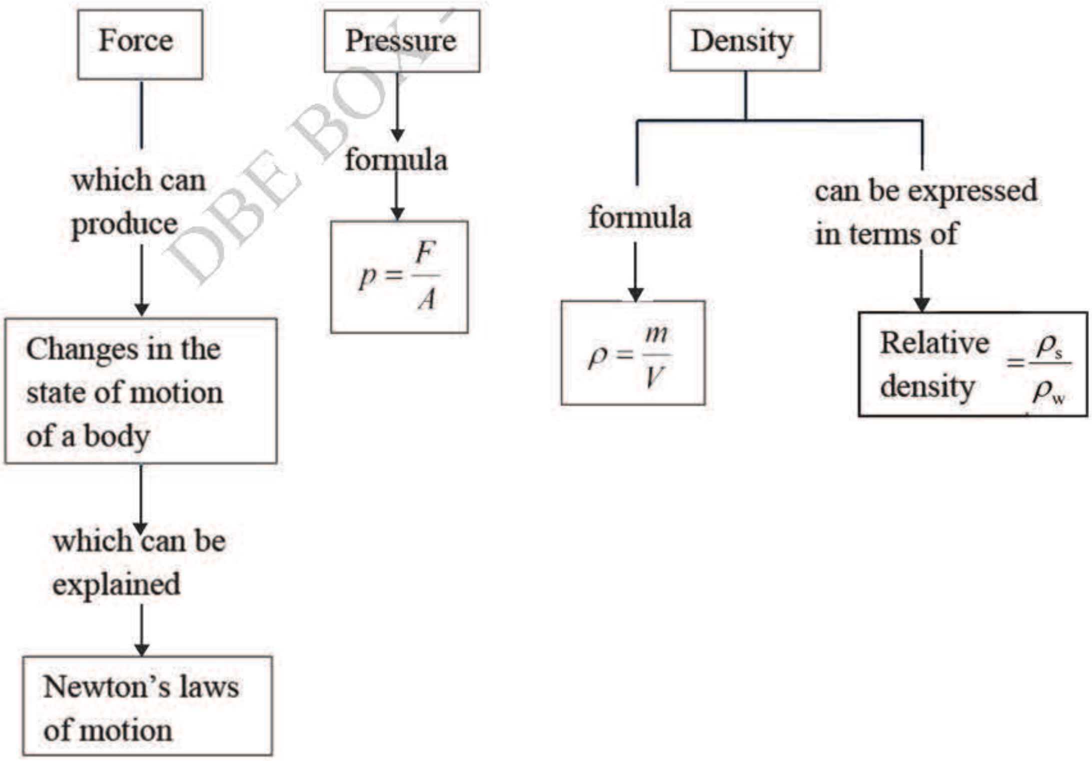
Gravitational force is force between two masses.

Pressure is force acting on unit area; pressure is scalar quantity.

Density is the ratio of mass to volume of a substance.

Relative density is the ratio of density of substance to density of water; it has no unit.

CONCEPT MAP



CHAPTER 3

WORK, ENERGY AND HEAT

In this chapter work and mechanical energy will be discussed. The concept of temperature is very important for the physical and biological sciences.

Learning Outcomes

It is expected that students will

- realize the relationship between work and energy.
- apply basic knowledge of work and energy to daily-life phenomena.
- explain why heat is form of energy.

3.1 WORK AND ENERGY

Work

Normally, the work is used to describe the different kinds of activities that people do every day. In physics, work specifies the action (force) and the movement produced by the force. Work is said to be done when a force produces motion.

Work is defined as the product of force and distance moved in the direction of the force.

$$W = F\,s \qquad (3.1)$$

where W is work done, F is force acting on the particle and s is the distance moved.

Two conditions required for work done:

(i) a force should act on an object and (ii) the object must be displaced.

If force is applied on an object but it does not move, work on the object is zero (no work is done).

Work is a scalar quantity. The SI unit of work is the joule (J). One joule of work is done when a force of one newton moves an object through a distance of one metre in the direction of the force. When the unit of force is in pound (lb) and the distance is in foot (ft), the unit of work is foot-pound (ft-lb). When the unit of force is in dyne and the distance is in centimeter, the unit of work is erg.

Units

Quantities	MKS / SI	CGS	FPS
Force	N	dyne	lb
Distance moved	m	cm	ft
Work	J	erg	ft-lb

Example (1) How much work is done when a box is pushed by a force of 20 N through horizontal distance of 3.0 m?

$F = 20\text{ N}, s = 3.0\text{ m}$

$W = F\,s$

$= 20 \times 3$

$= 60\text{ J}$

Energy

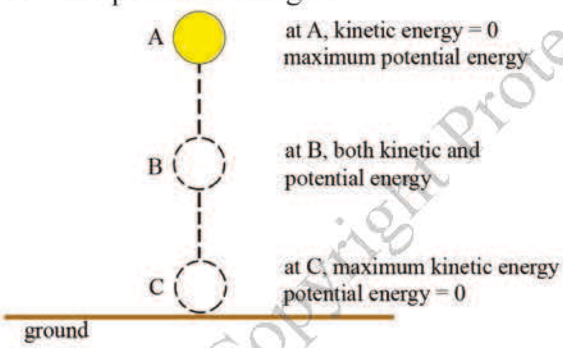
Energy is defined as the capacity to do work. The SI unit for energy is joule (J). Energy is a scalar quantity. Energy possessed by a body is measured by the amount of work done. There are different forms of energy. They are mechanical energy, heat energy, light energy, electrical energy, nuclear energy and so on.

Mechanical Energy

The mechanical energy is divided into two types. They are kinetic energy and potential energy. Kinetic energy is energy due to motion. For example, an object moving with a velocity has kinetic energy.

Potential energy is energy due to the position and configuration of the body. For examples, when an object is raised to a height above the ground, it possesses potential energy.

The energies stored in compressed (or) stretched springs, the stretched rubber band of a catapult (or) a stretched bow are potential energies.



Law of Conservation of Energy

The law of conservation of energy is a very important rule. It states that:
The total energy of an isolated system is constant.
Energy can neither be created nor destroyed, it can only be transformed from one form to another.

Reviewed Exercise

- Why are the unit of energy and that of work the same?

Key Words : kinetic energy, potential energy

3.2 HEAT AND TEMPERATURE

The sensations of hotness, warmness and coldness can be experienced by touching the objects. Temperature is the quantity that determines how cold (or) how hot the object is. The temperature of a hot body is higher than that of a cold body. To measure temperature accurately, we use instruments called thermometers.

There is a relation between heat and temperature. The energy exchanged between an object and its surrounding due to different temperatures is defined as heat. The unit of heat is the joule in SI units. Heat and temperature are different quantities. When a body at a higher temperature is in contact with a body at a lower temperature heat flows from the first to the second body.

Temperature units depend on the scale used. The temperature scales most widely used today are Celsius (Centigrade), Fahrenheit and Kelvin scales. The SI unit of temperature is kelvin (K).

Table 3.1 Temperature scale and units

Temperature scale	Unit
Celsius (Centigrade)	degree Celsius (˚C)
Fahrenheit	degree Fahrenheit (˚F)
Kelvin	kelvin (K)

To calibrate a thermometer, two reference points are chosen and the interval between these points is subdivided into a number of equal parts. The freezing point and boiling point of water under normal atmospheric pressure are chosen as reference points which are marked on the thermometer. The interval between these two points is divided into one hundred equal parts for the Celsius scale. If the freezing point of water (or) ice point is marked 0˚C and the boiling point of water (or) steam point is marked 100 ˚C, the thermometer scale is the Celsius scale. On the Celsius scale, the ice point is 0 ˚C and the steam point is 100 ˚C. On the Fahrenheit scale the ice point is 32 ˚F and the steam point 212 ˚F. On the Kelvin scale the ice point is 273 K and the steam point is 373 K.

The relationship between the Celsius temperature T_C and the Fahrenheit temperature T_F is given by the equation:

$$T_C = \frac{5}{9}(T_F - 32) \qquad (3.2)$$

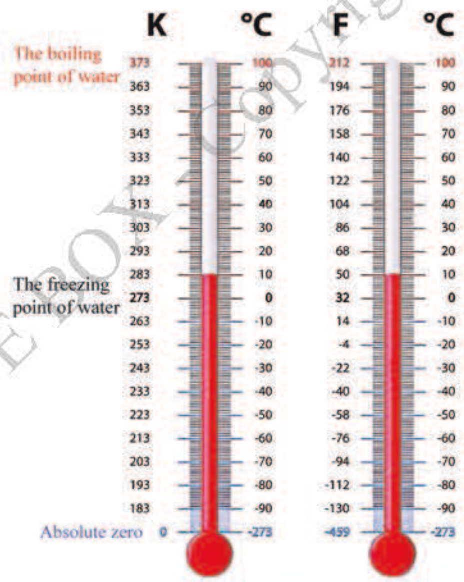


Figure 3.1 Celsius and Fehrenheit Thermometer

Example (2) Normal body temperature is 98.6 ˚F. Convert Celsius scale.

$$T_C = \frac{5}{9}(T_F - 32)$$

$$= \frac{5}{9}(98.6 - 32)$$

$$= 37.0\ ^\circ C$$

The relationship between the Celsius temperature T_C and kelvin temperature T_K is given by $T_C + 273 = T_K$.

Example (3) The room temperature is found to be 27 ˚C. What is this temperature in kelvin?

$$T_K = T_C + 273$$
$$= 27 + 273 = 300 \text{ K}$$

Reviewed Exercise

- Is the temperature 250 K lower than the ice point?

Key Words : freezing, boiling

SUMMARY

Work is defined as the product of force and distance moved in the direction of the force.

Energy is defined as the capacity to do work.

Energy acquired by a body due to its motion is called **kinetic energy.**

The energy stored in a body due to its position or configuration is called the **potential energy.**

The law of conservation of energy states that: the total energy of an isolated system is constant.

Temperature is a measure of hotness (or) coldness of a body.

Heat is a form of energy. It is the energy exchanged between an object and it surrounding due to different temperatures.

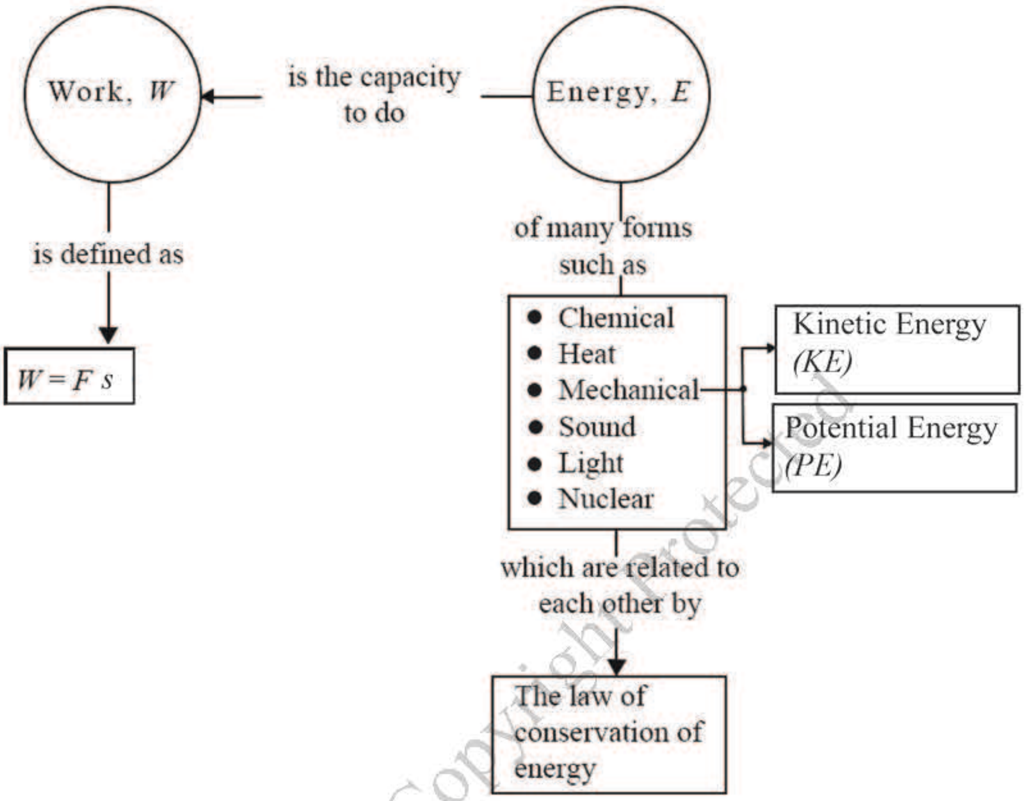
EXERCISE

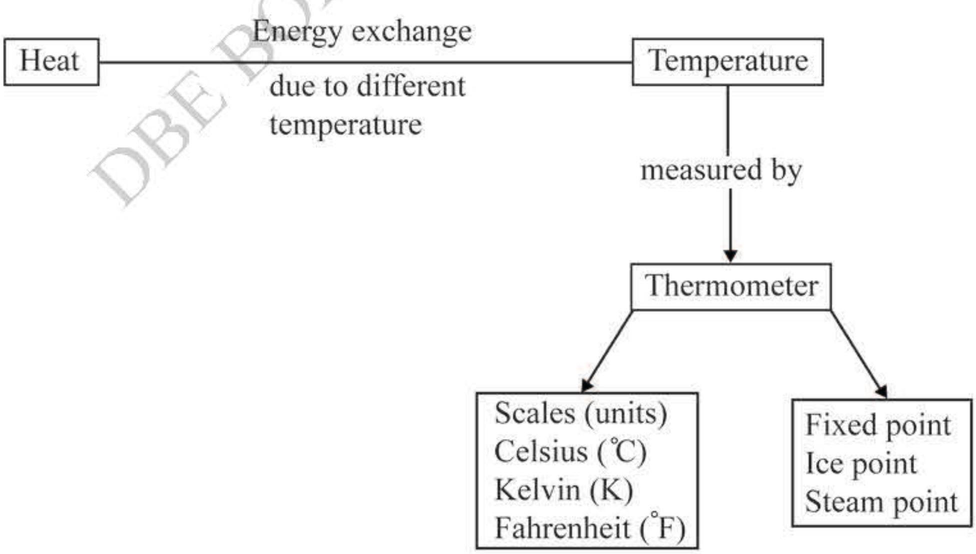
1. A woman is pushing a chair along a horizontal plane with a 300 N. Find the work done for the followings :

   (i) the chair moves 2 m parallel to the force (ii) the chair does not move at all.

2. What temperature on the Celsius scale corresponds to 104 ˚F , the body temperature of a person who is gravely ill?

CONCEPT MAP


Work, W
is the capacity to do
Energy, E
is defined as
$W = F\,s$
of many forms such as
Chemical
Heat
Mechanical
Sound
Light
Nuclear
Kinetic Energy (KE)
Potential Energy (PE)
which are related to each other by
The law of conservation of energy


Heat
Energy exchange
due to different temperature
Temperature
measured by
Thermometer
Scales (units)
Celsius (°C)
Kelvin (K)
Fahrenheit (°F)
Fixed point
Ice point
Steam point

CHAPTER 4

WAVE, SOUND AND LIGHT

Wave is a basic concept of physics. Energy and momentum are transferred through the medium from the wave source. All waves are produced by a vibrating source. Sound and light have wave nature. The characteristic of sound and phenomena of light are discussed here.

Learning Outcomes

It is expected that students will

- examine wave motion as a form of energy transfer.
- compare transverse and longitudinal wave and give suitable examples of each.
- discuss sound wave and speed of sound.
- identify sources of light.
- examine reflection of light and the laws of reflection.

4.1 TRANSVERSE AND LONGITUDINAL WAVES

Waves are classified as transverse and longitudinal waves depending on vibration of particles in the medium through which they propagate.

If the displacements of particles of the medium are perpendicular to the direction of the wave, such a wave is called transverse wave. Waves on the vibrating string are transverse waves. They can be demonstrated by moving up and down the free end of a rope (or) slinky spring which is fitted at one end as shown in Figure 4.1.

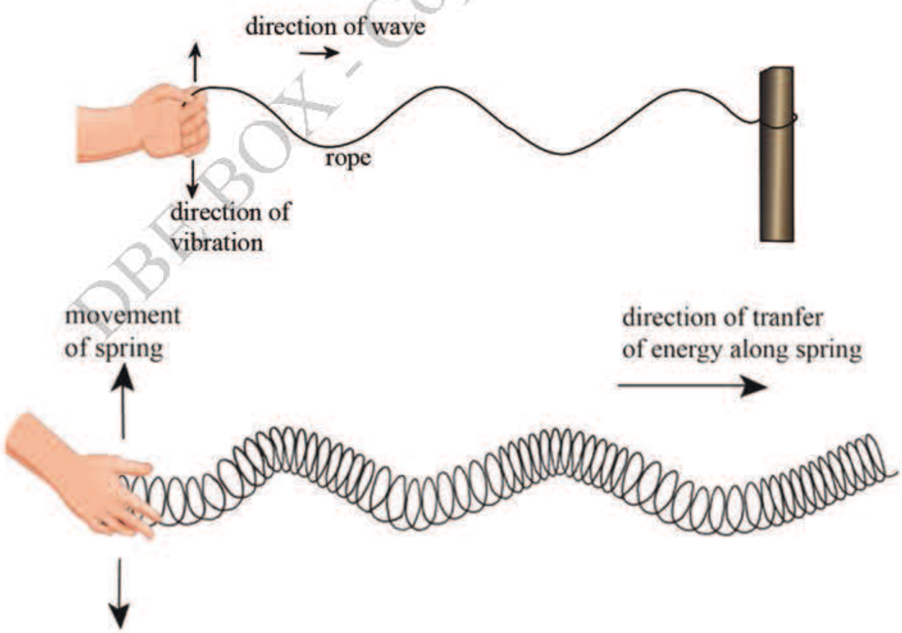


Figure 4.1 The transverse waves

If the displacements of particles of medium are parallel to the direction of the waves, such a wave is called longitudinal wave. Compressional waves in a slinky coiled spring and sound waves are longitudinal waves.

A longitudinal wave is demonstrated by rapidly pushing forth and pulling back at one end of a slinky coiled spring, another end is fixed. It can be seen that movement of the particular coil move back and forth is parallel to the wave directions as shown in Figure 4.2.

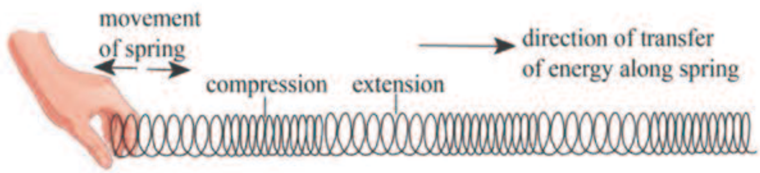


Figure. 4.2 Longitudinal waves on slinky coiled spring

The longitudinal wave on slinky coiled spring is represented by a graph (Figure 4.3) which shows the compression and extension of spring segments. This graph is similar to the wave produced by the vibrating rope shown in Figure 4.1.

Some waves in nature exhibit a combination of transverse and longitudinal waves. Water waves are good example of combinational waves.

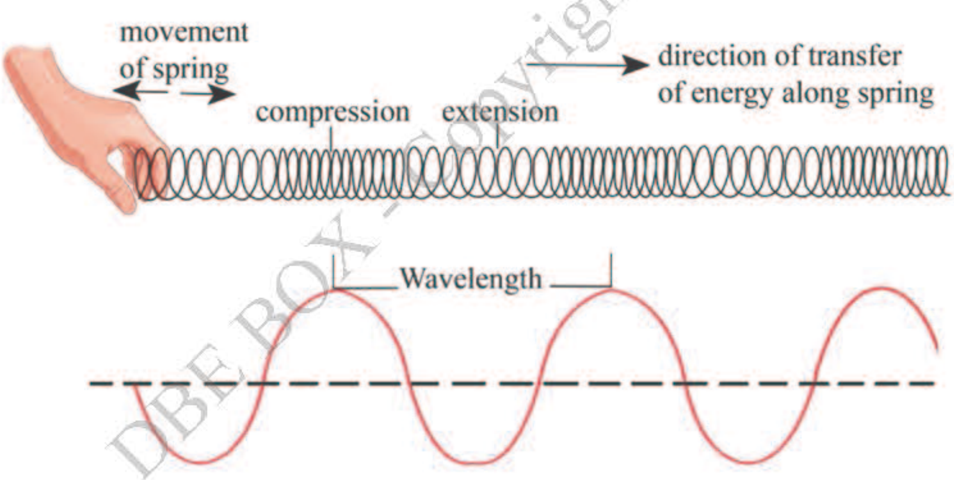


Figure 4.3 Graphical presentation of longitudinal wave

Reviewed Exercise

- Describe the similarities and differences between sound waves and water waves.

Key Words : transverse waves, longitudinal waves, compression, extension

4.2 CHARACTERISTICS OF WAVES

Wave crest and trough of periodic waves

The highest and the lowest points (see in Figure 4.4) which show the maximum displacement of vibrating particle from its rest position (or) equilibrium line are called wave crest and wave trough respectively. The arrows indicate the direction of displacement of the vibrating particle.

Wavelength (λ): The distance between any two consecutive wave crests (or) two consecutive wave troughs is called wavelength. The unit of wavelength in SI unit is metre (m).

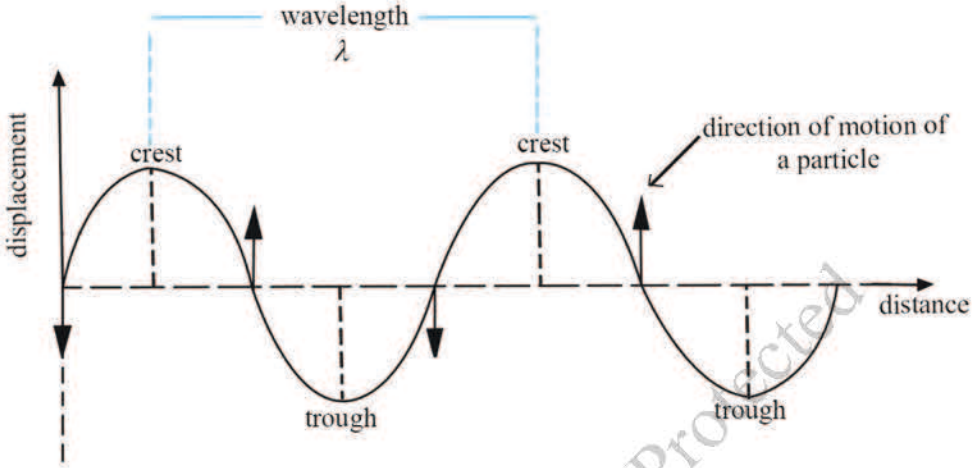


Figure 4.4 Wave in a vibrating string

Frequency (f) **:** The number of complete waves passing a point per second is called frequency of a wave. The frequency of the wave depends on the vibrating source. The number of oscillation of a vibration source in one second is also called frequency. The SI unit of frequency is hertz (Hz). One hertz is equal to one vibration per second.

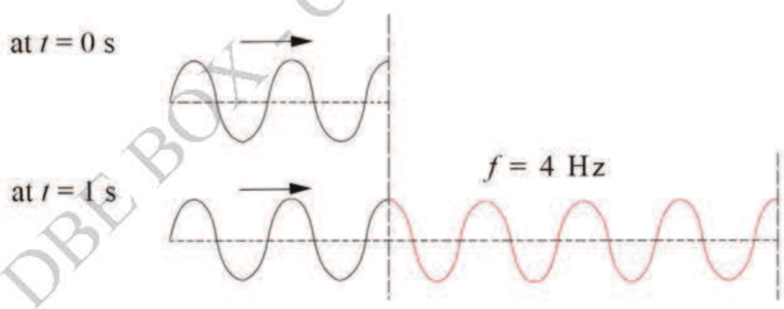


Figure 4.5 Frequency of a periodic wave (four complete waves pass a point in one second = 4 Hz)

Period (T) : The time taken by the wave to travel the distance between any two consecutive wave crests (or) the time required for one complete vibration is called period of a wave. The unit of period is the second (s).

The period is the reciprocal (or) inverse of the frequency.

Thus,

$$T = \frac{1}{f} \tag{4.1}$$

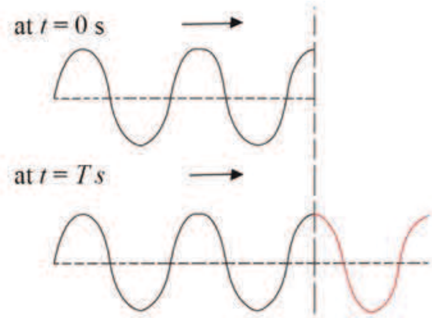


Figure 4.6 Period of a periodic wave

Amplitude : The amplitude of a wave is the maximum value of displacement of vibrating element. It can be seen on the wave graph shown in Figure 4.1 as the perpendicular distance from the wave crest (or) trough to the equilibrium line.

Velocity of wave (v) : Velocity of wave is the speed with which a wave crest travels. The unit of wave velocity is metre per second (m s^{-1}).

The relationship between the frequency, wavelength and velocity of a periodic wave can be obtained by

$$\text{Velocity} = \frac{\text{distance moved}}{\text{time taken}}$$

A complete wave travels through the distance equal to its wave length in time period T.

$$\text{Velocity} = \frac{\text{wavelength}}{\text{period}}$$

$$v = \frac{\lambda}{T}$$

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

$$v = f\lambda \qquad (4.2)$$

Reviewed Exercise

- Write down the relation between period and frequency. Explain it.

Key Words : hertz, oscillation

4.3 SOUND WAVE AND SPEED OF SOUND

Sound Wave

Sound is a form of energy that is transferred from one place to another in a certain medium. Sound wave is produced by a vibrating object placed in a medium. The pressure changes occur alternately in the medium by vibrating object. The medium is usually air, but it can be any gas, liquid (or) solid. Sound wave propagates as a series of compression and rarefaction like longitudinal waves on a vibrating spring. Like other waves sound wave can be reflected and diffracted.

The compression is created in the medium as the vibrating object moves forward, since it pushes molecules together. The compression region has higher pressure. When the object moves back, the molecules are spread out and rarefaction is created and the pressure of that region is low. After the object is vibrated several times, it has created a series of compression and rarefactions travelling away from the vibrating object. The pressure of the medium is changed into higher and lower alternately. In this way, sound energy propagates through the medium to the ear. When waves enter the ear, they strike the ear drum and make it vibrate. This vibration of ear drum results the hearing of the sound. Sound energy is transferred through the medium by the successive pressure changes among the adjacent parts without moving the medium as a whole.

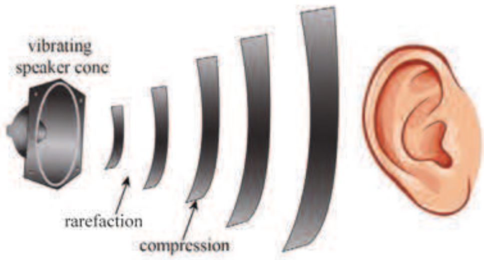


Figure 4.7 Vibrating loud speaker produces sound wave and travels through air to ear

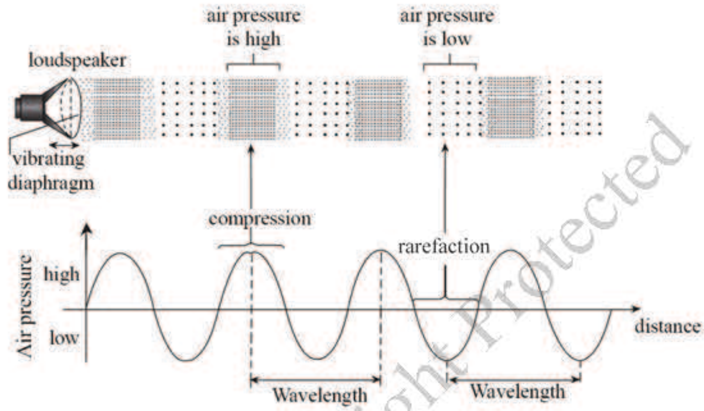


Figure 4.8 Pressure-distance graph of a propagated sound waves

Audible range : The average person can only hear sound that has a frequency higher than 20 Hz and lower than 20 000 Hz. This interval of frequency is called the audible range (or) hearing range. But the range becomes reduced according to age and health conditions. The frequencies greater than 20 000 Hz are called ultrasounds. Some objects vibrating with frequencies under 20 Hz produces sound which cannot be heard by human. This is called infrasound.

Speed of Sound

Since sound propagates from one place to another through a distance in a time interval in a given medium, the speed of sound is

$$\text{speed of sound} = \frac{\text{distance travelled by the sound}}{\text{time taken}}$$

$$v = \frac{d}{t} \tag{4.3}$$

However, sound waves travels at different speeds in different media through which it is passing. Generally, the speed of sound depends on the density of the medium. The denser the medium is, the greater the speed because the particles of the medium are tightly bound together. This means that the disturbance can be transferred more quickly from one particle to next.

Table 4.1 The speed of sound in some solids, liquids and gases

Medium	Speed		Temperature
	$m\ s^{-1}$	$ft\ s^{-1}$	°C
Air	332	1 090	0
CO_2	259	850	0
Cl_2	206	676	0
Water, pure	1 404	4 605	0
Copper	3 560	11 680	20
Iron	5 130	16 830	20

Speed of sound in air varies with temperature. At 0˚C the speed of sound in air is 332 m s^{-1}. Whenever the air temperature increases by 1˚C, speed of sound will increase by 0.2 %.

Example (1) A distance of 0.33 m separates a wave crest from the adjacent trough, and the vertical distance from the top of a crest to the bottom of a trough is 0.24 m. What is the wavelength? What is the amplitude?

The wavelength, $\lambda = 2 \times 0.33 = 0.66$ m

The amplitude, $A = \frac{0.24}{2} = 0.12$ m

Example (2) What is the speed of a 256 Hz sound with a wavelength of 1.35 m?

$f = 256$ Hz, $\lambda = 1.35$ m

The speed of sound $v = f\lambda = (256)(1.35) = 346\ m\ s^{-1}$

Example (3) A typical sound wave associated with human speech has a frequency of 500 Hz and the frequency of the yellow light is about 5×10^{14} Hz. The velocity of sound in air is 344 m s^{-1} and the velocity of light is 3×10^8 m s^{-1}. Find the wavelengths of the waves.

For the sound wave, $\lambda = \frac{v}{f} = \frac{344}{500}$ m = 0.688 m

For the light wave, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5 \times 10^{14}}$ m = 6×10^{-7} m = 6 000 Å

Reviewed Exercise

- You dip your finger into a pan of water 14 times in 7 s, producing wave crests seperated by 0.16 m. (a) What is the frequency? (b) What is the period? (c) What is the velocity?

Key Words : rarefaction, ultrasound, infrasound, frequency.

4.4 SOURCES OF LIGHT

Some objects such as the sun, the stars, fluorescent lamps and candles make their own light. These sources are called luminous sources. Most objects do not emit their own light but reflect light from luminous sources. They are non-luminous objects.

The sun is the chief source of light. The fact that light coming from the sun passes through the empty space on its way to the earth shows that light can travel through vacuum.

4.5 REFLECTION OF LIGHT

When light is incident on the surface of an object some of the light is sent back and this phenomenon is called reflection of light. A ray of light is a path along which the light travels. A ray is represented by a straight line with an arrow-head. The arrow-head points in the direction of propagation of light.

A beam of light is a collection of rays of light. Figure 4.9, Figure 4.10 and Figure 4.11 show the parallel rays of light, the convergent rays and the divergent rays respectively.

Figure 4.9 Parallel rays

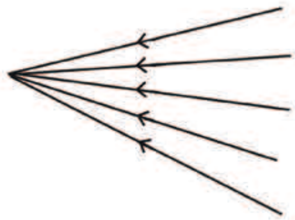


Figure 4.10 Convergent rays

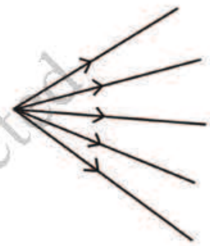


Figure 4.11 Divergent rays

Searchlights, used in trains and light houses, emit parallel beam of light. Parallel beam of light become convergent beam after passing through a convex lens. A beam emitted by a light bulb is a divergent beam.

In Figure 4.12, a ray which represents the incident light is an incident ray (AO). A line perpendicular to the surface at the point of incidence is called normal (NO). A ray which represents the reflected light is a reflected ray (OB). An angle between the incident ray and the normal is an angle of incidence (*i*) and an angle between the reflected ray and the normal is an angle of reflection (*r*).

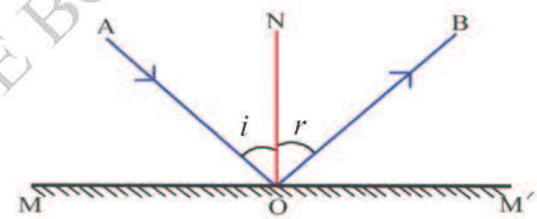


Figure 4.12 Illustration of reflection of light at a plane surface

Laws of Reflection

1. The incident ray, the reflected ray and the normal all lie in the same plane.
2. The angle of incidence is equal to the angle of reflection.

Light is just one form of electromagnetic radiation that travels in the form of transverse waves. In the seventeenth century, Sir Isaac Newton showed experiments that 'white light' (visible light), when passed through a prism, contains the colours violet, indigo, blue, green, yellow, orange and red (abbreviated as VIBGYOR). Each colour of light is characterized by a different wavelength and frequency.

The speed of light has a definite value. All the electromagnetic radiations, including light, travel with a speed of 3×10^8 m s^{-1} in vacuum.

Reviewed Exercise

- Give the names of light source which emit parallel beam and divergent beam.

Key Words : divergent beam, convergent beam, parallel beam

SUMMARY

Transverse wave: If the displacements of particles of the medium are perpendicular to the direction of the wave, such a wave is called transverse wave.

Longitudinal wave: If the displacements of particles of medium are paralleled to the direction of the waves, such a wave is called longitudinal wave.

Wavelength (λ): The distance between any two consecutive wave crests (or) two consecutive wave troughs is called wavelength.

Frequency (f): The number of complete waves passing a point per second is called frequency of waves.

Period (T): The time taken by the wave to travel the distance between any two consecutive wave crests or the time required for one complete vibration is called period of a wave.

Amplitude: The amplitude of a wave is the maximum value of displacement of vibrating element.

Velocity of wave (v): Velocity of wave is the speed with which a wave crest travels.

When light is incident on the surface of an object some of the light is sent back and this phenomenon is called **Reflection of light**.

Laws of Reflection

(1) The incident ray, the reflected ray and the normal all lie in the same plane.
(2) The angle of incidence is equal to the angle of reflection.

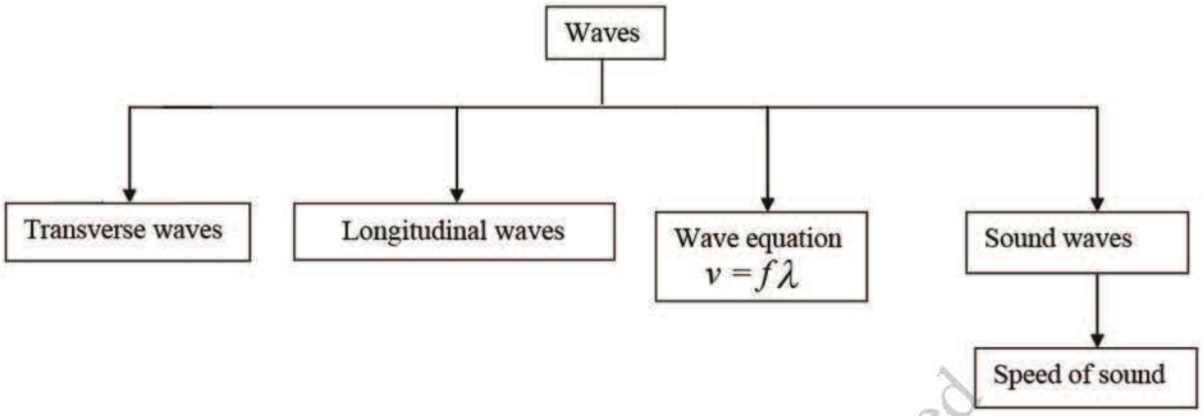
EXERCISE

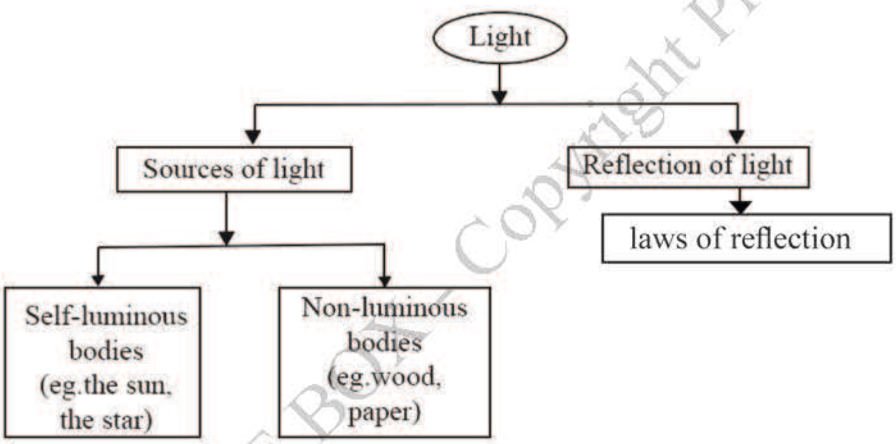
1. How does the speed of sound vary in the following media; water, air and wood?

	Highest speed	Lowest speed
A.	Air	water
B.	Water	wood
C.	Wood	water
D.	Wood	air

2. Can the velocity of sound change when sound wave travels from air into water?

CONCEPT MAP


Waves
Transverse waves
Longitudinal waves
Wave equation $v = f\lambda$
Sound waves
Speed of sound


Light
Sources of light
Reflection of light
laws of reflection
Self-luminous bodies (eg.the sun, the star)
Non-luminous bodies (eg.wood, paper)

CHAPTER 5

ELECTRICITY AND MAGNETISM

Electricity is a form of energy. There are two types of electricity: electrostatic (or) static electricity and electrodynamics (or) current electricity. Electrostatics is the study of electric charges at rest.

Magnetism is a phenomenon associate with magnetic field. A magnet has magnetic field around it. In this chapter charges at rest (electrostatic charges) and basic knowledge of magnets are studied.

Learning Outcomes

It is expected that students will

- investigate electric charges.
- distinguish the repulsive and attractive force between two charges.
- discuss that a charged body has electron deficiency (or) excess.
- identify the characteristics of conductors, insulators and semiconductors.
- differentiate between the magnetic and non-magnetic materials.
- determine the magnetic properties of the magnets.

5.1 ELECTRIC CHARGES AND ELECTRIC FORCES

Electric charge is the physical property of matter that causes an electric force when placed in an electromagnetic field. Electric charges may be either at rest (static charges) or in motion (moving charges). Flow of charges is called an electric current

A French scientist, Du Fay, studied the nature of electric charges possessed by the substances and found that there were only two kinds of charges. Benjamin Franklin named them positive charge which is represented by a plus sign (+) and negative charge by a minus sign (–). Like charges repel and unlike charges attract. The closer the charges are, the greater the force between them. When two charged objects are brought together, they produce either attractive or repulsive force (see Figure 5.1).

The electric force between two charged objects is one of the fundamental forces of nature. The electric force holds the particles that make up an atom together. Charged objects can exert forces to other charged objects without being in contact with them. This is possible because there is an electric field around each charge.

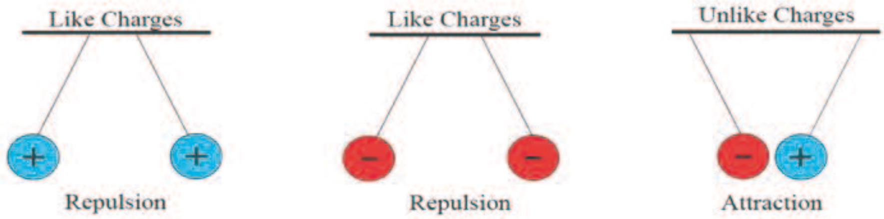


Figure 5.1 Repulsion and attraction between like and unlike charges

Unit of charge

Charge is measured in coulomb (C), in honour of Charles Augustin de Coulomb, a French physicist. The magnitude of charge of an electron is 1.6×10^{-19} C.

Reviewed Exercise

1. (a) How many kinds of charges exist?

   (b) What is the SI unit of charge?

Key Words : positive charge, negative charge, repulsive force, attractive force

5.2 MATTER AND ELECTRICITY

Matter is composed of atoms which are very small in size. An atom consists of core called the nucleus around which the particles called electrons are moving in orbits.

An electron is a negatively charged particle having a charge of -1.6×10^{-19} C. The nucleus consists of two kinds of particles called proton and neutron. A proton is a positively charged particle and a neutron is an uncharged particle. An electron and a proton have the same magnitude of electric charge. The nucleus has net positive charge. The magnitude of charge of the nucleus is the sum of the positive charges of all the protons present in the nucleus. In a normal atom the number of orbiting electrons is always equal to the number of protons. Since the magnitude of positive charge of the nucleus is equal to that of the total negative charge of electrons, a normal atom has no net charge. It is said to be electrically neutral.

If an atom gains one (or) more electrons, it carries negative charge. If an atom loses one (or) more electrons, it becomes positively charged. When an atom becomes a charged atom, it is called an ion.

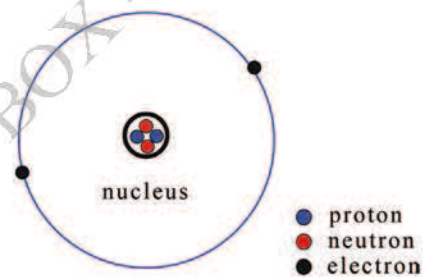


Figure 5.2 A neutral atom has the same number of electrons and protons

5.3 CONDUCTORS, INSULATORS AND SEMICONDUCTORS

As already mentioned, in an atom the negatively charged electrons are moving around a positively charged nucleus. Some of these electrons are near the nucleus while other electrons are further away from the nucleus. Since positive and negative charges attract each other, electrons experience an attractive force of the nucleus. As the attractive force is greater for the electrons closer to the nucleus so these electrons cannot move freely. This means that the inner electrons are tightly bound by the nucleus. The electrons closer to the nucleus are called bound electrons.

The electrons far away from the nucleus (or) the outer electrons experience less attractive force of the nucleus. This means that the outer electrons are loosely bound and are called free electrons. They can move from one atom to another.

The number of free electrons in a substance depends upon the nature of that substance. The substance which has plenty of free electrons is called a conductor and the substance which has very few (or) no free electrons is called an insulator.

Metals are good electrical conductors. Some of their electrons are so loosely held to their atoms that they can pass freely between them. These free electrons make metals good conductors. Example: gold, silver, copper, brass, aluminium, etc.

Most non-metals conduct electricity poorly (or) not at all, although carbon is an exception.

In insulators all the electrons are held tightly in position and unable to move from atom to atom. Insulators are materials that hardly conduct electricity. Although the electrons are not free to move in insulators, they can be transferred from one object to another. Example: plastics, glass, rubber, wax, quartz.

Some substances which contain a moderate amount of free electrons are called semiconductors. Such substances are neither conductors nor insulators. Silicon and germanium are widely used as semiconductors. Transistors and other electronic components are made from semiconductors.

Reviewed Exercise

1. Distinguish between an electrical insulator and an electrical conductor.
2. Mention five insulators and five conductors.

Key Words : bound electrons, free electrons, conductor, insulator, semiconductor

5.4 MAGNETS AND MAGNETIC MATERIALS

Magnets are the material which exhibit magnetic properties such as (1) attract magnetic materials (2) have two poles and (3) like poles repel, unlike poles attract.

Magnetic and Non-Magnetic Materials

Magnetite consists of an oxide of iron. This natural magnet attracts certain materials such as cobalt, nickel and some alloys such as steel. These materials are called magnetic materials. Materials such as brass, copper, wood and plastics that are not attracted by a magnet are called non-magnetic materials.

The material (such as magnetite) that is able to keep its magnetism for a long time is called a permanent magnet. Modern-day permanent magnets are usually made of steel (an alloy of iron) and special alloys such as alcomax and alnicol which contain metals such as iron, nickel, copper, cobalt and aluminium. Another type of permanent magnet is ceramic magnet which made from powders called ferrites (compounds of iron oxide with other metal oxides). However, these ceramic magnets are brittle.

Figure 5.3 (a) Examples of magnetic materials

Figure 5.3 (b) Examples of non-magnetic materials

Properties of Magnets

Besides exhibiting the property of attracting magnetic materials, all magnets also exhibit the following properties:

Magnetic Poles

The Figure shows what happens when we sprinkle some steel pins onto a bar magnet. Most of the pins are attracted to the two ends of the poles of the magnet.

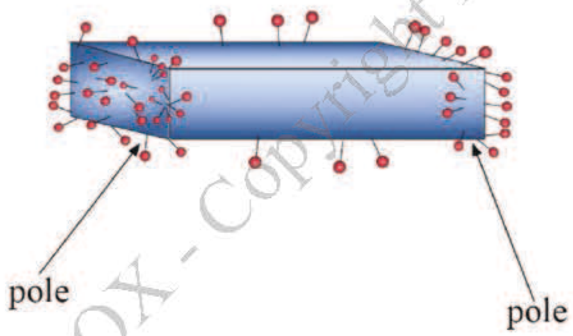


Figure 5.4 The pins show the positions of the poles of the magnet

North and South Poles

In Figure 5.5, the suspended bar magnet oscillate freely in air.

When the suspended bar magnet comes to rest, one end always points towards the northern end of the Earth. This end of the magnet is thus called the north-seeking pole. Similarly, the other end of the magnet is called the south-seeking pole.

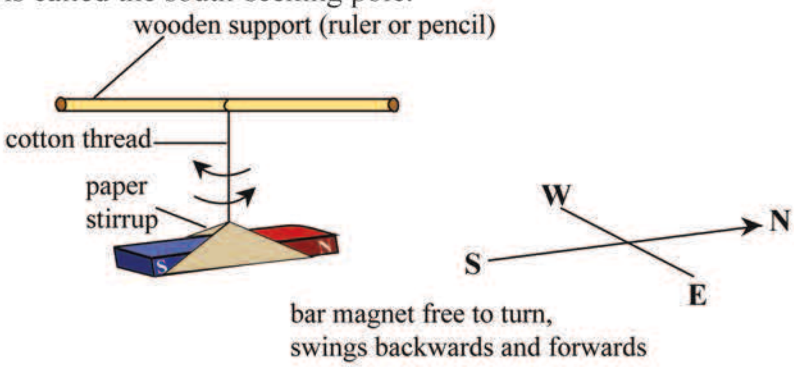


Figure 5.5 A suspended magnet always points north and south directions

The north-seeking pole and south-seeking pole of the magnet are usually referred to as simply the north pole (N-pole) and the south pole (S-pole) of the magnet. A magnet can therefore be used as a compass for navigation.

Law of magnetic poles : Like poles repel and unlike poles attract.

Magnetic Pole Strength and Magnetic Force

Magnetic pole strength is a measure of the strength of magnetic poles. When two magnetic poles are brought close to each other, one pole exerts certain force, either attractive (or) repulsive, on the other magnetic pole.

Reviewed Exercise

1. Give three examples of magnetic materials.
2. Give three examples of non-magnetic materials.
3. State the properties of magnets.

Key Words : Magnet, pole, alloy

SUMMARY

Electrostatics is the study of electric charges at rest .

The two kinds of static electric charge are positive charge and negative charge.

Like charges repel and unlike charges attract.

The electric force between two charged objects is one of the fundamental forces of nature.

Charge is measured in coulomb (C).

The inner electrons that are tightly bound by the nucleus are called **bound electrons**.

The electrons far away from the nucleus (or) the outer electrons are loosely bound and are called **free electrons**.

The substance which has plenty of free electrons is called a **conductor**.

The substance which has very few (or) no free electrons is called an **insulator**.

Some substances which contain a moderate amount of free electrons are called **semiconductors**.

Magnets are the material which exhibit magnetic properties such as; (1) they attract magnetic materials (2) they have two poles and (3) like poles repel, unlike poles attract.

Magnetite consists of an oxide of iron. This natural magnet attracts certain materials such as cobalt, nickel and some alloys such as steel.These materials are called **magnetic materials**.

Materials such as brass, copper, wood and plastics that are not attracted by a magnet are called **non-magnetic materials**.

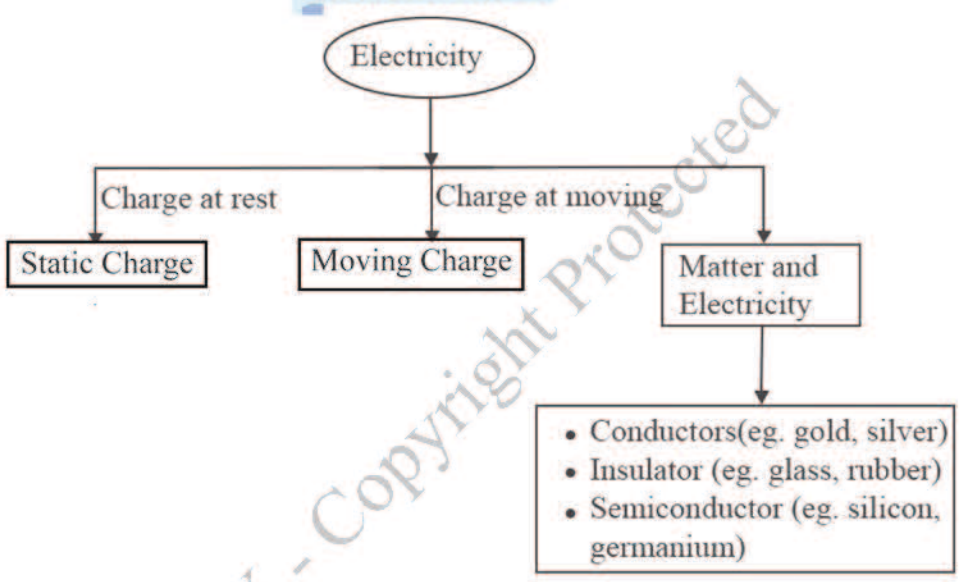
EXERCISE

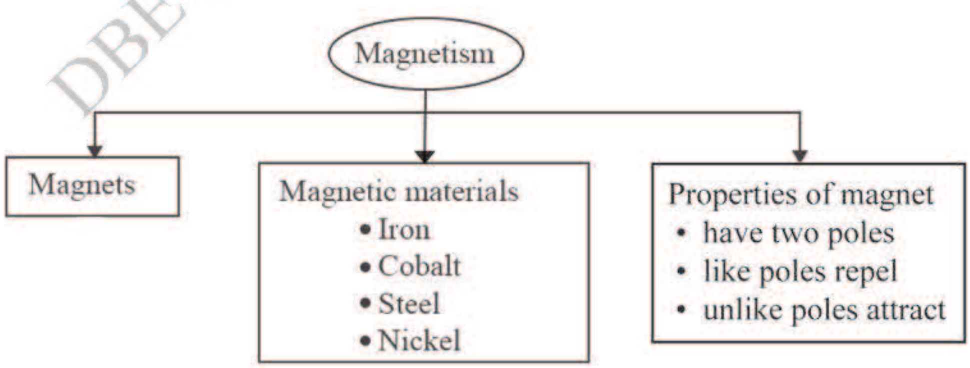
1. Match the following.

(i) electron	A. positively charge
(ii) proton	B. repel
(iii) like charges	C. attract
(iv) unlike charges	D. negative charge

2. It can be confirmed that a metal bar is already magnetised if
   - A. a magnet is attracted to it.
   - B. an aluminium bar is attracted to it.
   - C. both ends of a compass needle are attracted to the same end of the bar.
   - D. one end of a compass needle is repelled by one end of the bar.

CONCEPT MAP





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CHAPTER 1
INTRODUCTION TO BIOLOGY

Learning Outcomes

It is expected that students will

- explain how the study of biology is important in daily life
- identify the common characteristics of living things
- know how living things are classified into three domains and six kingdoms

1.1 THE STUDY OF BIOLOGY

Biology is the study of living things. A large variety of living things exists on the land, in the water and in the air. Living things (organisms) include plants, animals including humans and other organisms. Thus, biology deals with the study of all organisms that live or have ever lived on the earth.

1.1.1 The Importance of Biology in Everyday Life

Biology is very fundamental and important science dealing with bacteria, protista, fungi, plants and animals including humans. Their structures and functions are associated with one another in their respective environments. To a great extent, we owe our daily high standard of living to biological advances in two areas: food production and disease control.

Plant and animal breeders have modified organisms to yield greater amounts of food than did older varieties. The improvements in the plants, along with better farming practices, have greatly increased food production.

Biological research has also improved food production by developing controls for the disease organisms, pests and weeds that reduce yields. Biologists must understand the nature of these harmful organisms to develop effective control methods.

1.1.2 The Different Fields of Study in Biology

The main branches of biology are:

Botany	: study of plants
Zoology	: study of animals
Microbiology	: study of microscopic organisms

Some other branches of biology are:

Morphology	: study of forms and structures of organisms
Anatomy	: study of gross internal structures
Histology	: study of microscopic structures of tissues
Cytology	: study of cells
Physiology	: study of living processes or functions of the various parts of organisms
Embryology	: study of early development of organisms
Palaeontology	: study of fossils (the remains of organisms that lived millions of years ago; now preserved in rocks)

Taxonomy	: study of classification of organisms
Ecology	: study of the relationships of organisms to their environments
Biodiversity	: study of varieties among living organisms
Evolution	: study of the origin and change in forms of organisms over time
Genetics	: study of heredity and variations
Mycology	: study of fungi
Protistology	: study of protists
Phycology	: study of algae
Virology	: study of viruses
Bacteriology	: study of bacteria
Molecular Biology	: study of molecules in organisms
Biotechnology	: study of utilization of living organisms in industrial processes
Bioinformatics	: study of information technology to interpret molecular biology data

1.1.3 Characteristics of Living Things

The main characteristics of living things are their cellular structure, metabolism, growth, movement, irritability, reproduction and adaptability.

Cellular structure

All living things consist of the living substance called protoplasm which forms the basis of cells. These cells contain DNA (deoxyribonucleic acid) molecules that carry biological information. Cells of plants and animals are organized into tissues and tissues are in turn organized into organs and systems. These structures are responsible for carrying out the various life processes.

Metabolism

Metabolism is the sum of the various processes that give the organism's life. The two aspects of metabolism are anabolism and catabolism. The food material is made into a part of the organism in the process of anabolism. The food material, when broken down, releases energy and results in the formation of waste products. This process is termed as catabolism. The important metabolic processes that take place in organisms involve the utilization of food. This includes nutrition, respiration and excretion.

Growth

The growth of an organism is seen as an increase in size and weight resulting from the use of food to further develop structures in the organism.

Movement

All living things show some kinds of movement. This is more obvious in animals since they have organs of movement or locomotion. Movements in plants mainly take place inside the cells although some results from a stimulus such as light.

Irritability

Living things respond to stimulus. The stimulus can be any changes in the environment (light, sound, touch, temperature, etc.) which bring about a reaction in an organism due to a sensitivity to the stimulus.

Reproduction

Reproduction is the production of a new generation of offspring. The two types of reproduction are asexual reproduction and sexual reproduction. In asexual reproduction, the new individual may be produced by a part of the old one. There is only one parent organism needed for asexual reproduction.

Sexual reproduction produces a new individual as a result of the fusion of two parental sex cells. These two cells come, one from each individual of the same species. The cells are fused to form a single new organism.

Adaptability

Living organisms are able to adjust and adapt themselves to changes in their external and internal environments. Adaptability increases the chances of species surviving and can result in the formation of a new species. For instance, a change of seasons or a shortage of food may cause certain birds to migrate to another place where the conditions are more favourable. A plant may grow very straight and upright to stand above plants around it. This enables this plant or plant species to get enough sunlight to survive and even to dominate the environment.

1.2 TAXONOMY

The science of classification of organisms is taxonomy. This is the general name for groups or categories within a classification system.

1.2.1 Diversity of Organisms

There are vast numbers of living things in the world. The word 'biodiversity' is a short form of 'biological diversity' which means that the abundance of different types of species.

Scientists are not aware just how many different types of organisms exist in nature. It is because, previously unknown species are being discovered all the time.

1.2.2 Taxonomy in the Study of Biology

Classification is essential to biology because there are too many different living things to sort out and compare unless they are organized into manageable categories. With an effective classification system in use, it is easier to organize the ideas about organisms and make generalizations.

The scheme of classification has to be flexible, allowing newly discovered living organisms to be added into the scheme where they fit best. As living and extinct species are related, fossils should also be considered in this scheme.

The process of classification involves:

- giving every organism an agreed name
- placing the organism into a group based on the common characteristics it shares with others in the group.

1.2.3 The Importance of Taxonomy

By taxonomy, it is much easier to learn biology as there are millions of known and unknown organisms. Taxonomy can be used to examine the evolutionary history of organisms and the relationships between organisms.

1.2.4 Taxonomic Hierarchy

Biological classification schemes are the invention of biologists, based upon the best available evidence at that time. In classification, the aim is to use as many characteristics as possible in placing similar organisms together. Just as similar **species** are grouped together into the same **genus** (*plural* genera).

Similar genera are grouped together into **families**. This approach is extended from families to **orders**, then **classes**, **phyla** or **divisions** and **kingdoms**. This is the hierarchical scheme of classification, each successive group containing more and more different kinds of organisms. When a classification of a species is written, it starts with the kingdom followed by other taxonomic ranks of division or phylum, class, order, family, genus and species.

For examples,

Kingdom	: Plantae	Kingdom	: Animalia
Division	: Magnoliophyta	Phylum	: Chordata
Class	: Monocotyledons	Class	: Mammalia
Order	: Cyperales	Order	: Primates
Family	: Poaceae	Family	: Hominidae
Genus	: *Oryza*	Genus	: *Homo*
Species	: *O. sativa*	Species	: *H. sapiens*

1.2.5 Classification of Plants and Animals

Everyone must be able to identify objects and to relate their observations to other people. Most people are familiar with some of the common forms of plants and animals. However, since there are so many different kinds of plants as well as animals, the word 'plant' or 'animal' is not sufficient for identification.

Linnaeus (1707-1778), a Swedish naturalist, studied and gave scientific names to thousands of plants and animals. He introduced the **Binomial System of Nomenclature** in the year 1753. Each plant and animal is given a two-word name by this system. The first name is the **genus** and the second is the **species**. The name of the genus is always started with a capital letter and the name of the species is started with a small letter. These two names constitute the scientific name of the organism. For example, the scientific name of human is *Homo sapiens* and that of paddy plant is *Oryza sativa.*

1.3 KINGDOMS

A **Kingdom** is a subdivision of a **Domain**. The living things are classified and placed in one of the six kingdoms. The three domains - **Bacteria**, **Archaea** and **Eukarya** diverged early in the history of life. Subsequently, many new kinds of organisms have evolved. Each of these kingdoms has its own set of characteristics.

1.3.1 Kingdoms of Living Things

Organisms are divided into six kingdoms. There are two kingdoms within the domains **Archaea** and **Bacteria**, namely kingdoms **Archaebacteria** and **Eubacteria**. Their differences are based primarily on the metabolism and genetic composition of the organisms. Within the domain **Eukarya**, there are four kingdoms: **Protista**, **Fungi**, **Plantae** and **Animalia** (Figure 1.1 and Table 1.1).

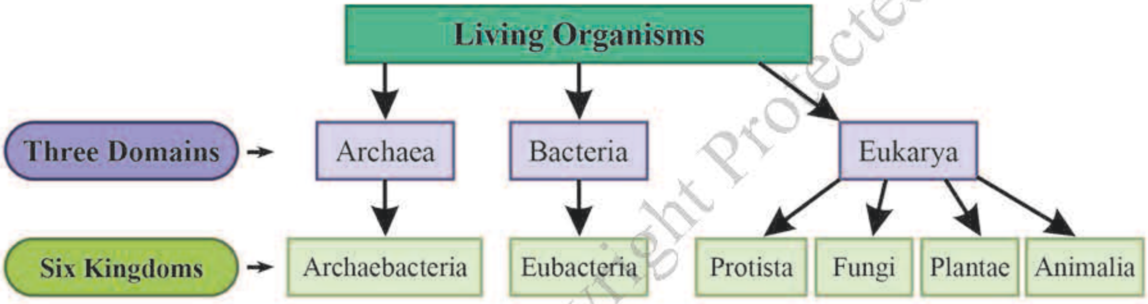


Figure 1.1 Relationship between three domains and six kingdoms of classification

Table 1.1 Characteristics of six kingdoms

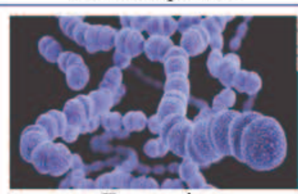
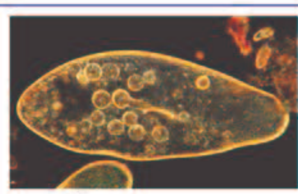
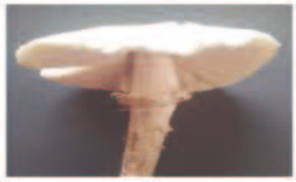
Kingdoms	Characteristics	Examples	Diagrams
Archaebacteria	- Primitive - Live in extreme environment - Prokaryote - Unicellular - Obligate anaerobic	Thermophiles Methanogens	 Thermophiles
Eubacteria	- Prokaryote - Unicellular - Autotrophs or heterotrophs - Asexual reproduction by fission	Bacteria Cyanobacteria	 Bacteria
Protista	- Eukaryote - Unicellular - Autotrophs or heterotrophs - Asexual or sexual reproduction	*Amoeba* *Euglena* Slime mold *Paramecium*	 *Paramecium*

Table 1.1 Characteristics of six kingdoms (continued)

Kingdoms	Characteristics	Examples	Diagrams
Fungi	- Eukaryote - Unicellular or multicellular - Heterotrophs - Asexual or sexual reproduction	Yeast *Rhizopus* Mushroom	 Mushroom
Plantae	- Eukaryote - Multicellular - Autotrophs - Vegetative, asexual or sexual reproduction	Algae Liverworts Mosses Ferns Conifers Angiosperms	 Angiosperm
Animalia	- Eukaryote - Multicellular - Heterotrophs - Asexual or sexual reproduction	Earthworms Insects Fish Birds Mammals	 Mammal

Viruses

Viruses are not included in the six kingdoms of living organisms. Viruses, although not considered as living organisms, cause common diseases such as colds and influenza (Figure 1.2) and also more serious ones such as AIDS (Acquired Immune Deficiency Syndrome).

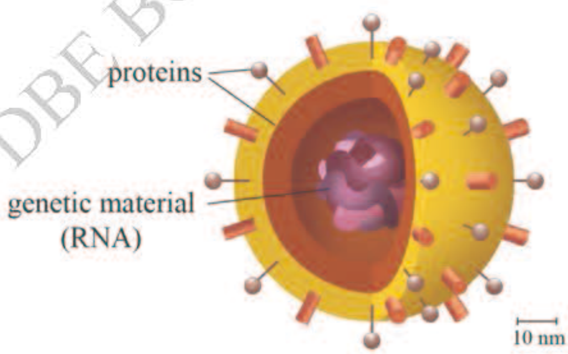


Figure 1.2 An influenza virus

1.3.2 Kingdom Plantae

Plants are eukaryotic and chlorophyll containing organisms. They obtain their energy from sun through photosynthesis. Cell wall of plant is composed of cellulose. Plants reproduce by vegetative, asexual and sexual methods. In life cycle of plants, interchanges occur from the embryo and are supported by other tissues. They lack motility. The plantae are subdivided into five divisions (Table 1.2).

Table 1.2 Divisions of plantae

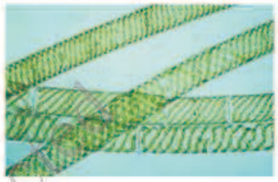
Divisions	Characteristics	Examples
Thallophyta	- Plant body is simple (thallus) - Grow in water, on damp soil, on wet rocks and on tree trunks - Vascular system absent - Reproduce by means of asexual or sexual	 *Spirogyra*
Bryophyta	- Most primitive land plants - Grow on damp and shaded soil - Thallus dorsiventral with thread-like rhizoids - No vascular system - Have parenchymatous tissue - Sporophyte upright, foliose type - Life cycle of bryophytes shows two distinct generations (gametophytic and sporophytic generations) - Those two generations regularly alternate with each other in a single life cycle, is called alternation of generations	 Liverworts (*Riccia*)  Hornworts (*Anthoceros*)  Mosses (*Funaria*)
Pteridophyta	- More advanced than bryophytes - Grow chiefly in shaded moist places - Differentiated into rhizome, rachis and pinna - A well-developed vascular system - Reproduction by spores - Life cycle shows distinct alternation of generations.	 Ferns (*Adiantum*)

Table 1.2 Divisions of plantae (continued)

Divisions	Characteristics	Examples
Gymnospermae	- Woody, non-flowering plants - Seed-bearing vascular plants - Seeds are not enclosed in a fruit. - Seeds develop either on the surface of scale or leaf-like appendages known as sporophylls.	 Coniferous trees (Pine)
Angiospermae	- Flowering vascular plants - The plants with roots, stems and leaves - Widely distributed on the earth's surface - Reproduce by means of flowers, fruits and seeds - Seeds are produced inside the ovary of the flower. - Seed with one cotyledon (monocots) - Seed with two cotyledons (dicots)	 Monocots (Maize)  Dicots (Mango)

1.3.3 Kingdom Animalia

Animals are multicellular and heterotrophic organisms. Animals are divided into two main groups: those that do not have a backbone (vertebral column) are grouped as invertebrates and those that have a backbone are grouped as vertebrates (Table 1.3). Invertebrates make up more than 95 percent of all animal species alive today.

Table 1.3 Major groups of vertebrates

Groups	Characteristics	Examples
Fish	- Vertebrates with scaly skin, except a few are scaleless - Live in water - Have gills - Have fins for swimming - Poikilothermic (e.g., bony and cartilaginous fish)	 Fish

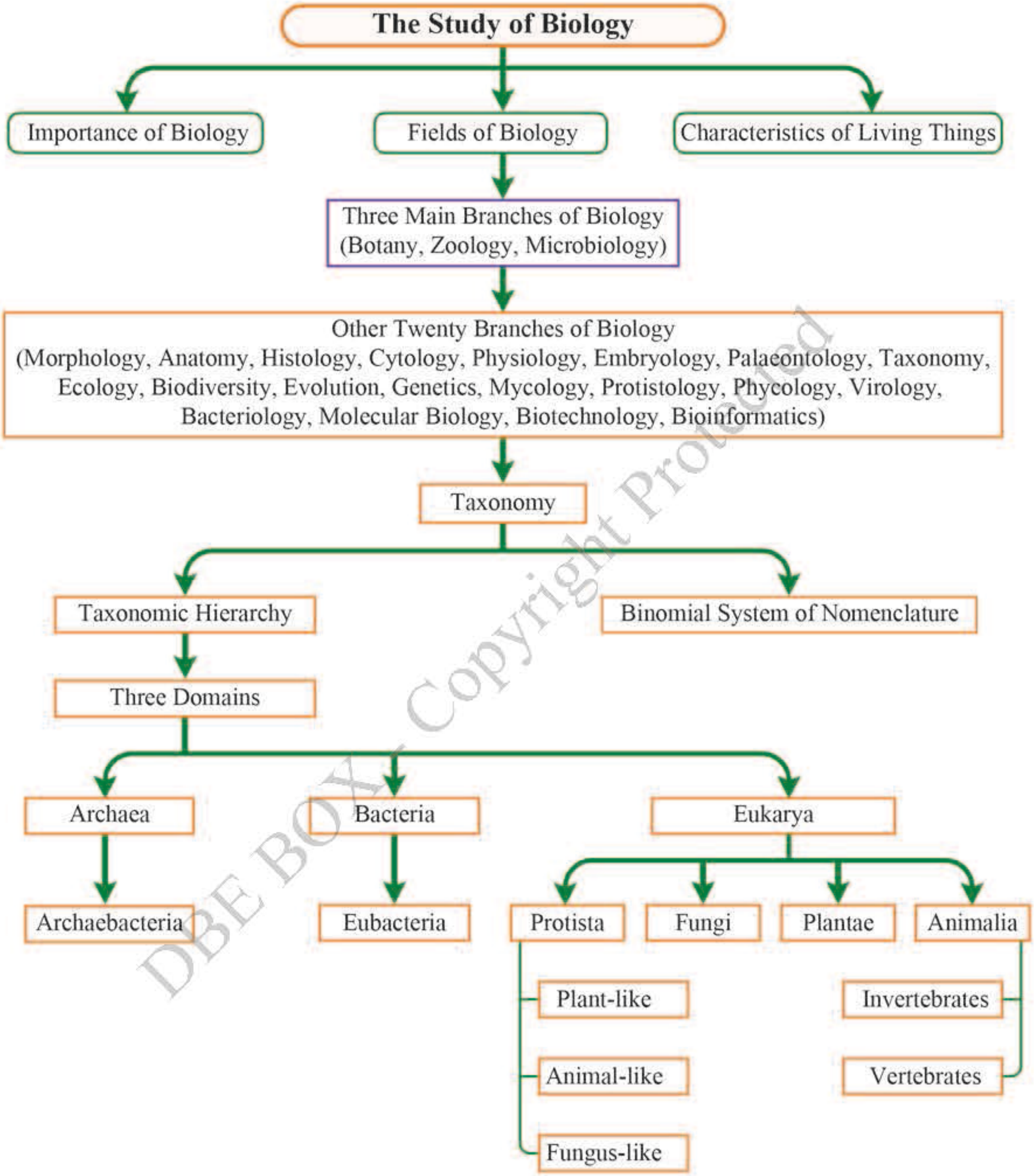
Table 1.3 Major groups of vertebrates (continued)

Groups	Characteristics	Examples
Amphibians	- Vertebrates with moist, scaleless skin - Larva has gills and adult has lungs. - Poikilothermic - Eggs laid in water, larva (tadpole) lives in water which metamorphoses into adult. - Adult often lives on land (e.g., frogs, newts and salamanders).	 Frog
Reptiles	- Vertebrates with scaly skin, some limbless - Lungs present - Poikilothermic - Lay eggs with shells (e.g., lizards, snakes, turtles)	 Snake
Birds	- Vertebrates with feathers and beak - Forelimbs have become wings for flight. - Lungs present - Homoiothermic - Lay eggs with hard shells (e.g., birds)	 Bird
Mammals	- Vertebrates with hair - Have different types of teeth (incisors, canines, premolars and molars) - Have lungs and diaphragm - Homoiothermic - Have a placenta and young feed on milk from mammary glands (e.g., cats, dogs, humans)	 Wild cat

Review questions

1. What are the main branches of biology?
2. State the different fields of biology and their definitions.
3. Explain the term taxonomy in your own words.
4. Define the term biodiversity.
5. Why are living organisms grouped into domains, kingdoms and lower category hierarchies?
6. Briefly explain what is meant by the Binomial System of Nomenclature.
7. Write down the names of the three domains and the six kingdoms.
8. Distinguish eubacteria from archaebacteria citing major differences and similarities.
9. Explain how living things have been separated into six kingdoms.
10. What are the characteristics of Bryophyta with examples?
11. Describe the nature of Flowering plants.
12. Describe the characters of fish.
13. State the general characters of amphibians.
14. Describe the characteristics of birds.
15. State the general characteristics of mammals.

Concept map


The Study of Biology
Importance of Biology
Fields of Biology
Characteristics of Living Things
Three Main Branches of Biology
(Botany, Zoology, Microbiology)
Other Twenty Branches of Biology
(Morphology, Anatomy, Histology, Cytology, Physiology, Embryology, Palaeontology, Taxonomy, Ecology, Biodiversity, Evolution, Genetics, Mycology, Protistology, Phycology, Virology, Bacteriology, Molecular Biology, Biotechnology, Bioinformatics)
Taxonomy
Taxonomic Hierarchy
Binomial System of Nomenclature
Three Domains
Archaea
Bacteria
Eukarya
Archaebacteria
Eubacteria
Protista
Fungi
Plantae
Animalia
Plant-like
Animal-like
Fungus-like
Invertebrates
Vertebrates

CHAPTER 2
CELL STRUCTURE AND ORGANIZATION

Learning Outcomes

It is expected that students will

- distinguish between the prokaryotic and eukaryotic cells by reviewing their common characteristics, roles and functions
- examine cellular components and describe their characteristics and functions
- study how cells are organized into tissues, organs and organ systems

2.1 CELLS AS THE BUILDING BLOCKS OF LIFE

All living organisms are composed of basic functional units called cells. The simplest organisms are made up of the single cells which perform all the functions of life. The complex organisms are composed of millions of cells. In multicellular (many-celled) organisms, there may be hundreds of different types of cells with different structures. They are specialized to carry out particular functions in plants or animals.

Cells are made up of a number of different subunits called organelles. These subunits are often of a particular size but all are microscopically small. So that a microscope with a high magnification and resolution is needed to observe cells and their subunits.

2.1.1 The Cell Theory

The basic principles of the cell theory are:

1. Cells are the building blocks or basic structures in all living things.
2. Cells are the smallest units of living things, they are the basic units of organization of all organisms.
3. All cells are derived from other cells (pre-existing cells) by means of division.
4. Cells contain a blueprint (i.e. information) outlining their growth, development and function.
5. Within cells, there are sites and structures where the chemical reactions of life occur (metabolism).

2.1.2 Prokaryotic and Eukaryotic Cells

Both types of cells are bounded by the plasma membrane which is semipermeable. Inside the cells is a semifluid jelly-like substance called cytoplasm, in which cellular organelles are suspended. All cells contain chromosomes which carry genes in the form of DNA. All cells have ribosomes, tiny organelles that make proteins according to instructions from the genes.

The cells of bacteria and archaea are prokaryotic (Figure 2.1) while those of protists, fungi, plants and animals are of eukaryotic (Figure 2.2 and 2.3). Prokaryotic cells evolved before eukaryotic cells and they lack a true nucleus. A membrane bounds the nuclear materials of a true nucleus. Eukaryotic cell possesses a true nucleus. Prokaryotic cell possesses nuclear materials but lacks a nuclear membrane. Prokaryotic cells are 0.1 - 5.0 μm in diameter while eukaryotic cells are typically 10 - 100 μm in diameter.

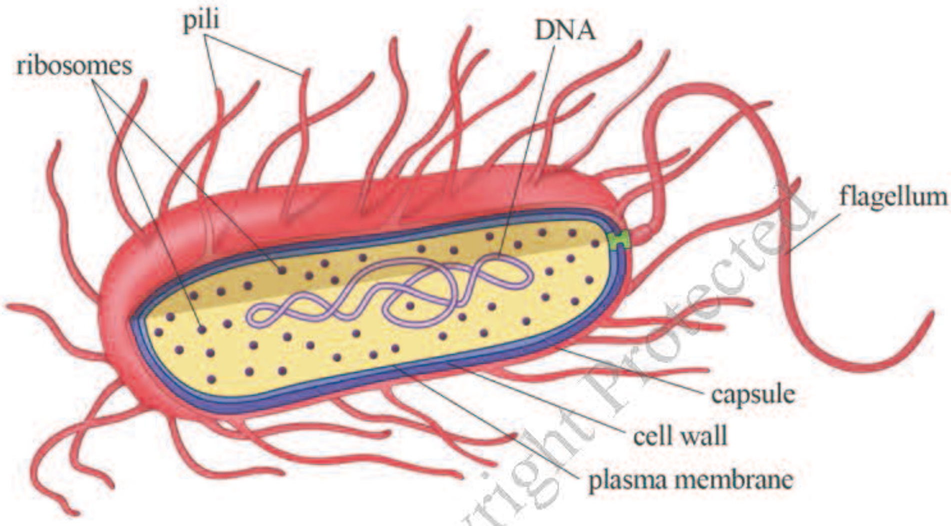


Figure 2.1 Prokaryotic cell: a rod-shaped bacterium

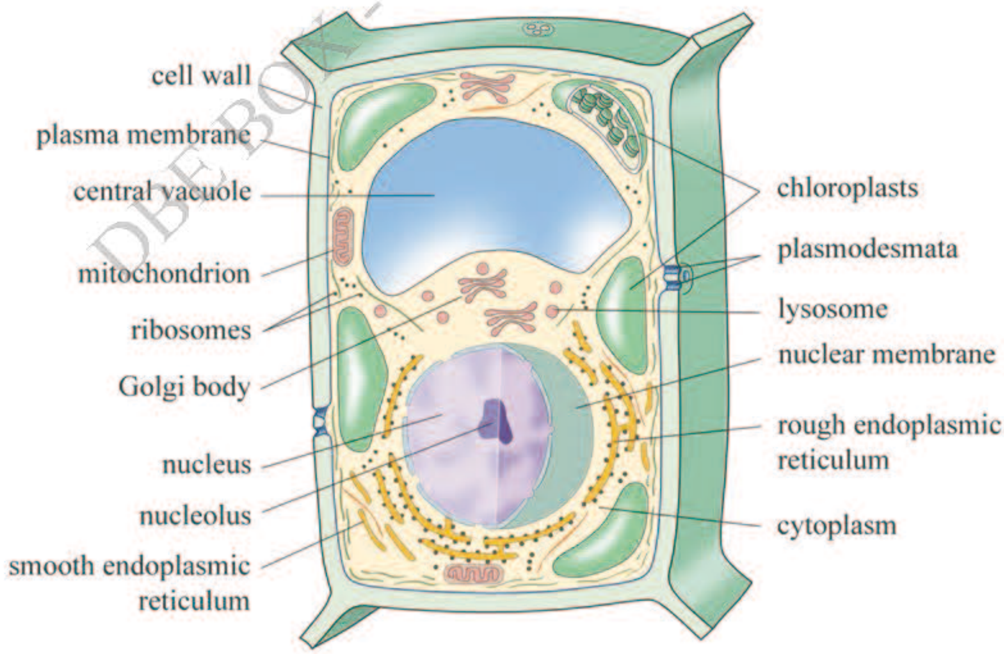


Figure 2.2 Eukaryotic cell: a plant cell

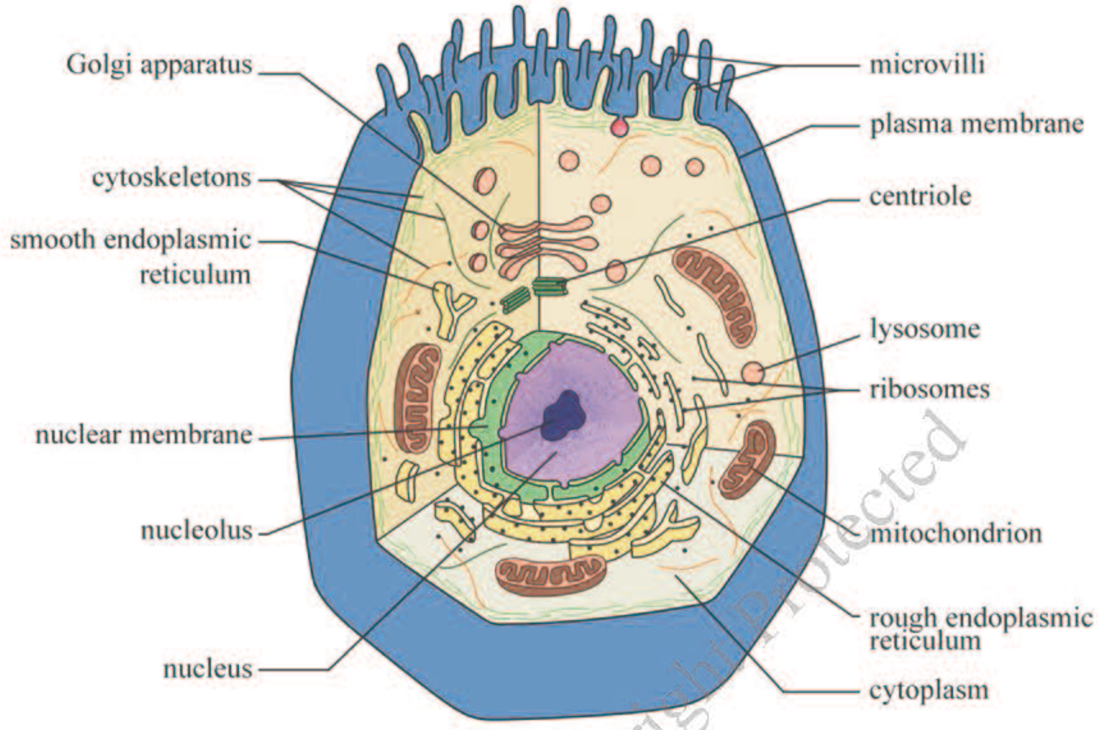


Figure 2.3 Eukaryotic cell: an animal cell

The major difference between prokaryotic and eukaryotic cells is the location of their DNA. In a eukaryotic cell, most of DNA is in the nucleus, which is bounded by a double membrane. In a prokaryotic cell, the DNA is concentrated in a region that is not membrane bound called the nucleoid, which is part of cytoplasm. The DNA of prokaryotic cell is circular and contains only nucleic acid with no proteins while that of eukaryotic cells is linear and made up of nucleic acid and the proteins called **histones**.

Membrane bounded organelles are present in eukaryotic cell, whereas membrane bounded organelles are not present in prokaryotic cell. In eukaryotes, cell walls are absent except in plants and fungi. In prokaryotes, cell walls are present (Table 2.1).

Table 2.1 Comparison between the structure of prokaryotic and eukaryotic cells

Prokaryotic cell	Eukaryotic cell
- Average diameter is 0.1 - 5 µm.	- Average diameter is 10 - 100 µm.
- Single copy DNA present and it is circular and contains only nucleic acid with no proteins.	- Multiple copies DNA present - They are linear and made up of nucleic acid and proteins.
- DNA is located in the cytoplasm.	- DNA is located in the nucleus, chloroplasts and mitochondria.
- Nucleus absent	- Nucleus present
- Ribosomes are about 20 nm in size.	- Ribosomes are about 25 nm in size.
- No membrane bounded organelles	- Membrane bounded organelles present
- Cell wall present which is made up of murein, a peptidoglycan	- Cell wall present in plants and fungi only - In plants, it is made up of cellulose or lignin while in fungi, it is made up of chitin. Cell wall absent in animal cell.

2.2 EUKARYOTIC CELL STRUCTURE

Plant and animal cells have common features which include a **plasma membrane** (cell membrane), a **nucleus** and **cytoplasm**. Not all the ultrastructures of a cell are seen with a light microscope.

2.2.1 Differences in Cell Structure

Cells of different organisms and even cells within the same organisms are very diverse in terms of shape, size, internal organization and function. One theme that occurs repeatedly throughout biology is that form follows function. In other words, a cell's function influences its physical features. The diversity in cell shape and structure reflects the different functions of cells.

2.2.2 Cell Components

Most plant and animal cells contain certain parts such as the nucleus, cytoplasm and cell membrane. But other cell components may be present or absent in plant and animal cells (Table 2.2).

Table 2.2 Summarized account of the components found in plant and animal cells

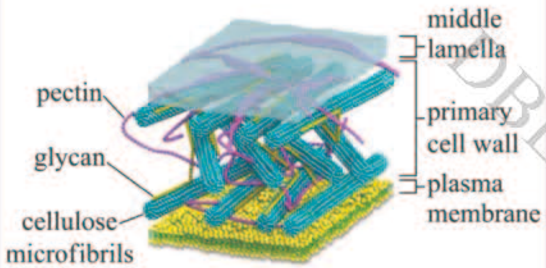
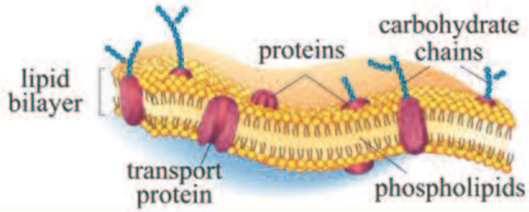
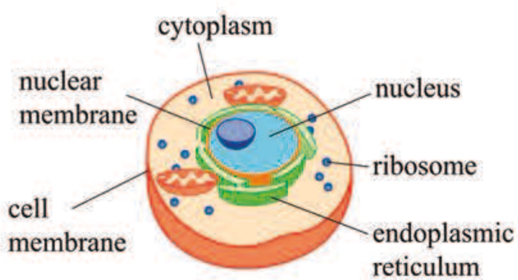
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Cell wall 	- Outside the cell membrane	- A structural layer surrounding some types of cells, just outside the cell membrane	- Give the cell strength and structure, and to filter molecules that pass in and out of the cell	Present	Absent
Cell membrane (Plasma membrane) 	- Around the cytoplasm	- Phospholipid bilayer with proteins attached to or embedded in it	- Surround the cell - Act as partially permeable membrane	Present	Present
Cytoplasm 	- Outside of the nucleus and within the cell membrane	- Jelly like structure, in which organelles are embedded	- Act as a site for chemical reactions to take place - Hold the organelles	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

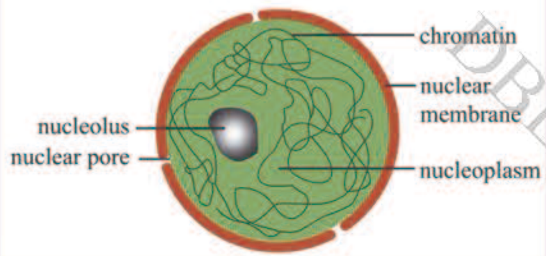
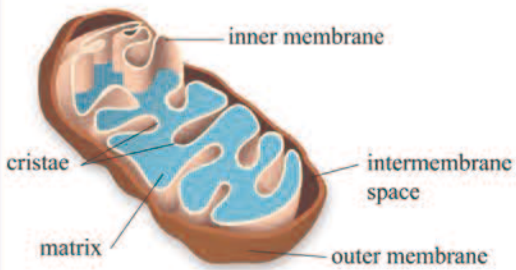
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Nucleus 	- Inside the cytoplasm	- A circular (or) oval structure	- Control the cell's activities	Present	Present
Mitochondrion 	- Inside the cytoplasm	- Rod (or) spherical shape	- Aerobic respiration - Act as a site for synthesis of lipids - Generate ATP as energy molecules	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

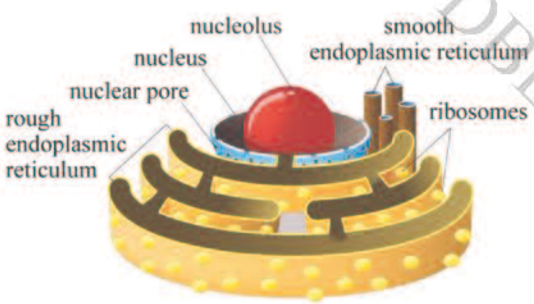
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Endoplasmic reticulum (ER) (Smooth ER, Rough ER)  	- Inside the cytoplasm	- A network of tubules and flattened sacs - Smooth ER; its outer surface lacks ribosomes - Rough ER is studded with ribosomes on the outer surface of its membrane	- Continuous with the outer membrane of the nuclear envelope - Smooth ER: synthesis of lipids, metabolism of carbohydrates, calcium storage, detoxification of drugs and poisons - Rough ER: aids in synthesis of secretory and other proteins on bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

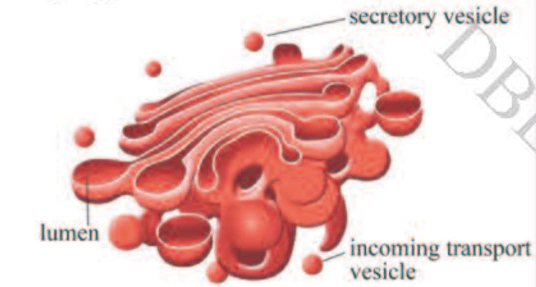
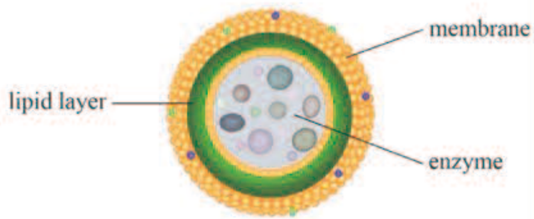
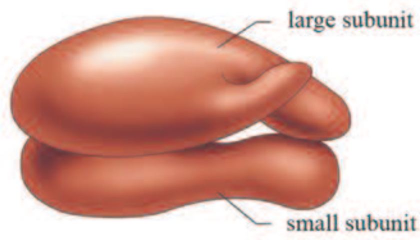
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Golgi apparatus 	- Located very near the rough endoplasmic reticulum and hence near the nucleus	- A stack of flattened sacs	- Collect, process and sorts molecules - Convert sugars into cell wall components - Make lysosomes	Present	Present
Lysosome 	- Inside the cytoplasm	- Spherical sacs - Surrounded by a single membrane and having no internal structure	- Breakdown (digestion) the unwanted structures such as old organelles or even whole cells	Present	Present
Ribosome 	- Some are attached to rough endoplasmic reticulum - Some are free in cytoplasm	- Tiny organelle - Has two subunits	- Protein synthesis	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

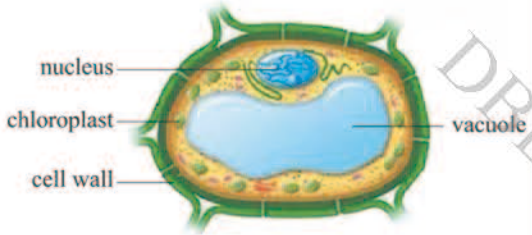
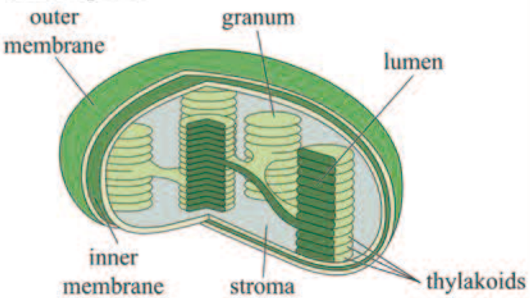
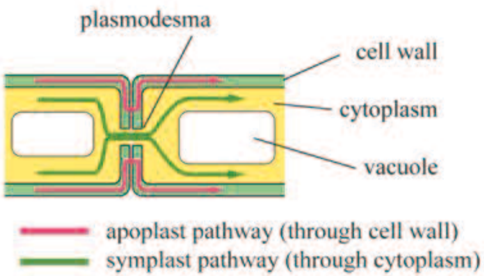
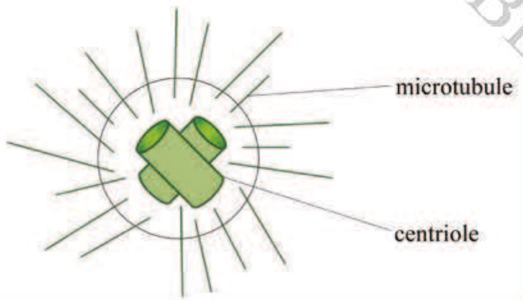
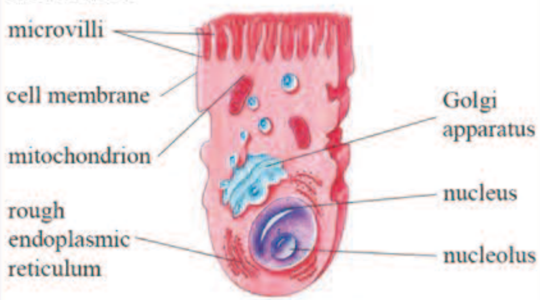
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Vacuole 	- Inside a cell	- A fluid-filled space enclosed by a membrane	- Control exchange between the vacuole and the cytoplasm, regulate the osmotic properties of cells	Present	Present
Chloroplast 	- Present in the leaves	- Large organelle	- Photosynthesis - Generate chemical energy as glucose molecules	Present	Absent
Plasmodesmata 	- Only in plant and algal cells	- Fine strands of cytoplasm - Pass through pore-like structures	- Connect the internal chemical environment of adjacent cells - Allow water and small solutes to pass freely from cell to cell	Present	Absent

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Centrosome and centrioles 	- Near the nucleus	- Within the centrosome is a pair of centrioles - Each composed of nine sets of triplet microtubules arranged in a ring	- Grow spindle microtubules for nuclear division	Absent	Present
Microvilli 	- Located on cell surface	- Finger-like extensions	- Absorption (in the gut), reabsorption (in the kidney)	Absent	Present

2.2.3 Cell Organization

Atoms are organized into molecules, molecules into organelles and organelles into cells. Cells are divided into several compartments called organelles, each with a characteristic structure, biochemical composition and function. The cell must possess enough information to specify which molecules are to be associated in a specific compartment. It is ensured to route the appropriate groups of molecules to their compartments. According to the cell theory, all living things are composed of one or more cells as unicellular and multicellular organisms.

In unicellular organisms, the single cell performs all life functions independently. In multicellular organisms, various levels of organization are present. They are made up of more than one type of cells and have specialized cells that are grouped together to carry out specialized functions. Individual cells may perform specific functions and also work together for the survival of the entire organism. The cells become dependent on one another. There are five levels of organization in multicellular organisms: cells, tissues, organs, organ systems and organisms.

Cells are the simplest level of organization. Specialized cells show division of labour by being grouped into tissues; the tissues may be further grouped into organs and the organs into systems. Each tissue, organ or system has a particular function and a structure appropriate to that function.

Tissues

A **tissue** is a group of cells with similar structures, working together to perform a particular function. In each tissue, the cells are alike, with the same characteristics of size, form and arrangement. They are specialized or differentiated both structurally and physiologically to perform some particular functions.

(A) Plant tissues

Plant tissues deal with the study of internal structure of various parts of the plant like root, stem and leaf. All these parts are made up of different kinds of tissues. The cells of a tissue generally have a common origin. In the higher plants, tissues show a division of labour and form three basic tissue systems in plants (Figure 2.4).

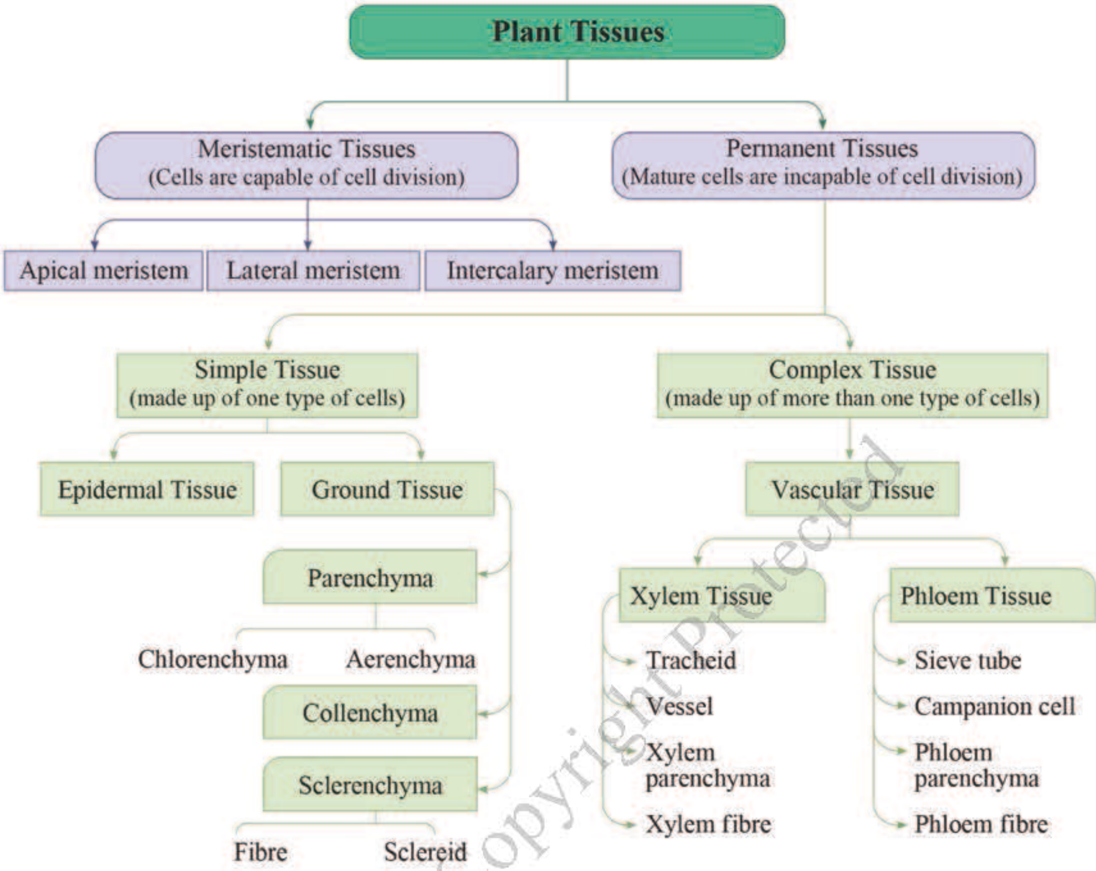


Figure 2.4 Types of tissue system in plant

Level of organization in plants

The plant body of most vascular plants is constructed from millions of tiny cells. They have characteristic shapes and functions and are grouped together to form tissues. Various types of tissues are grouped together into a structural and functional unit called an organ. The organs that perform major activity together are formed as a system.

Organs

1. Plant organs include roots, stems, leaves and flowers which consist of tissues.
2. There are less organs in plants as compared to animals.

Organ systems

1. The plant body consists of two main systems:

(a) The root system (underground part) - is composed of main roots and branches. These organs are formed as the absorptive system; absorb water and mineral salts from the soil.

(b) The shoot system (above ground part) - is composed of stems, leaves, buds, flowers and fruits. The stem acts as a support system and the flower performs as a reproductive system.

Root system and shoot system work together as a plant.

(B) Animal tissues

Animal tissues can be classified into four basic groups: (1) **epithelial or covering** (2) **connective or supporting** (3) **muscle or contractile** and (4) **nervous**. Each tissue type is assembled from individual cells that determine the structure and the function of the tissue. The structure and integrity of a tissue depend on the structure and organization of the cytoskeleton within the cells, the type and organization of the extracellular matrix (ECM) surrounding the cell and the junctions holding cells together (Figure 2.5).

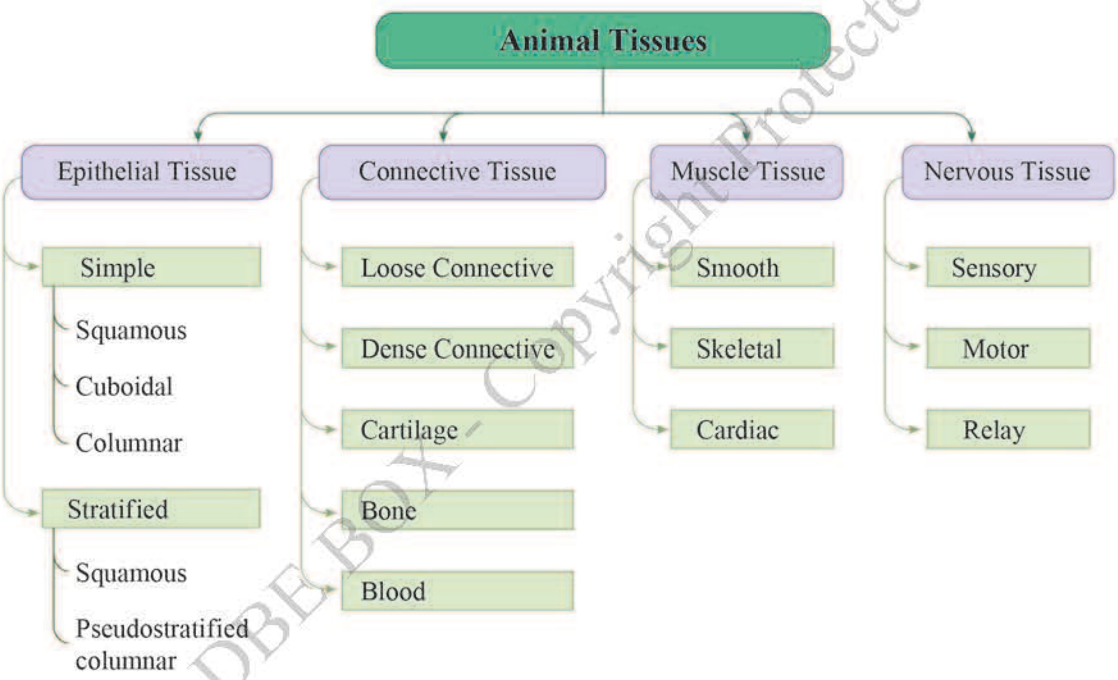


Figure 2.5 Types of tissue system in animal

Organs

Organs are body structures composed of several different types of tissues that form a structural and functional unit. One example is the heart which contains cardiac muscle, connective tissue and epithelial tissue and is laced with nerve tissue that helps to regulate the heartbeat.

Organ systems

An organ system is a group of organs that function together to carry out the major activities of the body. For example the seven main systems in the human body is given below.

(1) Digestive system	- the digestive system is composed of the digestive tract, liver, gall bladder and pancreas. These organs cooperate in the digestion of food and the absorption of digested products into the body
(2) Gas exchange system	- including the lungs which exchange oxygen and carbon dioxide
(3) Circulatory system	- including the heart and blood vessels which transport materials around the body
(4) Excretory system	- including the kidneys which filter toxic waste materials from the blood
(5) Nervous system	- consisting of the brain, spinal cord and nerves which coordinate the body's actions
(6) Endocrine system	- glands secreting hormones which act as chemical messengers
(7) Reproductive system	- producing male and female gametes, respectively and allowing the development of the embryo

Review questions

1. Define the basic principles of cell theory.
2. What are the features that are common to cells in all living things?
3. State the differences of DNA between prokaryote and eukaryote.
4. Compare and contrast the structures of cells with and without a nuclear membrane.
5. What are the functions of plant cell wall?
6. Energy is essential in cells. Which organelles of a cell generate energy to support cell activities?
7. Mention the levels of cell organization in multicellular organism such as human being.
8. Which components of the cell control the cell activities?
9. Define the terms tissue, organ and system?
10. Differentiate plant tissues with a relevant flow chart.
11. Identify the basic tissue groups found in animals.
12. Which organ systems are responsible for
    (a) gaseous exchange
    (b) filtering toxic waste materials
    (c) coordination of the body's actions

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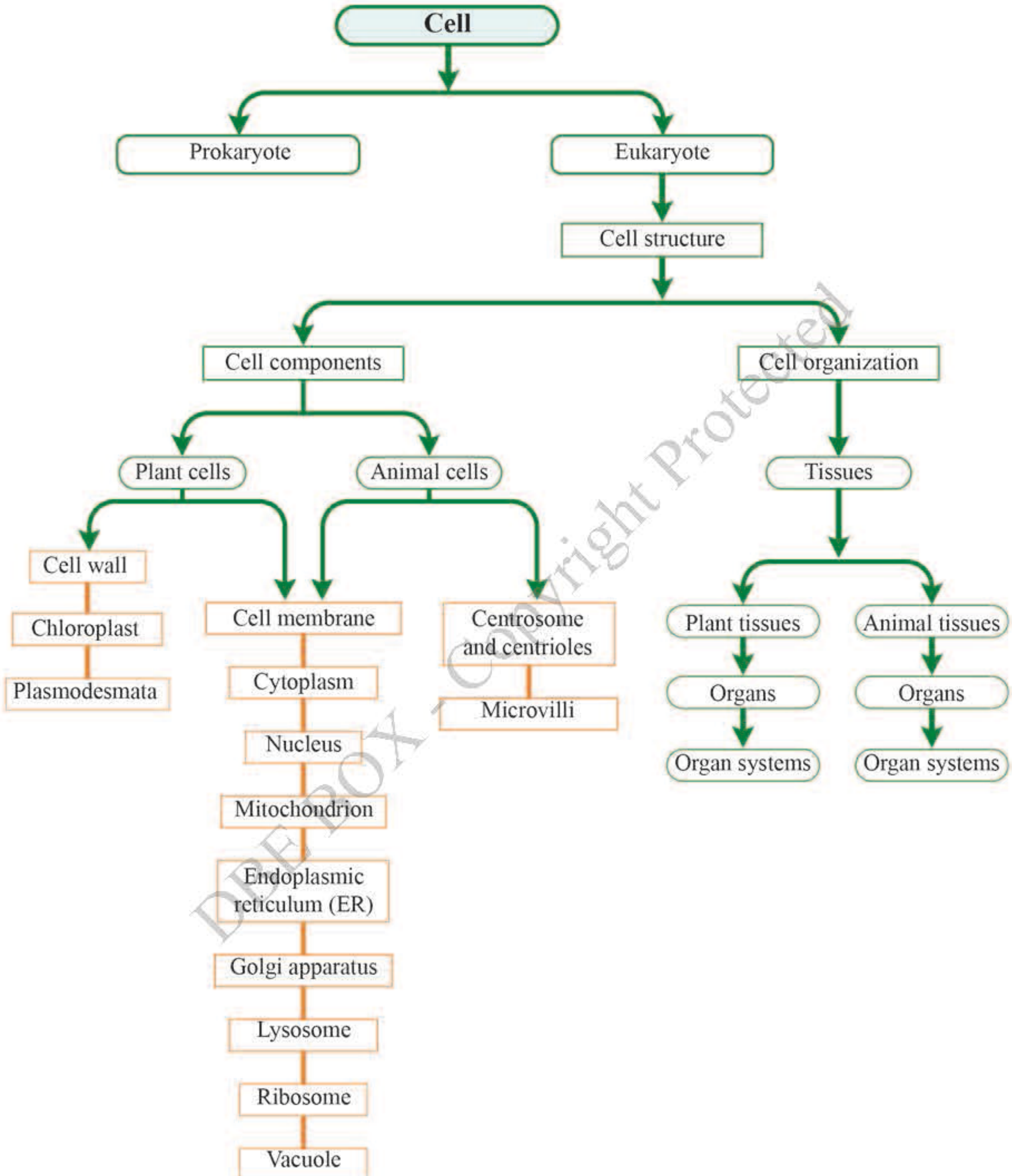
Concept map


Cell
Prokaryote
Eukaryote
Cell structure
Cell components
Cell organization
Plant cells
Animal cells
Tissues
Cell wall
Chloroplast
Plasmodesmata
Cell membrane
Cytoplasm
Nucleus
Mitochondrion
Endoplasmic reticulum (ER)
Golgi apparatus
Lysosome
Ribosome
Vacuole
Centrosome and centrioles
Microvilli
Plant tissues
Animal tissues
Organs
Organs
Organ systems
Organ systems

GLOSSARY

A

adenosine triphosphate (ATP) A nucleotide consisting of adenine, ribose sugar, and three phosphate groups; ATP is the energy currency of cellular metabolism in all organisms.

aerenchyma tissue A spongy tissue that forms spaces or air channels in the leaves, stems and roots of some plants, which allows exchange of gases between the shoot and the root.

aerobic respiration Glucose and oxygen are converted to carbon dioxide and water, producing on average 38 ATP molecules per oxidized glucose molecule.

atom The smallest unit of an element that contains all the characteristics of that element. Atoms are the building blocks of matter.

autotroph A plant that can make its own food.

C

cartilage A connective tissue in skeletons of vertebrates.

cell wall The rigid, outermost layer of the cells of plants, some protists, and most bacteria; the cell wall surrounds the plasma membrane.

cellulose The chief constituent of the cell wall in all green plants, some algae, and a few other organisms.

centriole A self-replicating, small, fibrous, cylindrical-shaped organelle, typically located in the cytoplasm near the nucleus in cells of most animals. It is involved in the process of nuclear division.

centrosome Material present in the cytoplasm of all eukaryotic cells and important during cell division; also called microtubule-organizing center.

chitin A tough, resistant, nitrogen-containing polysaccharide that forms that cell walls of certain fungi, the exoskeleton of arthropods, and the epidermal cuticle of other surface structures of certain other invertebrates.

chlorenchyma tissue The primary tissue of higher plants composed of thin-walled cells that remain capable of cell division even when mature; constitutes the greater part of leaves.

chloroplast A cell-like organelle present in algae and plants that contains chlorophyll (and usually other pigments) and carries out photosynthesis.

chromatin A complex of DNA and protein found in eukaryotic cells.

chromosome A threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes.

collenchyma tissue A plant tissue that consists of living usually elongated cells with unevenly thickened walls and acts as support especially in areas of primary growth.

companion cell A specialized parenchyma cell, located in the phloem of flowering plants and closely associated in development and function with a sieve-tube element.

cytoskeleton A network of protein microfilaments and microtubules within the cytoplasm of a eukaryotic cell that maintains the shape of the cell, anchors its organelles, and is involved in animal cell motility.

D

deoxyribonucleic acid (DNA) The genetic material of all organisms; composed of two complementary chains of nucleotides wound in a double helix.

detoxification The process of removing harmful chemicals from something.

domain (1) A distinct modular region of a protein that serves a particular function in the action of the protein, such as a regulatory domain or a DNA-binding domain. (2) In taxonomy, the level higher than kingdom. The three domains currently recognized are Bacteria, Archaea, and Eukarya.

E

endoplasmic reticulum (ER) Internal membrane system that forms a netlike array of channels and interconnections within the cytoplasm of eukaryotic cells. The ER is divided into rough (RER) and smooth (SER) compartments.

epithelium In animals, a type of tissue that covers an exposed surface or lines a tube or cavity.

eukaryote A cell characterized by membrane bounded organelles, most notably the nucleus, and one that possesses chromosomes whose DNA is associated with proteins; an organism composed of such cells.

F

family A taxonomic grouping of similar species above the level of genus.

G

glycoprotein Protein molecule modified within the Golgi complex by having a short sugar chain (polysaccharide) attached.

granum A stack of coin-shaped thylakoids in the chloroplasts of plant cells.

Golgi apparatus (Golgi body) A collection of flattened stacks of membranes in the cytoplasm of eukaryotic cells; functions in collection, packaging, and distribution of molecules synthesized in the cell.

H

haemoglobin A globular protein in vertebrate red blood cells and in the plasma of many invertebrates that carries oxygen and carbon dioxide.

histone A small protein with high proportion of positively charged amino acid that binds to the negatively charged DNA and plays a key role in its chromatin structure

K

kingdom The second highest commonly used taxonomic category.

L

lignin A highly branched polymer that makes plant cell walls more rigid; an important component of wood.

lipid bilayer The structure of a cellular membrane, in which two layers of phospholipids spontaneously align so that the hydrophilic head groups are exposed to water, while the hydrophobic fatty acid tails are pointed toward the center of the membrane.

lumen The space inside the thylakoid discs is called the lumen.

lysosome A membrane-bounded vesicle containing digestive enzymes that is produced by the Golgi apparatus in eukaryotic cells.

M

microtubule In eukaryotic cells, a long, hollow protein cylinder, composed of the protein tubulin; these influence cell shape, move the chromosomes in cell division, and provide the functional internal structure of cilia and flagella.

microvillus Cytoplasmic projection from epithelial cells; microvilli greatly increase the surface area of the small intestine.

murein Any of several polymers containing sugars and amino acids which help to make up the cell walls of certain bacteria.

N

nervous tissue Tissue composed of neurons.

nuclear membrane The double-layered membrane enclosing the nucleus of a cell. Also called nuclear envelope.

nuclear pore Each nuclear pore is a large complex of proteins that allows small molecules and ions to freely pass, or diffuse, into or out of the nucleus.

nucleic acid A nucleotide polymer; chief types are deoxyribonucleic acid (DNA), which is double stranded, and ribonucleic acid (RNA), which is typically single-stranded.

nucleolus The nucleolus is the largest structure in the nucleus of eukaryotic cells.

nucleoplasm The nucleoplasm is a type of protoplasm, and is enveloped by the nuclear envelope.

O

obligate anaerobes Organism which can only live in environments which lack oxygen.

organ A body structure composed of several different tissues grouped in a structural and functional unit.

P

parenchyma tissue A soft tissue made up of thin-walled, undifferentiated living cells with air spaces between them, constituting the chief substance of plant leaves and roots, the pulp of fruits, the central portion of stems, etc.

peptidoglycan (murein) A polymer consisting of sugars and amino acids that forms a mesh-like layer outside the plasma membrane of most bacteria, forming the cell wall.

phloem In vascular plants, a food-conducting tissue basically composed of sieve elements, various kinds of parenchyma cells, fibers, and sclereids.

phospholipid Molecules that constitute the inner bilayer of biological membranes, having a polar, hydrophilic head and a nonpolar, hydrophobic tail.

plasma membrane The membrane surrounding the cytoplasm of a cell; consists of a single phospholipid bilayer with embedded proteins.

prokaryote A cell lacking a membrane bounded nucleus or membrane bounded organelles.

protein A chain of amino acids joined by peptide bonds.

R

rhizoids Simple or branched filaments that arise from a stem that serve to anchor the plant.

S

sclerenchyma tissue Supporting or protective tissue composed of thickened, dry, and hardened cells.

semipermeable Allowing some substances to pass; permeable to smaller molecules but not to larger ones, as a membrane in osmosis.

sieve tube A longitudinal tube in the phloem of flowering plants, consisting of a connected series of individual cells (sieve cells) and serving to conduct organic food materials through the plant.

stroma In chloroplasts, the semiliquid substance that surrounds the thylakoid system and that contains the enzymes needed to assemble organic molecules from CO_2.

T

thallus A type of body found among plants and fungi that is not differentiated into roots, stems, or leaves.

tracheids Elongated cells in the xylem of vascular plants that serve in the transport of water and mineral salts.

V

vacuole A membrane-bound organelle which is present in all plant and fungal cells and some protist, animal and bacterial cells.

vascular tissue The conducting tissue in the plant and consists of xylem (water conduction) and phloem (food conduction) tissue.

X

xylem In vascular plants, a specialized tissue, composed primarily of elongate, thick-walled conducting cells, which transports water and solutes through the plant body.

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