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Sangam's

SCIENCE

FOR TODAY AND TOMORROW

BOOK 9

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Preface to the Revised Edition

Time changes and so do other things. And today's world is the world of science and technology. Today we are enjoying all the comfort and conveniences only because of science and technology.

Therefore, understanding of facts, concepts, mechanism and principles of science plays a pivotal role in a student's life for further progress and it all starts from our school days. Keeping the same fact in mind, I tried to make this "Sangam's Science for Today and Tomorrow, Book– 9" more comprehensive and more understandable based on new syllabus prescribed by CDC. I have given more emphasis on developing concepts rather than providing unnecessary details.

Special effort is made on stimulating learners' creative thinking by incorporating MCQ, Fact file, Project work and conceptual questions with answers. Apart from this, efforts have been made to encourage students to get involved in learning activities by themselves. The best feature of this book is that, each chapter is written in a very logical and sequential manner in a simple and lucid language, to keep up with the ability of the young learners.

To substantiate this work I must acknowledge my mentor **Mrs. Satyabhama Labh** (Teacher & Academician), and Mr. Kumar Bahadur Rai of Sangam Books Publication Pvt. Ltd. I would also like to acknowledge **Niraj Ghimire and Bivek Adhikari** for extending their help and support.

Last but not the least, I extend my thanks to Mr. S.P. Sapkota (Managing Director) Sangam Books Publication Pvt. Ltd.

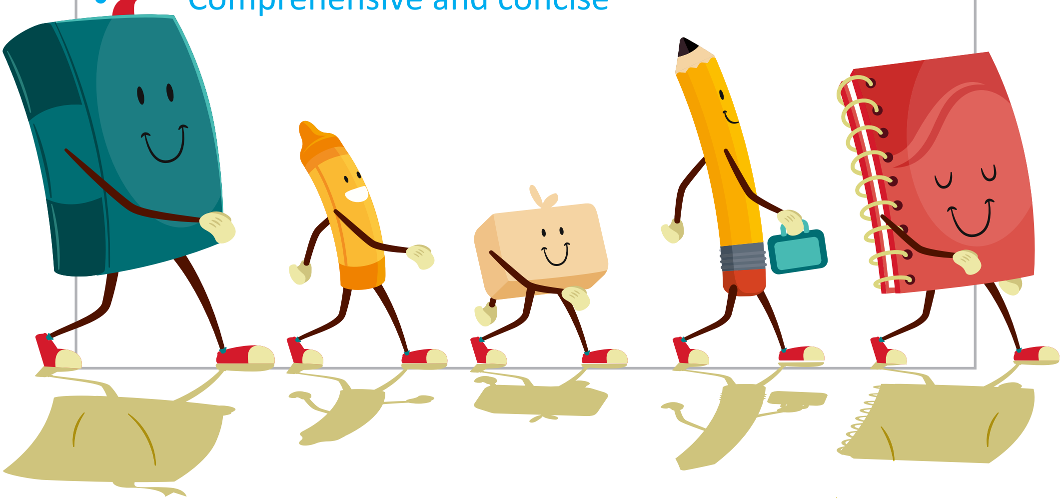
Finally constructive suggestions and recommendations from subject experts teachers and well-wishers will be highly appreciated.

For any query and advice you can mail me at adityalabh1@gmail.com.

-Aditya Labh

Highlights of the Book

- Strictly based on syllabus prescribed by CDC
- Each topic includes:
  - Key words with their meaning
  - Several fact files
  - Solved numericals
  - Conceptual questions and their answers
  - Lesson Summary
  - Learning outcomes
  - MCQ (Multiple Choice Question)
- Simple and lucid language
- Error-free
- Ample data and illustrative figures
- Project work and activities emphasizing on practical approach
- Student- friendly
- Numerical tips are given
- Unnecessary details are avoided
- Comprehensive and concise



CONTENTS

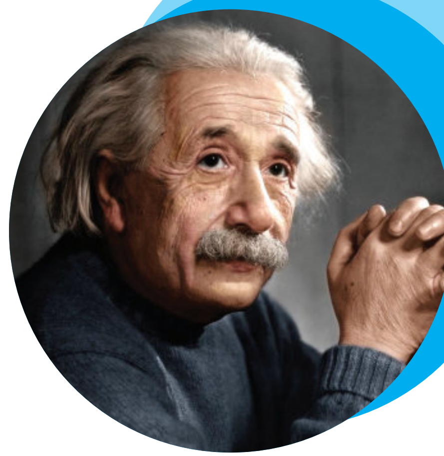
Physics

ALBERT EINSTEIN

(14 March 1879 – 18 April 1955)

Known for

General relativity, Special relativity,
Photoelectric effect
$E=mc^2$ (Mass–energy equivalence)



Putting heart, mind and soul to the smallest act is the secret of success.

- Albert Einstein

Chapters to study

1. Measurement
2. Force
3. Simple Machines
4. Work, Energy and Power
5. Light
6. Sound
7. Current, Electricity and Magnetism

Unit 1

Measurement

Total estimated teaching hours = 4

Learning Outcomes

After the completion of this unit, students will learn:

- *definition of fundamental and derived quantities.*
- *definition of fundamental and derived units.*
- *relation of fundamental and derived units.*
- *SI units and their importance.*

Johannes Kepler (1571AD-1630AD)

KEY WORDS

1. **Luminous** : capable of emitting light - by itself
2. **Moment** : turning effect of force
3. **Frequency** : number of complete wave vibrations produced in one second (F = vibration/Second) or no. of cycles per second
4. **Density** : amount of mass per unit volume (D = m/v)
5. **Electric current** : rate of flow of electric charge in a circuit
6. **Hertz (Hz)** : cycle per second i.e. unit of frequency
7. **Volt (V)** : joule per unit charge (J/Q) i.e. unit of potential difference
8. **Ampere** : electric charge per second (Q/S) i.e. unit of electric current
9. **Momentum** : the product of mass and velocity

Introduction

We measure different physical quantities for different purposes in our daily life. We use different reference standards for different physical quantities. When we buy things from a shop the shopkeepers use different instruments to measure them. Kilogram and physical balance are used to measure mass, scale and measuring rod or tape are used for length, area and volume, etc. Similarly we use watches and clocks for the measurement of time. When we buy biscuits and other packed materials, there is no need to measure them in the shop because they are already measured in the factories where they are made. The science of measurement is called metrology. In this unit we will study different types of fundamental and derived units and the relation among them.

Physical quantities

There are different things and events around us. Some of them are measurable and others are not measurable. The measurable quantities like mass, length and time are called physical quantities. They are classified into the following two major types.

Fundamental physical quantities and Derived physical quantities

The physical quantities which are basic and independent are fundamental physical quantities. The length, mass, time, current, temperature, amount of substance, and luminous intensity are the examples of fundamental physical quantities.

The physical quantities, which are dependent on and derived from fundamental physical quantities are derived physical quantities. Area, volume, density, force, work, energy, power are some examples of derived physical quantities.

Measurement

Measurement is the process of comparison of an unknown physical quantity with a similar known standard quantity. Measurement has two parts- the numerical part and the unit.

The numerical part of measurement gives the frequency of measurement and the unit provides it with the physical meaning. For example: 2, 3, 4 are numbers but 2 kg, 3 m and 4 s give their meaning as mass, length and time.

Fact file:

One standard kilogram is defined as the mass of platinum (90%), iridium (10%) cylinder set by International Bureau of Weights and Measurement in Sevres near Paris in France. 1 kg mass is equivalent to the mass of 1 lit. pure water at 4 °C.

Units

Different reference standards are used to measure different physical quantities which are called units. Units are used with a number. The number shows the multiple of unit. Units are also classified into fundamental units and derived units.

a. Fundamental units:

a. Physical balance *b. Pendulum clock* *c. Digital thermometer*

Fig.1.1: *Some devices used to measure fundamental physical quantities*

Those units which are used to measure fundamental physical quantities are called fundamental units. They are independent of units of other quantities. Some fundamental physical quantities and their units are given in the following table.

Fundamental physical quantity	Fundamental unit
Length (l)	Metre (m)
Mass (m)	Kilogram (kg)
Time (t)	Second (s)
Temperature	Kelvin (K)
Current (I)	Ampere (A)
Amount of substance	Mole (mol)
Luminous intensity (I)	Candela (cd)

b. Derived units

Those units which are used to measure derived fundamental quantities are called derived units. They are dependent on fundamental units. Some derived physical quantities and their units are given in the following table.

Derived physical quantity	SI unit	Fundamental units involved	Fundamental units relation
Area [A=l×b]	m^2	m	$m \times m = m^2$
Volume [V=l×b×h]	m^3	m	$m \times m \times m = m^3$
Density [d=m/v]	kg/m^3	kg, m	$\frac{kg}{m \times m \times m} = kgm^{-3}$
Speed/velocity[v=s/t]	m/s	m, s	$\frac{m}{s} = ms^{-1}$
Force [F=m×a]	Newton (N)	kg, m, s	$\frac{kgm}{s \times s} = kgms^{-2}$
Work [W=F×s]	Joule (J)	kg, m, s	$\frac{kgm \times m}{s \times s} = kgm^2s^{-2}$
Power [P=w/t]	watt (W)	kg, m, s	$\frac{kgm \times m}{s \times s \times s} = kgm^2s^{-3}$
Pressure [P=F/a]	Pascal (Pa)	kg, m, s	$\frac{kg}{m \times s \times s} = kgm^{-1}s^{-2}$
Acceleration [a=v-u/a]	m/s^2	m, s	$\frac{m}{s \times s} = ms^{-2}$
Moment [m=F×s]	Nm	kg, m, s	$\frac{kg \times m \times m}{s \times s} = kgm^2s^{-2}$

Frequency [f= v/λ]	Hz	cycle/s	$1/s = s^{-1}$
Potential difference [V=W/Q]	Volt (V)	kg, m, s, A	$kgm^2s^{-3}A^{-1}$
Electric resistance	Ohm (Ω)	kg, m, s, A	$kgm^2s^{-3}A^{-2}$

Unit of power is a derived unit. Why?

We know that power is defined as the work done per unit time.

$$\text{or, Power (P)} = \frac{\text{Work done}}{\text{time taken}}$$

$$\text{or, } P = \frac{F \times d}{t} \qquad [\because w = F \times d]$$

$$\text{or, } P = \frac{m \times a \times d}{t} \qquad [\because F = m \times a]$$

By placing the related units

$$\text{or, } W = kg \times \frac{m}{s^2} \times m \times \frac{1}{s}$$

$$\text{or, } W = kg \times \frac{m^2}{s^2} \times \frac{1}{s}$$

$$\therefore W = kgm^2s^{-3}$$

The unit of power 'W' depends on the fundamental units like kg, m and s. Therefore, the unit of power (watt) is a derived unit.

Pascal is a derived unit. How?

Pascal is a unit of pressure. We know that pressure is the force applied per unit area.

$$\text{or, } P = \frac{F}{A}$$

$$\text{or, } P = \frac{m \times a}{A} \qquad [\because F = m.a]$$

By placing the related units

$$\text{or, } Pa = kg \times \frac{m}{s^2} \times \frac{1}{m^2}$$

$$\text{or, } Pa = kgm^{-1}s^{-2}$$

The unit pascal depends on fundamental units like kg, m and s. That is why it is a derived unit.

Differences between fundamental unit and derived unit

Fundamental units	Derived units
1. They are independent units.	1. They depend on fundamental units.
2. They are only seven.	2. They are more than seven.
3. They are used for fundamental physical quantities. eg. kg, m, s, mol, cd, A and K	3. They are used for derived physical quantities. eg. m^2, m^3, m/s, m/s^2, W, J, Pa etc.

SI System

In 1960 AD an international conference held in France decided to use particular units to make similarities in measurement all over the world. These units are called "System International de units" or SI units in short. The units are extended from MKS system of measurement. In this system, length is measured in metre, mass in kilogram and time in second. The importance of the units is as follows.

1. It helps to bring similarity in measurement all over the world.
2. It comprises sub-multiples and multiples.
3. It eases global trade, business and exchange of goods.
4. It is convenient to use.

Fact file:

One standard metre is defined as the distance between two fine parallel lines of gold engraved near the ends of a bar of Platinum-Iridium alloy at 0 °C and at one atmospheric pressure set by International Bureau of Weights and Measurement in Sevres near Paris of France.

Enhance your knowledge

Precise definitions of 1kg, 1metre and 1second.

1kg = mass of 5.0188×10^{25} atoms of C^{12}

1m = 1650763.73 wavelengths of orange-red light emitted by Kr-86.

1 second = duration of 9192631770 periods of radiation corresponds to the transition between two hyperfine levels of ground state of Ceasium-133 atoms.

Use of dimension of interconversion of units

The dimension notation of a physical quantity can be used to convert the unit of one system of measurement into the other one. The relation of SI unit of force and work with their CGS unit is obtained as follows.

i. Dimension of force = $M^1L^1T^{-2}$

$$1 \text{ newton} = \left[\frac{M_1}{M_2}\right]^1 \left[\frac{L_1}{L_2}\right]^1 \left[\frac{T_1}{T_2}\right]^{-2} \text{ dynes}$$

Where M_1 = 1kg, L_1 = 1metre and T_1 = 1sec

M_2 = 1g, L_2 = 1cm and T_2 = 1sec

$$\therefore\ 1\text{N} = \left[\frac{1000\text{g}}{1\text{g}}\right]^1 \times \left[\frac{100\text{cm}}{1\text{cm}}\right]^1 \left[\frac{1\text{s}}{1\text{s}}\right]^{-2} \text{ dynes}$$

$$= \left[\frac{1000\text{g}}{1\text{g}}\right] \times \left[\frac{100\text{cm}}{1\text{cm}}\right] \left[\frac{1\text{s}}{1\text{s}}\right]^{-2} \text{ dynes}$$

[$\therefore$ 1N = 10^5 dynes]

ii. Dimension of work = $M^1L^2T^{-2}$

$$1 \text{ Joule} = \left[\frac{M_1}{M_2}\right]^1 \left[\frac{L_1}{L_2}\right]^2 \left[\frac{T_1}{T_2}\right]^2 \text{ ergs}$$

Where M_1 = 1kg, L_1 = 1m and T_1 = 1sec

M_2 = 1g, L_2 = 1cm and T_2 = 1sec

$$\therefore\ 1 \text{ Joule} = \left[\frac{1\text{kg}}{1\text{g}}\right]^1 \left[\frac{1\text{m}}{1\text{cm}}\right]^2 \left[\frac{1\text{s}}{1\text{s}}\right]^{-2} = \text{ ergs}$$

$$= \left[\frac{1000\text{ g}}{1\text{g}}\right]^1 \times \left[\frac{100\text{ m}}{1}\right]^2 \times \left[\frac{1\text{s}}{1\text{s}}\right]^{-2}$$

[$\therefore$ 1 Joule = 10^7 ergs]

Lesson Summary

1. The quantities which can be measured is known as Fundamental physical quantities are independent physical quantities.
2. Derived physical quantities are dependent on fundamental physical quantities.
3. Fundamental units are used to measure fundamental physical quantities.
4. Derived units are used to measure derived physical quantities.
5. SI units are the group of units suggested by the International Convention of Scientists in 1960 AD to make similarities in measurement all over the world.
6. There are seven fundamental SI units.

Project work

Make a list of units used in your locality by enquiry and sort them out into fundamental and derived units.

Conceptual questions with their answers

Q.1. The unit volume is a derived unit. Why?

The unit volume is m^3 (cubic metre) which is derived from the fundamental unit metre. That's why it is a derived unit.

Q.2. Kilogram is a fundamental unit, How?

Kilogram is a fundamental unit because

a. it is independent and

b. it can express the magnitude of mass by itself.

Exercise

1. Write differences between.

a. Fundamental and derived units

b. Fundamental and derived quantities

2. Answer the following questions.

a. What are measurement and units?

b. Define fundamental quantity and fundamental unit with examples.

c. Define derived quantity and derived unit with examples.

d. Define SI units. Also mention their importance.

e. Write units of the following physical quantities.

i. Force   ii. Area   iii. Electric current   iv. Power

v. Density   vi. Amount of substance   vii. Volume

f. Identify and separate the fundamental and derived physical quantities from the above question 'e'.

3. Give reasons for the following.

a. Pascal is a derived unit.

b. Mass is a fundamental quantity.

c. Unit of power is a derived unit.

d. Unit of length is a fundamental unit.

Multiple Choice Questions

1. Tick (√) the correct answer.

a. What is the physical quantity in which force is divided by area called?
   i. Density   ii. Pressure
   iii. Volume   iv. Moment

b. Which one of the following is a derived unit?
   i. N   ii. m
   iii. K   iv. A

c. Which physical quantity has Hz as a unit?
   i. Moment   ii. Electric power
   iii. Frequency   iv. Acceleration

d. Which of the following is SI unit?
   i. g   ii. cm
   iii. mol   iv. g/cm^3

e. What does the s/t show?
   i. Velocity   ii. Acceleration
   iii. Density   iv. Amount of matter

f. What does the electric power show?
   i. $V \times R$ ii. R/I
   iii. $V \times I$ iv. V/I

Unit 2 Force

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *define and demonstrate inertia and momentum of the bodies in their rest and motion states.*
- *describe Newton's laws of motion and verify them by experiments.*
- *differentiate in between balanced and imbalanced forces.*
- *show the interrelation among velocity, acceleration and distance of the bodies*
- *at rest and motion and to solve numerical problems related to them.*

Sir Issac Netwon (1642AD-1727AD)

KEY WORDS

1. **Retardation** : negative acceleration
2. **Inertia** : inability of a body to change its state of rest or uniform motion in a straight line by the body itself
3. **Momentum** : the product of mass and velocity in moving bodies
4. **Scalars** : the physical quantity, which can be expressed without direction
5. **Vectors** : the physical quantity which needs direction also for its expression
6. **Mass** : amount of matter contained in a body
7. **Acceleration due to gravity** : the rate of change of velocity produced by the force of gravity

Introduction

Force is an external agent that changes or tends to change the state of body. It also may change rate of motion, direction of motion, and shape and size of the object. Force is the push and pull in an object.

Effects of force

Force can produce the following effects on an object.

i. It can change the state of motion of an object. Force can bring moving object into rest and a resting body into motion.

ii. It can change the rate of motion. Force can accelerate or decelerate a moving body.
iii. It can change the direction of a moving object.
iv. It can change the structure, shape and size of an object.

Measurement of force

Force is measured by a spring balance and its SI unit is newton and CGS unit is dyne.

$$1 \text{ newton} = \frac{1\text{kg}\times 1\text{m}}{1\text{s}^2} \qquad [\because F = m.a = \frac{\text{kg}\times\text{m}}{\text{s}^2}]$$

$$= \frac{1000\text{g}\times 100\text{cm}}{1\text{s}^2} \qquad \begin{bmatrix} \because 1\text{kg} = 1000\text{g} \\ 1\text{m} = 100\text{cm} \end{bmatrix}$$

$$= 10^5 \text{g cm/s}^2$$

It is equivalent to 1 dyne

$\therefore$ 1 newton = 10^5 dyne.

Rest and Motion

We see objects in different conditions around us. Some of them do not change their location relative to the surrounding objects. They are called in rest state. For example book kept on the table, bike in garage, chair in your room, etc.

Fig.2.1: *Some bodies at rest*

Those objects, which change their location relative to the surrounding objects are called in motion state. They change the distance between them and their surroundings continuously. Water flowing in river, wind, a running car, a swimming fish are some examples of motion state.

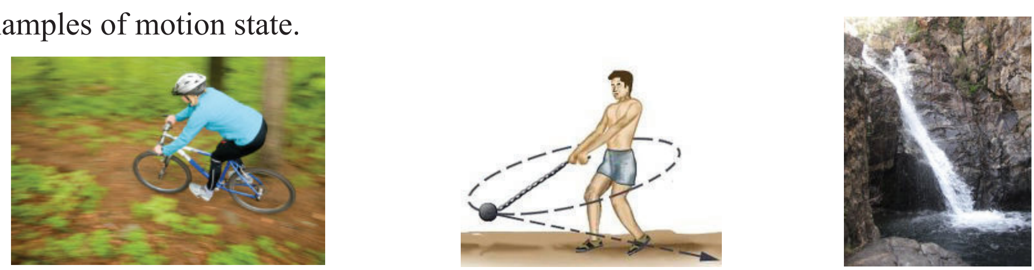


Fig.2.2: *Some bodies in motion*

In fact, nobody on the earth is in rest as the earth is in motion. We know that the earth is revolving round the sun. In this way, all the bodies on the earth are moving. But the term rest and motion are relative terms and they are used with reference to another place, point or objects. The point of reference is used to compare an object for its rest or motion state.

For example, we are in classroom now. All of us are in rest relative to each other and relative to the wall. But relative to the sun and other stars we are in motion state. It is because the earth is revolving round the sun.

Speed and Velocity

Speed

Speed is the rate of distance travelled by a body. Its SI unit is m/s. It is a scalar quantity and remains unchanged with changing direction.

$$\text{or, Average Speed} = \frac{\text{distance travelled (d)}}{\text{time taken (t)}}$$

Velocity

Velocity is the rate of change of displacement. Its SI unit is m/s. It is a vector quantity and varies with change in direction.

$$\text{or, Average Velocity (V)} = \frac{\text{displacement (s)}}{\text{time taken (t)}}$$

The following illustrations help to understand the difference between speed and velocity.

The speed of the car from A to B is 25 m/s. The velocity of the car is also 25 m/s from

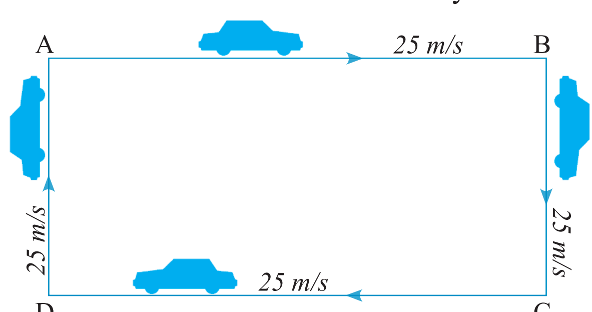


Fig.2.3: *Variable velocity*

A to B. From B to C, speed is still 25 m/s but velocity is 0 m/s as the displacement produced along the direction AB is zero. From C to D and D to A speed remains unchanged as the rate of distance covered is constant. The displacement from C to D and D to A is negative and zero and hence the velocity from C to D is also negative and that from D to A is zero.

The speed of an object uniformly revolving in a circular track like fan is constant whereas the velocity changes from point to point.

Uniform velocity

If the velocity of a moving body does not change with time, the velocity possessed by the body is called uniform velocity. A uniformly moving body is neither accelerated nor decelerated. The rate of change of displacement is constant. i.e. acceleration produced is zero.

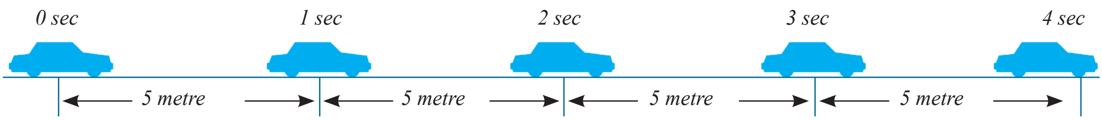


Fig.2.4: *Uniform motion*

Average velocity/Non-uniform velocity

The average velocity or non-uniform velocity possessed by a body is defined as the ratio of total displacement covered by the body to the time taken. Its SI unit is m/s.

$$\text{or, Average Velocity (V)} = \frac{\text{displacement}}{\text{time taken}}$$

$$\therefore \text{AV} = \frac{s}{t}$$

The average velocity is also defined as the arithmetic mean of initial and final velocity possessed by a body having uniform motion.

$$\text{or, Average Velocity (V)} = \frac{\text{initial velocity + final velocity}}{2}$$

$$\therefore \text{AV} = \frac{v+u}{2}$$

Fact file:

A body with uniform speed may have variable velocity if the body is moving on a circular path or not on a straight line.

Acceleration

If a body is moving, there are three possible conditions. First, the body has constant velocity. Second, velocity of the body is increasing with time. And the third, the velocity of the body is decreasing with time. In condition first velocity is not changing but in second and third condition velocity is changing. By what rate the velocity is changing, that is acceleration. Thus, acceleration is defined as the rate of change of velocity.

$$\text{or, Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$\text{or, Acceleration} = \frac{\text{final velocity (v)} - \text{initial velocity (u)}}{\text{time taken (t)}}$$

The SI unit of acceleration is m/s^2. A body is said to have uniform acceleration if the rate of change of velocity is constant. If the velocity of a body decreases with time, acceleration is negative and is called retardation or deceleration. It is also termed as negative acceleration.

$$\text{Retardation} = -\text{acceleration}$$
$$= -a$$

Fact file:

When a body is thrown vertically upward its velocity is zero at the maximum height but its acceleration is not zero.

The acceleration produced on a freely falling object toward the centre of gravity is called acceleration due to gravity. It is denoted by g. The acceleration due to gravity on the earth surface is $9.8 \ m/s^2$.

Displacement-time graph

The variations occurred in displacement with a certain interval of time are different in different conditions. A curve of displacement produced against time is called displacement-time graph. In displacement-time graph, displacement produced is shown as Y-axis and time taken is shown as X-axis. The nature of curve in different conditions is explained below.

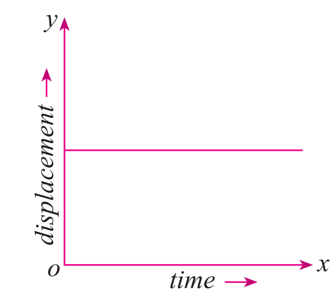


Fig.2.5: *Rest body*

i. When the body is at rest

When a body is at rest, it does not change its position with respect to time and displacement is zero. The displacement time curve is parallel to the x-axis.

ii. When a body is moving with uniform velocity

When a body is moving with uniform velocity, the displacement produced in the body is directly proportional to the time taken by the body. It is a straight line and passes through the origin.

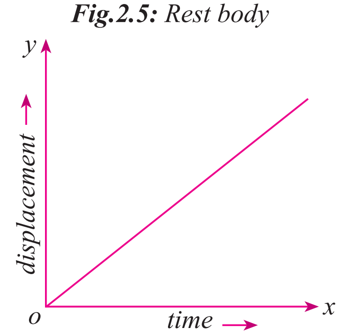


Fig.2.6: *Uniform velocity*

iii. When a body is moving with variable velocity

When a body is moving with uniform acceleration, the displacement produced with time is not the linear equation and is represented by a curve line.

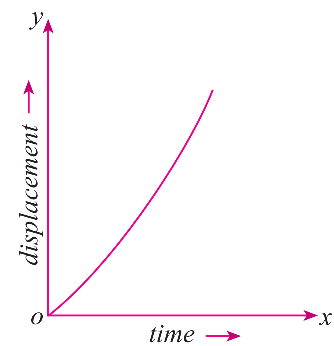


Fig.2.7: Uniform acceleration

Velocity time graph

Velocity is the rate of change of displacement.
The velocity of an object varies with time. The velocity of a body in different conditions can be expressed as given in the diagrams. The velocity time graph is drawn by taking time in x-axis and velocity in y-axis.

i. When a body moves with uniform velocity

When a body moves with uniform velocity, rate of change of velocity is zero. i.e. acceleration of the body = 0 m/s. And the curve of velocity with time is a straight line parallel to x-axis. The y-intercept is equal to the magnitude of uniform velocity.

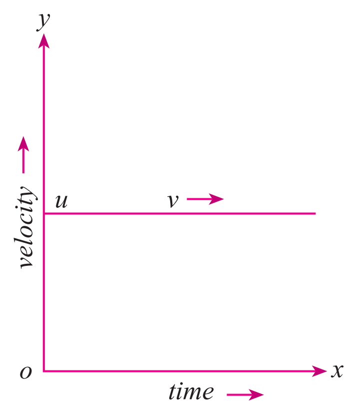


Fig.2.8: Uniform velocity

ii. When a body is moving with uniform acceleration

When a body is moving with uniform acceleration, the velocity time curve is a straight line. It passes through origin for a body starts to move from rest and has y-intercept equal to its initial velocity.

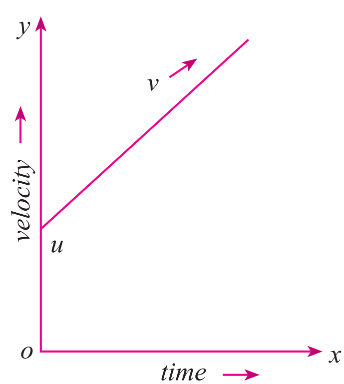


***Fig.2.9:** a*

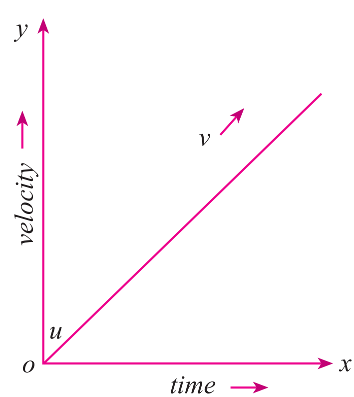


***Fig.2.9:** b*

***Fig.2.9:** Uniform acceleration*

iii. When a body has uniform retardation

When a body is facing an opposing force, its velocity goes on decreasing with time. The velocity time curve is straight and has negative slope.

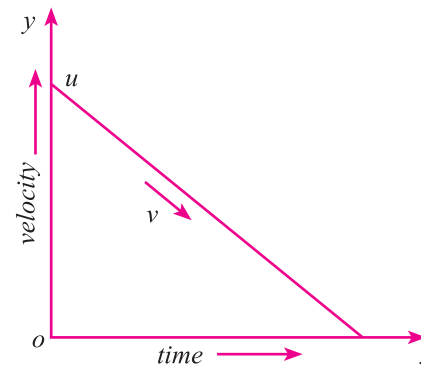


Fig.2.10: *Retardation*

Equations of motion

The equations that are used to describe the linear motion of an object are called equation of motion. These equations describe the motion of the objects having uniform acceleration. The following notations are used to derive equations of motion.

Let, (SUVAT)

s = Displacement

u = Initial velocity

v = Final velocity

a = Acceleration

t = Time taken

The equations of motion are derived as follows:

First equation (Relation of v, u, a and t)

We know that the acceleration is defined as the rate of change of displacement.

$$\text{or, } a = \frac{v - u}{t}$$

$$\text{or, } at = v - u$$

$$\therefore\ v = u + at \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Second equation (Relation of s, u, t and v)

We know that average velocity is given by:

$$\text{or, } AV = \frac{u + v}{2} = \frac{s}{t}$$

$$\text{or, } 2s = (u + v) \times t$$

$$\text{or, } s = \frac{u + v}{2} \times t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Third equation (Relation of s, u, a and t)

We have first equation of motion.

$$v = u + at \text{ .... (i)}$$

We also have second equation of motion.

$$s = \frac{u+v}{2} \times t \text{ .... (ii)}$$

When we place value of 'v' from equation (i) into equation (ii), we get

$$s = \frac{u+(u+at)}{2} \times t$$

$$\text{or, } s = (\frac{2u+at}{2})\, t$$

$$\text{or, } s = \frac{2ut}{2} + \frac{at^2}{2}$$

$$\therefore\ s = ut + \frac{1}{2}/at^2 \text{ .... (iii)}$$

Fourth equation (Relation of v, u, a and s)

From first equation

We have,

$$v = u + at \text{ .... (i)}$$

$$\text{or, } at = v\text{-}u$$

$$\text{or, } t = \frac{v-u}{a}$$

Again we have,

$$\text{or, } s = \frac{u+v}{2} \times t$$

$$\text{or, } s = \frac{u+v}{2} \times \frac{v-u}{a} \quad [\because \text{ from eq}^{n.} \text{ (ii) } t = \frac{v-u}{a}\ ]$$

$$\text{or, } 2as = v^2 - u^2$$

$$\therefore\ v^2 = u^2 + 2as \text{ .... (iv)}$$

If a body is under the force of gravity then:

i. $v = u + gt$

ii. $h = \frac{u+v}{2} \times t$

iii. $h = ut + \frac{1}{2} gt^2$

iv. $v^2 = u^2 + 2gh$

Here, h = height and g = acceleration due to gravity

Solved numerical problems

i. Calculate the acceleration produced on a body whose velocity changes from 10m/s to 25m/s in 5 seconds.

Here,

Initial velocity (u) = 10 m/s
Final velocity (v) = 25 m/s
Time taken (t) = 5 seconds

Now,

$$\text{Acceleration produced (a)} = \frac{v-u}{t} = \frac{25-10}{5} = 3 \text{ m/s}^2$$

∴ Acceleration produced on the body is 3 m/s^2

ii. What is the final velocity if taranga starts to ride with velocity 15 m/s and has uniform acceleration of 2 m/s^2, after 2 minutes?

Here,

Initial velocity (u) = 15 m/s
Acceleration (a) = 2 m/s^2
Time taken (t) = 2 min = 2×60 s = 120 s

Now,

$$\text{Final velocity (v)} = u + at = (15 + 2 \times 120) \text{ m/s} = 255 \text{ m/s}$$

∴ Final velocity of taranga is 255 m/s.

iii. A body started from rest and achieved velocity 20 m/s with uniform acceleration of 0.5 m/s² in a certain interval of time. How far did it move in the same interval of time?

Here,

Initial velocity (u) = 0 m/s

Final velocity (v) = 20 m/s

Acceleration (a) = 0.5 m/s²

Now,

The distance travelled (s) $= \dfrac{v^2 - u^2}{2a}$

$= \dfrac{20 \times 20 - 0 \times 0}{2 \times 0.5}$

$= 400$ m

∴ Total distance covered by the body is 400 m.

iv. Aabriti drops a stone into a river from a bridge. If the stone reached the water surface after 12 s. Calculate the distance between the bridge and the water surface.

Here,

Time taken (t) = 12 s

Initial velocity (u) = 0 m/s

Acceleration due to gravity (g) = 9.8 m/s²

Height (h) = ?

Now, We have

Height or distance (h) $= ut + \dfrac{1}{2}gt^2$

$= 0 \times 12 + \dfrac{1}{2} 9.8 \times 12^2$

$= 4.9 \times 12 \times 12$

∴ h = 705.6 m

Thus the bridge is 705.6 m high from river surface.

v. Slok throws a ball vertically upward in the velocity of 30 m/s. Now calculate:

i. the maximum height covered by it.

ii. the time taken by the ball to come back to initial place.

Here,

Initial velocity (u) = 30 m/s

Final velocity (v) = 0 m/s

Acceleration due to gravity (g) = –9.8 m/s^2
Height or distance travelled (h) = ?
Total time in the air (2t) = ?

Now, we have

$v^2 = u^2 + 2gh$

or, $0 = 30^2 + 2(-9.8)h$

or, $0 - 900 = -19.6h$

or, $h = \frac{900}{19.6} = 45.92$ m

Again,

$v = u + gt$

or, $0 = 30 + (-9.8)t$

or, $-9.8t = 0 - 30$

or, $t = \frac{30}{9.8} = 3.061$ s

or, $2t = 2 \times 3.061 = 6.21$ s

$\therefore$ $2t = 6.21$ s (neglecting air resistance)

Thus the ball will reach 45.92 m high and it will take 6.21 s to come to initial place.

Balanced and imbalanced forces

Activity: To demonstrate balanced and imbalanced forces.

Materials: string, spring balance, wooden block fitted with a hook.

Method:

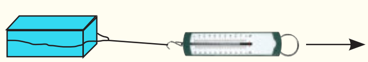


Fig.2.11: *Force applied to a wooden block*

i. Weigh the wooden block by using a spring balance. Consider its weight is 100 g.
ii. Keep the block on a table and pull it by applying force less than 100 g using the spring balance. Observe the state of the block. The block does not move. Why?
iii. Now, repeat the activity (ii) by applying more force till the block begins to move and note the reading shown by the spring balance.

The activity gives the concept of balanced forces and imbalanced forces. When the block was in rest even though external force was applied on it, there were balanced forces. But in activity (iii) When the applied force was greater than the weight of the block, it started to move. It is because, now imbalanced forces are affecting the block.

Thus balanced forces on a body are those forces which do not cause any change on the state of the body.

Imbalanced forces are those forces which cause the change in the state of a body that is from rest to motion or from motion to rest. Such forces may accelerate the moving body.

Inertia

"The inability of a body to change its state of rest or of uniform motion in a straight line" is called inertia. It is of the following three types.

1. Inertia of rest: The inability of a body at rest to bring itself into motion is called inertia of rest. The inertia possessed by a body at rest is inertia of rest. For example when a carpet is beaten it comes into motion but the dust particles in it remain at rest because of the inertia of rest and are separated out from the carpet.

2. Inertia of motion: The inability of a moving body to bring itself into rest is called inertia of motion. i.e. the inertia possessed by a moving body is inertia of motion. Because of inertia of motion, a fan keeps on rotating for some time even after it is switched off.

3. Inertia of direction: The inability of a body moving in a particular direction to change its direction of motion itself is called inertia of direction.

The inertia possessed by a body is directly proportional to its mass. The object having greater mass has greater inertia and having less mass has less inertia.

Activity: To demonstrate the relation of inertia with mass.

Materials required: cans, sand, rope

Method:

1. Take two tin cans. Fill can A with sand and keep can 'B' empty.
2. Hang both cans A and B as shown in the diagram.
3. Push the cans to oscillate and observe them till they come into rest.

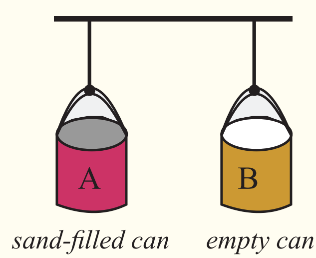


Fig.2.12: *Varification of inertia*

Which can -A or -B requires, more force to displace and why?
Which can requires more force to bring into rest and why?

In both cases can A requires more force as it has more mass and therefore has more inertia.

Momentum

Activity: To demonstrate momentum is directly proportional to mass and velocity.
Materials required: A cricket ball, two tennis balls
Method:
1. Place a tennis ball on the table.
2. Hit it using another tennis ball gently and observe the motion of the tennis ball kept on the table.
3. Repeat the activity '2' but hit the ball forcibly.
4. Repeat the activity '2' and '3' using a cricket ball. Observe the difference.

Why does the ball on the table show different motions in different conditions? It is due to different momentum of the balls thrown on it. If a ball is thrown in less velocity, it has less momentum but if the same ball is thrown in more velocity it shows more momentum. If a cricket ball and a tennis ball are in the same velocity the cricket ball shows more momentum due to its more mass.

Thus, momentum is the property of a body, that is product of mass and velocity. It is denoted by 'P' and its SI unit is $kgms^{-1}$.

or, $P = m \times v$

here, P = momentum
m = mass
v = velocity

The rate of change in momentum is directly proportional to the force applied in the direction of motion.

or, $\frac{P}{t} = F$

Law of motion

Sir Issac Newton, a British scientist, explained the motion of a body on a straight path under his three famous laws called the laws of motion. These laws are most frequently applicable to explain the different phenomena occurring around in our daily life. These laws are equally applicable to explain the motion of bodies of different masses such as heavenly bodies and electron. They are

Fact file:
i. First law of motion defines force.
ii. Second law of motion calculates the magnitude of force.
iii. Third law of motion shows the effect of force.

1. Newton's first law of motion

Newton's first law of motion states, "Everybody in this universe continues its state of rest or uniform motion in a straight line unless it is acted imbalanced forces".

It means that a body does not change its state of rest or motion itself. The first law of motion is also known as the law of inertia.

Some examples of the phenomena that are explained by Newton's first law of motion and inertia are as follows:

i. When a branch of mango is shaken, the mangoes fall down.

ii. Passengers jerk forward when brakes are suddenly jammed on a moving bus.

iii. A ball thrown vertically upward in a moving bus with a uniform motion returns to the throwers hand.

iv. A coin kept on a cardboard falls into the glass, if the cardboard is suddenly flicked by a finger.

v. When a wet shirt is flapped water droplets come out.

vi. The soil particles from the wheels of a cycle fly away tangentially.

vii. The soldier does not stop running as soon as commander orders to stop.

viii. A fan keeps on moving for some time even after it is switched off.

ix. Body of a passenger bends right as the vehicle turns to the left.

x. It is dangerous to jump out from a moving bus.

2. Newton's second law of motion

It is also called law of acceleration. The law states that, "Acceleration produced on a moving body is directly proportional to the force applied in the direction of motion and inversely proportional to the mass of the object".

From the statement,

Acceleration $\propto$ force .... (i)

similarly

Acceleration $\propto$ 1/mass .... (ii)

on solving eq^n (i) and eq^n (ii)

Acceleration $\propto$ F/m

or, F $\propto$ ma

or, F = kma .... (iii) [$\because$ k is proportionality constant]

If 1N force is applied to an object of 1 kg mass to produce acceleration of 1 m/s^2

Then,

F = 1N, m = 1 kg and a = 1 m/s^2

Now,

Substituting the above value in eq^n (iii) Then, We get, k = 1

on substituting value of k in eq^n (iii)

we get, F = ma

It also gives relation of momentum with force; as-

$F = m.a$

Acceleration produced on a body is inversely proportional to the mass of the body for the constant external force applied to it. A body of greater mass possesses less acceleration for constant force.

Relation to establish force with momentum

$$F = ma$$

$$\text{or, } F = m.\frac{v-u}{t}$$

$$\therefore F \propto P$$

Therefore, Momentum is directly proportional to the force applied.

Some examples of the phenomena that are explained by Newton's second law of motion are as follows:

i. It is difficult to walk on a sandy place.
ii. A cricketer moves his/her hands along with the ball to catch it.
iii. An empty truck moves faster than a loaded truck.
iv. It is easy to drag a stone rather than to kick it.
v. It is easier to jump out on sand than on a cemented floor.

Activity: To demonstrate Newton's second law of motion.

Materials required: 2 wooden blocks of same size, spring balance.

Method:

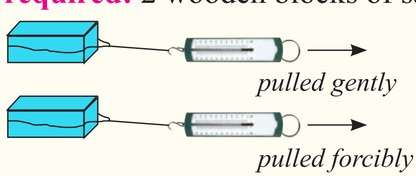


***Fig.2.13:** Activity 1 & 2*

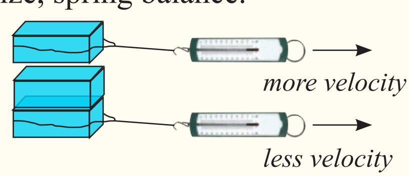


***Fig.2.14:** Activity 3 & 4*

1. Place the wooden block on a table and pull it by using a spring balance till it begins to move.
2. Now, increase the applied force and observe the change in velocity.
3. Repeat the activity 1 but place two blocks one over another keeping the applied effort constant.

What change in acceleration is seen? Why?

Activity 1 and 2 show that acceleration is directly proportional to the force applied in the direction of motion and Activity 3 and 4 show that acceleration produced in a body is inversely proportional to the mass of the moving body. i.e.

$$a \propto \frac{F}{m}$$

Newton's third law of motion

Newton's third law of motion states that, "To every action there is an equal and opposite reaction". It is also called as the law of action-reaction.

i.e. A pair of forces act on two different bodies. The magnitudes of forces are equal but act in the opposite directions.

Activity: To demonstrate third law of motion.

Materials required: Two spring balances.

Method:

1. Manage two spring balances having equal capacity. Hook them into each other as shown in the diagram.
2. Pull them in opposite directions.

Is the magnitude of force shown by both spring balance the same? What does it mean?

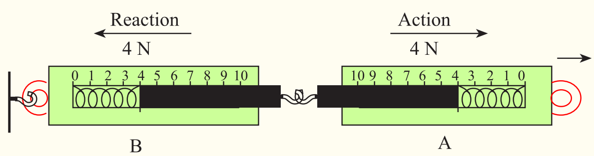


Fig.2.15: Varification of law of action & reaction

Some examples that can be explained by Newton's third law of motion are given below:

i. When a bullet is fired, the gun recoils.
ii. A swimmer pushes the water backward to move his/her body forward.
iii. The burnt hot air moves downward and the rocket moves upward.
iv. When a person jumps from a boat onto a shore, the boat moves back.
v. When a balloon is filled with air and the air through its mouth downward is released, it moves upward.

Lesson Summary

1. The bodies which do not change their location relative to the other bodies are called in rest.
2. The bodies which change their location relative to the other bodies are called in motion.
3. The rate of displacement of a body is called velocity of that body.

   or, $AV = \frac{s}{t}$ and $AV = \frac{u + v}{2}$

4. In uniform velocity a body covers equal displacement per equal interval of time.
5. In non-uniform velocity a body covers unequal displacement per equal interval of time.
6. The rate of change of velocity is called acceleration.

   or, $a = \frac{v - u}{t}$
7. Negative acceleration is also called deceleration or retardation.
8. Equations of motion are:

	If the moving body is under action of g:
i. $v = u + at$	$v = u + gt$
ii. $s = \frac{u + v}{2} \times t$	$h = \frac{u + v}{2} \times t$
iii. $s = ut + \frac{1}{2} at^2$	$h = ut + \frac{1}{2} gt^2$
iv. $v^2 = u^2 + 2as$	$v^2 = u^2 + 2gh$

9. The inability of a body to change its state of rest or uniform motion in a straight line by the body itself is called inertia of the body.
10. A body in rest possesses inertia of rest. A body in motion possesses inertia of motion and inertia of direction.
11. Newton's laws of motion

First law: Everybody in the universe continues in its state of rest or uniform motion in a straight line, unless it is acted on by an imbalanced force.

Second law: Acceleration produced in a body is directly proportional to the force applied in the direction of motion of the body and inversely proportional to the mass of the moving body.

Third law: To every action there is equal but opposite reaction.

Project work

Activity: To make a model boat based on the third law of motion.

Materials required: Thermocoal, candle, an egg shell with a single hole, water, matches, metal wires, tub.

Method:

1. Cut the thermocoal into the shape of a boat.

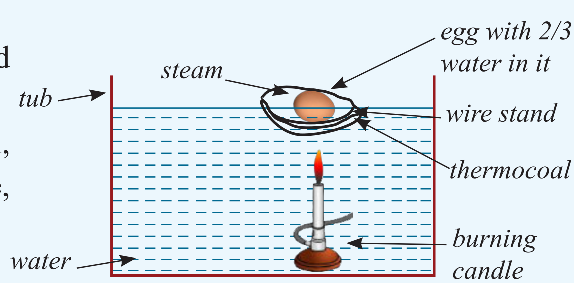


Fig.2.16:

2. Fill 2/3 of the egg shell with water and adjust it onto the wire stand over the thermocoal.
3. Put a burning candle under the egg and observe.

   Study the cause of motion of the model boat.

Conceptual questions with their answers

Q.1. The retardation of a car is 5 m/s^2. What does this mean?

It means that the car is decreasing its velocity by 15m/s in each second.

Q.2. Why are rest and motion called relative terms?

They are called relative terms because both rest and motion require the frame of reference and can only be defined with respect to each other.

Exercise

1. Define the following terms.

a. force

b. inertia

c. momentum

d. acceleration

2. Answer the following questions.

a. On which factor does the inertia of rest depend?

b. State Newton's second law of motion and establish the relation F = m × a.

c. State the first law of motion with an example.

d. State the third law of motion with two examples.

e. Prove that:

i. $v^2 = u^2 + 2as$ ii. $s = ut + \frac{1}{2}at^2$ iii. $F = m.a$

f. Define momentum with suitable examples.

g. Describe in short inertia of rest and inertia of motion with two examples each.

h. What are velocity and acceleration?

i. Define retardation.

j. How does the first law of motion give definition of inertia?

k. How does the second law of motion show relation of momentum with force?

3. Write the difference between.

a. inertia of rest and inertia of motion

b. velocity and speed

c. uniform velocity and variable velocity

d. speed and acceleration

4. Give reasons for the following.

a. Blades of a running electrical fan continue to spin for some time even after electricity is switched off.
b. A carpet is beaten to remove dust.
c. It is dangerous to jump from a moving bus.
d. Gun recoils when it fires a bullet.
e. When we jump off a boat towards the shore, the boat moves back.
f Passengers jerk forward when brakes are suddenly jammed on a moving bus.
g. A running soldier cannot stop instantly when the commander asks him to stop.
h. Mudguard is used above the wheels of vehicles.
i. Even though there is equal and opposite reaction, usually the two forces are not seen balanced.
j. It is easier to drag a stone than to kick it for the same distance.

5. Study the given diagram 2.17 of displacement time graph and answer the questions given below.

a. What does the portion OA of the curve indicate?
b. What does the curve line AB mean?
c. What is the state of body from B to C?

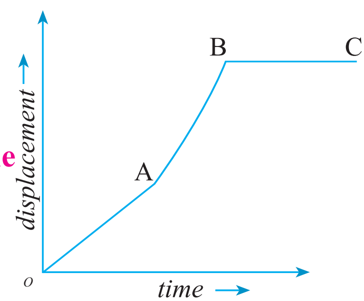


Fig.2.17:

6. Study the given diagram 2.18 of velocity time graph and answer the questions given below.

a. Calculate the acceleration of body from 0 to A.
b. How much distance does the body cover from A to B?
c. Calculate the retardation of body from C to D. How long does it move from C to D?

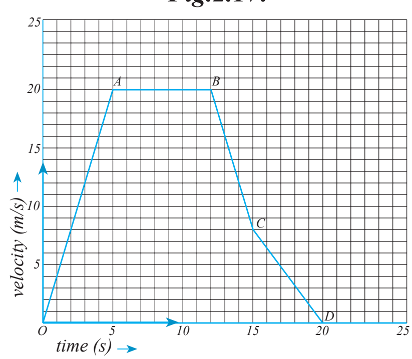


Fig.2.18:

7. Solve the following numerical problems.

a. A body started to move from rest and with uniform acceleration 1.6 m/s^2. Calculate the final velocity and distance travelled by the body in two minutes. [192 m/s, 11520 m]
b. A bus started from Kathmandu and reached Khanikhola, 26 km far from Kathmandu, in one hour. If the bus had uniform acceleration, calculate the final velocity of the bus and acceleration. [14.4 m/s, 0.004 m/s^2]
c. A driver of a car moving with speed 90 km/h saw a child on the road 25 m ahead of him. He jammed on the brakes and brought the car to rest and the child was saved. Calculate the time taken to bring the car to rest and retardation of the car. [2 s, 12.5 m/s^2]

d. A van of mass 1200 kg is moving with speed 90 km/h. It is brought to rest in 3 seconds by applying brakes, calculate [8.33 m/s^2, 10000 N, 37.5 m]
   i. retardation of the van.
   ii. force applied to it to bring to rest.
   iii. distance travelled by the van before it came to rest.
e. A stone is dropped in a well. If the stone takes 3 s to reach the water surface. Calculate [44.1 m, 29.4 m/s]
   i. the depth of the water surface in the well
   ii. the velocity with which the stone strikes the water.
f. A stone is thrown vertically upward with the velocity of 40 m/s. Calculate
   i. the velocity of stone after 1.5 s
   ii. the time taken by the stone to reach the maximum height
   iii. the total distance travelled by the stone before it returned to the earth surface, [25.3 m/s, 4.08 s, 163.2 m]
g. A stone is projected vertically up with the velocity of 19.6 m/s. Calculate
   i. the time taken by the stone to reach the maximum height.
   ii. total height covered by the stone. [2 s, 39.2 m]
h. A stone is projected vertically up with the velocity of 19.6 m/s. Calculate
   i. time taken by the stone to reach the maximum height.
   ii. how long it takes to travel 294 m below the point of projection. [2s,6s]

Multiple Choice Questions

1. Tick the correct answer.

a. Rate of displacement is
   i. Inertia ii. Momentum
   iii. Velocity iv. Retardation
b. Negative acceleration is
   i. Retardation ii. Deceleration
   iii. Both of above iv. None
c. Unit of acceleration is
   i. kgm/s ii. m/s^2
   iii. m/s iv. kgm/s^2
d. To every action there is equal and opposite reaction shows:
   i. Law of momentum ii. First law of motion
   iii. Second law of motion iv. Third law of motion

Unit 3 Simple Machines

Total estimated teaching hours = 7

Learning Outcomes

After the completion of this unit, students will learn:

- *meaning of the mechanical advantage, velocity ratio of simple machines such as lever, pulley, inclined plane and wheel and axle.*
- *solution of mathematical problems related to mechanical advantage, velocity ratio and efficiency.*
- *explanation of theory of moment in lever.*

Franz Reuleaux (1829AD-1905AD)

KEY WORDS

1. **Fulcrum** : the point about which a lever rotates
2. **Load** : the resisting force in a simple machine
3. **Effort** : the force applied to do work
4. **Input work** : work done by effort
5. **Output work** : work done by load
6. **Friction** : opposing force at the surface of moving bodies
7. **Lubricant** : the liquid or paste that is used to reduce friction
8. **Equillibrium** : balanced condition
9. **Co-axial cylinders** : the cylinders spinning on the same axis

Introduction

Several devices are used to make our work easy and safe. These devices are called machines. Some of them are structurally simple and do not require fuel to run. Scissors, fork, pulley, etc. are some examples of such types of machine. A simple machine is a simply constructed mechanical device that enables us to apply effort at a convenient point and in the convenient direction. We use different types of simple machines such as lever, pulley, inclined plane and wheel and axle etc. in our daily life.

Function of a simple machine

The main functions of a simple machine are as follows.

i. A simple machine changes the direction of applied force.
ii. It magnifies the applied force.

iii. It increases the rate of doing work.
iv. It makes our work safe and more convenient.

In this lesson, we will study in detail about mechanical advantage, velocity ratio and efficiency of the different types of simple machines.

A. Mechanical Advantage

A simple machine is used to make our work easier and faster. The magnitude of applied force should be multiplied by a simple machine in order to make the work easier. Mechanical advantage gives the ratio of load lifted to the force applied in a machine. Thus the mechanical advantage of a machine is defined as the ratio of load lifted by the machine to the effort applied to the machine.

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

$$\text{or, } MA = \frac{L}{E}$$

MA is simply a number and does not have unit as it is the simple ratio of two forces. A machine having MA 1 changes direction of force in it. The simple machine having MA more than 1 magnifies the applied effort. The simple machines having MA less than 1 increase the rate of doing work.

B. Velocity ratio

The ratio of velocity of effort to the velocity of load in a machine is called velocity ratio of that machine.

$$\text{or, } VR = \frac{\text{velocity of effort}}{\text{velocity of load}}$$

$$\text{or, } VR = \frac{\text{distance covered by effort}}{t} \times \frac{t}{\text{distance covered by load}}$$

$$\therefore VR = \frac{ED}{LD}$$

Thus, velocity ratio of a machine is the ratio of effort distance to load distance. Velocity ratio does not have any unit as it is a simple ratio of two distances. V.R. is not affected by friction.

Fact file:

MA is affected by friction but VR is not affected by friction. Thus value of VR in a machine is always greater than the value of MA in it.

Velocity ratio of a machine shows for what distance a force has to be applied to lift a load for a particular height. For example, a machine has velocity ratio 3 means, to lift a load up to 5 m high the force has to be applied for 5 × 3 = 15 m distance.

C. Efficiency

Efficiency (η) of a machine is defined as the percentage of ratio of output work (i.e. work done by the machine) to the input work (i.e. work done on the machine.)

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

$$= \frac{\text{load} \times \text{distance travelled by load}}{\text{effort} \times \text{distance travelled by effort}} \times 100\%$$

$$\text{or } \eta = \frac{L}{E} \times \frac{Ed}{Ld} \times 100\%$$

$$\therefore \eta = \frac{MA}{VR} \times 100\% \qquad \left[MA = \frac{L}{E} \text{ and } VR = \frac{Ed}{Ld} \right]$$

Ideal machine

Every practical machine suffer from friction so that efficiency becomes less than 100%. Efficiency of a machine is 70% means the machine can change 70% of the input work into output work and the rest 30% of input work is wasted due to friction.

A machine which can convert total input work into output work is considered as ideal or perfect machine. It is an imaginary machine as it is not possible to construct such a machine in practice. The efficiency of such machine is considered to be 100%.

Factors affecting efficiency

Efficiency of a machine is decreased due to the internal friction and weight of movable parts of the machine. The output work in a machine is always less than its input work because of the internal resistance of the machine. Thus, the efficiency of a machine is always less than 100%.

Lubrication and polishing of the parts of a machine decreases the internal friction of the machines. Use of lighter movable parts of the machine reduces the wastes of input energy to bring them to motion. So the lubrication and polishing of the parts of machine and replacement of heavier movable parts with the lighter parts increase the efficiency of the machine. Similarly the use of wheels, polishing the surface and streamlining the body also help to reduce friction.

A first class lever with VR one is considered as 100% efficient machine in practice.

Some commonly practised simple machines

The commonly practised simple machines can be categorized into the following six groups.

i. Lever
ii. Wheel and axle
iii. Pulley iv. Inclined plane
v. Screw vi. Wedge

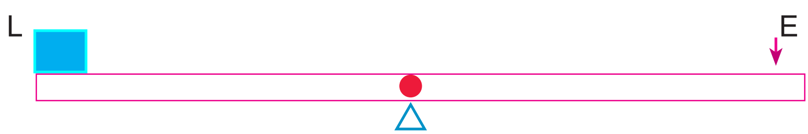
Fact file:

Amount of input work is always greater than the amount of output work. It is because all the input work does not change into output work as some of the input work is wasted in the form of heat energy due to friction.

1. Lever and its types

Lever is a rigid bar that is capable to move freely on a fixed support called fulcrum or pivot. Load and effort are applied to different points of the lever according to its structure and our convenience. Lever is classified into three different groups according to the position of load, effort and fulcrum.

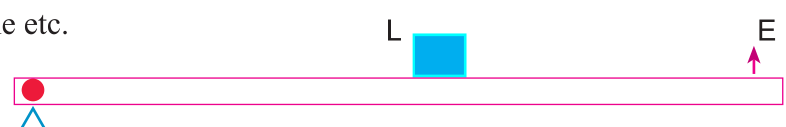
i. In first class lever, fulcrum lies in the middle and load and effort lie on either sides. Eg:- Scissors, crow bar, seasaw, physical balance, pliers etc.



LFE or EFL

Fig.3.1: *First class lever*

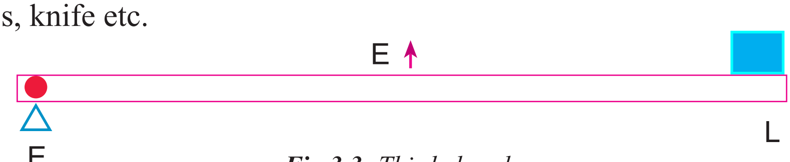
ii. In second class lever, load is in the middle. Fulcrum and effort are on either sides. Eg:- Bottle opener, nut cracker, lemon squeezer, wheel barrow, paper cutter, punching machine etc.



FLE or ELF

Fig.3.2: *Second class lever*

iii. In third class lever, effort is in the middle. Fulcrum and load are on either sides (effort is in between). Eg:- Fishing rod, fire tongs, shovel, human arm, broom forceps, knife etc.



FEL or LEF

Fig.3.3: *Third class lever*

Velocity ratio of lever

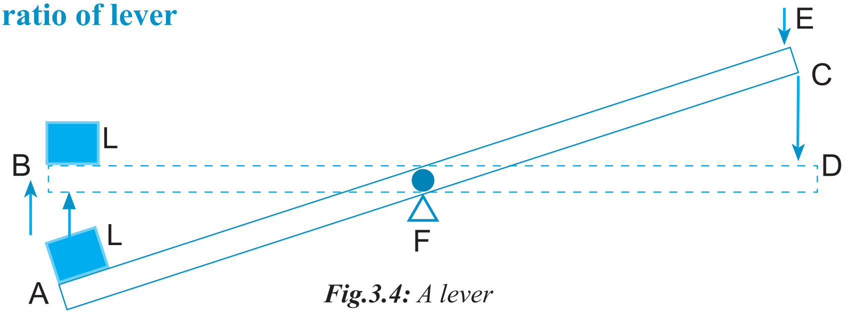


Fig.3.4: A lever

In the given figure, load is kept on A and effort is being applied to C. To bring it into equilibrium condition, the distance AB is travelled by the load and the distance CD is travelled by the effort. The distance BF between points of action of load and fulcrum is the load arm. The distance CF between point of action of effort and fulcrum is the effort arm.

In between the ΔABF and ΔCDF

i. ∠AFB = ∠CFD = Vertically opp. angles

ii. ∠ABF = ∠CDF = Both are right angles

iii. ∠BAF = ∠DCF = Remaining angles

iv. ΔABF ~ ΔCDF = AAA facts

Now,

$$\therefore \frac{CD}{AB} = \frac{DF}{BF} \quad \text{= Corresponding sides are proportional}$$

$$\text{or, } \frac{\text{Distance travelled by effort (CD)}}{\text{Distance travelled by load (AB)}} = \frac{\text{Effort distance (DF)}}{\text{Load distance (BF)}} = \text{Velocity ratio}$$

$$\therefore \text{Velocity ratio} = \frac{\text{Effort distance}}{\text{Load distance}} = \frac{Ed}{Ld}$$

Solved numerical problem

Calculate the effort applied to the given diagram to maintain the load to equilibrium condition.

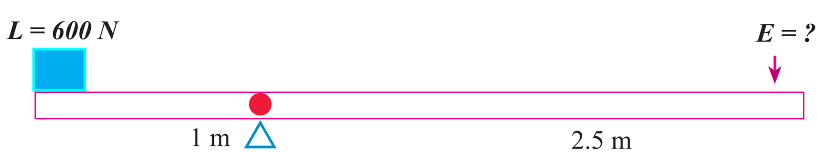


Fig.3.5:

Here,

Effort = ?

Load = 600 N

Effort arm = 2.5 m

Load arm = 1 m

Now,

$$\text{effort} = \frac{\text{load} \times \text{load arm}}{\text{effort arm}}$$

$$= \frac{600 \times 1}{2.5}$$

$$= 240 \text{ N}$$

$\therefore$ Effort applied is 240 N.

Working with second class lever is always easier. Why?

Load lies between effort and fulcrum in second class lever so effort distance is always greater than load distance. Hence it can multiply the effort applied. As a result, it makes the work easier to do.

Activity: To demonstrate variation in MA, VR and efficiency of the given first class lever.

Materials required: Model lever, spring balance, weight.

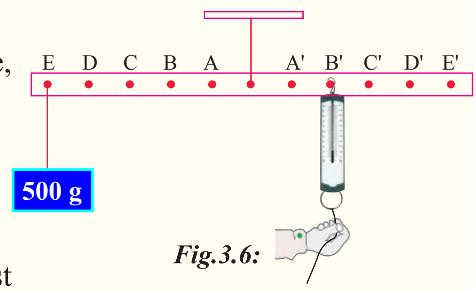


Fig.3.6:

Method:

1. Hang the model lever as shown in the diagram.
2. Hang the standard weight (500 g) and adjust the spring balance at other side to balance the load (equilibrium condition).
3. Repeat the activity (2) by adjusting the spring balance at C' D' E' and A'. Calculate MA, VR and η of each condition.

SN	Load (L)	Effort (E)	Effort distance (Ed)	Load distance (Ld)	$MA = \frac{L}{E}$	$VR = \frac{Ed}{Ld}$	$\eta = \frac{MA}{VR} \times 100\%$
1	500 g			40 cm			
2	500 g			40 cm			
3	500 g			40 cm			
4	500 g			40 cm			

Analyse the effect of distance of effort from fulcrum.

2. Pulley and its types

A freely rotating circular disc having groove in its circumference is a pulley. Pulley can be categorized into three different groups.

i. Single fixed pulley

ii. Single movable pulley
iii. Block and tackle (mixed/compound pulley)

In pulleys

$$MA = \frac{\text{load}}{\text{effort}}$$

VR = No. of string segments that supports the load

$$\text{Efficiency } (\eta) = \frac{MA}{VR} \times 100\%$$

i. Single fixed pulley

The distance travelled by effort and that of load is equal in this type of pulley system. It does not magnify the effect of force but it changes the direction of applied force. Its VR is 1.

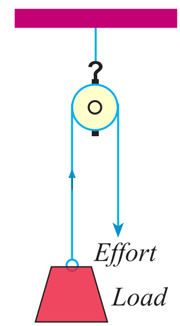


Fig.3.7: *Fixed pulley*

ii. Single movable pulley

In this type of pulley system both load and pulley move together. The distance travelled by effort is double than the distance travelled by load. It does not change the direction of applied force. Its VR is 2.

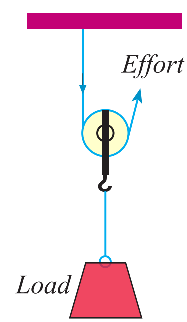


Fig.3.8: *Movable pulley*

iii. Block and tackle (mixed or compound pulley)

A combination of fixed and movable pulleys forms a block and tackle that has both qualities. It not only changes the direction of the applied forces but also magnifies the applied effort.
The ratio of distance travelled by effort to the distance travelled by load are equal to the number of pulleys used in the block and tackle system. Its velocity ratio is given by VR = number of pulleys used in the system

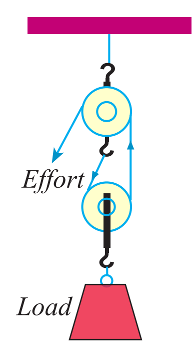


Fig.3.9: *Block and tackle*

Activity: Calculate MA, VR and η of pulley.

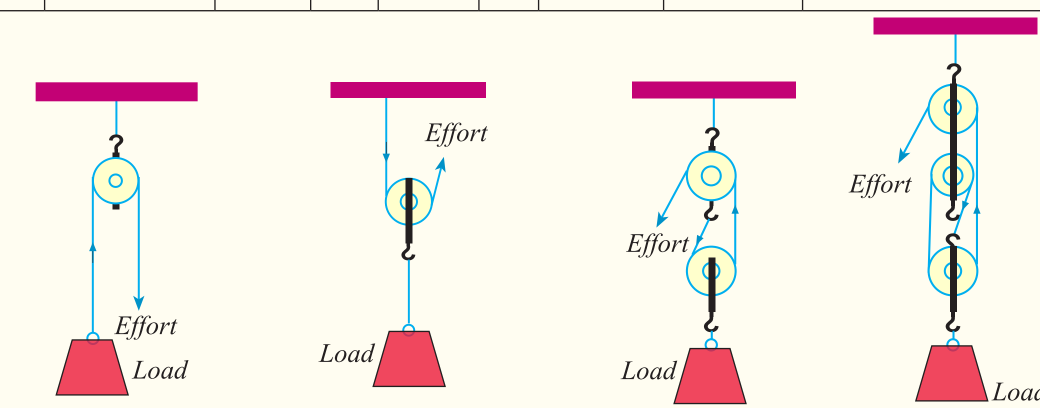
Materials required:

Model pulleys, single-2, block and tackle (2 pulley system and 3 pulley system), string, spring balance, standard weight.

Method:

Use the same load (500 g) for each pulley system and lift the load for the same height (20 cm). Fill the following table and calculate MA, VR and velocity ratio.

SN	Type of pulley	L	E	Ld	Ed	$MA=\frac{L}{E}$	$VR=\frac{Ed}{Ld}$	$\eta = \frac{MA}{VR} \times 100\%$
1	single fixed pulley	500 g		20 cm				
2	single movable pulley	500 g		20 cm				
3	block and tackle (2 pulley system)	500 g		20 cm				
4	block and tackle (3 pulley system)	500 g		20 cm				



Single fixed pulley *Single movable pulley* *Block and Tackle 2 pulley system* *3 pulley system*

Fig.3.10:

You will find that in single fixed pulley, VR is 1 but in single movable pulley and in 2 pulley system block and tackle velocity ratio is 2. In 3 pulley system VR is 3. It shows that except in single movable pulley, the velocity ratio is equal to the number of pulleys used in the pulley system.

Solved numerical problem

Calculate the efficiency of a pulley system having four pulleys if it lifts 3000 N load with the help of 1000 N force.

Here,

Effort = 1000 N

Load = 3000 N

VR of pulley = no. of pulley = 4

Now,

$$\text{Efficiency } (\eta) = \frac{MA}{VR} \times 100\%$$

$$= \frac{\text{load/effort}}{VR} \times 100\%$$

$$= \frac{3000}{4 \times 1000} \times 100\%$$

$$= 75\%$$

$\therefore$ Efficiency of the pulley system is 75%.

3. Wheel and axle

A wheel and axle is an arrangement of two co-axial cylinders with different radii in which one rotates to give rotation of another.

Usually, effort is applied in bigger cylinder to lift load at smaller cylinders. String rollers, screw drivers, steering of vehicle, etc. are some examples of it.

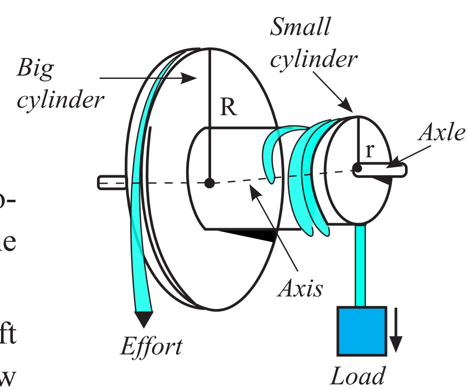


Fig.3.11: *Wheel and axle*

In wheel and axles

$$MA = \frac{\text{load}}{\text{effort}} = \frac{L}{E}$$

Distance travelled by effort = no. of rotations × circumference of wheel

$= n.2\,\pi\,R$

distance covered by load = no. of rotations × circumference of axle.

$= n.2\,\pi\,r$

Where, R = radius of wheel

r = radius of axle

$$\text{velocity ratio (VR)} = \frac{n.2\,\pi\,R}{n.2\,\pi\,r}$$

$$\text{Thus, VR} = \frac{\text{radius of wheel (R)}}{\text{radius of axle (r)}}$$

$$\text{Efficiency} = \frac{MA}{VR} \times 100\%$$

Wheel and axle as a continuous lever

Wheel and axle can be considered as a continuous lever. It is because fulcrum lies between load and effort in wheel and axle so that it works on the principle of first class lever. First class lever rotates about an acute angle during lifting a load but wheel and axle rotates about 360° continuously, until load gets lifted completely. That is why it is considered as a continuous lever.

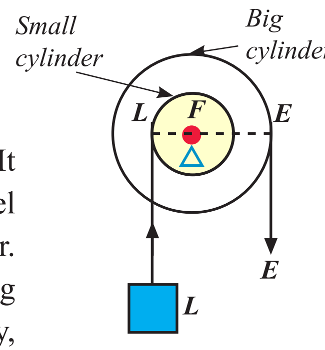


Fig.3.12: *As continuous lever*

Solved Numerical

In a wheel and axle radius of wheel is 10 cm and diameter of axle is 0.05 m. If a load of 1500 N is lifted by using an effort of 500 N, calculate MA, VR and efficiency in it.

Here,

Radius of wheel (R) = 10 cm

Diameter of axle (d) = 0.05 m

$$\text{or, radius of axle (r)} = \frac{0.05 \times 100}{2}\ \text{cm} = 2.5\ \text{cm}$$

Load (L) = 1500 N

Effort (E) = 500 N

Now,

MA = ?

VR = ?

η = ?

$$MA = \frac{L}{E} = \frac{1500}{500} = 3$$

Again,

$$VR = \frac{R}{r} = \frac{10}{2.5} = 4$$

$$\text{Finally, } \eta = \frac{MA}{VR} \times 100\%$$

$$= \frac{3}{4} \times 100\% = 75\%$$

Thus, MA of the machine is 3, VR is 4 and its efficiency is 75%.

Inclined plane

A simple device that makes small angle with horizontal surface and is applicable to load upward is an inclined plane.

In an inclined plane, the load acts towards the centre of earth whereas the effort acts parallel to the plane of the inclined plane.

When an object is pulled upward or is made to climb a height, the distance travelled by load is equal to the height and the distance travelled by effort is equal to the length of the inclined plane. Thus, in inclined plane:

$$MA = \frac{L}{E}$$

$$VR = \frac{\text{distance travelled by effort}}{\text{distance travelled by load}}$$

$$\text{or, } VR = \frac{\text{length of inclined plane}}{\text{height of inclined plane}} = \frac{l}{h}$$

$$\eta = \frac{MA}{VR} \times 100\%$$

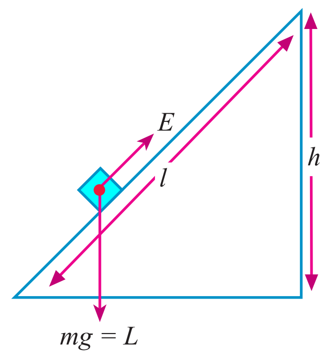


Fig.3.13: *Inclined plane*

> ***Fact file:***
>
> *The value of VR in an inclined plane is always more than 1 (VR > 1). It is because the length of plane is always longer than the height of plane.*

Solved Numerical

In an inclined plane the height of slope and the length of slope are 15 m and 30 m respectively. If a load of 1800 N can be lifted by using a force of 1500 N on the slope, calculate:

i. MA	**ii. VR**	**iii. input work**
iv. output work	**v. Efficiency**	**vi. loss of energy**

Here,

Height of slope (h) = 15 m

Length of slope (l) = 30 m

Load (L) = 1800 N

Effort (E) = 1500 N

i. MA = ?

ii. VR = ?

iii. Input work = ?

iv. Output work = ?

v. η = ?

Now,

i. $MA = \frac{L}{E} = \frac{1800}{1500} = \frac{6}{5} = 1.2$

ii. $VR = \frac{l}{h} = \frac{30}{15} = \frac{6}{3} = 2$

iii. Input work $= E \times l$

$= 1500 \times 30 = 45000$ J

iii. Output work $= L \times h$

$= 1800 \times 15 = 27000$ J

v. $\eta = \frac{MA}{VR} \times 100\%$

$= \frac{1.2}{2} \times 100\%$

$= 60\%$

vi. loss of energy

= Input work - Output work

= 45000 J - 27000 J

= 18000 J

Moment

Moment is the turning effect produced by a force on a body. Moment is the vector product of force and moment arm, (the perpendicular distance between the lines of action of force and the axis of rotation of the body.)

Moment = force × moment arm

Clockwise moment

If a force produces clockwise rotation on a body, the moment called clockwise moment and it is taken as a negative moment.

Anti-clockwise moment

If a force produces anti-clockwise rotation on a body, the moment is called anti clockwise moment and it is taken as a positive moment.

Law of moment

In an equilibrium condition of a lever sum of clockwise moments and sum of anti-clockwise moments produced at a point are equal.

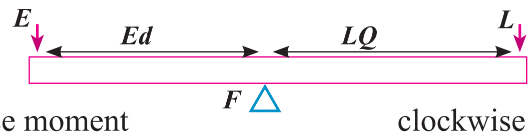


Fig.3.14:

clockwise moment = anti-clockwise moment

Activity: To verify the law of moment

Materials required: Model lever, different standard weights (20 g, 50 g, 100 g), spring balance, thread, stand.

Method:

Adjust the model lever as shown in the diagram. Fill the following table after the lever is balanced and calculate the product of effort and effort distance as well as the product of load and load distance.

Here, clockwise moment is E×Ed and anticlockwise moment is L×Ld.

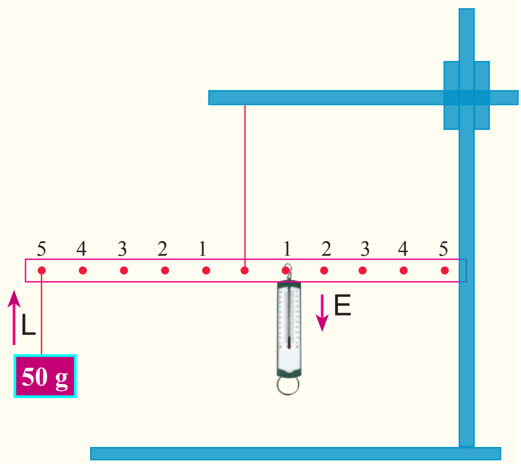


Fig.3.14:

SN	Load (L)	Effort (E)	Load distance (Ld)	Effort distance (Ed)	L × LD	E × ED
1	50 g					
2	20 g			20 cm		
3	100 g					
4	20 g			40 cm		

The activity shows and proves that

E × Ed = L × Ld

∴ Clockwise moment = anticlockwise moment

Torque: The unlike parallel forces acting on a body may produce turning effect called torque.

Solve Numerical problem

Calculate the value of E if the device is in equillibrium condition.

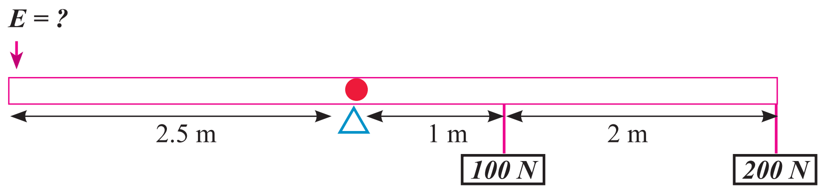


Fig.3.15:

Here,

Clockwise moment = 1 m × 100 N + 3 m × 200 N

= 700 Nm

Anti-clockwise moment = 2.5 × E

Here,

According to the law of moment,

Clockwise moment = Anti-clockwise moment

or, 700 N = 2.5 E

or, $E = \frac{700}{2.5} = \frac{7000}{25} = 280$ N

> ***Fact file:***
> *If a person moves towards the tip of a branch, the chance for the branch to break increases. It is due to the effect of moment.*

Effects of moment

i. A taller tree has greater chances to fall down during storm than a shorter tree as it has longer moment arm than that of the shorter tree and experiences greater moment.

ii. A longer spanner is used to open a tight nut as its longer arm produces greater moment even with smaller force.

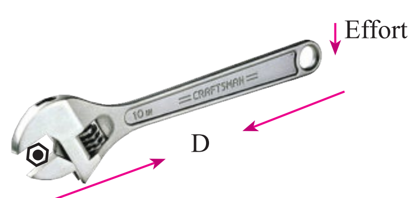


Fig.3.16: *a. Rotating spanner*

Some application of moment

i. Steering of truck is made bigger than the steering of a car.

ii. Branches are likely to break as one moves towards the tip of the branch.

iii. Handle of metal cutting scissors is made longer than cloth cutting scissors.

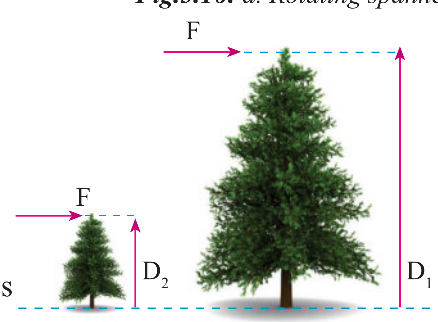


Fig.3.16: *b. Difference in moment arm D_1 & D_2*

Lesson Summary

1. A machine is a simply constructed mechanical device that enables us to apply effort at a convenient point and in the convenient direction.
2. A simple machine:
   - changes the direction of force.
   - increases the effect of force.
   - increases the rate of doing work.
   - makes work more convenient.
3. Mechanical advantage is the ratio of load to the effort applied.

   $$MA = \frac{\text{load}}{\text{effort}}$$

4. Velocity ratio is the ratio of distance travelled by effort to the distance travelled by load.

   $$VR = \frac{\text{distance travelled by effort}}{\text{distance travelled by load}}$$

5. In lever, $VR = \dfrac{\text{Effort distance (Ed)}}{\text{Load distance (Ld)}}$
6. In pulleys, VR = No. of pulleys used (Except single movable pulley)
7. In wheel and axle, $VR = \dfrac{\text{radius of wheel (R)}}{\text{radius of axle (r)}}$
8. In inclined plane, $VR = \dfrac{\text{length of plane } (l)}{\text{height of plane } (h)}$
9. Input work = effort × distance travelled by effort.
10. Output work = load × distance travelled by load.
11. Efficiency

    $$\begin{aligned}\text{Efficiency} &= \frac{\text{Output work}}{\text{Input work}} \times 100\% \\ &= \frac{\text{load} \times \text{distance travelled by load}}{\text{effort} \times \text{distance travelled by effort}} \times 100\% \\ &= \frac{MA}{VR} \times 100\%\end{aligned}$$

12. Efficiency of a machine can be increased by lubrication and using lighter movable parts of the machine.

13. Moment is the turning effect of force.
    Mathematically,
    Moment = force × perpendicular distance between fulcrum and the point of force applied
14. **Law of moment**
    In equilibrium condition of a lever, the sum of clockwise moments and the sum of anti-clockwise moments are equal.
    or, Clockwise moment = Anti-clockwise moment

Project work

Make a model of an inclined plane as shown in the diagram. Use a load and a spring balance to pull the load on the slanted surface. Change the inclination by fitting the inclining plank on different grooves.

Analyze the amount of effort required to lift the same load on different inclinations of the slope.

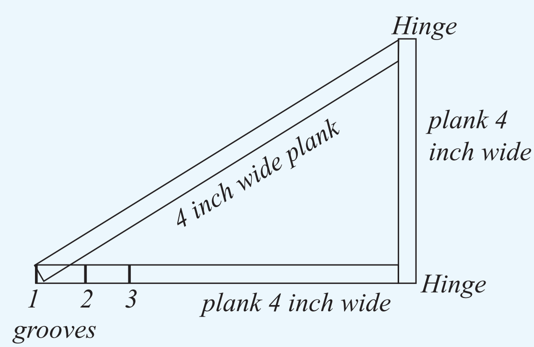


Fig.3.17:

Conceptual questions with their answers

Q.1. V.R. is always greater than M.A. in simple machines. Why?
It is because M.A. is affected by friction while V.R. is not affected as Velocity Ratio is the ratio of two distances.

Q.2. 'M.A. is more than one in an inclined plane. Why?
It is due to the fact that the length of an inclined plane (effect arm) is greater than its vertical height (load arm).

Q.3. The efficiency of a simple machine is 75% What does it mean?
It means 75% of our effort is converted into useful work and the rest 25% is wasted to overcome frictional and gravitational force.

Q.4. The velocity ratio of a simple machine is 4. What does it mean?
It means that the distance covered by the effort is 4 times more than the distance covered by the load.

Exercise

1. Answer the following questions.

a. Define MA and VR.
b. Write the formulae used to find out VR in levers, pulleys, wheel and axle and inclined plane.
c. Define output work and input work.
d. What is efficiency? How can we increase the efficiency of a machine?
e. What is moment? On what factors does it depend?
f. State the law of moment.
g. The spanners of different lengths are used to open a rusted nut. Which spanner do you prefer and why?

2. Write the difference between:

a. input work and output work
b. ideal machine and practical machine
c. movable pulley and fixed pulley
d. MA and VR

3. Give reason.

a. Simple machines are widely used in our daily life.
b. A taller tree has greater chance to fall down than a shorter tree during storm.
c. A branch of a tree has greater chance to break down if someone moves towards its end.
d. Block and tackle is used in a crane.
e. VR of a single movable pulley is always 2.
f. MA in an inclined plane is always greater than 1.
g. Wheel and axle is a continuous lever.
h. A hilly road is spiral in shape.
i. A fixed pulley is generally used in daily life although it does not magnify the force.
j. No machine is perfect in practice.
k. VR is always greater than MA.
l. Output work is always less than input work.
m. In practice, a machine is never 100% efficient.

4. What do you mean by

a. MA of a machine is 4?

b. VR of a lever is 3?
c. efficiency of a wheel and axle is 75%?

5. Solve the following numerical problems.

a. A crow bar of length 2 m is used to lift a stone of weight 200 kg. If the fulcrum is set 50 cm apart from the stone, how much effort should be applied to the other end of the crowbar to balance it? [1500 N]

b. If the efficiency of a pulley system having 12 pulleys is 80%, calculate the amount of load it can lift using 800 N effort. [7680 N]

c. Calculate the moment produced on a nut if 60 N force is required to open it with the help of a spanner of length 25 cm. [15 Nm]

d. A homogenous rod of length 5 m and a mass of 60 kg is kept as shown in the diagram 3.18. Calculate the effort required to balance the lever.

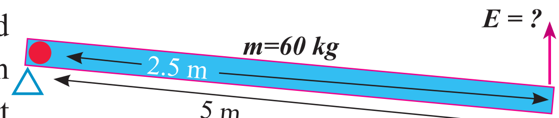


Fig.3.18:

[300 N]

e. Calculate the amount of force required to lift the given load as shown in the diagram 3.19. if efficiency of the system is 70%. What should be done to decrease the amount of effort without changing its efficiency? [285.71 N]

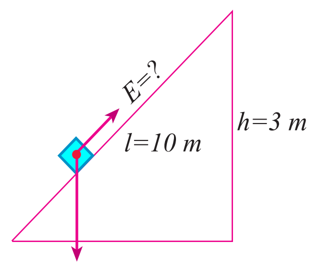


Fig.3.19: *An inclined surface*

f. If the efficiency of the given simple machine is 75% in fig. 3.20, calculate total effort required to lift the load. [47.5 N]

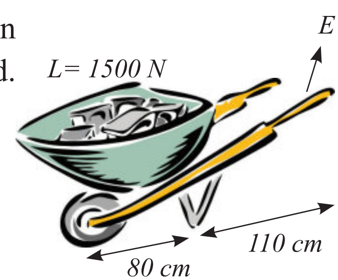


Fig.3.20: *A wheel borrow*

g. A single movable pulley is used to lift 4000 N load to the height of 50 cm. If the efficiency of the pulley system is 75%, calculate effort distance, effort applied, input work, output work and loss of energy in the simple machine.

h. Calculate the efficiency of given simple machine in fig. 3.21. If the load is lifted to the height of 70 m, calculate the loss of energy during the lifting of the load. [80%, 20%]

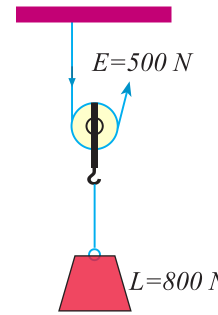


Fig.3.21: *A movable pulley*

i. A load of 500 N is lifted to the height of 18 m by applying an inclined plane through the distance of 27 m. If the effort applied is 400 N, calculate the efficiency of the simple machine. If the same load is to be lifted to the same height by using effort of 300 N keeping the efficiency constant, calculate the length of the slope.

j. Calculate the value of 'W' in the given fig. 3.22. [222.857 N]

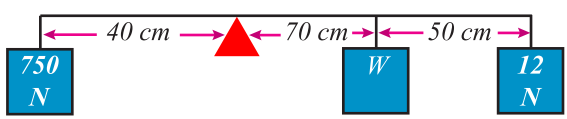


Fig.3.22:

k. A nut is opened by using 25 cm long spanner. If the spanner required 200 N force, calculate the force of the moment on the nut. [50 Nm]

l. Can the given lever in fig. 3.23 be in balanced condition? If not, what extra load is to be given along with 50 N load in anti-clockwise direction? Calculate.

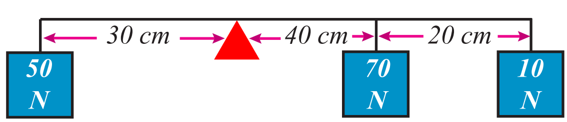


Fig.3.23:

Multiple Choice Questions

1. Tick (√) the correct answer.

a. A machine has fulcrum, load and effort. The load and effort change their location continuously during their work. Identify the machine.

i. First class lever　　ii. Wheel and axle

iii. Third class lever　　iv. Pulley

b. The machine which consists of co-axial cylinders is:
   i. Wheel and axle ii. Pulley
   iii. Inclined plane iv. Lever
c. MA of a machine is:
   i. Ratio of effort to load ii. Ratio of load to load distance
   iii. Ratio of effort to effort distance iv. Ratio of load to effort
d. $\frac{MA}{VR} \times 100\%$ indicates
   i. Output work ii. Input work
   iii. Efficiency iv. Velocity ratio
e. Velocity ratio of an inclined plane is calculated by
   i. $\frac{l}{h}$ ii. $\frac{h}{l}$
   iii. $\frac{V}{R}$ iv. $\frac{R}{r}$

Unit 4 Work, Energy and Power

Total estimated teaching hours = 10

Learning Outcomes

After the completion of this unit, students will learn:

- *identification of different forms of energy such as potential energy and kinetic energy.*
- *definition of work, energy and power and their SI units.*
- *relation of work, energy and power and interpretation of human power.*
- *solution to simple numerical problems related to work, energy and power.*

James Watt (1698AD-1782AD)

KEY WORDS

1. **Metabolism** : life sustaining chemical activities
2. **Tangential** : relating to a tangent
3. **Deformity** : disfigurement, structural change from normal
4. **Isotope** : form of element with the same atomic number
5. **Generator** : a device for producing electricity
6. **Dynamo** : a device that converts kinetic energy into electrical energy usually in the form of direct current
7. **Bob** : a load suspended to move freely

Introduction

A. Work

We generally say that we are working. The mental and physical activities carried out by using energy are generally termed as work in our daily life. But in science, the work is said to be done only when a force produces motion.

The following conditions are required to say that work is done on a body.

- the force acting on the body in the direction of motion. (F)
- displacement produced on the body. (S)

Work is said to be done when an object covers some distance along the direction of force. On pull and push, force performs some work.

Mathematically, work is the product of force applied to an object and displacement produced on it.

i.e. work is the scalar quantity.

And $W = Fs$ if object moves along the direction of force.

The work done is zero if the displacement is zero or the displacement produced is perpendicular to the direction of applied force.

Unit of work

$$W = Fd = Nm = \text{Joule}$$

SI unit of work done is joule.

$$1\ J = 1\ Nm$$

And one joule work is defined as the amount of work done when one newton force produces one metre displacement on a body.

One erg work done

If 1 dyne force is applied on an object to displace through the distance of 1 cm in the direction of force applied, the work done is said to be one erg. Remember 1 dyne force is the required force to accelerate a mass of 1 g at the rate of 1 cm/s^2.

Work is done against two forces

i. Work is done against the gravity.
ii. Work is done against the friction.

i. Work is done against the gravity.

The force of gravity acts on all objects and around the earth towards its centre. When a body is lifted upward, work is done against gravity and the work is said to be done on the body. When a body falls from a height, the work is done by the gravity and the work is said to be done by the body.

When a body of mass m is lifted up to a height h, force applied to the body is:

F = mass. acceleration due to gravity

$F = mg$

and,

Work done = force × displacement

$= F.h$

$W = mgh$ [or, $W_g = mgd \sin \theta$]

ii. Work done against friction

When a body moves on to another body in a horizontal plane, there exists a force in the opposite direction of motion and this force is called friction. Frictional force acts tangential to the surface of contact.

To produce motion on a body, work should be done against friction. It is given by the scalar product of force and displacement.

Work done = force × displacement

W = F.d $\qquad\qquad$ [W_f = mgd cos θ]

Solved numerical problems

i. Calculate the work done by Aakriti of 40 kg when she climbs a ladder of height 3.2 m.

Here,

Mass of Aakriti (m) = 40 kg

Height of ladder = 3.2 m

Since she had performed work orgainst gravity,

Work done = mgh $\qquad$ (consider $g = 10\ m/s^2$)

= 40 × 10 × 3.2 joules

= 1280 joules

∴ Work done by Aakriti is 1280 joules.

ii. A car of mass 450 kg is moving with acceleration 0.2 m/s^2. Calculate the work done by the car when it covers 3 km along the straight path.

Here,

mass of car (m) = 450 kg

acceleration of car (a) = 0.2 m/s^2

distance covered (d) = 3 km = 3000 m.

Now,

force applied (f) = ma

= 450 × 0.2

= 90 N

And

Work done by the car = F.s

= 90 × 3000

= 270000 J

∴ Work done by the car is 270000 J i.e. 270 KJ

B. Energy

Energy is defined as the capacity of doing work. Machines and living organisms also require energy to do work. To continue our metabolic activities, energy is needed even when we are sleeping.

The SI unit of energy is joule and CGS unit is erg.
$1\ J = 10^7$ erg

Different forms of energy

Some common forms of energy present around us are:

1. Mechanical energy
   a. Kinetic energy
   b. Potential energy
2. Heat energy
3. Light energy
4. Sound energy
5. Electrical energy
6. Chemical energy
7. Nuclear energy (Atomic energy)
8. Magnetic energy

1. Mechanical energy

The form of energy possessed by an object by virtue of its state i.e. structural and positional deformities or its motion is called mechanical energy.
There are two forms of mechanical energy.

a. Kinetic energy
b. Potential energy

a. Kinetic energy

It is the form of mechanical energy that is possessed by an object by virtue of its motion. The kinetic energy possessed by a moving object is equal to the work done on the object to produce motion. Wind, flowing water, bullet fired from a gun, rolling stone, etc. have kinetic energy in them.

(DERIVATION):

Kinetic energy of a body in motion is given as $KE = \frac{1}{2} mv^2$

If an object with mass m kg starts to move from rest and gains velocity v m/s in t sec

Here,

Workdone (W) = Fd = m.a.s

$$\text{or, } W = m\frac{v-u}{t} \times \frac{u+v}{2} \times t \quad [\because a = \frac{v-u}{t} \text{ and } s = \frac{u+v}{2} \times t]$$

$$W = m\frac{v^2-u^2}{2t} \times t$$

$$= m\frac{v^2-0}{2} \qquad u = 0 \text{ m/s (Since the body starts from rest)}$$

$$\therefore W = \frac{1}{2} mv^2,$$

After the work done on the body, it gains kinetic energy equal to the work done.

Thus, $KE = \frac{1}{2} mv^2$

It means that kinetic energy (KE) increases or decreases with increase or decrease in mass and velocity of a body.

b. Potential energy

The form of energy stored in an object because of deformities on its state or position is called potential energy.

The amount of potential energy stored in an object is equal to the amount of work done to produce deformities on its state or position.

An object kept at a height, a stretched rubber, water stored in dam, etc. possess potential energy. An object that possesses potential energy is always ready to do work to achieve zero potential state which is the most stable state.

Derivation

Let us suppose a body of mass 'm' is raised to a height of 'h' then

PE = work done

= f × s (f = mg, s = h)

= mg × h

$\therefore$ [PE = mgh]

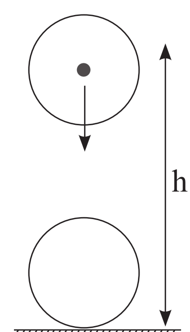


Fig.4.1:

Solved numerical problems

a. Calculate the kinetic energy possessed by a body having mass20 kg and uniform velocity 5 m/s.

Here,

Mass of the body (m) = 20 kg

Average velocity of the body (v) = 15 m/s

Now,

Kinetic energy $= \frac{1}{2} mv^2$

$= \frac{1}{2} \times 20 \times 15 \times 15$

$\therefore$ KE = 2250 J

$\therefore$ Kinetic energy possessed by the body is 2250 J.

b. Calculate the potential energy stored in a body of mass 35 kg brought to a height 9 m from ground.

Here,

Mass of the body (m) = 35 kg

Height from the ground = 9 m

Now,

Potential energy stored in the body = mgh (where g is acceleration due to gravity)

$= 35 \times 10 \times 9$ [consider g = 10 m/s^2]

= 3150 J

2. Heat energy

Every material is composed of molecules. When molecules vibrate they possess kinetic energy and the sum of such kinetic energy is the heat energy stored in the material. The sun is the main source of heat energy. Fire, friction, electricity, etc. also provide heat. Heat is used for many kinds of useful work in our daily life.

3. Light energy

A strongly heated object radiates energy. One energy so radiated is light that helps to see bodies around us remaining itself invisible. It is transmitted in the form of transverse wave and can propagate even in vacuum. Light energy is utilized by green plants to synthesize food. Photo cell converts light energy into electrical energy. Its main source is the sun. We also get light from different types of lamps.

4. Sound energy

The energy possessed by the vibration of bodies medium for its propagation is sound energy. It is transmitted through mechanical wave and so it needs material. A microphone diaphragm converts sound energy into electrical energy. Different types of musical instruments, vocal cord, radio etc are some sources of sound energy.

5. Electrical energy

Electrical energy is widely used to run different devices used in our daily life. It is an easy means of energy that can be easily produced and transmitted. Electrical energy can be produced by cell, generator and dynamo. Dynamo and generator convert kinetic (mechanical) energy into electrical energy. Cell converts chemical energy into electrical energy.

6. Chemical energy

We use food materials to produce energy to run our metabolic functions as well as our daily work. Mineral oil, coal, bio gas and firewood that are used as fuels are the sources of chemical energy. They burn and produce heat, light and mechanical energy to run factories, vehicles, etc. Food items like bread, pulses, rice, ice cream, crackers, matchsticks, etc. and electric cells also contain chemical energy.

7. Nuclear energy

The energy possessed by an object because of the change that occurs in nucleus is nuclear energy. Nuclear energy is released either by fusion of nuclei of isotopic lighter elements or fission of nucleus of an isotopic heavier element. The nuclear energy is produced because of the decay of mass. It is also called atomic energy. It is found in the sun, atom bomb, nuclear power plants, stars, hydrogen bomb etc.

8. Magnetic energy

Magnet produces magnetic energy and it is utilized to generate electricity by a generator or dynamo. Super fast train is also designed to run with the help of magnetic energy. The magnetic energy is also used in different electrical appliances, cassette player, telephone receiver, microphone that produce sound.

Transformation of energy

The process of conversion of energy from one form to another by means of a device is called transformation of energy.

Example,

The transformation of energy from water in dam to bulb:
The water in a dam possesses potential energy. The flowing water in tunnels and turbines has kinetic energy. The spinning generator has electrical energy that is carried by the conducting wire to the bulb. The bulbs changes the electrical energy into light and heat energy.

Potential energy (water in dam)	→	Kinetic energy (when turbine moves)	→	Electrical energy (when the generator spin)	→	Light energy (when the lamp glows)

Energy flow chart

Classical principle of conservation of energy

The classical principle of conservation of energy states, 'Energy can neither be created nor be destroyed but can be transferred from one form to another.'

Therefore, energy transfers from one form into another form. It can be shown with the energy flow chart as given below.

Electrical energy	Electrical bulb →	Heat and light energy
Electrical energy	Fan/Electrical Motor →	Kinetic energy
Kinetic energy	Generator/Dynamo →	Electrical energy
Sound energy	Microphone →	Electrical energy
Electrical energy	Speaker/Door bell →	Sound energy
Light energy	Photo cell →	Electrical energy
Chemical energy	Cell/Battery →	Electrical energy
Chemical energy	Burning candle →	Heat and Light energy
Light energy	Green plants →	Chemical energy

Transformation of energy

Relation between energy and work

We have studied that when we have to do any type of work we need energy i.e. energy is capacity to do work. When a body displaces in the direction of force applied or when the energy changes from one type to other, work is done. In this way energy and work are very close to each other. For better understanding, do the following activity:

Activity:

Hang a bob freely to move as shown in the diagram. Now displace the bob from A to B. Does it need energy? Obviously yes. The applied energy causes displacement too. It means the energy changes into work. When the bob comes at B, the work done on it helps to gain potential energy in the bob. Now if the bob is left freely to move it comes at 'B' again. During that, the potential energy of the bob changes into kinetic energy, which does not stop at B but moves to C. This activity shows that energy and work are interchangable. Due to it both of them have same unit J (Joule).

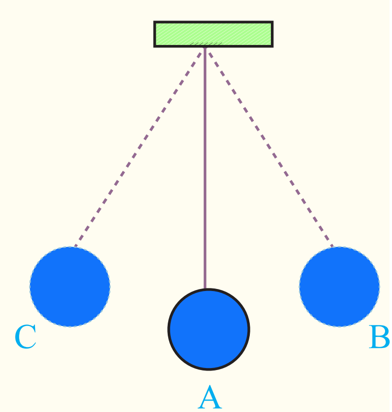


Fig.4.2: *A hanging bob*

Power

Different bodies have different capacities of doing work. Two bodies having equal capacity of doing work may also perform it in different time. The rate of doing work is power. Power is defined as the rate of doing work or rate of energy transformed.

$$\text{i.e. Power} = \frac{\text{work done}}{\text{time}}$$

$$= \frac{\text{energy transformed}}{\text{time}}$$

$$\therefore P = \frac{W}{t} \text{ or } \frac{E}{t}$$

Consider same amount of load is carried by two different persons A and B for the same distance. If person 'A' performs the work in less time than the person B, 'A' has more power. As power is inversely proportional to time taken.

Although both of them do the same amount of work but due to different times used by them, they have different powers. A needs less time, thus he/she has more power. Unlike it 'B' needs more time, thus he/she has less power.

SI unit of power

$$\text{Power} = \frac{W}{t} = \frac{\text{Joule}}{\text{second}} = \frac{J}{S} = \text{watt}$$

and,

$$1 \text{ watt} = \frac{1 \text{ Joule}}{1 \text{ second}}$$

1 watt: 1 watt power is the rate of doing 1 joule work in 1 second.

Other units of power

Horse power (HP): Generally power of an engine is measured in HP and,

1 HP = 746 watt and is roughly equals to 750 watt

1 KW = 10^3 watt

1 MW = 10^6 watt

The devices that have equal energy may also have different power. The power depends upon the rate of work done or rate of energy transformed.

The 100 watt written in an electric bulb means that it converts 100 joules of electrical energy into heat and light energy per second.

Differences between work, energy and power.

Work	Energy	Power
1. It is the product of force and displacement in the direction of force applied. 2. It's SI unit is Joule.	1. It is capacity to do work 2. It's SI unit is Joule.	1. It is rate of doing work. 2. It's SI unit is watt.

Activity: To measure own power.

Materials required: Stopwatch, staircase

Method:

1. Select a staircase having steps of equal height.
2. Do your stopwatch on and run up immediately as fast as you can.
3. Switch off your stopwatch when you step on the last step. Find the time taken by you to cover the distance.

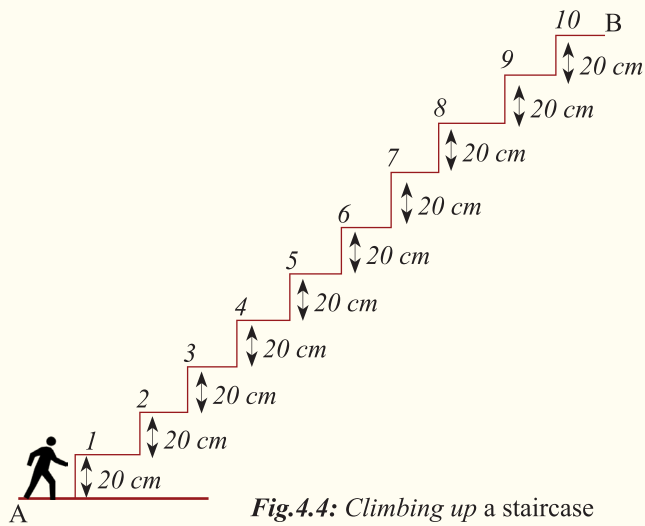


Fig.4.4: *Climbing up* a staircase

Calculate the total height of the staircase multiplying the height of each step and the number of steps in the staircase.

Finally calculate your power by using the following formula:

$$P = \frac{m.g.h}{t}$$

Here, P = Power
m = Mass
g = Acceleration due to gravity ($9.8\ m/s^2$)
h = Height of the stair case
t = Time taken to reach at the height

Solved numerical problem

Calculate the power of an electric motor if it fills a tank of 1000 litres with water kept at height 10 m in 15 minutes.

Here,

mass of water (m) = 1000 kg $\quad (\because 1l \text{ water} = 1 \text{ kg})$

height (h) = 10 m

time taken (t) = 15 min.

= 15 × 60 second

= 900 second

Now, work done to lift water

$$W = mgh = 1000.10.10 \text{ joules} = 100000 \text{ joules}$$

Now,

Power of the motor

$$P = \frac{W}{t} = \frac{100000}{900}$$

$$= 111.11 \text{ W}$$

∴ The power of the motor is 111.11 W

Lesson Summary

1. Work is said to be done when an object covers some distance along the direction of force.
   $$W = F \times s$$
2. SI unit of work is 'joule'. One joule is defined as the work done by one newton force when it produces one metre displacement on a body along its direction.
   $$1 \text{ J} = 1 \text{ Nm}$$
   $$1 \text{ J} = 10^7 \text{ ergs}$$
3. Work is done against gravity and against friction.
4. Work against gravity = mgh or = mgs sin θ
5. Work against friction = FS = mgs cos θ
6. Energy is the capacity to do work. Its SI unit is joule.
7. There are two types of mechanical energy.
   - kinetic energy
   - potential energy
8. Kinetic energy is the energy possessed by a moving body. It is given by
   $$KE = \frac{1}{2} mv^2$$

9. Potential energy is the energy possessed by a body because of deformities that occur in position, structure and chemical composition. Potential energy is possessed by an object at a height. PE = mgh
10. The classical principle of conservation of energy states, " Energy can be neither created nor destroyed but it can be transformed from one form to the other."
11. Energy and work are closely related to each other, so they have the same unit.
12. Power is the rate of doing work or rate of energy transformation.

$$\text{Power} = \frac{\text{work done (W)}}{\text{time (t)}} = \frac{\text{energy transformed (E)}}{\text{time (t)}}$$

13. Its SI unit is watt.
14. One watt power is defined as that power of a device that can perform one joule work in one second.
15. Other units of power are:

1 HP	= 746 W
1 Kilowatt	= 10^3 W
1 Megawatt	= 10^6 W

Project work:

Calculate power of your five friends of your class. Use stopwatch and staircase of your school.

Conceptual questions with their answers

Q.1. An electric bulb is marked 60W.What does it mean?

It means that the marked bulb can convert 60 Joule of electrical energy into light and heat energy in 1 second.

Q.2. What are the conditions where the work done is zero, no matter how high force is applied?

There are mainly two conditions where force does not work at all.

(i) when the body does not move i.e. displacement is zero.

(ii) when the force and displacement are perpendicular to each other.

Exercise

1. Define the following.

a. work
b. one joule
c. potential energy
d. kinetic energy
e. energy
f. one watt

2. Write the difference between:

a. Potential energy and kinetic energy
b. Work and power
c. Energy and power

3. Name the form of energy converted by the followings.

a. Dynamo
b. Electric bell
c. Electric fan
d. Generator
e. Green plants
f. Burning candle
g. Fired bullet
h. Fired cracker
i. Turnning radio by using dry cells
j. Running toy car by using dry cells
k. Microphone
l. Speaker

4. Which form of energy do the following have?

a. The sun
b. Match box
c. Rice
d. Coal
e. Water in a dam
f. Loaded bullet
g. Stone at certain height
h. Stretched rubber
i. Running fan

5. Answer the following questions.

a. Define work and mention its different types.
b. What are work against friction and work against gravity?
c. Define energy and mention its different types.
d. What are potential energy and kinetic energy? Also give two examples each.
e. How are the work and energy closely related?
f. Define power. How is it different from work?
g. Distinguish among work, energy and power.
h. What do you mean by 60 watt written on an electric bulb?
i. Define i. One joule energy   ii. One joule work   iii. One watt power

6. Give reasons.

a. Nikki is walking on the road with a load on her head. She does not do work against gravity.
b. A body at a higher place has greater potential energy than an object at a lower place.
c. Two objects that perform equal work may not have equal power.
d. An object at a height always tries to move down.

7. Solve the following numerical problems.

a. Calculate the amount of work done by a stone of mass 10 kg when it falls from a height of 12 m to the ground. [1200 joules]

b. How much displacement is produced on a body if 12800 joules of work is done by a force 320 N. [40 m]

c. Calculate the kinetic energy possessed by a uniformly moving body of mass 40 kg if it covers 800 m in 40 seconds. [8000 joules]

d. Calculate the power of a crane that lifts 20 tonnes at a height 12 metres in 2 minutes. [20 kW]

e. A stone needs 1350 J of energy to crack down. A bullet of 120 gm is fired on it with the velocity of 140 m/s. Can it crack it down? Calculate. If not, what minimum mass should the bullet have in order to break the stone? Calculate. [No, 137.75 gm]

f. A rubber ball is dropped from 10 m height. If it gains 14 J energy at that height, calculate its mass. Consider 'g' is 10 m/s^2. [200 g]

g. A stone falls from 90 m height. If its total PE converts into KE, Calculate the velocity with which the stone stikes the ground. ($g=9.8ms^2$) [42 m/s]

h. Stuti of 45 kg climbs up 200 steps each with 30 cm height carrying a flower vase of 6 kg on her head. If she climbs the height in 8 min, calculate
   i. the work done
   ii. power

[29,988 J, 62.475 W]

Multiple Choice Questions

1. Tick (√) the correct answer from the following.

a. The rate of doing work is:
   i. Kinetic energy ii. Potential energy
   iii. Power iv. Work

b. The stored energy in a body that is possessed due to chemical reaction in it is:
   i. Kinetic energy ii. Potential energy
   iii. Chemical energy iv. Heat energy

c. The CGS unit of energy is:
   i. Erg ii. Joule
   iii. Horse power iv. Watt

d. The product of m,g and h indicates.
   i. Kinetic energy ii. Sound energy
   iii. Magnetic energy iv. Potential energy

e. If the velocity of a moving body increases by 3 times, kinetic energy of the body increases by.
   i. 9 times ii. 6 times iii. 3 times iv. 2 times

Unit 5 Light

Total estimated teaching hours = 4

Learning Outcomes

After the completion of this unit, students will learn:

- *to demonstrate refraction of light.*
- *to demonstrate dispersion of light.*
- *to explain light wave and electromagnetic wave.*
- *uses of electromagnetic waves of different frequencies and wave length, their sources and harmful effects.*

Willebrord Snellius (1580AD-1626AD)

KEY WORDS

1. **Defracts** : bends in the same medium
2. **Emergent ray** : the ray passing out from denser medium
3. **Refractive** : the ratio of speed of light in a medium to that in vacuum
4. **Convection current** : the motion of hot particles upwards and cold particles downwards
5. **Wave length** : distance between two consecutive crests or troughs
6. **Frequency** : number of complete waves produced in one second
7. **Cataract** : a type of eye disease that leads to blindness

Introduction

Light is a form of energy that gives us the sensation of vision. As a form of energy it propagates in the form of wave. It reflects, refracts, interferes and defracts. When light is produced or reflected by an object and reaches our eyes, the object is seen or the illumination of the source is visualised. So our eye can see either luminous objects or those objects that reflect light. Purely transparent objects are invisible. Study of light and its different behaviours is called optics.

Denser and rarer medium

Speed of light in different mediums are different. The medium through which light travels faster is an optically rarer medium. The medium through which light travels slower is an optically denser medium. Air is a rarer medium. Water and glass are denser media in comparison to air. Vacuum is the rarest medium. Speed of light in air or vacuum is 3×10^8 m/s and in glass it is 2.00×10^8 m/s. Similarly the speed of light in water is 2.25×10^8 m/s. Light is a form of energy which makes things visible.

Refraction of light

Light always travels in a straight path in a homogenous medium but it changes its path when it passes from one optical medium to another optical medium. The phenomenon of bending of light when it travels from one optical medium to another is called refraction of light.

In the diagram, refraction of light through a glass slab is given where,

ABCD	= glass slab
PQ	= incident ray
QR	= refracted ray
RS	= emergent ray
∠PQM	= angle of incidence = ∠i
∠NQR	= angle of refraction = ∠r
d	= lateral displacement
MN	= Normal on AB surface
XY	= Normal on CD surface

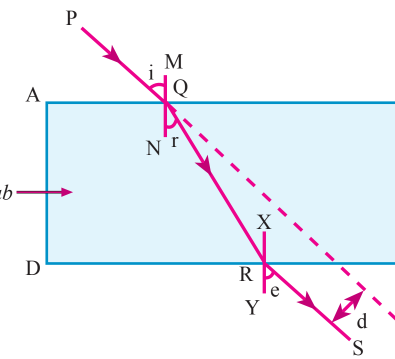


***Fig.5.1:** Refraction of light through a glass slab*

Terminology of refraction of light

Incident ray : The ray of light in the first medium from the source.

Refracted ray : The ray of light that bends on passing from a medium to another medium.

Normal : The imaginary perpendicular line drawn on the point of incidence.

Emergent ray : The ray that passes out from the medium of refraction.

Angle of incidence (∠i) : The angle made by incident ray with normal.

Angle of refraction (∠r) : The angle made by refracted ray with normal.

Laws of refraction of light

When a ray of light undergoes refraction, it abides by certain rules which are called refraction of light. These are:

i. The incident ray, refracted ray and the normal lie at a point on the plane of incidence.

Fact file:

When incident ray passes from rarer to denser medium it bends towards the normal and when it passes from denser to rarer medium it bends away from the normal. A ray passing normally on the plane of incidence it does not bend.

ii. The ratio of sine of angle of incident to the sine of angle of refraction for a particular pair of medium always remains same (snell's law) i.e.

$$\frac{\text{Sin i}}{\text{Sin r}} = \text{constant } (\mu) \qquad [\ \mu = \text{a constant factor}]$$

The constant is also called as refractive index (μ).

We can calculate refractive index by using following formulae also.

$$\mu = \frac{\text{c (speed of light in vacuum)}}{\text{v (speed of light in the medium)}}$$

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Acitvity: To demonstrate refraction of light.

Materials required: white paper sheet, glass slab, pins, pencil, thumb pins, card board.

Method:

1. Fix a plain sheet of paper on a soft board.
2. Put a glass slab on it and draw its outline.
3. Fix two pins in a straight line for an incident ray.
4. Look at it from another side of the glass slab and fix two pins straight with the previous two.
5. Remove the glass slab and connect the points Q and R.

Does the ray follow the straight path inside and outside the glass?

Why does it bend? It demonstrates refraction of light.

ABCD = Glass Slab

PQ = Incident Ray

QR = Refracted Ray

RS = Emergent Ray

∠PQN = Angle of incidence (∠i)

∠N'QR = Angle of refraction (∠r)

NN, = Normal on AD surface

MM, = Normal on BC surface

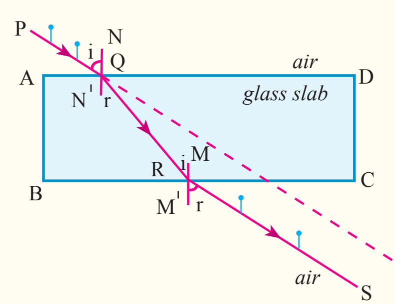


Fig.5.2:

Cause of refraction of light

The speed of light in vacuum is 3×10^8 m/s. But when it travels through different mediums its speed changes. When it travels from optically rarer medium to denser medium its speed decreases and bends towards the normal and when it goes from denser medium to rarer medium its speed increases and it bends away from the normal. This the cause of refraction of light is the different speed of light in the different mediums.

Some effects of refraction of light

Refraction of light produces various effect in our daily life. Some of them are described detail here.

Some events of them are explained below.

i. A pond appears shallower than its actual depth

The ray of light reflecting from the bottom of the pond bend away from the normal when they enter in air. The rays appear to meet at B' and the pond appears shallower than its real depth.

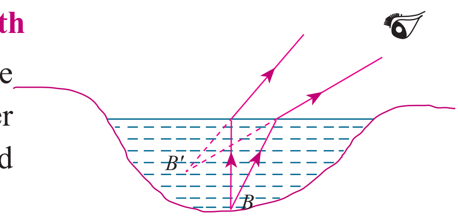


Fig.5.3:

ii. A pencil partially dipped into water appear to bent

The rays of light reflecting from the immersed part of straight pencil bends aways from the normal when enters in air like rarer medium. Due to it point 'p' appear at p'. In fact in the same way number of refractions takes place from Q, R, S, T and U points. It makes the immersed part of the pencil bent.

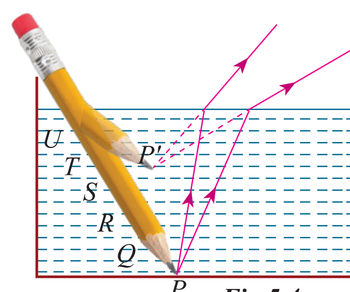


Fig.5.4:

iii. How do stars twinkle?

The different layers of air have different densities which vary in a small range. Due to the convection current of layers of air the density vary continuously and the apparent position of star seems to change in a very small range. It causes the twinkling of stars.

Some more examples of refraction of light

a. A coin kept in a cup becomes visible when water is poured in it.

b. Letters of a page appear upward when a glass slab is placed over it.

Critical angle (∠c)

Whenever light refracts from denser medium to rare medium, it bends away from the normal. As the angle of incidence gradually

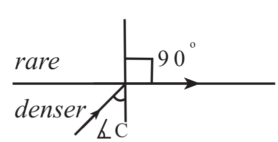


Fig.5.5: *Critical angle*

goes on increasing, the angle of refraction too increases. At a point, the angle of refraction becomes 90°. The angle of incidence for 90° angle of refraction is called a critical angle.

This is the angle in which refracted ray comes inter face between two media.

Substances	Critical angle
1. Glass	42°
2. Ice	50°
3. Water	49°
4. Paraffin	44°
5. Glycerin	43°
6. Diamond	24°
7. Turpentine oil	43°
8. Quartz	35°

Table: Critical angle of some substances

Total interval reflection

We have studies that light bends away from normal on refracting from denser medium to rare medium. If the angle of incidence becomes greater than the critical angle the light bends towards the same medium which process is called total interval reflection. Hence, Total interval reflection of light is the phenomenon of bending of light to the same medium on refracting from denser medium to rare medium.

The conditions necessary for total internal reflection of light are

i. The ray of light must pass from a denser medium to a rarer medium.
ii. The angle of incidence in the denser medium must be greater than the critical angle.

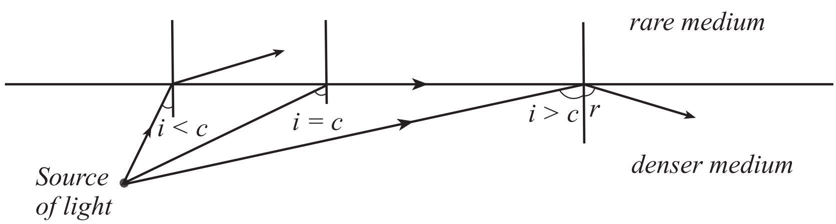


Fig.5.6:

With increase of angle of incidence the angle of refraction increases gradually and finally it comes to the same medium and shows the phenomenon of reflection of light also known as Total internal reflection.

Effects of total internal reflection of light

i. Gems shine brilliantly in the dark
ii. Periscope work based on total internal reflection
iii. Optical fibers function based on total internal reflection
iv. 'Mirage' in summer days is due to the total internal reflection

Dispersion of light

On some rainy days, rainbow is seen in the sky in the morning and in the evening. A rainbow possesses seven different colours. It lies in the order of red, orange, yellow, green, blue, indigo and violet.

How does a rainbow possess these colours?

Why is a rainbow not seen at mid-day?

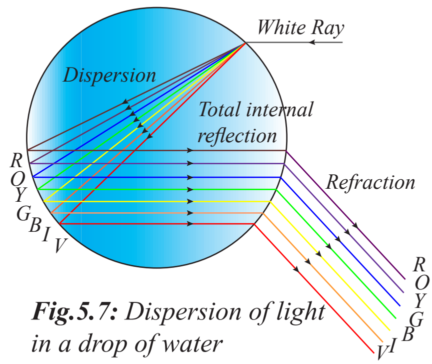


Fig.5.7: *Dispersion of light in a drop of water*

A rainbow is formed when a beam of light undergoes two different processes- The total internal reflection and splitting of visible ray into corresponding colours.

The process of splitting a white beam of light into corresponding visible colours when it passes through a prism like denser medium is called dispersion of light.

The band of seven colours on the screen after dispersion of light is called spectrum of light. The seven colours of specturm of light are red, orange, yellow, green, blue, indigo, violet as in the rainbow.

Dispersion of light by a glass prism

The visible ray of light is a chromatic light that possesses different visible colours with different wave lengths. When a ray of visible light refracts through a prism, it bends towards the base AC inside the prism. As it emerges out from prism, it again bends towards the base AC. Because of different wave lengths of visible colours, they split of and dispersion of light occurs.

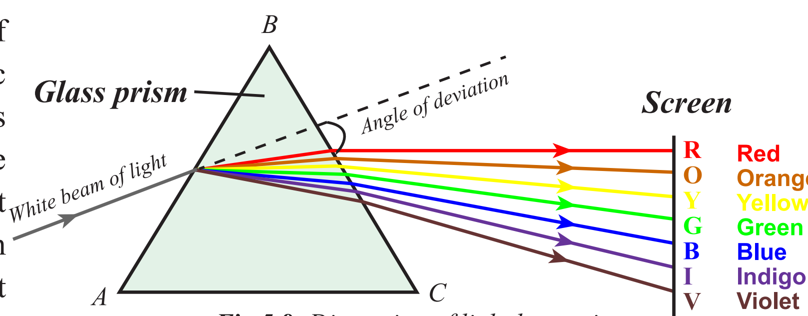


Fig.5.8: *Dispersion of light by a prism*

Unlike it inside a glass slab the refraction with spliting of light occurs in opposite directions on the two faces of it, thus dispersion of light does not occur.

In the diagram 5.8, the light bends towards AD when enters through AB. The light bends towards BC when passes out from CD.

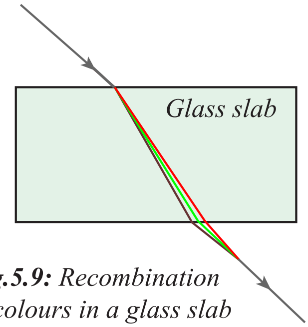


Fig.5.9: *Recombination of colours in a glass slab*

Cause of dispersion of light

White beam of light consists of seven different colours. The coloured rays of visible light have different wave lengths. Red has the longest wave length (7×10^{-7} m) and violet has the shortest wave length (4×10^{-7} m).

We know that $v = f \times \lambda$ where f is frequency and λ is wavelength of light. Thus v and λ are directly proportional.

The deviation produced in violet colour ray is maximum among the seven visible colours as it has minimum wave length. But the deviation produced in red colour ray is the least as it has a maximum speed in prism due to it maximum wave length.

Activity: Prove the presence of invisible rays in light.

Materials required: prism, thermometer, light, white paper

Method:

1. Take a glass prism.
2. Allow a narrow beam of light to refract through a glass prism.
3. Put a piece of white paper to project the spectrum of light.
4. Keep the bulb of a thermometer above the red light on the paper.

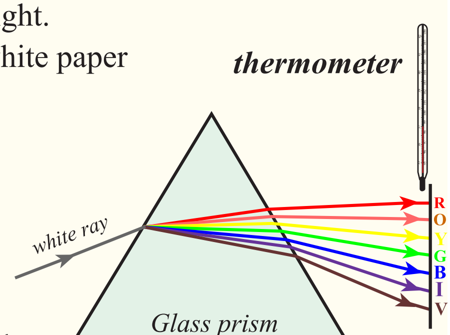


Fig.5.10: *Varification of infra-red ray*

Does the level of mercury raise? Why?

The rise in temperature indicates the presence of invisible ray. There is an infrared ray having a shorter wave length than the red colour ray and it possesses more amount of heat energy.

Similarly, there are some more invisible rays having shorter wave lengths than the violet colour ray. These are called ultraviolet rays. They lie below the voilet colour.

Wave

A wave is the disturbance which travels through the medium with certain definite velocity without any change in its form.

Waves can be classified into longitudinal and transverse waves as well as mechanical and electromagnetic waves. Mechanical waves are those which need material medium to propagate and electromagnetic waves are those which do not need material medium for their propagation.

Transverse wave

Light is a form of energy that can also propagate in vacuum. The light from the sun reaches us travelling through vacuum. When it travels through a materials medium, particles of the medium vibrate perpendicular to the direction of wave. Thus it produces a transverse wave. About longitudinal wave we will study in the next unit sound.
The maximum positive displacement produced from the mean position is called crest and the negative displacement is called trough. A transverse wave has a speed equal to the speed of light in vacuum.

Electromagnetic wave

Some forms of energy can propagate in vacuum by means of radiation. It interacts with molecules present in a substance. It is absorbed and is converted into other forms of energy.
The wave that can propagate in vacuum by means of radiation can be absorbed and converted into other forms of energy is an electromagnetic wave. It has the speed of light in vacuum.

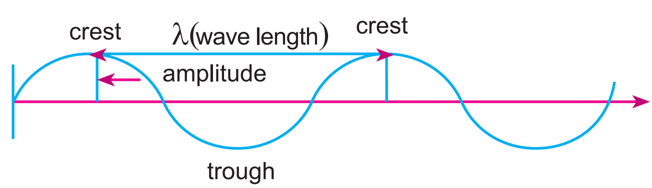


Fig.5.11: *Propagation of transverse wave*

The electromagnetic waves are divided into different types on the basis of their frequency and wave length. The electromagnetic spectrum, their wave lengths, frequency, sources and effects are given in the diagram 5.11 in the next page.

Properties of electromagnetic wave

i. Electromagnetic waves can cast shadow. Objects can block them to some extent.
ii. They travel with the speed of light in vacuum.
iii. They can propagate in vacuum.
iv. They interact with the molecules of matter.
v. Electromagnetic waves are transverse in nature.
v. Electromagnetic waves reflect, refract and interfere.

Fact file:

Refractive index can be calculated by following formulae.

1. $\mu = \dfrac{\text{Sin i}}{\text{Sin r}}$ 2. $\dfrac{c}{v}$

3. $\mu = \dfrac{1}{\text{SinC}}$ 4. $\mu = \dfrac{\text{Real depth}}{\text{Apparent depth}}$

SinC = Sine of critical angle
c = Speed of light in vacuum
v = speed of light in the medium

X-ray

X-ray is an electromagnetic wave that has wave length 10^{-11} m to 10^{-8} m. Its source is X-ray machine. X-rays are used to detect faults and fractures in our body. They are also used to treat harmful tumor before it spreads in the human body. It identifies infections, injury, abnormal bones and bone cancer. It is also used in locating foreign objects inside or around the bones.

Uses of X-ray

- It is used to study the structure of hard tissues like bones, teeth etc.
- It is used in the treatment of cancer which is called radiotherapy.
- It is used in security check up like in Airport, custom officers etc.
- It is used in the study of molecular structure of crystals.

X-ray causes cancer of different organs inside our body. Thus, we should avoid the excessive contact of x-rays.

UV rays

The electromagnetic wave that has wave length 10^{-7} m to 4×10^{-7} m is called ultra violet rays. Its sources are the sun, electric arc, tube light etc. It forms vitamin D underskin of human body and glows fluorescent lamp. The rays are also used in pest centrol and authentification of documents.

Uses of UV ray

- It is use in sterilization of water (SODis), milk and diary products, medical tools etc.
- It is used to ensure the purity of Gems.
- UV-ray is used to prepare vitamin D by the animals in their skin.
- UV is produced in fluorescent lamp to generate visible rays.
- Different pest can be controlled using UV rays.

UV rays harm our skin, eye and immune system. Skin cancer and acceleration in aging of skin may be caused by the exposal of skin in sun heat for a long time. It may cause disease like cataract and damage of cornea, lens and retina of our eyes. Immune system of our body is also weakened by UV rays.

Lesson Summary

1. A transparent medium is said to be rare through which light travels faster and is said to be denser through which light travels slowly.
2. The phenomenon of bending of light when it goes from one optical medium to another optical medium is called refraction of light.
3. The laws of refraction of light are:
   - Incident ray, normal and refracted ray lie at the same point and same plane.
   - $\frac{\text{Sin i}}{\text{Sin r}}$ = constant; for a pair of **mediums**. It is called snell's law. The constant is refractive index of a medium.
4. Refractive index of a transparent medium is the ratio of speed of light in vacuum to the speed of light in the medium.

   $$\text{Refractive index } (\mu) = \frac{\text{speed of light in vacuum (c)}}{\text{speed of light in a medium (v)}}$$
5. The cause of refraction of light in different speeds of light in different mediums is different.
6. Dispersion is the splitting of visible white beam of light into seven different colours after refraction through a transparent object.
7. The band of seven visible colours of light obtained from dispersion is called colour spectrum. The colours of spectrum are red, orange, yellow, green, blue, indigo and violet.
8. Dispersion is caused by the difference of wave lengths of different coloured lights and their speed in transparent medium.
9. The wave on which particles vibrate perpendicular to the direction of wave is called a transverse wave.
10. Electromagnetic waves interact with the molecules of medium and carry energy radiation.
11. Electromagnetic wave can travel in vacuum and has the speed of 3×10^{8} m/s.
12. Electromagnetic waves have both useful and harmful effects.

13. X-ray has wave length 10^{-11} to 10^{-8} m. It is used widely in the field of medicine to diagnose diseases.
14. UV-rays are the electromagnetic waves having wave length of 10^{-7} to 4×10^{-7} m. They are used for various purposes in our daily life.

Project work

Make your own Newton's disc.

Manage a cardboard and make a circle of about 5 cm diameter. Cut the disc to separate it. Paste a piece of white paper on it and mark it in seven different colours as shown in the diagram. Make two holes in the centre and pass a thread through the holes as shown in the diagram. Now spin the disc with the help of the thread. Observe the coloured surface. What change is seen? And why? Discuss the cause in the class.

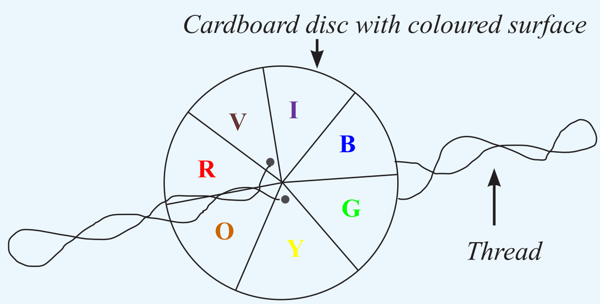


Fig.5.12: *Newton's ring model*

Conceptual questions with their answers

Q.1. Why do we prefer a convex mirror as a rear view mirror in vehicles?

As we know that a convex mirror forms the virtual, erect and diminished image of the objects. For the same reason a convex mirror is capable of covering the wider range of view than the other mirrors of the same size. Therefore a convex mirror is preferred for the vision of larger traffic behind the vehicle by drivers.

Q.2. Which mirror is used as a shaving mirror? Why?

A shaving mirror is used as a shaving mirror as it forms an erect and enlarged image if the object is placed between its pole and focus.

Q.3. A fresh pond appears shallower than it actually is. Justify.

When the light from the object at the bottom of the pond comes, it bends away from the normal at the surface of water. When the refracted rays are traced backwards, they meet at a point at the lesser depth and for this reason, a fresh pond appears shallower than it actually is.

Exercise

1. Write short notes on:

a. Refraction of light
b. Dispersion of light
c. X-rays
d. Ultra-violet rays
e. Spectrum
f. Electromagnetic wave
g. Refractive index
h. Denser medium of light

2. Write the difference between

a. Mechanical and electromagnetic waves
b. Rarer medium and denser medium
c. X-ray and Ultraviolet ray.

3. Give reason.

a. It is difficult to position a fish in water.
b. A clear pond seems shallower than its real depth.
c. A pencil partially dipped in water appears bent.
d. A ray of light bends when it passes from one optical medium to another medium.
e. A thermometer liquid rises up, when placed above the glass prism refracting light.
f. A white visible ray splits into corresponding colours when it passes through a prism.
g. Rainbow can't be seen at midday even in the rain.
h. Light does not disperse through a glass slab.

4. Answer the following questions.

a. Define refraction of light. Why does light bend when it passes from one medium to other medium?
b. Define rarer and denser mediums of light. Also mention the speed of light in air, water and glass.
c. State laws of refraction of light. What is the ratio of sine i to sine r called?
d. Write any three uses each of X-rays and ultraviolet rays.
e. Write the characters of electromagnetic waves.
f. Light is electromagnetic wave. Justify.
g. How can you prove that the spectrum formation by a prism is the product of dispersion of light?

5. Copy and complete the following diagrams. Also mention rarer and denser mediums.

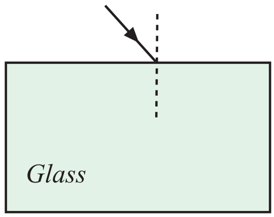


Fig.5.13:

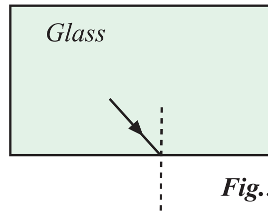


Fig.5.14:

6. Calculate the missing factors in the following figures.

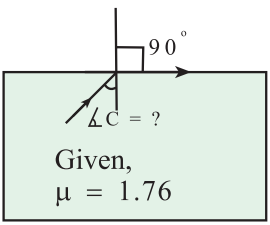


Fig.5.15:

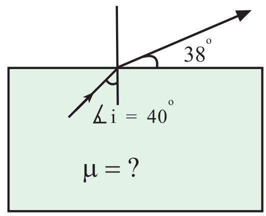


Fig.5.16:

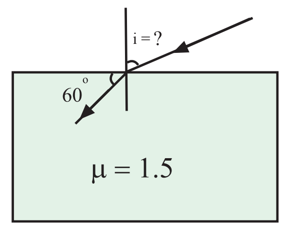


Fig.5.17:

7. Solve the following numerical problems.

a. The frequency of Nepal FM is 104 MHz. Calculate the wave lengths of radio waves. (speed = 3×10^8 m/s) [Ans: 2.88 m]

b. Calculate the frequency of red ray if its wave length is 7×10^{-7} m. [Ans: 4.29×10^{14} HZ]

Multiple Choice Questions

1. Tick the correct answers.

a. Which colour of light has maximum wave length?
   i. Violet ii. Red iii. Orange iv. Yellow

b. In which medium is the speed of light 2.25×10^8 m/s?
   i. Air ii. Alcohol iii. Glass iv. Water

c. When a ray of light passes from denser to rarer medium, it:
   i. passes straight ii. bends away from normal
   iii. bends towards normal iv. reflects back

d. Which wave can pass through vacuum?
   i. Water wave ii. Longitudinal wave
   iii. Electro-magnetic wave iv. Sound wave

e. Which colour of light is found at lowest position of spectrum?
   i. Violet ii. Green iii. Red iv. Pink

Unit 6
Sound

Total estimated teaching hours = 12

Learning Outcomes

After the completion of this unit, students will learn:

- *identification of the sources of infrasound, audible sound, and ultrasound and their uses.*
- *description of the nature of sound wave.*
- *explanation of refraction and reflection of sound and their effects in our daily life.*
- *definition of speed, intensity and pitch of sound.*

Reginald A.Fessenden
(1866AD-1931AD)

KEY WORDS

1. **Echo** : Repetition of sound
2. **Reverberation** : Prolongation of sound
3. **Compression** : The part of longitudinal wave having maximum density
4. **Rarefaction** : The part of transverse wave having minimum density
5. **Tuning fork** : A metallic device having prongs and handle and used as a source of sound
6. **Seismograph** : An electronic device used to measure the magnitude of earthquakes
7. **Humidity** : The measure of amount of moisture in air

Introduction

Sound is a form of energy that gives us the sensation of hearing. The science of study of sound is called acoustics. We listen to different types of sound and these sounds are produced by different sources because of vibration. Usually sound shows property of reflection, refraction and defraction. Echo and reverberation are the products of reflection of sound. Sound transmits from place to place in the form of waves.

Activity: To demonstrate that vibration is a source of sound.
Materials needed: Tuning fork, water, trough, rubber pad

Method:

1. Pour some water in to a bowl.
2. Take a tuning fork and strike it on a rubber pad. Bring it near your ear. Do you hear something?
3. Strike again and touch it gently with your finger. Do you feel any vibration?
4. Touch the surface of water with a vibrating tuning fork. Do water particles vibrate?

Do you see ripples in the water?

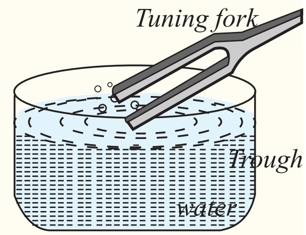


Fig.6.1: *Transmission of energy in water*

Sound is produced during the vibration of tuning fork. The waves are produced on water when a vibrating tuning fork is brought in contact with it.

Wave

Wave is a path of energy. Energy transfers from one place to another by disturbing the particle of a medium. The disturbance produced in a medium by energy is called as wave. A wave has periodic motion. It is made of crests and troughs or compressions and rarefactions. As sound wave is longitudinal wave it consists of compressions and rarefactions. You have learnt about the types of waves in the unit light. Do you remember about transverse wave and electromagnetic wave studied in sound. Now study about longitudinal wave or sound wave.

Wave

On the basis of the direction of motion of particles of medium.
- Transverse wave
- Longitudinal wave

On the basis of type of medium required for their motion
- Mechanical wave
- Electromagnetic wave

Wave can be transverse or longitudinal based on the direction of motion of particles.

Longitudinal wave

Those waves in which particles of medium move to and fro about a point parallel to the direction of propagation are called longitudinal waves. It comprises compression and rarefaction.

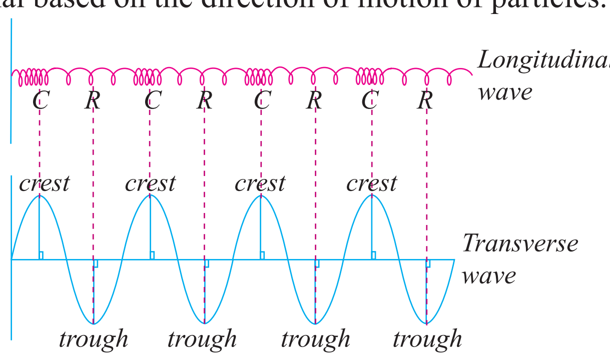


Fig.6.2: *Transverse wave and longitudinal wave*

As sound transmits by this method it

is also called as sound wave. It has less speed. This wave needs material medium for its propagation. Eg. wave formed in spring.

Nature of sound waves

Sound wave is produced by the vibration of molecules of material mediums. When an object vibrates, it produces disturbances on the neighbouring molecules. The neighbouring molecules start to vibrate along and opposite to the direction of energy transmission i.e. in the direction of wave. The to and fro motion of molecules produces a series of successive compression and rarefaction.

Compression is the region in the wave where the particles' density is more. **Rarefaction** is the region in the wave where the particles' density is less.

As the sound wave propagates in the form of kinetic energy of molecules of material medium, it is considered as the mechanical wave and can't propagate in vacuum because of the absence of the molecules of material medium.

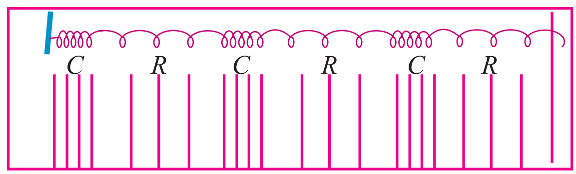


Fig.6.3: *Longitudinal wave*

> ***Fact file:***
> *As sound wave needs material medium for its propagation, normal talking is not possible in space. Thus astronauts use transmitter (electronic media) for their conversation.*

Some terms related with waves:

1. Frequency

The total numbers of complete waves produced from source per unit time is called frequency of that wave. It is measured in Hertz (Hz). It is the reciprocal of time taken. It is denoted by f.

$$\text{Frequency } (f) = \frac{\text{Number of complete waves (N)}}{\text{time taken (t)}}$$

2. Wave length

The distance between two successive crests or troughs is called wave length of a transverse wave. Similarly, the distance between successive compression and rarefaction is called wave length of that longitudinal wave. It is denoted by λ (lambda), and measured in metre.

3. Amplitude

The maximum displacement made by the particles of medium from its mean position is called its amplitude of a wave. It is denoted by a and measured in unit metre (m).

4. Time period

Time period is defined as the time required to form a complete wave. It is denoted by t and its unit is second (s). It is calculated by using the following formula.

$t = 1/f$

Here, t = time period

f = frequency

5. Wave velocity

The distance covered by a complete wave in one second is known as wave velocity. It is denoted by 'v' and its SI unit is m/s. It is calculated by the following formula-

$v = f \times \lambda$

Here, v = wave velocity

f = wave frequency

λ= wave length

The relation shown above is also known as wave equation. It shows that a wave have more frequency if there is less wave length and vice-versa.

Fact file:

Wave velocity is the product of frequency and wave length of the wave. Where frequency is inversely proportional to wave length and velocity of all wave remains same in a particular medium.

Relation of wave length and frequency

Since,

$v = \lambda \times f$ (wave equation)

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

$$f \propto \frac{1}{\lambda} \text{ (for constant velocity)}$$

Frequency of a wave is inversely proportional to the wave length of the wave i.e. a wave having greater frequency has shorter wave length and a wave having less frequency has longer wave length.

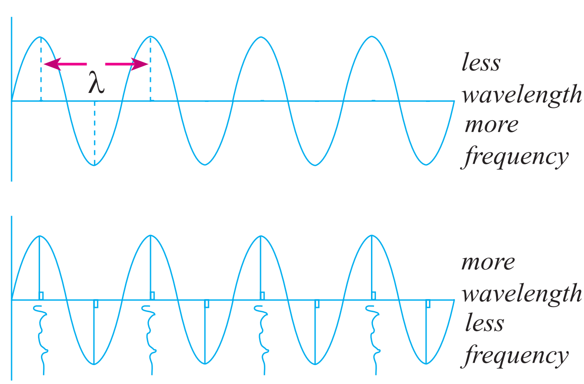


Fig.6.4: Relation of wavelength and frequency

Differences between transverse wave and longitudinal wave.

Transverse wave	Longitudinal wave
1. Particles of medium move up and down perpendicular to the direction of motion in this wave. 2. These waves consists of crests and troughs. For eg: Light wave, radio waves.	1. Particles of medium move to and for about a point parallel to the direction of propagation in this wave. 2. These waves consist at compressions and rarefactions. For eg: Sound wave

Differences between electromagnetic wave and mechanical wave.

Electromagnetic wave	Mechanical wave
1. These waves transmits by carying electric and magnetic field alternately.	1. These waves need mechanical medium to travel.
2. These waves have high energy. For eg: Light wave, radio waves.	2. These waves have low energy.
3. They have high speed.	3. They have low speed.
4. For eg: Light waves	4. For eg: Sound waves

Why do all types of sound have same speed in same medium?

Sound spectrum and its sources

Longitudinal wave has a large range of frequency. Some longitudinal waves have very less frequency and some may have the frequency equivalent to the light wave also.
The sound waves are classified into three different groups on the basis of range of frequency of the longitudinal wave. These are infra-sound, audible sound and ultra-sound.

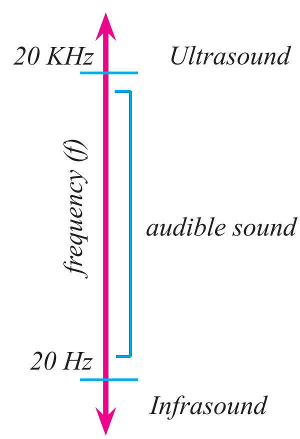


Fig.6.5: *Sound spectrum*

1. Infra-sonic sound (Infra-sound)

The longitudinal wave that has frequency less than 20Hz is called infrasonic sound. The infrasonic sound is produced by huge vibrating objects. The wave of earthquake, some sound of elephants are some examples of infrasonic sound. It is detected by seismograph. It can also be detected by touching the vibrating object but we can't hear it.

2. Audible sound

The longitudinal range of sound that has frequency from 20 Hz to 20 kHz so called Audible sound. Audible sound can be heard by human but the sound wave between 12 kHz to 14 kHz can be heard by many people. Very few people can hear sound above 14 kHz.

3. Ultrasonic sound

The longitudinal wave that has frequency more than 20 kHz is called ultrasonic sound. The ultrasound can be produced by the vibration of crystals. Animals like bats and dolphins can also produce and detect ultrasound. They use this quality of sound to locate prey and enemy around them. Some animals like cat and dog can also detect ultrasound but they can't produce it.

Uses of ultrasound

Ultrasound is used for various purposes. Some of them are listed below.

a. Ultrasound is used by some animals like bat, cricket, whale etc to detect preys and obstacles.
b. It is used to detect the fault in human body and even in metal.
c. It is used to cure problems in neuron by ultrasonic heating.
d. It is used for surgery.
e. It is used to kill bacteria in dairy. (sterilization of milk)
f. It is done by SONAR ie. sound navigation and ranging. The ultrasound produced from the source reaches to ocean bed. The sound reflects from the bed and is received by the sound detector. By using the duration between the two events the depth of the ocean is calculated. The following formula is used for it.

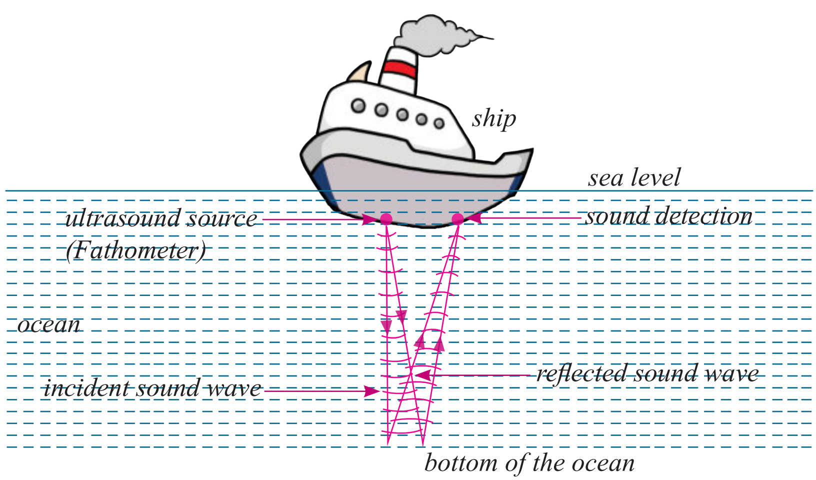


Fig.6.6: *Ocean depth measurement*

Fathometer: An instrument which is used to measure the depth of sea and oceans.

Calculation of depth or distance of sea/ocean

$$\text{Depth of ocean} = \frac{\text{Velocity of sound in the given medium} \times \text{Time taken to hear echo}}{2}$$

$$v = \frac{2s}{t} \quad \text{or, } s = \frac{vt}{2}$$

Solved numerical

An ultrasound originated from a ship is detected after 3 s. by the sound detector. If speed of sound in water is 1500 m/s, calculate the depth of the ocean.

Here,

Time taken (t) = 3 s

speed of sound in water (v) = 1500 m/s

depth of ocean (s) = ?

We have for echo

$$s = \frac{vt}{2}$$

$$s = \frac{1500 \times 3}{2}$$

$$= \frac{4500}{2}$$

$$= 2250 \text{ m}$$

Thus, depth of the ocean is 2250 m.

Speed of sound in different mediums

As sound produces mechanical wave to propagate, it needs a material medium. It does not mean that in every medium, sound travels with equal speed. In fact sound travels with different speeds in different media. Speed of sound in some media are mentioned in the table below:

Medium	Speed (m/s)
carbondioxide	258
air	332
hydrogen	1270
water	1498
brick	5000
aluminium	5100
steel	5200
granite	6000

Table 6.1 speed of sound in different mediums

From the table 6.1 you can easily draw the idea that speed of sound is the least in gaseous medium and is the highest in solid medium. In solid, molecules are tightly packed and energy can be easily transferred from one molecule to another at a very short interval of time and sound propagates faster. But in gaseous medium molecules are quite apart and takes a longer time to share energy with the next neighbouring molecules and sound propagates slowly.

In short, speed of sound in gas < speed of sound in liquid < speed of sound in solid

Speed of sound in gaseous medium

These are different physical factors that affect the speed of sound in gaseous medium. Although sound has the least speed in gas, but it is also affected by different physical factors. Some of them are listed below:

Density of gas (ρ): The speed of sound in a gas is inversely proportional to the square root of density of the gas.

$$v \propto \frac{1}{\sqrt{\rho}}$$

The heavier molecule requires more energy to oscillate. Sound moves faster in lighter medium and moves slowly in heavier medium.

Temperature: The speed of sound in gaseous medium is directly proportional to the square root of absolute temperature for constant pressure.

$$v \propto \sqrt{T}$$

A hot molecule of gas has greater kinetic energy and it supports the speed of sound.

Humidity: The density of vapour is less than that of dry air. Thus the humid air has less density than dry air and sound moves faster in it as it travels faster in lighter media.

Direction of wind: Sound moves faster along the direction of flow of air and it moves slowly along its opposite direction.

The speed of sound is independent of pressure, its frequency and amplitude.

Some characteristics of sound

a. Pitch of sound

The sound from all the sources does not hear same. It hears sharp or hoarse. This relative quality of sound is pitch. Pitch is the sharpness or shrillness of sound. The sound from girls are generally with more pitch than from boys. This difference is due to the frequency of sound produced from them. The frequency of sound from girls is higher than the frequency of sound from the boys.

Hence, The pitch can be increased by

i. Increasing stress or tension on the source
ii. Decreasing cross-sectional area of source
iii. Decreasing the length of the wire

Activity: To demonstrate pitch of sound.

Materials required: Guitar

Method:

1. Take a guitar and plank its thin wire.
2. Repeat the activity but by losing or tighting the wire.
3. Repeat the activity on the wire of different thickness.

Fig.6.7: *Guitar*

Now answer the following questions.

a. Which wire-loose or tight-produces shriller sound?
b. Which wire-thin or thick-produces shriller sound?
c. What will happen if the length of a wire is reduced?

The thin wire has greater pitch. It produces a sharper sound. The sharpness of sound increases with its tension when the wire is tightened. Pitch of sound increases as the length of wire decreases. Thus,

Pitch of sound depends upon.

i. **Thickness of wire:** Lesser the thickness greater the pitch.
ii. **Tension of wire:** Greater the tension greater the pitch.
iii. **Length of wire:** Short the wire, greater the pitch.

b. Intensity of sound

Sound produced may be louder or fainter. The loudness of sound is difficult to be judged just by hearing as the response of hearing of ears of different people is different. The loudness of sound depends upon the energy that it carries with its wave motion. The loudness of sound depends upon the intensity of sound.

Intensity of a sound at a point of wave is defined as the rate of flow of energy away from source per unit area perpendicular to the direction of wave.

$$\text{or, } I = \frac{E}{A \times t}$$

Intensity of sound depends upon the energy that sound wave carries and the energy carried by a wave depends upon the amplitude of wave.

$$\text{i.e.: Intensity} \propto (\text{amplitude})^2$$

$$I \propto a^2$$

Intensity of sound is directly proportional to the square of amplitude of wave produced.

A baby or a woman produces sharper sound as they have smaller vocal chambers and produce sound of lower amplitude and higher frequency. An adult produces hoarse, loud and flat sound as he has a larger vocal chamber that produces sound wave of greater amplitude and lower frequency.

Unit of intensity is Wm^{-2} but loudness of sound is measured in decibel (dB). 1 decibel means $1/10^{th}$ bel. standard intensity of sound is 10^{-12} watt m^{-2}. The sound which is 10 times intense than standard intensity is called 1 bel or 10 decibel.

Unit of intensity of sound

As we know that,

$$I = \frac{E}{A \times t}$$

$$\text{unit of intensity} = \frac{\text{Joule}}{m^2.s}$$

$$= \text{watt } m^{-2}$$

$$= Wm^{-2}$$

Threshold of hearing

The threshold of hearing is the lowest intensity of sound that can be perceived by human ears. It may vary with frequency of sound and sensitivity of ears of different people. But it is defined for normal ears at a frequency of 1000 Hz. i.e. threshold of hearing is defined as the lowest intensity of sound having frequency 1 kHz that can be perceived by normal human ears.

The intensity of sound for threshold of hearing is 10^{-12} watt m^{-2}. It is also known as standard intensity of sound.

Some sources of sound and their loudness:

Sound	10 Decibel
Threshold hearing	0 decibel ($10^{-12}wm^{-2}$)
Rustling of leaves	10 decibel
Whispering	0 db - 20 db
Silence in library	20 db - 40 db
Normal conversation	40 db - 60 db
Heavy traffic on road	60 db - 70 db
Printing press machine	70 db - 80 db
Railway station sound	85 db - 110 db
Motor car sound	110 db - 120 db
Limit of hearing ache	120 db - 140 db
Jet plane launch	above 140 db

Table 6.2 sound source and their intensity

The measure of loudness of sound

The loudness of sound at any intensity level is measured in terms of the intensity of the threshold of hearing.

The loudness of sound is measured in bel (B). The small unit of loudness of sound is decibel (dB).

i.e.: 1 b = 10 dB

The loudness of threshold of hearing of sound is considened as 0 decibel. Intensity of the sound is 10^{-12} watt m^{-2}.

It is also called as standard intensity of sound. A sound having loudness of 20 dB is 10 times louder than the sound having the loudness of 10 dB. In the same way, the sound having loudness of 30 decibel is 100 times louder than the sound having loudness of 10 dB.

Reflection of sound

If someone shouts in front of a hill, a large wall or a building, a reflected sound is heard. While speaking inside a small room or bathroom prolongation of sound is experienced. As sound is a form of energy it is also reflected and follows the laws of reflection.

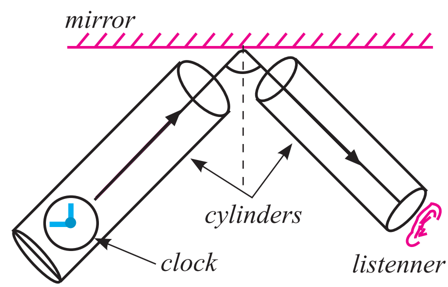


Fig.6.8: *Reflection of sound*

Two types of effects develops due to the reflected sound according to their nature.

i. Echo
ii. Reverberation

Persistance of hearing

The human ear-drum continue beating for 0.1 sec time of stoping source to produce sound. This helps to hear the sound for 0.1 even after the source steps to produce sound. This feature of human ear is called persistance of hearing.

Hence,

time taken to hear sound (t) = 0.1 sec
velocity of sound in air (v) = 332 m/s

Now,

Distance = velocity × time taken
= 332 × 0.1
= 33.2 m

Hence, Sound travels 33.2 m distance in 0.1 sec time (persistance hearing time)

During 0.1 sec time, sound travels 33.2 m, then the sound reflects from 33.2/2 m (16.6

m) distant object from the source and get mixed during hearing and form prolonged sound to hear. If it is reflected from the surface more than 16.6 m distance then same sound can be heard again and again which is called repetition of sound.

Echo

Echo is distinctly heard repeated reflected sound. It occurs when reflecting surface is sufficiently large and distance between the source and the reflecting surface is more than 16.6 m. ($\approx$17 m). In this condition, the reflected sound does not mix with the original sound and the sound heard is repeated.

Conditional of echo

i. Distance between the source and the reflecting surface should be more than 16.6 m. (17 m App.)
ii. Time interval between the original sound and the reflected sound is more than 0.1 s.
iii. Reflecting surface should be of hard nature and of wide area.
iv. The original sound should be so loud that it can come back to listener after reflection.

Reverberation: Reverberation is the prolongation of sound. It is heard when reflection of sound is caused by a close surface. It is heard in small rooms, bathrooms and musical opera. Sound absorbing materials are kept in lecture halls, auditoriums, etc. to minimize reverberation. In this conditions, the reflected sound mixes with original sound and the sound is prolonged.

Condition for reverberation

i. Distance between the source and the reflecting surface should be less than 17 m.
ii. Time interval between the original sound and the reflected sound is less than or equal to 0.1 second.

The differences between echo and reverberation are as follows.

Echo	Reverberation
i. Reflected sound can be heard distinctly ii. Distance between source of sound and reflecting surface should be 17 m or more. iii. It is heard in front of mountain, large rock, forest, building etc.	i. Reflected sound is overlapped with original sound. So it is not distinct. ii. Distance between source of sound and reflecting surface should be less than 17 m. iii. It is heard in room, bathroom, corridor etc.

Absorption of sound

Sound is absorbed by different materials present on the way of propagation. The materials present in the room absorb sound. Sound absorbing materials (absorbent) are kept on walls of auditorium, conference hall, lecture hall etc. to minimize reverberation.

Refraction of sound

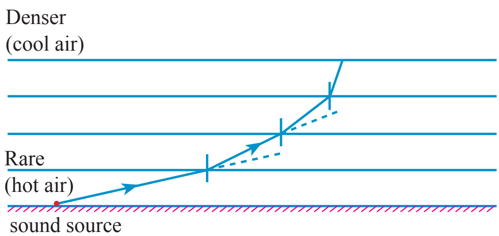


Fig.6.9: Refraction of sound in the air during day

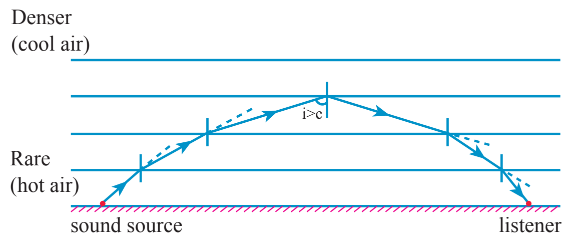


Fig.6.10: Refraction of sound in the air during night

Sound is the form of energy and like other forms of energy it also undergoes refraction during its propagation when density of the medium changes.

During the day, the earth's surface warms up faster and heats the lower layer of the earth's surface than the upper surface. This makes lower surface rarer than the upper surface.

As same produces at a place, it refracts from rare medium to denser medium. This causes sound to bend towards the normal and reach gradually to upper layer. Such sound gradually gets fainter and disappear to degrade into heat.

But during the night, lower layer gradually loose heat to the upper layer. This makes lower layer to be cooler and acts as denser medium and upper layer as rare medium.

When sound produces at a point on the earth's surface. Sound wave refracts from denser medium to rare medium and bends gradually away from the normal. At a point, the angle of incidence becomes greater than critical angle ($i > c$). So the sound suffers from total interval reflection such totally internally reflected sound wave reach back to the earth surface. Hence, sound travels a long distance in the air in the night to hear distinctly to the long distance in day.

Similarly, it is silent at night than the day to hear sound distinctly.

$I \propto \frac{1}{R^2}$ (inverse square law) the intensity of sound propagated is inversely proportional to the square of radius of imaginary sphere around the source and the sound becomes fainter and fainter as it travels a longer distance.

Noise

In fact there is no standard demarcation in between noise and music. Sometimes a music at high volume also may be a source of noise. Noise is an annoying, stressful and unpleasant sound. A sound of more intensity or more loudness is the cause of noise. Different types of vehicles, industries, machineries fire crackers, explosion of bombs, lightening, music systems, public lectures etc are the major sources of noise.

As noise is unpleasant, it causes stress in our body. People also may sick by noise. It may cause deafness too in human beings. Thus an exposure of ears in noise for a long time is very harmful to us. It also increases blood pressure, anger and irritation.

We can reduce noise and can minimise its adverse effect our surrounding.

The following measures can be applied for this purpose.

1. By plantation at the sides of a road and around industrial areas.
2. By shifting human settlements away from industrial areas, international, airports etc.
3. By blowing horn less loudly instead of more loud.
4. By using ear muffs by the people working in industries.
5. By keeping machineries in good conditions.
6. By providing awareness programmes to people about the adverse effects of noise on their health.

Lesson Summary

1. Sound is the form of energy that produces the perception of hearing.
2. Sound wave is longitudinal in nature and is also called mechanical wave.
3. Sound wave cannot propagate in vacuum.
4. Compression is the region of longitudinal wave having greater particle density.
5. Rarefaction is the region of longitudinal wave having less particle density.
6. Number of complete waves produced in one second is the frequency of that wave.
7. Speed of sound is the product of wave length and frequency.
   or, $v = \lambda \times f$
8. An audible sound has frequency between 20 Hz and 20 kHz. An infrasound has frequency less than 20 Hz. An ultrasound has frequency more than 20 kHz.
9. Infrasound is produced by huge vibrating objects.

10. Ultrasound is produced by vibration of crystals.
11. Ultrasound is used to detect fault in human body, to measure depth of ocean and to kill bacteria.
12. Speed of sound in gas < speed of sound in liquid < speed of sound in solid.
13. Speed of sound in gaseous mediums depends upon the following factors.
    - $v \propto \frac{1}{\sqrt{\rho}}$ (density)
    - $v \propto \sqrt{T}$ (Temperature)
    - $v \propto$ Humidity
    - speed of sound is higher along the direction of wind.
14. Pitch is the measure of shrillness of sound.
15. Intensity of sound is the propagation of energy per unit area perpendicular to the direction of wave per second. Its unit is watt per metre^2.
    Intensity $\propto$ (amplitude)^2.
16. Threshold of hearing is the lowest intensity of sound that can be perceived by normal ears at the frequency of 1 kHz.
    The intensity of threshold of hearing = 10^{-12} watt m^{-2}.
17. The loudness of sound at any intensity level is measured in terms of intensity of threshold of hearing. Its unit is bel and its small unit is decibel.
18. The loudness of threshold of hearing is considered 0 decibel.
19. Echo and reverberation are the products of reflected sound.
20. Sound also refracts like other forms of energy. It travels longer distance at night and shorter distance at day.
21. The unpleasant sound is called noise.

Project work

Make your own sonometer.

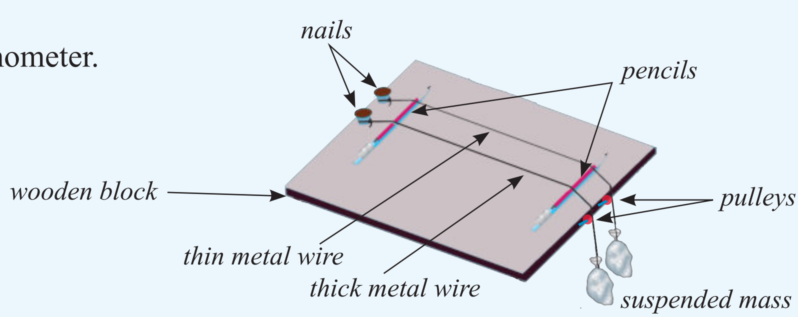


Fig.6.11: *Sonometer model*

Study the diagram and make your own sonometer. Study the pitch and loudness of sound using it.

Conceptual questions with their answers

Q.1. Sound is a mechanical wave. Justify.

It is a matter of fact that sound cannot propagate itself without any material medium which is the property of mechanical wave. Therefore sound is a mechanical wave.

Q.2. In which medium (among solid, liquid and gas) does sound wave travel fastest?

Sound travels fastest in solid. It is because molecules are closest in solid. Therefore they can transmit energy easily among each other in contrast to liquid or gas.

Q.3. Why is the flash of light seen before the sound that comes from the thunder? Explain.

As we know that both sound and light are the forms of wave. And the velocity of light wave is much faster than that of sound in air. That is why sound is heard later but light is seen earlier during thunder.

Velocity of light in air = 3×10^8 m/s

Velocity of sound in air = 332 m/s

Exercise

1. Define the following terms

a. wave b. longitudinal wave c. echo

d. amplitude e. intensity of sound f. ultrasound

2. Write the difference between.

a. Transverse wave and longitudinal wave
b. Echo and reverberation
c. Music and noise
d. Infrasound and ultrasound
e. Compression and rarefaction

3. Answer the following questions

a. What is the speed of sound? On which factors does it depend?
b. What are the necessary conditions to produce echo?
c. What does threshold of hearing mean? What is the intensity and loudness of threshold of hearing?
d. What are the effects of noise?

e. Write some ways to reduce noise?
f. What does audible sound mean? Write the frequency of sound that can be detected by human ears. Calculate the maximum and minimum wave lengths of such waves. (speed of sound in air is 332 m/s)
g. If you are blindfolded and kept in a place with hands and legs tied, how do you identify whether you are in
   i. an open place
   ii. a room with household materials
   iii. an empty room
h. The sound produced at a place is heard fainter in the long distance. Why?

4. Give reason.

a. Sound waves are called mechanical waves.
b. Sound cannot propagate in vacuum.
c. Sound travels longer distance at night.
d. Sound propagates slowly in gaseous medium.
e. Sound-absorbing materials are kept on the walls and ceilings of conference halls.
f. Sound produced by a woman is sharper than that is produced by a man.
g. Airports are to be constructed far from the city.
h. All types of sound have the same speed in a particular medium.

5. Solve the following numerical problems.

a. Calculate the depth of the ocean if ultrasonic pulses produced are received after 9 seconds. (Speed of sound in water = 1498 m/s) [Ans: 6741 m]
b. Calculate the maximum and minimum wave lengths of sound wave that can be heard by human ears. (speed of sound in air = 332 m/s) [Ans: 16.6 m, 0.0166]
c. A fathometer sends ultrasound and hears its echo after 7.5 sec area point in the Pacific ocean. Calculate the depth at the point if the speed of sound in water is 1490 m/s. [Ans: 5587.5 m]
d. If X, Y and Z are the sound waves produced by a crying child a mosquito flying and a girl speaking, Answer the following questions.
i. Identify the sound produced by each of them
ii. If the speed of sound in air is 332 m/s, calculate the wave length of sounds X and Z.

Source	Frequency
X	750 Hz
Y	1200 Hz
Z	1000 Hz

[Ans: 0.44 m, 0.033m]

e. The speeds of sound in solid, liquid and gaseous medium are given in the table. Study them and answer the following questions.

Medium	Speed (m/s)
X	332
Y	5100
Z	1498

i. Identify the medium X, Y and Z.
ii. Calculate the frequency of the sound wave in Z medium if the wave length is 2 m. [Ans: 749 Hz]
f. Calculate the maximum and minimum wave lengths of sound that can be heard by human ears. [Ans: 16.6 m, 0.0166 m]
g. Stuti shouts from an echo centre and hears echo after 4 sec. Calculate the distance of the reflecting hill from Stuti. [Ans: 664 m]

Multiple Choice Questions

1. Tick (√) the correct answer.

a. Which wave never needs material medium?
   i. Sound wave ii. Electromagnetic wave
   iii. Transverse wave iv. Longitudinal wave
b. The frequency of audible sound is:
   i. 15 Hz to 15 kHz ii. 10 Hz to 10 kHz
   iii. 18 Hz to 18 kHz iv. 20 Hz to 20 kHz
c. When reflected sound mixes with original sound it is called
   i. Reverberation ii. Echo
   iii. Defraction iv. Refraction
d. For echo, the distance between the source of sound and reflector should be
   i. 19 m ii. 30 m
   iii. 15 m iv. 17 m
e. Speed of sound in water is:
   i. 332 m/s ii. 1500 m/s
   iii. 3000 m/s iv. 1000 m/s

Unit 7 Current, Electricity and Magnetism

Total estimated teaching hours = 12

Learning Outcomes

After the completion of this unit, students will learn:

- *demonstration of Ohm's law and relation of ampere, volt and ohm.*
- *factors that affect resistance.*
- *measurement of conductivity and resistivity.*
- *definition of magnetic field and magnetic lines of force.*
- *to explain terrestrial magnetism and angle of dip and declination.*

George S. Ohm (1787AD-1854AD)

KEY WORDS

1. **Potential energy** : the energy possessed by the position or condition of a body
2. **Kinetic energy** : the energy possessed by the motion of a body
3. **Turbine** : a device connected with a number of blades used to spin by flowing water
4. **Geographical meridian** : the imaginary line connecting geographical north and south poles
5. **Magnetic meridian** : the imaginary line connecting magnetic north and south poles
6. **Magnetic poles** : the points in a magnet having maximum magnetic strength
7. **Ammeter** : an instrument used to measure electric current
8. **Voltmeter** : an instrument used to measure pd and emf
9. **Absolute temperature** : the temperature at which motion of molecules ceases. (-273°C)

Introduction

Electrical energy is very useful for human beings. It is a renewable source of energy and used for doing very simple to complex work. Many machineries and industries use current electricity. Current electricity is that which can be transferred from one place to another through a conducting wire. In our country, the main source of electrical energy is hydroelectrical power. For it, the water flowing in rivers is stored in reservoirs. The stored water has potential energy due to its height. The water flows through a tunnel that changes into kinetic energy and spins turbine. When the turbine spins electric generator, the kinetic energy changes into electrical energy. In generators, magnets are also used with the help of magnetic energy. The conversion of kinetic energy into electrical energy facilitates. We also get electrical energy from different types of electric cells which change chemical energy into electrical energy.

Some terms related to current electricity

Electric current, potential difference, electromotive force and electric resistance are some common terms used frequently while explaining about current electricity. Now a short description of them is given below.

a. Electric current

The rate of flow of electric charge is called as electric current. It is denoted by 'I' and its SI unit is ampere (A).

$$\text{or, } I = \frac{Q}{t}$$

Here,

I = Electric current

Q = Electric charge

t = Time taken

1 A current is defined as the current flowing in a circuit when 1 coulomb charge flows through it in 1 s.

$$\text{or, } 1A = \frac{1c}{1s}$$

1 milli ampere (mA) = 10^{-3}A

1 micro ampere (μA) = 10^{-6}A

Fact file:

Coulomb is unit of electric charge. 1 c charge is the electric charge equivalent to the charge of 6.25×10^{18} electrons.

Ammeter is the instrument used to measure electric current. It is connected in series with load as shown in the diagram.

Why is ammeter connected in series?

Ammeter has low resistance so there is no change in the total resistance as a whole. Due to this reason, ammeter is connected with the electric circuit.

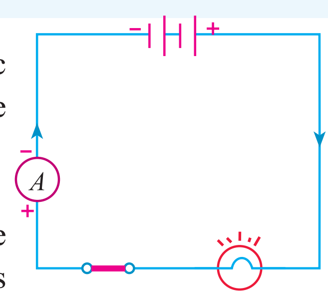


Fig.7.1: *Connection of ammeter (series with load)*

b. Potential difference (pd)

The amount of work done to bring about 1 coulomb charge from one point to of electric field to the other point is called potential difference between these two points. It is denoted by pd or v. SI unit of potential difference is volt (v)

$$\text{or, } V = \frac{W}{Q}$$

Here,

V = potential difference

W = work done

Q = electric charge

Voltmeter is connected parallel with load to measure pd. It can also be connected parallel with source in a closed circuit to measure pd.

1 v pd is defined as 1 joule work done by the flow of 1 coulomb charge.

$$1 \text{ v} = \frac{1\text{J}}{1\text{c}}$$

It is measured by using voltmeter which is connected in parallel with load, in closed circuit as shown in the diagram.

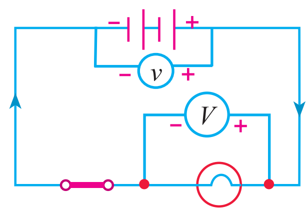


Fig. 7.2: Connection of voltmeter (parallel with load)

c. Electromotive force (emf)

Electromotive force is defined as the energy converted by a source of electric current to flow unit charge in a circuit. Its SI unit is also volt (v) and it is denoted by emf. Voltmeter is used to measure emf. Voltmeter is connected parallel to source in an open circuit to measure emf.

Activity: To demonstrate emf and pd.

Materials needed: conducting wire, switch, lamp, voltmeter, cell.

Method:

1. Complete an electric circuit using a cell, a torch bulb, switch, connecting wires and voltmeter as shown in the diagram.

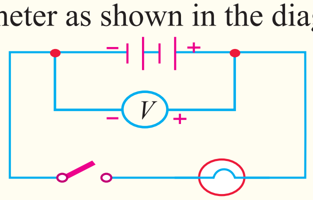


Fig. 7.3: Measurement of emf

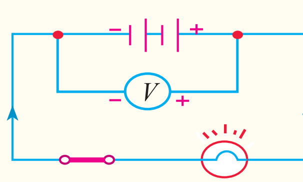


Fig. 7.4: Measurement of pd

2. Record the voltmeter reading while switch is off.

3. Switch it on to make the bulb glow and record the voltmeter reading again.
4. Do you find any difference?

The former reading is emf of cell and the later one is the terminal potential difference across the resistance.

The difference between emf and pd are given below.

Emf	Pd
1. It is the pd across the electrodes of a cell in an open circuit. 2. Emf is a cause. 3. Emf is independent of external resistance. 4. Emf is greater than Pd.	1. It is the pd across the electrodes of a cell in a closed circuit. 2. Pd is an effect. 3. Pd depends upon external resistance. 4. Pd is lesser than emf

d. Resistance

Resistance is the property of a conductor by virtue of which it opposes the flow of current through it. Different substances have different resistances. It also depends on length, thickness and temperature of wire. It is also defined as the potential difference across a conductor when 1 ampere current flows through it.

$$R = \frac{V}{I}$$

$$\therefore \Omega = \frac{\text{Volt}}{\text{Ampere}} = VA^{-1}$$

One Ohm Resistance is defined as the resistance produced in a conductor if 1 ampere current flows through it when 1 volt pd is applied across it.

Factors that affect resistance

The major factors which affect on resistance of a conductor are length of conductor, cross-sectional area of conductor, temperature of conductor, shape of conductor and nature of conductor. Their relation with resistance is described.

1. length of conductor: The resistance produced in a conducting wire is directly proportional to its length for a constant temperature.

i.e. $R \propto l$ .... (i)

2. Cross-sectional area of conductor: The resistance produced in a conducting wire is inversely proportional to the cross-sectional area of wire. i.e. thickness of wire at a constant temperature.

$R \propto \frac{1}{A}$ .... (ii)

3. Temperature of conductor: Resistance produced in a conducting wire is directly proportional to its temperature.

$$R \propto T$$

4. Shape of conductor: A coiled wire has more resistance than straight wire as it produces magnetic field that oppsoses the flow of current.

5. Nature of material: Different conductors have different scales of resistance under constant physical conditions.

Resistivity of a conductor

Resistivity of a conductor is defined as the resistance of unit cross sectional area of that conductor per unit length of it. It is denoted by Rho (ρ).

$$\text{or } \rho = \frac{RA}{l}$$

Unit of resistivity is ohm metre (Ωm)

$$\left[\begin{array}{l} R \propto \frac{1}{A} \text{ and } R \propto l \\ \textit{Thus, } R \propto \frac{l}{A} \\ \text{or, } R = \rho \frac{l}{A} \\ \therefore \rho = \frac{RA}{l} \end{array}\right]$$

Conductivity of a conductor

Conductivity is reciprocal of resistivity. It is denoted by sigma (σ).

$$\text{or } \sigma = \frac{1}{\rho}$$

Its SI unit is per ohm/meter or $\Omega^{-1}m^{-1}$.

The substances having more resistivity have less conductivity and vice-versa. Good conductors like copper aluminium, silver, gold, graphite etc. have less resistivity but more conductivity. Tungsten, constantan, nichrome, manganin etc like materials have more resistivity i.e. less conductivity.

Ohm's law

Ohm's law states that *"At constant physical conditions, the electric current flowing through a conducting wire is directly proportional to the potential difference across its two ends".*

Let, V be the pd across the conductor, I be the current flowing through it.

i.e. $\quad I \propto V$

or, $V \propto I$

or, $V = IR$

Where R is proportionally constant and is called resistance.

Activity: Verification of Ohm's law

Materials needed: dry cells, resistor, volt meter, ammeter and switch

Method:

1. Complete an electric circuit with the help of dry cells, a resistance wire, voltmeter, ammeter and connecting wires as shown in the diagram.
2. Use one dry cell in circuit and record the reading of voltmeter and ammeter connected in the circuit.
3. Increase the number of dry cells and record the reading again.
4. Complete the under mentioned table.

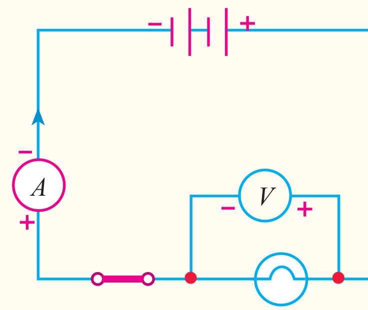


Fig.7.5: Verification of Ohm's law

Observation table

No. of cells	1	2	3	4
Voltmeter reading (V)	1.5 V			
Ammeter reading (I)	0.3 A			
$R = \frac{V}{I}$	5 Ω			

The voltmeter and ammeter reading gives the under mentioned curve.

i. The straight line represents that current is directly proportional to pd.

ii. I = 0 A for V = 0 V indicates that there is no flow of current between two equipotential points.

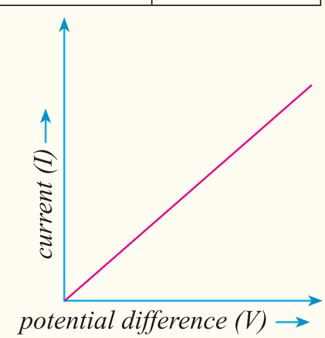


Fig.7.6: IV curve

Solved numerical problems

1. Calculate the resistance of a bulb if 4 A current flows through it when it is connected with 6 V battery.

Here,

Potential difference (V) = 6 V

Current flow through the bulb (I) = 4 A

Resistance of bulb (R) = ?

Now,

$$R = \frac{V}{I} = \frac{6}{4}$$

$$= 1.5\ \Omega$$

2. Calculate the potential difference of a bulb of 6 Ω to make 3.5 A current flow through it.

Here,

Current flow through the bulb (I) = 3.5 A

Resistance of bulb (R) = 6 Ω

Potential difference (V) = ?

Now,

$$V = I \times R \quad \text{(from Ohm's law)}$$

$$= 3.5 \times 6\ V$$

$$= 21\ V$$

Thus, required potential difference is 21 V.

Magnetism

Magnets show magnetic properties. They attract magnetic bodies and rest in north south directions when hanged freely to move. Like magnetic poles repel and unlike magnetic poles attract. Magnets can affect on magnetic bodies and magnets in their magnetic field only.

Magnetic field

The area around a magnet to which the magnet can affect on magnetic bodies is called as magnetic field of that magnet.

Activity: To demonstrate magnetic field around a bar magnet.

Materials required: magnet, white paper, iron filings.

Method:

Keep a bar magnet under a card board and sprinkle iron filings on the cardboard and tap it gently.

i. Does any pattern appear on the cardboard?

ii. Where are these patterns directed?

You will find that the iron filings are adjusted in a certain pattern showing magnetic field of that magnet.

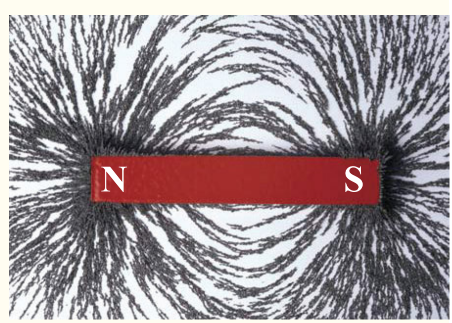


Fig.7.7: *A bar magnet showing magnetic field*

Magnetic lines of force

Magnetic field of a magnet is shown by lines of force. Magnetic lines of force are defined as the continuous imaginary path traced by a freely moving unit north pole in the magnetic field of a magnet. The direction of magnetic lines of force outside a magnet is from north to south but inside a magnet is from south to north. They do not intersect each other. It is because a line of force is in a single direction of magnetic force at a particular point of the magnetic field.

Activity: Plotting magnetic lines of force

Materials required: A bar magnet, card board, magnetic compass, pencil

Method:

1. Fix a white paper on a cardboard by using thumb pins.
2. Place a bar magnet at its middle in north south directions and draw its border line around the magnet.
3. Now, place a magnetic compass at the north and of the magnet. It attracts the south pole of the compass.
4. Tap the table gently. Mark the point shown by the north pole of the compass at rest by using a pencil.
5. Replace the compass in such a way that the south pole indicates the mark made.

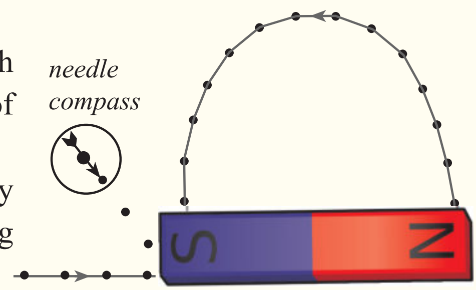


Fig.7.8: *Magnetic lines of force*

6. Repeat the processes till the compass reaches to the south pole of the bar magnet.
7. Get a magnetic line of force by connecting the points obtained with the two ends of the magnet. Also show direction on it from north to south.
8. Try to get all the magnetic field of the magnet using magnetic lines of force.

In magnetic field of a magnet you may discover some points at which the magnetic compass is passive.

The points are called neutral points.

Neutral points

Neutral points of a magnet are defined as the points where the magnetic field of the magnet is neutralized by the horizontal component of terrestrial magnetism. When lines of force are plotted inclining the north pole of bar magnet in geographical north, the neutral points lie at the sides of the magnet. When the south pole of the bar magnet is pointed in geographical north the neutral points lie at the ends of the magnet. Study the diagrams given in 7.9 and 7.10.

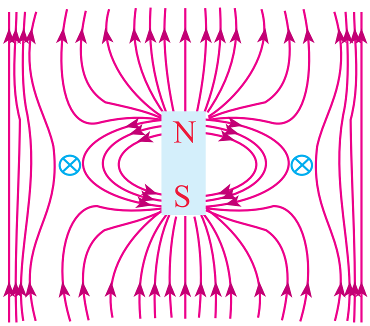


Fig.7.9: Neutral point for the north pole pointing to north

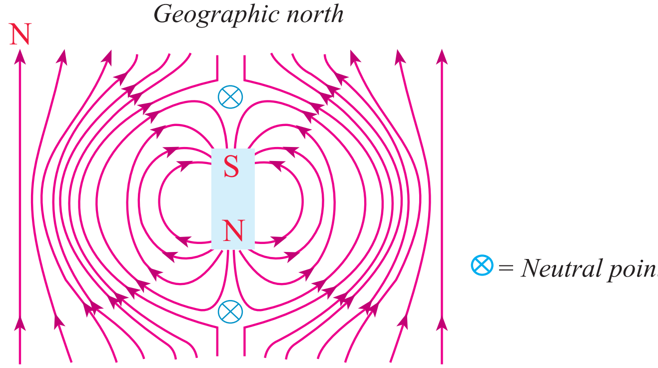


Fig.7.10: Neutral point for the north pole pointing to south

In other words it is a point in the magnetic field of a magnet where the resultant magnetic field is zero i.e. field due to the magnet and that of the earth is equal and opposite.

Terrestrial magnetism

Why does a freely suspended magnet always show the particular direction? It is the effect of repulsive property of a magnet. Where does the next magnet lie? The earth itself behaves as a huge magnet and property of the earth is called terrestrial magnetism. From studies it is known that the south pole of the earth's magnet lies near Thule, Greenland (North Canada) and is 1250 km west from geographical north pole. The north pole of the earth's magnet lies near Vostok, Antarctica (South Victoria land) that is about 1250 km east from the geohraphical south pole.

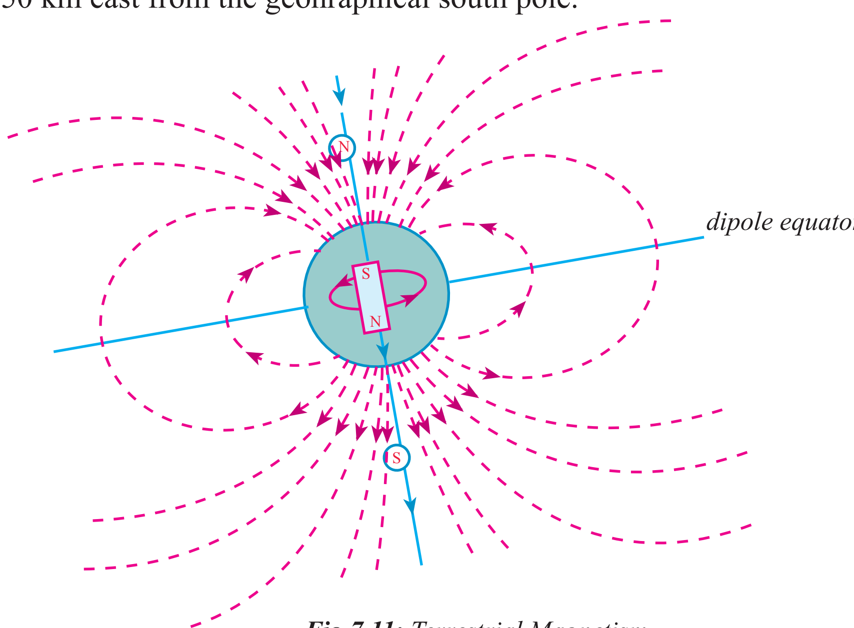


Fig.7.11: Terrestrial Magnetism

There are various assumptions about the cause of terrestrial magnetism. The latest and more relevant is "Magnetic field of the earth is caused by the electric currents arising from radioactive heating inside the earth".

Some supporting evidences of terrestrial magnetism.

1. A freely suspended magnet at its centre of gravity always points to a fixed direction at a place.
2. If magnetic lines of force are drawn using a magnetic compass, a set of parallel lines are obtained on a plane sheet of paper. It is due to the earth's magnetic field.
3. There are neutral points inside the magnetic field of a magnet.
4. There is exist once of an angle of declination and an angle of dip at any place of earth surface.
5. If a soft iron core is buried into the dry soil for some days, it acquires weak magnetism.
6. There is the existence of natural magnet inside the earth.

Angle of declination

The imaginary vertical plane passing through any place on the earth's surface and the geographic axis of rotation of earth is called geographic meridian. The imaginary vertical plane passing through the magnetic axis of freely suspended magnet at any place on the surface of the earth is called magnetic meridian at that place.

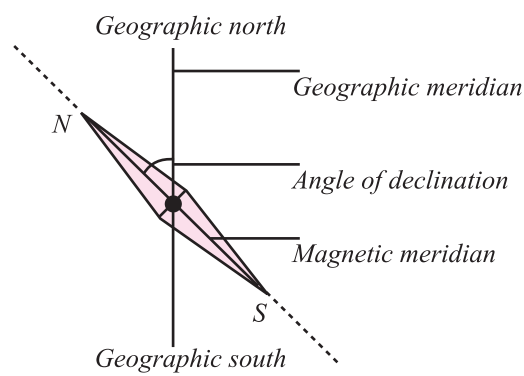


Fig.7.12: *Angle of declination*

The angle of declination at a place on the earth's surface is defined as an angle between the geographic meridian and magnetic meridian at that place.

The value of angle of declination varies from one place to another place on the earth's surface. Its value is 17° at equator. It may be towards east and west. It varies from place to place and time to time. Angle of declination is used to find the location of any place during navigation.

Angle of dip/Inclination

The angle of dip at a place on the surface of earth is defined as the angle between total magnetic intensity or earth magnetic field and with the horizontal direction. Angle of dip at a place may be measured by using a dip needle.

The angle of dip varies from place to another on earth's surface. It is zero in the magnetic equator of the earth as the earth magnetic field in this region is parallel to horizontal direction. It goes on increasing when we move to the north or south. It is 90° at the magnetic poles of earth. But it is not perpendicular to horizontal direction at geographical poles because geographical and magnetic poles of the earth do not coincide.

The angle of dip at Kathmandu is 42°. It means that the dip needle sets itself making 42° with horizontal line in Kathmandu.

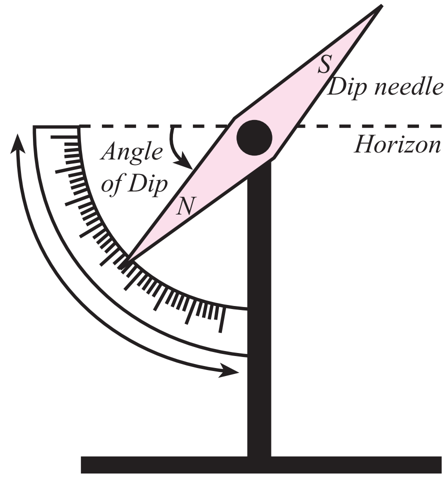


Fig.7.13: *Dip needle*

Lesson Summary

1. Cells and photocells are the chemical sources of electricity, and generator and dynamo are the mechanical sources of electricity.
2. Metals are the good conductors of electricity because they have almost free electrons in their outermost shell.
3. Rate of flow of charge through a conducting wire is called electric current. Its unit is ampere.
4. One ampere is the amount of current flowing through a conductor when one coulomb charge flows through it in one second.
5. Amount of work done to carry one coulomb charge from one end of conductor to another end is called potential difference. It is measured in volt.
6. One volt is defined as the potential difference between two points as an electric circuit that has done one joule work when one coulomb charge flows through it.
7. Electromotive force is the energy converted by an internal circuit of cell to make a flow of one coulomb charge in an external circuit.
8. Resistance is the property of a conducting material with the help of which it opposes the flow of current. Its unit is ohm.
9. One ohm is defined as the resistance of a conducting wire through which one ampere current flows when one volt pd is set across it.
10. Resistance of a wire depends upon:
    - length of wire
    - cross section area of wire

- absolute temperature of wire
- nature of material

11. Resistivity is the resistance of a wire of unit length having unit cross-section area per unit length of it.
12. Ohm's law states that "At constant physical condition the flow of current through a conducting wire is directly proportional to the potential difference between its two ends".
13. Magnetic field is the space around a magnet up to which its influence can be experienced.
14. Neutral point is the point where magnetic field of a magnet is neutralized by horizontal component of terrestrial magnet.
15. The earth behaves as a huge magnet.
16. The angle of declination at a place on the earth's surface is the angle between the geographic meridian and magnetic meridian at the place.
17. The angle of dip is the angle between the total magnetic intensity of earth's magnetic field and the horizontal direction

Project work

Activity: Study the resistance of wire.

Materials required: A conducting wire, cells, switch, thin copper wire, spirit lamp, pliers, ammeter, clamps

Method:

Make a circuit as shown in the diagram. Connect point A with point B with a thin copper wire. Note the reading shown by the ammeter.

Replace the wire with two pieces of wire of the same length, then three pieces and four pieces respectively. Find the difference in the current shown by ammeter.

Now connect A with B with a single wire again. Heat the wire using a spirit balance. Note the reading with the ammeter.

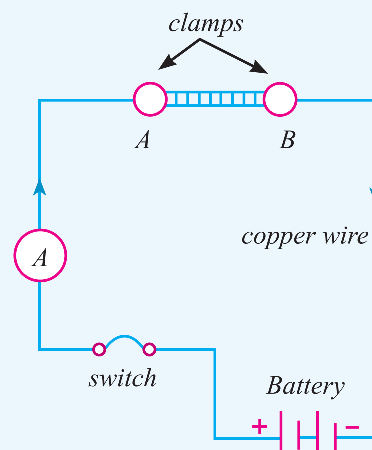


Fig. 7.15:

Analyze the result obtained. Note the final result and show it to your science teacher.

Conceptual questions with their answers

Q.1. Dry cells are safe from polarisation. Why?

As we know that dry cells consist of a paste of manganese dioxide (MnO_2) which acts as depolariser and also MnO_2 reacts with hydrogen to form water. Therefore there is no deposition of hydrogen gas for the polarisation.

Q.2. Soft iron is used in electric bell. Why?

On passing electric current through a soft iron the soft iron becomes temporary electromagnet having high strength. Therefore it is used in electric bell.

Q.3. Which one is better Fluorescent lamp or Filament lamp?

It is the Fluorescent lamp which is better because it is three times more efficient than Filament lamp. Out of 100% of electrical energy Fluorescent converts 30% into the light energy whereas Filament converts only 10% into the light energy.

Q.4. The two glass rods when rubbed with fur repel each other. Why?

They both develop similar changes when rubbed with fur. That's why they repel each other.

Q.5. A magnet exerts more influence (effect) on its poles than on its middle Why?

In the middle zone, the molecular magnets are engaged in each other but at poles they are all free to attract the other magnet or magnetic substance.

Q.6. Is it possible to separate the magnetic poles of magnet? If not, why?

No, it is not possible to separate the magnetic poles of a magnet as we know from the molecular magnet theory that each molecular consists of a pair of N.S. poles in it.

Q.7. A freely suspended magnet always remains in the north-south direction. Why?

It is because of the earth's magnetism. Earth's magnet whose north pole faces the geographic south pole and south pole faces the geographic north pole. Because of this fact suspended magnet comes to rest and align itself along the direction of magnetic field at the place. Simply, earth's magnetic poles are opposite to the geographic poles. Therefore the poles of a magnet are attracted by the opposite poles of the earth's magnetism.

Exercise

1. Define the following terms.

a. Potential difference
b. One ampere current
c. Resistance
d. Magnetic field
e. Neutral point
f. Angle of dip
h. One volt pd
g. Angle of declination
i. One volt emf

2. Give the difference between.

a. emf and potential difference.
b. resistivity and conductivity.
c. angle of dip and angle of declination.
d. voltmeter and ammeter.

3. Answer the following questions.

a. What is an electric circuit? Draw a schematic circuit diagram having 6 V dc, a load, voltmeter, switch, ammeter.
b. State Ohm's law. What does the curve through origin in I-V curve mean?
c. What are the factors on which resistance of a conductor depend?
d. Write some arguments to prove that the earth itself behaves as a magnet.
e. What is terrestrial magnetism?
f. Angle of dip in Kathmandu is 42°. What does it mean?
g. What do you mean by 1 V p.d?
h. What is neutral point?

4. Give reason.

a. Potential difference is always less than emf in a closed circuit.
b. Metals are good conductors of electricity.
c. A coiled wire produces more resistance than a straight wire of equal length.
d. A freely suspended magnet always shows north and south poles.
e. Angle of dip is not 90° at geographical pole.
f. Ammeter is connected in series with load in a circuit.
g. Voltmeter is connected parallel with load in the circuit.
h. Magnetic compass does not show exact direction.

5. Solve the following numerical problems.

a. A lamp is connected in 24 V supply. If 2.66 A current is flowing in it, calculate the resistance of the wire of the lamp. [9.02 Ω]

b. Calculate the amount of current flow through a circuit if 240 coulomb charge flows in 3 minutes. [1.33 A]

c. Calculate the resistance of 60 W bulb connected in 220 V supply. [806.67 Ω]

d. An electric load is connected in 220 V Mains. Calculate the flow of electric current in the circuit if its resistance is 50 Ω. [4.4 A]

e. An electric bulb of 100 W is connected to 220 V. Calculate the resistance of the bulb. Also calculate its resistivity and conductivity if its length is 2 m and 1 m^2 cross sectional area respectively.

[484 Ω, 242 Ωm, $4.13 \times 10^{-3}\ \Omega^{-1}m^{-1}$]

Multiple Choice Questions

1. Choose the correct answer:

a. The rate of flow of charge in a circuit is

i. Electric current　　ii. Electric resistance

iii. Potential difference　　iv. Electromotive force

b. The relation V/I shows

i. Electric current　　ii. Electric resistance

iii. Potential difference　　iv. Electromotive force

c. SI unit of potential difference is

i. Ω　　ii. A

iii. Ωm　　iv. V

d. The value of angle of dip at magnetic equator is

i. 90°　　ii. 0°

iii. 17°　　iv. More than 20°

e. The direction of magnetic lines of force inside a magnet is

i. North to south　　ii. South to north

iii. Random　　iv. No direction

Chemistry

ANTOINE LAVOISIER

(20 August 1743 – 8 May 1794)

Known as

the Father of modern chemistry
he recognized and named oxygen
and hydrogen and is best known for
combustion and stoichiometry

I consider as nature a vast chemical laboratory in which all kinds of composition and decomposition are formed

- Antoine Lavoisier

Chapters to study

Unit 8 Classification of elements

Total estimated teaching hours = 11

Learning Outcomes

After the completion of this unit, students will learn:

- *description and demonstration of atomic structure and electronic configuration of elements.*
- *definition of valency as combining capacity of element.*
- *description of radical and ion with examples.*
- *the method of writing molecular formula.*
- *chemical bonding and molecular structure of substances.*

Niels Bohr (1885AD-1962AD)

KEY WORDS

1.	**Sub-atomic particles**	: the particles of atoms which constitute them
2.	**Electronic configuration**	: arrangement of electrons in atom
3.	**Energy level**	: synonym of shell or orbit
4.	**Duplet**	: an atom containing a single shell with $2e^-$ in it
5.	**Octet**	: an atom containing eight electrons in the last orbit
6.	**Unstable**	: changeable
7.	**Vigorous**	: using great energy
8.	**Lone pair**	: the shared pair of electrons which is donated by only one component of a molecule
9.	**Aquous solution**	: a solution formed in water

Introduction

Any stuffs we see around us or beyond are matters. All matters are composed of atoms. Matters are of different kinds as they are composed of different atoms. Sometimes the arrangement of the same atoms varies from one substance to another substance. That makes matter different from each other. 118 elements are known till now, out of which 92 are natural and 26 are artificial. These elements have different types of atoms. Atoms contain sub-atomic particles in them in fixed numbers. In an atom, the number of protons and the number of electrons are equal naturally but the number of neutrons may be the same or different from the number of protons. From these atoms uncountable substances (elements and compounds) are formed. Now we will study atoms and the terms related to them.

Atom

The term atom was coined by John Dalton (1766-1844 AD).
An atom is the smallest particle of an element that can take part in a chemical reaction. Atoms may or may not exist independently.
All the elements and compounds are made of atom or atoms. For example a molecule of oxygen (O_2) is made of two atoms of oxygen but a molecule of magnesium (Mg) is made of a single atom of magnesium. Similarly, a molecule of water (H_2O) is made of two atoms of hydrogen and an atom of oxygen. As 118 elements are discovered till now, the types of atoms are also of the same number i.e. 118. All the atoms of the same elements are similar but the atoms of different elements are different. Hydrogen is the simplest element of all while Helium is the lightest element. Osmium is considered to be the heaviest element. Inert elements are relatively bigger and lighter than other elements.
Atoms are so small that a pin head contains millions of atoms. The radius of hydrogen atom is 10^{-10} m or 0.1 nm (nanometer) or 10^{2} pm (picometer).
$1 \text{ nm} = 10^{-9} \text{ m}$
$1 \text{ pm} = 10^{-12} \text{ m}$

Structure of an atom

Atoms are composed of sub-atomic particles called protons, electrons and neutrons. An atom of element is thought to consist of very small and extremely dense region called the nucleus which is surrounded by the cloud of negatively charged particles. Among the three sub-atomic particles, protons and neutrons are found in the dense nucleus and electrons are found in the planetory orbits.
The orbits around which the electrons go are named as K, L, M, N, O, P and Q for the first, second, third, fourth, fifth, sixth and seventh orbits from the nucleus respectively. These orbits are also called shells or energy levels. The region inside each of such orbit/shell is filled with a definite number of electrons. Such regions are called sub-shells or orbitals. They are named as s, p, d and f.

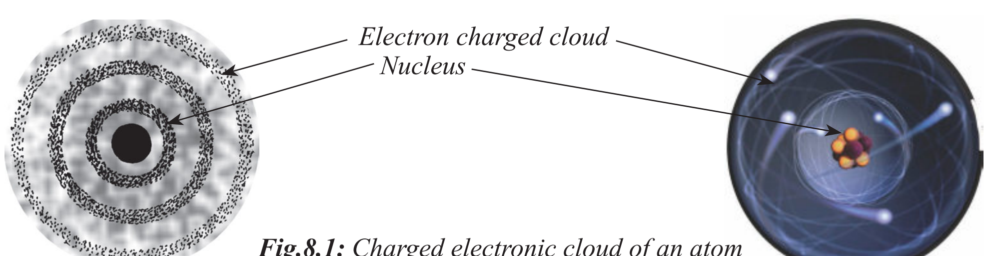
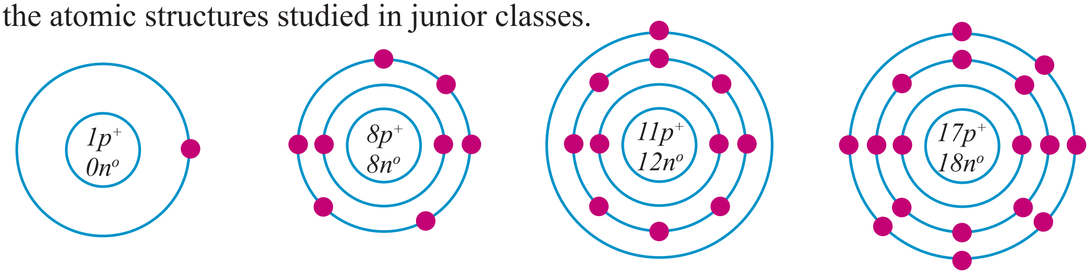


***Fig.8.1:** Charged electronic cloud of an atom*

The atoms of different elements have different number of protons, electrons and neutrons. Proton, electron and neutron are called sub-atomic particles. The number of protons present in the nucleus of an atom is a fundamental characteristic of the element. An atom is electrically neutral as the number of protons is always the same as that of electrons. Atomic structures of some atoms are given below to remind you of the atomic structures studied in junior classes.



Hydrogen atom *Oxygen atom* *Sodium atom* *Chlorine atom*

Fig.8.2: *Atomic model*

Properties of subatomic particles

Sub-atomic particles	Mass	Relative mass (with at mass of H)	Charge
Proton (p^+)	1.00758 amu	1	+ve
Neutron (n^0)	1.00898 amu	1	zero
Electron (e^-)	0.000544 amu	1/1840	-ve

Table 8.1 Details of sub-atomic particles

Atomic Number (Z)

The total numbers of protons or electrons present in an atom is called atomic number of that atom.

Atomic number = No. of protons = No. of electrons

or, $Z = p^+ = e^-$

Atomic number of phosphorus is 15. It shows that the atom of phosphorus has 15 protons and 15 electrons in it. Now try to tell the number of p^+ and e^- in Na, Ca, P and Ar.

Atomic Weight (A)

The sum of the number of protons and the number of neutrons present in the nucleus of an atom is called atomic weight of that atom. Atomic weight can also be called as atomic mass. It is denoted by A. Its unit is atomic mass unit (amu).

Atomic weight = No. of protons + No. of neutrons

or, $A = p^+ + n^0$

Phosphorus has 15 p^+ and 16 n^0, so its atomic mass is 31 amu. Now tell the atomic mass of Na, Ca, P and Ar giving reasons.

Electronic Configuration

The systematic arrangement of elements in different shells or orbits around the nucleus of an atom is called electronic configuration. A shell is the space around the nucleus of an atom in which electrons revolve round the nucleus of the atom. Shell or Orbit can be represented by K, L, M, N, O, P and Q with number 1, 2, 3, 4, 5, 6 and 7 respectively.

Every shell or orbit has a definite number of electrons that can be placed. This number of electrons can be calculated by a formula $2n^2$ called bohr and bury model.

$2n^2$ rule helps us to calculate maximum number of electrons that can be placed in a particular shell or orbit of an atom. The rule can be applied up to N shell only but more than 8 e^- and 18 e^- cannot be placed in the last and second last shells respectively.

Shell	Number of electrons according to $2n^2$ rule	Max. electrons available
K = 1	$2 \times 1^2 = 2$	2
L = 2	$2 \times 2^2 = 8$	8
M = 3	$2 \times 3^2 = 18$	18
N = 4	$2 \times 4^2 = 32$	32

Table 8.2 Bohr and bury model of electronic configuration

In O, P and Q shells the maximum numbers of electrons are 32, 18 and 8 respectively. The shells are also made of different sub shells s, p, d and f. Like in shells, sub-shells also have maximum limit of electrons. In s, p, d and f sub-shells the maximum numbers of electrons are 2, 6, 10 and 14 respectively.

Concept or Sub-shell

Main Shell	Sub-shell (Orbital)
K (n = 1)	s
L (n = 2)	s and p
M (n = 3)	s, p and d
N (n = 4)	s, p, d and f

Table 8.3

The maximum number of electrons that can be accommodated by each sub-shell is given below.

Sub-shell	Maximum no. of electron
s (sharp)	2
p (principal)	6
d (diffuse)	10
f (fundamental)	14

Table 8.4

Study the following table for the better concept of distribution of electrons in different shells and sub-shells.

Shell	Shell no.	Max. no. of e^-	Contained sub-shell	Sub-shell level electronic configuration
K	1	2	s	$1s^2$
L	2	8	s, p	$2s^2$, $2p^6$
M	3	18	s, p, d	$3s^2$, $3p^6$, $3d^{10}$
N	4	32	s, p, d, f	$4s^2$, $4p^6$, $4d^{10}$, $4f^{14}$
O	5	32	s, p, d, f	$5s^2$, $5p^6$, $5d^{10}$, $5f^{14}$
P	6	18	s, p, d	$6s^2$, $6p^6$, $6d^{10}$
Q	7	8	s, p	$7s^2$, $7p^6$

Table 8.5 Orbital electronic configuration model

In **$4d^{10}$**

4 indicates shell number, d is sub-shell and 10 is the maximum number of electrons that can be adjusted in sub-shell d.

If we have to write sub shell-level of electronic configuration, we follow aufbau principle. According to it the electronic configuration of calcium magnesium and neon will be:

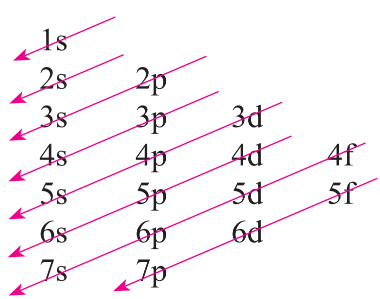
Mg = $1s^2$, $2s^2$, $2p^6$, $3s^2$ = 2, 8, 2

Ca = $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^2$ = 2, 8, 8, 2

Ne = $1s^2$, $2s^2$, $2p^6$, = 2, 8

Now try to write sub-shell level electronic configuration of Ar, K, Al and Si.

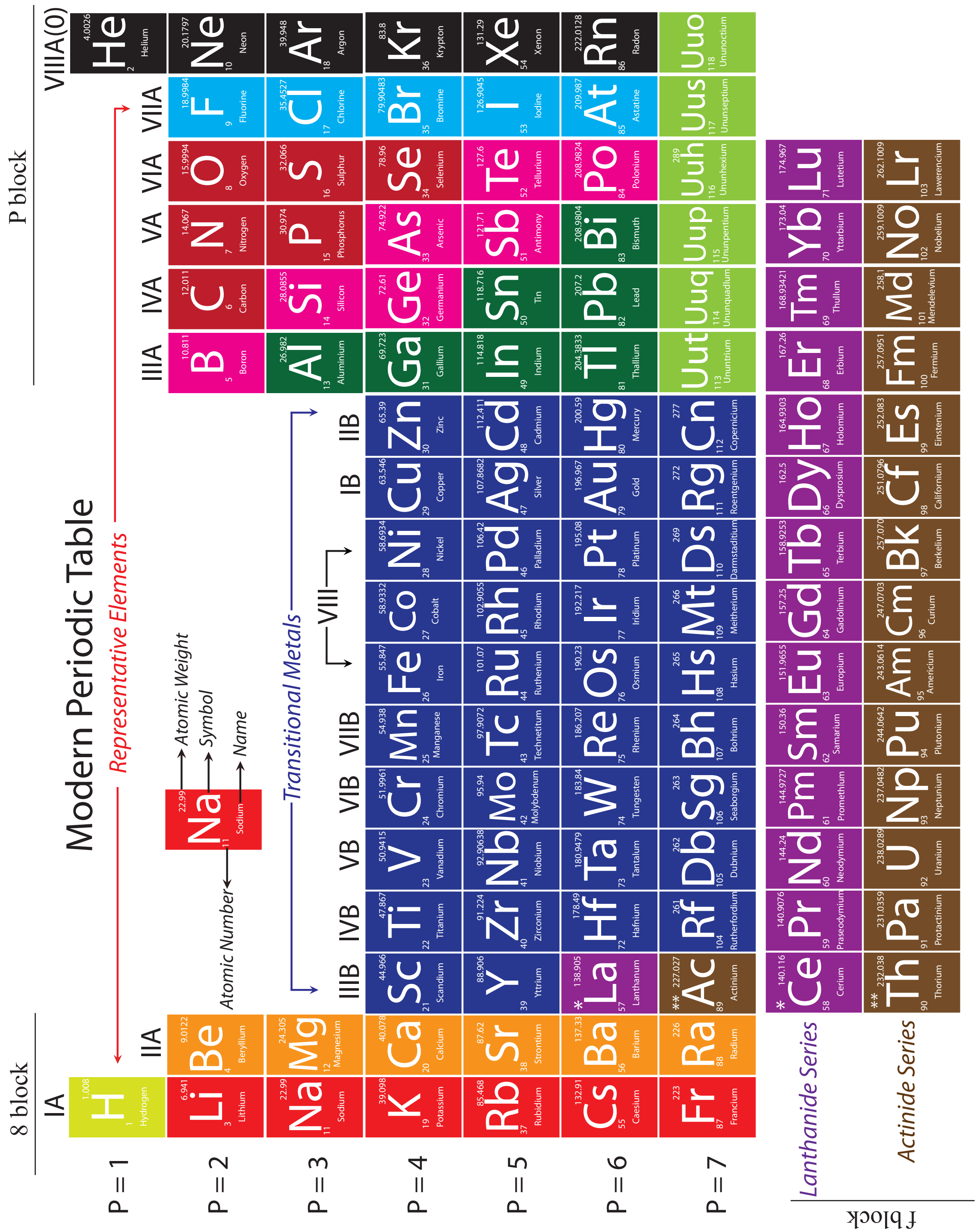
Aufbau principle-



In this way the sequence of sub-shell level of electronic configuration will be

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p$

It shows that electrons should be kept from low energy level to high energy level as shown above. The shells closer to nucleus have less energy than those which are far from the nucleus.



Modern Periodic Table
Representative Elements
Transitional Metals
8 block
P block
f block
IA
IIA
IIIB
IVB
VB
VIB
VIIB
VIII
IB
IIB
IIIA
IVA
VA
VIA
VIIA
VIIIA(0)
P = 1
P = 2
P = 3
P = 4
P = 5
P = 6
P = 7
Atomic Number
Atomic Weight
Symbol
Name
11 Na Sodium 22.99
1 H Hydrogen 1.008
2 He Helium 4.0026
3 Li Lithium 6.941
4 Be Beryllium 9.0122
5 B Boron 10.811
6 C Carbon 12.011
7 N Nitrogen 14.067
8 O Oxygen 15.9994
9 F Fluorine 18.9984
10 Ne Neon 20.1797
11 Na Sodium 22.99
12 Mg Magnesium 24.305
13 Al Aluminium 26.982
14 Si Silicon 28.0855
15 P Phosphorus 30.974
16 S Sulphur 32.066
17 Cl Chlorine 35.4527
18 Ar Argon 39.948
19 K Potassium 39.098
20 Ca Calcium 40.078
21 Sc Scandium 44.966
22 Ti Titanium 47.867
23 V Vanadium 50.9415
24 Cr Chromium 51.9961
25 Mn Manganese 54.938
26 Fe Iron 55.847
27 Co Cobalt 58.9332
28 Ni Nickel 58.6934
29 Cu Copper 63.546
30 Zn Zinc 65.39
31 Ga Gallium 69.723
32 Ge Germanium 72.61
33 As Arsenic 74.922
34 Se Selenium 78.96
35 Br Bromine 79.90483
36 Kr Krypton 83.8
37 Rb Rubidium 85.468
38 Sr Strontium 87.62
39 Y Yttrium 88.906
40 Zr Zirconium 91.224
41 Nb Niobium 92.90638
42 Mo Molybdenum 95.94
43 Tc Technetium 97.9072
44 Ru Ruthenium 101.07
45 Rh Rhodium 102.9055
46 Pd Palladium 106.42
47 Ag Silver 107.8682
48 Cd Cadmium 112.411
49 In Indium 114.818
50 Sn Tin 118.716
51 Sb Antimony 121.71
52 Te Tellurium 127.6
53 I Iodine 126.9045
54 Xe Xenon 131.29
55 Cs Caesium 132.91
56 Ba Barium 137.33
* 57 La Lanthanum 138.905
72 Hf Hafnium 178.49
73 Ta Tantalum 180.9479
74 W Tungesten 183.84
75 Re Rhenium 186.207
76 Os Osmium 190.23
77 Ir Iridium 192.217
78 Pt Platinum 195.08
79 Au Gold 196.967
80 Hg Mercury 200.59
81 Tl Thallium 204.3833
82 Pb Lead 207.2
83 Bi Bismuth 208.9804
84 Po Polonium 208.9824
85 At Astatine 209.987
86 Rn Radon 222.0128
87 Fr Francium 223
88 Ra Radium 226
** 89 Ac Actinium 227.027
104 Rf Rutherfordium 261
105 Db Dubnium 262
106 Sg Seaborgium 263
107 Bh Bohrium 264
108 Hs Hasium 265
109 Mt Meitherium 266
110 Ds Darmstaditium 269
111 Rg Roentgenium 272
112 Cn Copernicium 277
113 Uut Ununtrium
114 Uuq Ununquadium
115 Uup Ununpentium
116 Uuh Ununhexium 289
117 Uus Ununseptium
118 Uuo Ununoctium
Lanthanide Series
* 58 Ce Cerium 140.116
59 Pr Praseodymium 140.9076
60 Nd Neodymium 144.24
61 Pm Promethium 144.9727
62 Sm Samarium 150.36
63 Eu Europium 151.9655
64 Gd Gadolinium 157.25
65 Tb Terbium 158.9253
66 Dy Dysprosium 162.5
67 Ho Holomium 164.9303
68 Er Erbium 167.26
69 Tm Thullium 168.93421
70 Yb Yttarbium 173.04
71 Lu Lutetium 174.967
Actinide Series
** 90 Th Thorium 232.038
91 Pa Protactinium 231.0359
92 U Uranium 238.0289
93 Np Neptunium 237.0482
94 Pu Plutonium 244.0642
95 Am Americium 243.0614
96 Cm Curium 247.0703
97 Bk Berkelium 257.070
98 Cf Californium 251.0796
99 Es Einstenium 252.083
100 Fm Fermium 257.0951
101 Md Mendelevium 258.1
102 No Nobelium 259.1009
103 Lr Lawerencium 262.1009

Octet and Duplet elements

If we study the electronic configuration of the elements like Ne and Ar, it is seen that there are 8 electrons in the outermost shell/orbit. Such elements do not combine or react with others. Therefore, they are called inert elements (gas). Such a stable shell of eight electrons in an atom is called octet.

The behaviour of elements assuming as stable if they have 2 electrons in the single shell i.e. K shell only is called duplet rule. "He" is stable based on duplet rule.
Similarly, helium too has two electrons in the first (K) shell. K-shell can accommodate only two electrons. Therefore such a shell is also stable. The stable element of two electrons with a single shell of an atom is called duplet.

The atoms tend to adjust the arrangement of electrons in such a way that they achieve 8 electrons in the outermost shell by octet rule. The behaviour of elements assuming as stable when there are 8 electrons in the shell other than the first are Ne, Ar stable based on octet rule.

Element and compound and their molecules

Element and compound both are pure substances but they have fundamental differences between them. "The smallest particles of a substance having all the properties of that substance which can exist independently are called molecules." The molecules of elements are made of similar type of atoms. For example sodium molecule consists of single atom of sodium and have $11p^+$, $12n^0$ and $11e^-$ and oxygen molecule (O_2) consists of two atoms of oxygen and each of them has $8p^+$, $8n^0$ and $8e^-$. Thus elements are those pure substances which are made of similar type of atoms.

Unlike them, molecules of a compound contains two or more types of atoms. For example, molecule of table salt is NaCl. That consists of an atom of Na and an atom of Cl. Similarly, molecule of limestone ($CaCO_3$) consists of an atom of Ca, an atom of C and 3 atoms of O. Thus, compounds are those pure substances which consist of different types of atoms in a fixed ratio.

Valence electron and Valency

The elements are of different natures. Some of them are active and some are inactive. The degree of reactivity of elements is also different. The reactivity of elements depends on valency and atomic size of the elements. Valency of an element depends on valence electrons. The number of electrons that determines valency of an element is called valence electron. The shell containing valence electron is called valence shell. Normally, the last orbit of an atom is considered as valence shell. Study the following representative elements with their valence electrons and valency.

Valence electron and valency of some representative elements.

Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA (0)
Elements with their electronic configuration	H 1 Li 2, 1 Na 2, 8, 1	Be 2, 2 Mg 2, 8, 2	B 2, 3 Al 2, 8, 3	C 2, 4 Si 2, 8, 4	N 2, 5 P 2, 8, 5	O 2, 6 S 2, 8, 6	F 2, 7 Cl 2, 8, 7	He 2 Ne 2, 8 Ar 2, 8, 8
Valence electrons (ve^-)	1	2	3	4	5	6	7	8 (Except He)
Electrons required to lose or gain the stability	1	2	3	4	3	2	1	0 (stable)
Valency	1	2	3	4	3	2	1	0

Table 8.6 Valence electron & valency

Study the above table. In it H, Li and Na have $1e^-$ in the last orbit of their atom. Therefore, they have valence electron 1. In the same way valence electron of Be and Mg is 2, of B and Al is 3, and so on.

Answer it now.

1. Which group of elements is likely to lose and gain electrons to obtain the nearest inert gas configuration?
2. Why is the valency of group 0 (VIIIA) elements zero?
3. What kind of tendency do you expect to have in group IV elements to obtain the stable configuration?

Different elements have different combining capacity with other elements and radicals. The combining capacity of elements and radicals is called valency. All the elements always try to be stable having the closest inert element stage i.e. being duplet or octet state. For it they gain, lose and share electrons. The number of electrons gained or lost or shared by an atom to form duplet or octet state is the valency of that atom.

G.N.	Elements	ve^-	Way of duplet/octet state	Valency	Remark
I	H, Li and Na	1	By losing $1e^-$ (H shares $1e^-$)	1	H,Li-Duplet Na-Octet
II	Be and Mg	2	By losing $2e^-$	2	Be-Duplet Mg-Octet
III	B and Al	3	By losing $3e^-$	3	B-Duplet Al-Octet
IV	C and Si	4	By sharing $4e^-$	4	Octet
V	N and P	5	By gaining or sharing 3 electron	3	Octet
VI	O and S	6	By gaining or sharing 2 electron	2	Octet

VII	F and Cl	7	By gaining or sharing 1 electron	1	Octet
O	He, Ne and Ar	2,8	Already stable (Duplet/Octet)	0	He-Duplet Others-Octet

Table 8.7 Stability behaviour of elements

Valency of an element or a radical can be known by its combination with H, Cl and O too. The number of H or Cl combining with any element or radical indicates the valency of the element or radical. For example-

In,

1. NaCl = A single sodium atom is combining with a single chlorine atom. Thus valency of Na is 1.
2. CH_4 = A single carbon atom is combining with four atoms of hydrogen. Thus valency of C is 4.
3. NH_3 = A single nitrogen atom is combing with three hydrogen atoms. Thus valency of N is 3.
4. $MgCl_2$ = A single magnesium atom is combing with two chlorine atoms, thus valency of Mg is 2.

The combination of O with an element or radical also indicates its valency but the no. of oxygen combined multiplies with 2 gives the valency. eg.

1. CaO = A single Ca atom is combining with a single 'O' atom. Thus valency of Ca is 1×2 = 2.
2. Na_2O = Two Sodium atoms are combing with a single 'O' atom. Thus valency of Na is (no. of 'O') 1×2/2(no. of Na atom) = 1.
3. Al_2O_3 = Two aluminium atoms are combining with three 'O' atoms. Thus valency of Al is (no. of oxygen atom) 3×2/2 (no. of Al atom) = 3.
4. CO_2 = A single Carbon is combining with two 'O' atoms. Thus valency of carbon is 2×2 = 4.

Valency of some elements

	Valency 1 (Monovalent)	Valency 2 (Bivalent)	Valency 3 (Trivalent)	Valency (Tetravelent)
Metals (Except hydrogen)	Hydrogen (H) Sodium (Na) Potassium (K) Silver (Ag) Copper* (Cu) Mercury* (Hg) Gold* [Au]	Copper (Cu)* Calcium (Ca) Iron*(Fe) Magnesium Mg) Lead*(Pb) Zinc (Zn) Tin*(Sn) Mercuric*(Hg)	Aluminum (Al) Iron*(Fe) Gold*(Au)	Lead*(Pb) Tin* (Sn)

Non-metals	Fluorine (F) Chlorine (Cl) Bromine (Br) Iodine (I)	Barium (Ba) Oxygen (O) Sulphur (S)	Nitrogen (N) Phosphorus (P)	Carbon (C) Silicon (Si)

Table 8.8 valency details

[Iron (Ferrous-2, Ferric-3), Lead (Plumbous-2, Plumbic-4); Tin (Stannous-2, Stannic-4), Copper (Cuprous-1, Cupric-2), Mercury (Mercurous-1, Mercuric-2, and Gold (Aurous-1, Auric-3)] These elements have more than one valency i.e. variable valency.

* Remember that 'ous' indicates less valency and 'ic' indicates more valency.

Radicals

A radical is an atom or a group of atoms which behaves as a single unit in many chemical reactions and carries an electric charge in it. Like an element, a radical also has its own valency which is equal to the number of charges present in it. Radicals always show a constant valency.

Radicals cannot exist independently but remain as free ions in aqueous solution. Radicals may be simple or compound. Simple radicals are made of single atom like Na^+, K^+, Ca^{++}, S^{--} etc. Compound radicals are made of two or more atoms; eg. CO_3^{--}, SO_4^{--}, NO_3^-, NH_4^+. Radicals also can be classified as electropositive radicals and electronegative radicals. Electropositive radicals are also called basic radicals and they are positively charged while electronegative radicals are also called acidic radicals and they have negative charge.

In other words it can be said that electropositive radicals can lose electrons and electronegative radicals can gain electrons while forming molecules.

Some electropositive radicals

Hydrogen (H^+) Sodium (Na^+) Magnesium (Mg^{++}) Potassium (K^+) Ammonium (NH_4^+) Silver (Ag^+)	Zinc (Zn^{++}) Barium (Ba^{++}) Calcium (Ca^{++}) Ammonium (NH_4^+) Chromium (Cr^{+++}) Aluminium (Al^{+++}) Boron (B^{+++})

Table 8.9 Basic radicals

Some electronegative radicals

Name of radicals	Formula of radicals	ion formed
I. Radicals with combining power 1		
Hydroxide	OH	OH^-
Hydrogen carbonate or Bicarbonate	HCO_3	HCO_3^-
Hydrogen sulphate or bisulphate	HSO_4	HSO_4^-
Permanganate	MnO_4	MnO_4^-
Nitrate	NO_3	NO_3^-
Nitrite	NO_2	NO_2^-
Chlorate	ClO_3	ClO_3^-
Bisulphite or hydrogen sulphite	HSO_3	HSO_3^-
Chloride	Cl	Cl^-
Hydride	H	H^-
II. Radicals with combining power 2		
Sulphate	SO_4	SO_4^{--}
Sulphite	SO_3	SO_3^{--}
Carbonate	CO_3	CO_3^{--}
Dichromate	Cr_2O_7	$Cr_2O_7^{--}$
Thiosulphate	S_2O_3	$S_2O_3^{--}$
Peroxide	O_2	O_2^{--}
III. Radicals with combining power 3		
Phosphate	PO_4	PO_4^{---}
Nitride	N	N^{---}
IV. Radicals with combining power 4		
Carbide	C	C^{----}

Table 8.10 Acidic radicals

Chemical bonding

Chemical bonding is a process by which atoms are in stable conditions having duplet and octet state When they share or transfer electrons from one atom to another they get the condition and it results in the formation of a molecule. It is done by following two methods, mainly

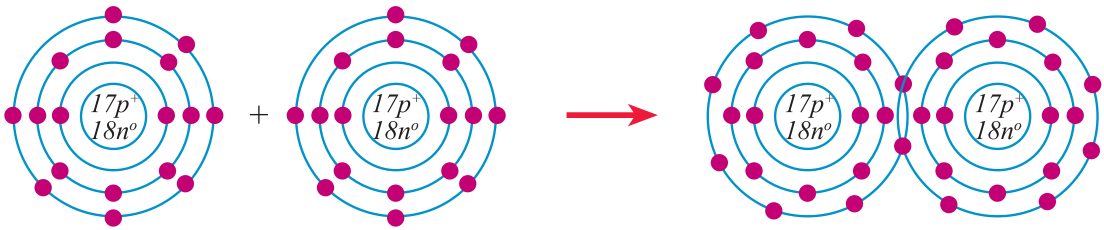
a. by sharing electrons and
b. by gaining or losing electrons

By the processes mentioned above the force is created and the force connects atoms in a molecule. The force is called chemical bond and the process of creating bond is called chemical bonding. Chemical bonding is of the following three categories.

1. Co-valent bonding
2. Electro-valent bonding or ionic bonding
3. Co-ordinate bonding

1. Covalent bonding

Consider the combination of two chlorine atoms to form a chlorine molecule. Each chlorine atom has the configuration 2, 8, 7 which is one electron lesser than the inert gas argon. Each atom can effectively attain the stable configuration of argon by contributing one electron to a pair shared by both the atoms. This may be represented as follows:



Chlorine atom + Chlorine atom — *Chlorine molecule*

Cl + *Cl* → *Cl_2*

Fig.8.3:

The two atoms are held together by the attraction of each positive nucleus for the pair of shared electrons. The binding force resulting from the sharing of a pair of electrons between atoms is known as covalent bond which may be single, double or triple. The compounds formed by this method of combination are called covalent compounds.

Examples of covalent compounds are: CH_4, NH_3, CO_2, H_2O

Molecular structures of some more co-valent compounds are given below.

1. Hydrochloric acid (HCl)

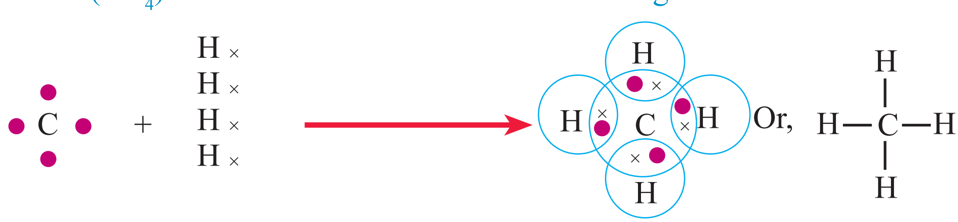
2. Water (H_2O)

Or, H-O-H, H_2O

Two hydrogen atoms (2H) + One Oxygen atom (O) — Water Molecule (H_2O)

3. Methane (CH_4)

Single covalent bond



CH_4

Four Hydrogen atoms (4H) | One Carbon atom (C) | Methane Molecule (CH_4)

4. Carbon dioxide (CO_2)

Double covalent bond

Or, $O = C = O$

Covalent compounds do not have metals in them. They do not contain any ions and are not electrolytes. Simple covalent compounds are gases or low boiling liquids. In covalent compounds, atoms are held together by a force of attraction. They have a low melting point and a low boiling point. Covalent compounds are often soluble in organic solvents like alcohol, benzene, ether etc. and insoluble in water.

Covalent bonding is divided into polar and non-polar covalent bonding. Polar covalent bonding is that which is formed between electronegative and electropositive elements. eg. HCl, H_2O, CH_4 etc.

Non-polar covalent bonding is that which is formed in between similar electronegative elements or the same type of atoms. eg. O_2, H_2, Cl_2 etc.

2. Electrovalent or Ionic bonding

When one atom of metallic element or group loses electrons from its outermost shell, the electrons pass over to the outermost shell of non-metallic element or group of elements. When electrons transfer from one atom to another, an octet is left behind in the metallic element and created in non-metal. Thus both species attain the nearest inert i.e. noble gas configuration. They differ from the noble gas in such a way that the atom which has lost the electrons gains positive charge and the atom that has gained electron develops the negative charge. These particles are no more atom and called ions. When unstable atomic form changes into ionic state by losing or gaining electrons and attains the stable configuration, the release of energy occurs so that the final state is more stable than the initial state. It is something like dropping a stone from the top of a cliff to its bottom. The stone at the edge of the cliff at the top is unstable and when it is dropped to bottom, it releases energy and comes to the stable state.

Consider a chemical reaction which occurs when the metal sodium is placed in a container with chlorine gas. A vigorous reaction takes place and sodium burns to form sodium chloride. Sodium chloride is a typical example of electrovalent compound.

Before combination

Elements	No. of p^+	No. of e^-	electronic configuration	electron charge
Sodium atom	11	11	2, 8, 1	neutral
Chlorine atom	17	17	2, 8, 7	neutral

Table 8.11

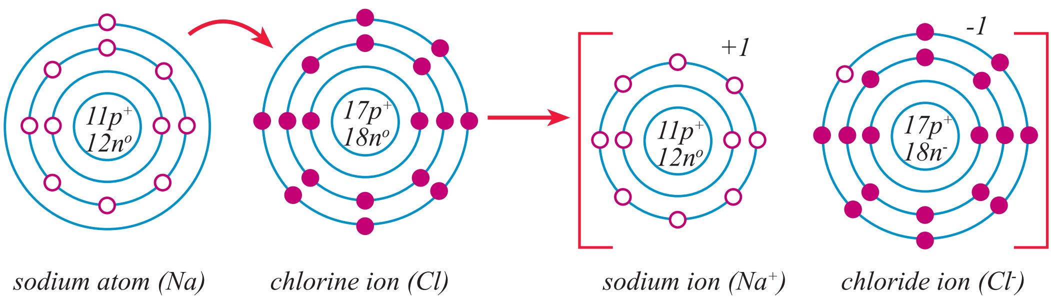
After combination

Elements	No. of p^+	No. of e^-	electronic configuration	electron charge
Sodium ion	11	10	2, 8	+ve
Chloride ion	17	18	2, 8, 8	-ve

Table 8.12 molecular formation of NaCl

By losing an electron the sodium ion gets the structure of Ne. Similarly, by receiving an electron from sodium, an atom of chlorine can attain the stable structure as argon.

When sodium atom loses electron, it will contain one more positively charged proton than electron. As a result it will form positively charged sodium ion. Similarly, by gaining one extra electron, chlorine atom develops into chloride ion.



Before combination
each individual atom is unstable

After combination
each ion is now stable

***Fig.8.4:** Formation of electrovalent bond in NaCl*

Answer it now.

1. Inspite of similar configuration (2, 8, 8), why is chloride ion not called argon atom?
2. Why is the sodium ion not neutral?
3. Does the chloride ion (Cl^-) show chemical properties similar to that of argon or chlorine atom? why?

The sodium chloride ions thus formed are held together by an electrostatic attraction. This attractive force is called electrovalent or ionic bond. In the solid state millions of Na^+ and Cl^- ions are held in place in the crystalline form by these bonds. The compounds formed by this method are called electrovalent compounds. These compounds have metal.

Molecular structure of some more electrovalent compounds

Some more examples of electrovalent compounds

1. Calcium oxide [CaO]

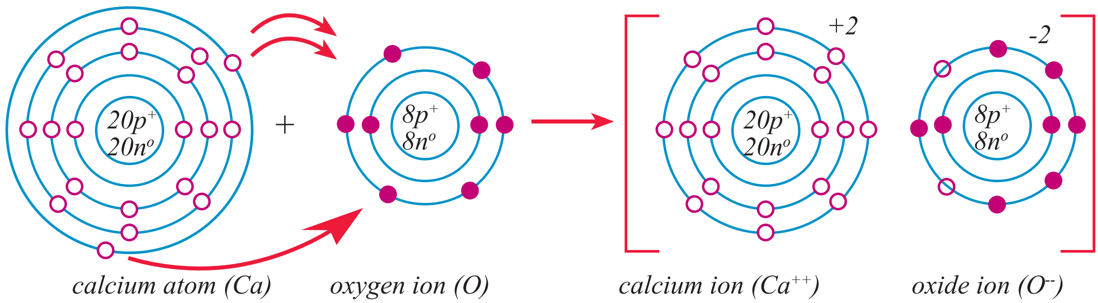


Fig.8.5: *Molecular structure of CaO*

2. Magnesium chloride [$MgCl_2$]

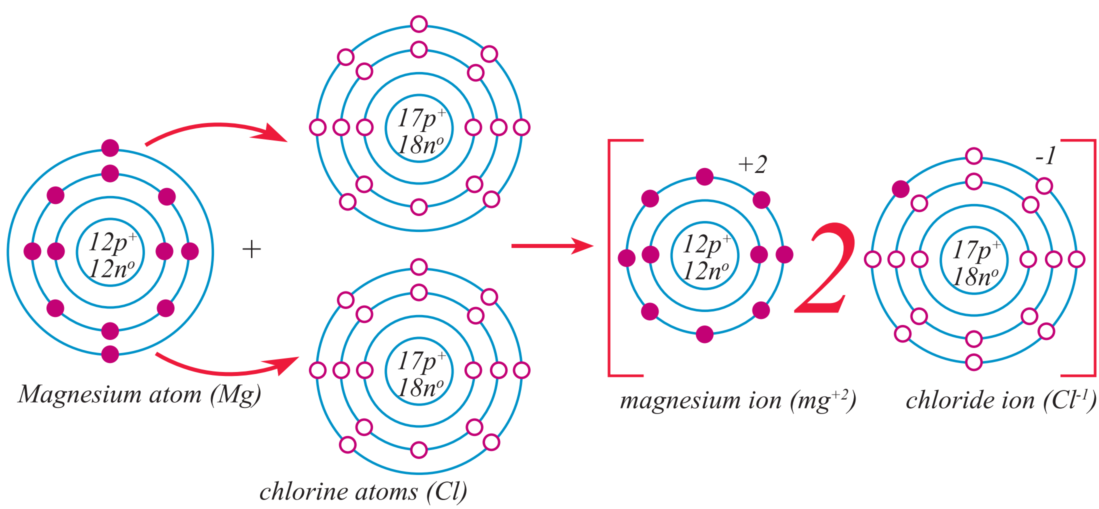


Fig.8.6: *Molecular structure of magnesium chloride*

3. Sodium oxide [Na_2O]

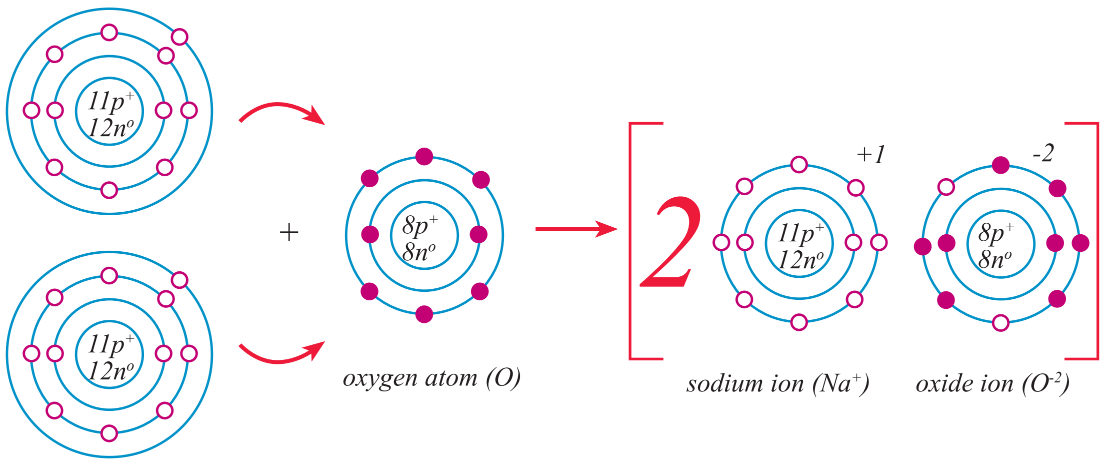


Fig.8.7: *Molecular structure of sodium oxide (Na_2O)*

Differences between electrovalent and covalent compounds

Electrovalent Compound	Covalent Compound
i. It is formed due to the complete transfer of electron from basic radical to acidic radical.	i. It is formed due to mutual sharing of electrons between the constituent atoms.
ii. It is mostly soluble in water.	ii. It is mostly insoluble in water.
iii. It conducts electricity in solution state.	iii. It doesnot conduct electricity.
iv. It contains metal in its molecule for eg NaCl, $MgCl_2$, Na_2O etc.	iv. It does not contain any metal in its molecule for eg CH_4, H_2O, NH_3 etc.

Molecular formula

A molecule is formed when atoms of the same or different elements combine chemically in a fixed ratio. When two chlorine atoms are combined by a covalent bond, there forms a chlorine molecule. In such a molecule, both atoms come from the same element. In water molecule two atoms of hydrogen and one atom of oxygen are combined. A molecule is represented with a formula by using the symbol of combining elements which represents the actual number of combining atoms.

Thus, the molecular formula of a compound is one which expresses the actual number of each kind of atom present in its molecule. So, the symbolic representation of molecules of elements is molecular formula,

In a molecule the number of atoms present is represented by a numeral which is written slightly below the right hand corner of the symbol. For example the molecular formula of water is written as H_2O, ammonia as NH_3 and so on. Appropriate coefficient is written in front of the formula to represent the number of molecules eg $2CO_2$ tells us 2 molecules of carbon dioxide.

Significance of Molecular Formula

It is important to express a chemical substance in the form of molecule as it conveys various important informations related to that molecule.

1. It helps to write long name of molecules in a short form.
2. A molecular formula represents the types of elements present in it eg the formula H_2SO_4 tells that there are hydrogen, sulphur and oxygen in it.
3. It represents the actual number of each type of atom present in one molecule of a compound. eg In H_2O molecule there are two atoms of hydrogen and one atom of oxygen.
4. Molecular weight of a given substance can be determined by adding atomic weights of all the atoms present in the molecule. For example in H_2O, molecular weight can be determined by adding $2\times1+1\times16 = 18$ amu.
5. A molecular formula also conveys the ratio of weight of the elements present in the compound.

Writing molecular formulae

The molecular formula shows the number and types of the atoms present in the molecule. Therefore it is important to know how to write these atoms and what number to assign to the combining atoms in a molecule. Before trying to construct a formula one must be aware of the symbols of elements and radicals with their respective valencies.

The following points should be taken into consideration while writing a molecular formula:

1. Decide the elements or radicals involved in the molecule and write their symbols in such a way that the symbol of electropositive radical is written at first and then the symbol of electronegative radical is written.
2. Write the valency of respective radical under each symbol.
3. If there is any common numeral, divide it by common factor and convert it into the simplest ratio.
4. Interchange/swap the valency by shifting the numerals. Write the numbers at the right lower corners of the elements or radicals.
5. If the valency is written at the side of a compound radical, enclose the radical with brackets.

The following are some examples of writing a molecular formula by valency exchange method.

i) Calcium Chloride

Ca   Cl
2   1

Ca_1 Cl_2

$= CaCl_2$

ii) Water

H   O
1   2

H_2 O_1

$= H_2O$

iii) Magnesium Sulphate

Mg SO_4
2   2

Mg_2 $(SO_4)_2$

$= MgSO_4$

iv) Ammonium Sulphate

NH_4 SO_4
1   2

NH_4 $(SO_4)_1$

$= (NH_4)_2SO_4$

v) Ferric Oxide

Fe   O
3   2

Fe_2 O_3

$= Fe_2O_3$

vi) Carbon di-oxide

C   O
$2\ \cancel{4}$ $\cancel{2}\ 1$

C_2 O_4

$= CO_2$

vii) Ammonium Chloride

NH_4 Cl
1   1

$(NH_4)_1$ Cl_1

$= NH_4Cl$

viii) Aluminium Sulphate

Al SO_4
3   2

Al_2 $(SO_4)_3$

$= Al_2(SO_4)_3$

Lesson Summary

1. All matters are composed of atoms. Atoms are made of subatomic particles. There are more than 118 elements known so far.
2. Number of protons or number of electrons is called atomic number of that atom. It is denoted by 'Z'.
3. The sum total of protons and neutrons present in the nucleus of an atom is called its atomic mass. It is denoted by 'A'.
4. The last orbit of an atom is called valence shell and the number of electrons present in the shell is called valence electron.
5. Valence electron determines the valency of an atom.

6. All the atoms always try to be stable by getting the condition of the nearest inert element.
7. Atoms of different elements combine together to form a compound. The combination of elements occurs when their atoms attain the stable electronic configuration. This may be obtained by the transfer or sharing of electrons between atoms.
8. If the transfer of electrons occurs in atoms, ions are formed from them. The atoms which are charged in an opposite way are combined to form a strong bond called ionic bond and compounds thus formed are ionic or electrovalent compounds. The compounds formed by sharing electrons are called covalent compounds.
9. Combining capacity of an element is called valency.
10. Radicals are the elements or group of elements that behave as a single unit.
11. A molecule is formed when atoms are joined together by a bond in a definite ratio.
12. A molecule is represented by a formula that shows the actual number of each kind of atoms present in a molecule and it is called a molecular formula.

Project work

Make models of molecular structures of methane, ammonia, water, carbon dioxide and hydrogen sulphide using tooth picks for bonds and clay balls of different sizes and different colours for atoms.

Conceptual questions with their answers

Q.1. What do you mean by Isotope?

The elements having the same atomic number but different atomic mass is known as isotope.

e.g. Protium, deuterium and tritium are the isotopes of hydrogen.

Q.2. Why does vegetable oil not dissolve in salt?

It is because "Like dissolves like" which means oil is made of covalent bond but salt (NaCl) is made of electrovalent bond. Therefore, due to different natures of bonding, they donot dissolve in each other.

Exercise

1. Write difference between

a. Element and Compound.
b. Atom and Molecule.

c. Co-valent compound and Electrovalent compound.
d. Atom and Ions.
e. Basic radical and Acid radical.

2. Give reasons.

a. An atom is neutral in charge.
b. Na^+ is an ion.
c. Ca is an atom.
d. H_2O is a covalent compound.
e. NaCl is an ionic compound.
f. Na^+ is smaller than Na

3. Answer the following questions.

a. Name three types of particles that occur in most atoms and give their relative charge and mass.
b. What is a molecule? How is the molecule of a substance formed?
c. How do the unstable atoms of elements attain stability? Illustrate your answer with two examples.
d. What is a bond? Write its types.
e. Draw a diagram showing the electronic structure of an atom whose nucleus carries out a positive charge of nine units. What is the valency of this element?
f. Define.
   i. Octet rule
   ii. Duplet rule
   iii. Compound
g. What are the two main methods of combination of elements? What is the force that results because of each kind of combination called?
h. Which groups of elements are likely to lose electrons from their valence shell?
i. What is a valence shell? What is the significance of the number of valence electrons?
j. What is valency in terms of electronic theory?
k. Ammonia is a covalent compound. Draw a diagram showing how the atoms in the ammonia molecule are bonded.
l. Name and explain briefly with the help of a diagram the type of bond linking fluorine in the molecule F_2.

4. Sketch molecular structures of the following and mention the bonds present in each.

a. Na_2O	b. $CaCl_2$	c. CO_2	d. H_2S	e. H_2SO_4	
f. SO_2	g. Cl_2	h. H_2O	i. O_2	j. N_2	k. CH_4

5. The elements W, X, Y and Z have atomic number seven, nine, ten and eleven respectively.

Write the formula for the compound you would expect to form between the following pairs of elements and indicate the type of bonds present in them.

a. W and X b. X and Z
c. X and X d. Is it possible to form molecule with the element of Y? Why?

6. For each of the following statements indicate whether it is true or false and then give the reason briefly.

a. All the atoms of an element contain the same number of protons.
b. The magnesium ion has two protons fewer than the magnesium atom.
c. The atom of chlorine has one electron in its outer shell.
d. The chloride ion has one electron more than chlorine atom.
e. Sodium ion has one electron fewer than sodium atom.

7. Write the valency of the following elements on the basis of the electronic configuration.

a. Na - 2, 8, 1
b. Cl - 2, 8, 7
c. Mg - $1s^2, 2s^2, 2p^6, 3s^2$
d. K - $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1$
e. Ca - 2, 8, 8, 2
f. Si - 2, 8, 4
g. O - $1s^2, 2s^2, 2p^4$
h. Al - 2, 8, 3
i. P - 2, 8, 5

8. Write the molecular formulas of the following compounds using the method explained in the text.

i.	Silver oxide	ii.	Zinc nitrate
iii.	Carbon dioxide	iv.	Hydrogen sulphide
v.	Potassium sulphate	vi.	Sodium iodide
vii.	Magnesium nitride	viii.	Hydrogen fluoride
ix.	Ammonium chloride	x.	Ammonium sulphate
xi.	Carbon tetrachloride	xii.	Ammonium sulphite
xiii.	Zinc sulphate	xiv.	Ammonium carbonate
xv.	Hydrogen chloride	xvi.	Ferrous nitrate
xvii.	Silver chloride	xviii.	zinc sulphide
xix.	Stannous chloride	xx.	Potassium thiosulphate
xxi.	Aluminium nitrate	xxii.	Cupric hydroxide
xxiii.	Stannic oxide	xxiv.	Sodium chloride
xxv.	Potassium dichromate	xxvi.	Copper sulphate
xxvii.	Sodium hyroxide	xxviii.	Ferric chloride
xxix.	Silver nitrate	xxx.	Hydrogen peroxide
xxxi.	Ammonium nitrite	xxxi.	Lead nitrate

9. Copy the given table and fill in the blank space with the correct molecular formula.

Acid radical / Basic radical	Sulphate	Chloride	Oxide	Nitrate	Carbonate	Hydroxide
Sodium			Na_2O			
Aluminium				$Al(NO_3)_3$		
Magnesium						
Calcium						
Potassium						
Ferrous						
Ferric						
Mercuric						
Stannous						
Plumbic						
Auric						

Multiple Choice Questions

1. Select the best answer from the alternatives.

a. Aluminium has 13 p^+, 13 e^- and 14 n^o. What is its atomic mass?
   i. 27 ii. 14
   iii. 13 iv. 26

b. Maximum number of electrons in 'N' shell of an atom is
   i. 10 ii. 32
   iii. 18 iv. 8

c. A duplet has
   i. 2 e^- in the last orbit ii. 8 e^- in the last orbit
   iii. Single shell with 2 e^- iv. 32 e^- in the last orbit

d. $CaCl_2$ is a
   i. Co-valent compound ii. Electrovalent compound
   iii. Acidic compound iv. Water insoluble compound

e. Valency of ferric is
   i. 1 ii. 2
   iii. 3 iv. 4

Unit 9
Chemical Reaction

Total estimated teaching hours = 9

Learning Outcomes

After the completion of this unit, students will learn:

- *to write simple balanced chemical equations.*
- *information obtained from a balanced chemical equation.*
- *limitation of a balanced chemical equation.*
- *catalyst and its types.*

Amedeo Avogadro (1776AD-1856AD)

KEY WORDS

1. **Physical change** : the change in which no new substances are formed
2. **Chemical change** : the change in which new substances are formed
3. **Atomicity** : number of atoms present in a molecule
4. **Reactants** : the chemicals participating in a chemical reaction
5. **Products** : the chemicals formed after a chemical reaction
6. **Catalyst** : the chemical used to charge the rate of chemical reaction
7. **Diatomic elements** : the element consisting of two atoms

Introduction

Chemistry is the study of properties of matter and preparation of new substances. In order to determine the nature of substances, chemists have been much interested in the changes the matters undergo when they are treated in different conditions of temperature and when they are mixed each other.

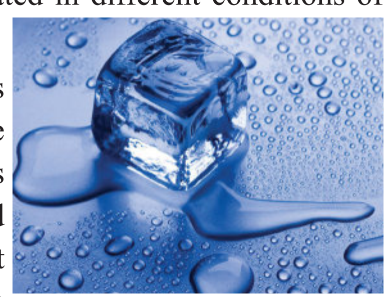


Fig.9.1: *Melting ice*

Changes in the nature are many and various. The changes may be viewed from different angles. The chemists are mainly concerned with what change in the properties occurs, how it behaves with other substances compared to the behaviour with the original substance, whether it can be regained easily or not etc. On the basis of the changes in the properties of a matter it is classified as physical change and chemical change. We have studied these types of changes in junior classes.

Chemical equation

A chemical reaction is represented by means of equation. In a chemical equation the substances i.e. elements or compounds that undergo chemical change are written on the left hand side of an arrow mark. The new substances formed as a result of the reaction are written on the right hand side. The substances that undergo chemical change are written on the left hand side of the arrow marks, and are called reactant. The new substances formed as a result of chemical change are written on the right hand side of an arrow mark and are called Products.

$$\underbrace{\text{Hydrogen + Oxygen}}_{\text{Reactants}} \longrightarrow \underbrace{\text{Water}}_{\text{Product}}$$

The arrow head or sign of equals to between reactants and products signifies "gives", "produces" or "forms". The '+' sign on the side of reactants indicates "reacts with" and on the side of products is read as "and" or "in addition to". e.g.

Calcium + Oxygen ⟶ Calcium oxide

An equation may be written by writing the name of elements and compounds involved in the chemical reaction called word equation. The equation representing a chemical change can be written by using the symbols and formulae of chemical substances is called chemical equation.

Thus, chemical equation is a short hand form of a chemical change in which reactants are written on the left hand side and products on the right hand side of an arrow mark by using their symbols and formulae.

A chemical equation can be divided into 2 types, They are:-

i. Word equation
ii. Formula equation (Symbolic equation)

A word equation is a type of chemical equation in which chemical substances are expressed by their name in word, for e.g.

Hydrogen + Nitrogen ⟶ Ammonia
Carbon + Hydrogen ⟶ Methane
Calcium carbonate ⟶ Calcium oxide + Carbon dioxide

The symbolic representation of chemical substances in an equation is called formula equation. A formula equation can be skeletal equation and balanced chemical equation. A skeletal equation has unequal numbers of atoms in reactant and product, for e.g:-

Formula equation:-

$H_2 + O_2 \longrightarrow H_2O$ (Skeletal equation)

$$2H_2 + O_2 \longrightarrow 2H_2O \text{ (Balanced equation)}$$

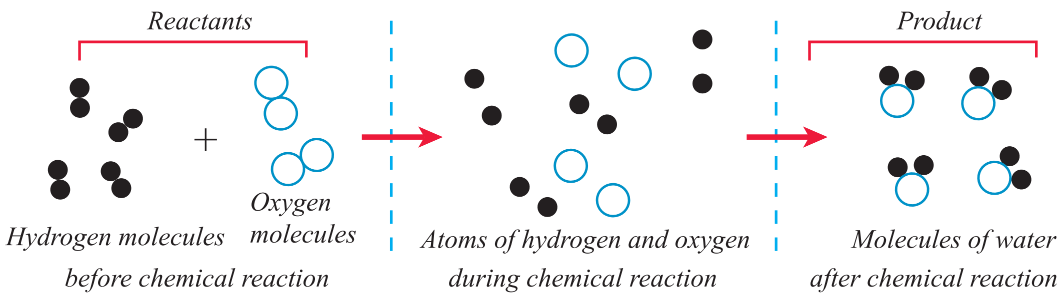


***Fig.9.2:** Formation of water molecule*

Clues for writing and balancing chemical equations

1. All the molecules must be written in the form of correct molecular formula. Molecules of compounds are written according to the symbol and valency of the radicals involved in the molecule. Molecules of elements are written according to their atomicity. Remember H_2, N_2, O_2, F_2, Cl_2, Br_2 and I_2 are diatomic elements.
2. The additional number used for balancing should be written in the front of molecule.
3. The atoms used at many places in an equation are balanced in the last.
4. For counting the number of atoms present in a molecule.

We remember that-

a. The number at right lower corner of an atom is for that atom only and the atom at right lower corner of a bracket is for all the atoms enclosed in the bracket. Eg. in $Al_2(SO_4)_3$ there are 2Al, 3 'S' and 12 'O'.

b. The number in front of a molecule is for all the atoms of the molecule. Eg. $3Al_2(SO_4)_3$ there are 6 'Al', 9 'S' and 36 'O'.

Activity: Count and write the number of atoms present in following molecules- $2CaSO_4$, $Mg(HCO_3)_2$, $NaNO_3$, $Al_2(SO_4)_3$, $2Zn(HSO_4)_2$, $3K_3PO_4$, $2Mg(NO_3)_2$, $CaCO_3$.

Some examples of chemical equations-

1. Magnesium + nitrogen $\longrightarrow$ Magnesium nitride

$$Mg + N_2 \longrightarrow Mg_3N_2 \quad \text{(Skeletal equation)}$$

$$3Mg + N_2 \longrightarrow Mg_3N_2 \quad \text{(Balanced equation)}$$

2. Potassium chlorate $\longrightarrow$ Potassium chloride + Oxygen

$$KClO_3 \longrightarrow KCl + O_2 \quad \text{(Skeletal equation)}$$

$$2KClO_3 \longrightarrow 2KCl + 3O_2 \quad \text{(Balanced equation)}$$

3. Hygrogen peroxide $\longrightarrow$ Water + Oxygen (word equation)

$H_2O_2 \longrightarrow H_2O + O_2$ (Skeletal equation)

$2H_2O_2 \longrightarrow 2H_2O + O_2$ (Balanced equation)

4. Zinc + Sulphuric acid $\longrightarrow$ Zinc sulphate + Hydrogen (word equation)

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$ (Balanced equation)

5. Aluminium + Oxygen $\longrightarrow$ Aluminium oxide (word equation)

$Al + O_2 \longrightarrow 2Al_2O_3$ (Skeletal equation)

$4Al + 3O_2 \longrightarrow 2Al_2O_3$ (Balanced equation)

6. Aluminium + Hydrochloric acid $\longrightarrow$ Aluminium + Hydrogen (word equation)

$Al + HCl \longrightarrow AlCl_3 + H_2$ (Skeletal equation)

$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$ (Balanced equation)

7. Mercury + Oxygen $\longrightarrow$ Mercuric oxide (word equation)

$Hg + O_2 \longrightarrow HgO$ (Skeletal equation)

$2Hg + O_2 \longrightarrow 2HgO$ (Balanced equation)

8. Sodium hydroxide + Sulphuric acid $\longrightarrow$ Sodium sulphate + Water (word equation)

$NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$ (Skeletal equation)

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$ (Balanced equation)

9. Calcium oxide + Nitric acid $\longrightarrow$ Calcium nitrate + Water (word equation)

$CaO + HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$ (Skeletal equation)

$CaO + 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$ (Balanced equation)

10. Ammonia + Water $\longrightarrow$ Ammonium hydroxide (word equation)

$NH_3 + H_2O \longrightarrow NH_4OH$ (Balanced equation)

Informations conveyed by a balanced chemical equation

Let's take the following simple example of a chemical equation.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

This equation provides the following informations.

1. Hydrogen gas reacts with oxygen to give water. It means the name of reactants and products can be known.
2. Two molecules of hydrogen react with one molecule of oxygen to form two molecules of water. It means that a balanced chemical equation gives the ratio of molecules of reactants and products.
3. $2H_2 + O_2 \longrightarrow 2H_2O$

$2(1\times2) + 16\times2 \longrightarrow 2(1\times2+16)$

$4\ \text{amu} + 32\ \text{amu} \longrightarrow 36\ \text{amu}$

4 parts by weight of hydrogen react with 32 parts by weight of oxygen to form 36 parts by weight of water.

∴ It means that a balanced chemical equation helps to calculate the ratio of molecular weight of reactants and products.

4. Type of chemical equation is also known. It is combination reaction.

Limitations of a balanced chemical equation

We cannot know the following things by a balanced chemical equation-

1. State of reactants and products cannot be known.
2. Concentration of reactants and products cannot be known.
3. It cannot be known that the chemical reaction will begin immediately or it will take time to be started.
4. The conditions required for the chemical reaction cannot be known.
5. The rate of chemical reaction cannot be known.

The way to make a chemical equation more informative

A chemical equation, therefore, can be made more informative by supplying necessary informations in the following ways.

1. Physical states of the involved substances are indicated by putting a letter (s), (l), (g) for solid, liquid and gas respectively on the lower right corner of the symbol or formula. e.g.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$
$$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}$$

For the aqueous state (aq) is written. Similarly, after the symbol or formula. A gaseous product can be indicated as (↑) and a precipitate is normally denoted by (↓).

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl\downarrow + NaNO_{3(aq)}$$
$$Zn_{(s)} + H_2SO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + H_2\uparrow_{(g)}$$

2. The condition under which a chemical reaction occurs is written briefly above or below the sign of equality or arrow mark.

$$N_{2(g)} + 3H_{2(g)} \xrightarrow[500^\circ C,\ Fe/Mo]{200\ \text{atmosphere}} 2NH_{3(g)}$$

3. Evolution or absorption of heat can be shown by writing amount of heat with plus sign at the site of product in case of the evolution and with minus sign in case of absorption of heat

$$N_{2(g)} + O_{2(g)} + \Delta \longrightarrow 2NO_{(g)} \quad \text{(needs heat)}$$
$$N_{2(g)} + 2H_{2(g)} \longrightarrow 2NH_3 + \Delta \quad \text{(gives heat)}$$

4. Reversible reactions are shown by two way arrows ($\rightleftharpoons$) rather than unidirection ($\longrightarrow$) arrow between reactants and products.

$$N_{2(g)} + 2H_{2(g)} \xrightleftharpoons{+\Delta} 2NH_{3(g)}$$

Exothermic and endothermic reactions

Any chemical reaction shows the change in energy. In some chemical reactions heat is released such chemical reactions are called as exothermic reaction. In such reactions heat is shown in products or symbol of heat [Δ] with - sign is written above the arrow. e.g.

1. $C + O_2 \longrightarrow CO_2 + \text{Heat}$ [or $C + O_2 \longrightarrow CO_2 + \Delta$]
2. $2H_2 + O_2 \longrightarrow 2H_2O + \text{Heat}$
3. $CH_4 + O_2 \longrightarrow CO_2 + 2H_2O + \text{Heat}$
4. $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 + \text{Heat}$

The chemical reactions in which heat is used are called as endothermic reactions. In this type of chemical reaction heat is written with reactants or +Δ is written above the arow-

E.g-

1. $CaCO_3 + \Delta \longrightarrow CaO + CO_2$ or
   $CaCO_3 + \text{Heat} \longrightarrow CaO + CO_2$
2. $N_2 + O_2 + \text{Heat} \longrightarrow 2NO$
3. $2KClO_3 + \text{Heat} \longrightarrow 2KCl + 3O_2$
4. $Mg(OH)_2 + \text{Heat} \longrightarrow MgO + H_2O$

Catalyst/Catalytic agent

Substance which is added to a mixture that helps to change the rate of chemical reaction and remains unchanged in terms of mass and chemical composition at the end of chemical reaction is called catalyst or catalytic agent. A catalyst also helps to change the rate of chemical reaction. In the preparation of oxygen gas by decomposing potassium chlorate, manganese dioxide (MnO_2) is used. Manganese dioxide (MnO_2) acts as a catalyst here. There are two types of catalysts.

i. Positive catalyst: The catalyst which increases the rate of a chemical reaction is called positive catalyst e.g. MnO_2 used in decomposition of potassium chlorate is a positive catalyst. To obtain oxygen by using hydrogen peroxide, also we use MnO_2 as positive catalyst.

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2 \quad \text{(fast reaction)}$$

$$2KClO_3 \xrightarrow{Heat/MnO_2} 2KCl + 3O_2$$

ii. Negative catalyst: The catalyst that decreases the rate of a chemical reaction is called negative catalyst. The use of glycerine decreases the decomposition of hydrogen peroxide. Glycerine acts as a negative catalyst in this reaction.

$$2H_2O_2 \xrightarrow{Glycerine} 2H_2O + O_2 \quad \text{(slow reaction)}$$

Characteristics of a catalyst

Some main characteristics of a catalyst are as given below-

1. There is no change in mass and chemical structure of the catalyst used.
2. They do not initiate chemical reaction but accelerate the chemical reaction.
3. They may increase or decrease the rate of chemical reaction.
4. Particular type of catalyst work for particular type of chemical reaction only.

Fact file:
Sodium is very active metal. To avoid its reaction with air it is stored by sinking it in kerosene.

Lesson Summary

1. Changes are of two kinds i.e. physical change and chemical change.
2. Chemical change is a permanent change. A new substance is formed during the change and the substance thus formed cannot be reversed.
3. A chemical change represented by symbol and the formulae used for reactants and products is called the chemical equation.
4. A chemical equation must show the actual chemical change in the molecular and balanced form.
5. A chemical equation provides qualitative and quantitative informations related to the equation.
6. There are some limitations of balanced chemical equation.
7. An equation can be made more informative by supplying relevant informations appropriately.
8. Balancing of simple equations can be done by trial and error method.
9. Chemical reactions may be exothermic or endothermic.
10. In exothermic reaction, heat is given out.
11. In endothermic reaction, heat is used from the surrounding.
12. Some chemicals are used to increase or decrease the rate of chemical reaction. Such chemicals are called catalyst.

Project work

Make a chart showing the list of symbols, valencies of basic and acid radicals. Paste the chart in front of your study table to activate your memory.

Conceptual questions with their answers

Q.1. Why must chemical reaction be balanced?

According to law of conservation of mass, matter can neither be created nor be destroyed. It remains the same before and after the chemical reaction. That is why chemical reaction must be balanced.

Q.2. "Heat increases the rate of chemical reaction." Justify.

As we know that heat provides the reacting (reactant) molecules with the kinetic energy. Therefore, the collision among these molecules increases more product at a faster rate.

Exercise

1. Answer the following questions.

a. What is chemical reaction?

b. What is a chemical equation?

c. What informations can be obtained from the following chemical equation?

$N_2 + 3H_2 \longrightarrow 2NH_3$

d. What are limitations of a balanced chemical equation?

e. Glycerine is a chemical used to decrease the rate of chemical reaction. Identify the type of catalyst with reason.

f. How do you overcome the lacking of the following informations of a chemical equation? Give an example of each.

a. Reversible nature b. Physical states of reactants and products

c. Precipitate

g. What is a catalyst? What is its main characteristic?

h. Define exothermic reaction with example.

i. Define endothermic reaction with example.

j. What are reactants and products in a chemical equation?

k. What are word equation and formula equation?

l. Define positive and negative catalysts with examples.

2. Write difference between.

a. Exothermic reaction and endothermic reaction.
b. Balanced chemical equation and skeletal chemical equation.
c. Reactants and products.
d. Positive catalyst and negative catalyst.

3. Balance the following skeletal equations.

a. $Mg + O_2 \longrightarrow MgO$
b. $Zn + N_2 \longrightarrow Zn_3N_2$
c. $Fe + O_2 \longrightarrow Fe_2O_3$
d. $HCl + Ca(OH)_2 \longrightarrow CaCl_2 + H_2O$
e. $Ca + N_2 \longrightarrow Ca_3N_2$
f. $N_2 + H_2 \longrightarrow NH_3$
g. $H_2 + O_2 \longrightarrow H_2O$
h. $Al + HCl \longrightarrow AlCl_3 + H_2$
i. $Al + O_2 \longrightarrow Al_2O_3$

4. Change the following word equations into chemical equations.

a. Sodium + Oxygen ⟶ Sodium oxide
b. Hydrogen + Sulphur ⟶ Hydrogen sulphide
c. Mercury(II) oxide ⟶ Mercury + Oxygen
d. Calcium carbonate ⟶ Calcium oxide + Carbon dioxide
e. Magnesium + Hydrochloric acid ⟶ Magnesium chloride + Hydrogen
f. Zinc + Sulphuric acid ⟶ Zinc sulphate + Hydrogen
g. Hydrogen + Copper oxide ⟶ Copper + Water
h. Aluminium + Nitrogen ⟶ Aluminium nitride
i. Lead carbonate ⟶ Lead oxide + Carbon dioxide
j. Hydrochloric acid + Ammonium hydroxide ⟶ Ammonium chloride + Water
k. Potassium chlorate ⟶ Potassium chloride + Oxygen
l. Hydrogen peroxide ⟶ Water + Oxygen
m. Sodium nitrite + Ammonium chloride ⟶ Sodium chloride + Water + Nitrogen
n. Calcium bicarbonate ⟶ Calcium carbonate + Water + Carbon dioxide

Multiple Choice Questions

1. Encircle the correct answer.

a. The chemical used to increase the rate of chemical reaction is called

i. Reactant
ii. Reaction
iii. Catalyst
iv. Exothermic

b. The reaction in which heat is used is

i. Endothermic
ii. Negative catalyst
iii. Exothermic
iv. Positive catalyst

c. The chemicals that participate in chemical reaction are called

i. Products
ii. Catalysts
iii. Reactants
iv. Endothermics

d. The chemical which is used to reduce the rate of chemical reaction is

i. Positive catalyst
ii. Positive reactant
iii. Negative reactant
iv. Negative catalyst

e. In the molecule $3Ba_3(PO_4)_2$, number of 'O' is

i. 34
ii. 24
iii. 18
iv. 8

Unit 10

Solubility

Total estimated teaching hours = 8

Learning Outcomes

After the completion of this unit, students will learn:

- *identification and preparation of unsaturated and saturated solutions.*
- *definition of unsaturated, saturated and supersaturated solutions.*
- *description of solubility of a substance and to solve simple numerical problems related to it.*
- *interpretation of the relation between solubility and temperature.*
- *preparation of crystals and to explain the process.*

Yuchuan Gong

KEY WORDS

1. **Solute** : the component of a solution that dissolves in solvent
2. **Solvent** : the component of a solution that dissolves solute
3. **Crystal** : granular structure having sharp edges and smooth surface
4. **Amorphous** : non-crystalline solids
5. **Evaporating basin** : a vessel made of porcelain used to heat things in it
6. **Metabolism** : the combined form of catabolism and anabolism
7. **Evaporation** : the process of changing liquid into vapour
8. **Kinetic energy** : the energy possessed following the motion of bodies
9. **Ionization** : the chemical process of splitting a compound into ions
10. **Polar solvent** : the solvent made of two components of very different electronegativity

Introduction

There are different types of pure and impure substances around us. We have studied elements and compounds like pure substances in unit 8. We have studied in junior classes also about impure substances like suspensions, colloids and solution. The impure substances are called mixtures. They are made by mixing different substances in any ratio. Mixtures are classified into heterogeneous and homogeneous.

In heterogeneous mixtures, particles are visible under naked eyes or light microscope but in homogeneous mixtures particles are visible under ultramicroscopes only. Solution is an example of homogeneous mixture, which is very important for the metabolism of living organisms.

Activity: Make a solution of salt and water

Materials required: Water, beaker, spoon, salt

Method:

1. Take a beaker with half filled water.
2. Place a spoonful of salt in it. Observe the mixture.
3. Now stir the mixture till the salt disappears in it.

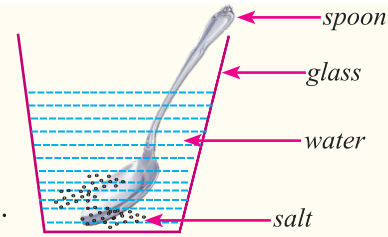


Fig.10.1: *Salt solution*

Now your salt solution in water is ready. Before the salt was unshaken and the particles were visible, it was heterogeneous mixture. When the salt became invisible after stirring the mixture it changed into homogeneous mixture that is solution.

Solution

A homogeneous mixture of two or more substances is called a solution which is usually transparent. A solution may be made of any state of two or more substances. The two components of a solution are solute and solvent. Thus, the solution is a homogeneous mixture formed by mixing a solute with a solvent e.g. Sugar solution, salt solution, tincture iodine, air, etc.

Solution = Solute + Solvent

Solute

Solute is a component of a solution that gets dissolved in a solution. If solute and solvent are in different states, solute changes its state and if both are in the same state solute is found in less amount. In salt solution salt is a solute as salt disappears in water.

Solvent

Solvent is a substance that dissolves a solute in it to form a solution. In a salt solution water is a solvent. Generally water is used as a solvent as it can dissolve several substances in it. Other examples of solvent are alcohol, ether, petrol etc.

Now study solute and solvent in different examples of solution given below-

Some examples of solution, solute and solvent-

S.N.	Solution	Solute	Solvent
1.	Salt solution	Salt (solid)	Water (liquid)
2.	Soft drinks	CO_2 (gas)	Water (liquid)
3.	Moisture in air	Water (liquid)	Air (gas)

4.	Brass	Copper (solid)	Zinc (solid)
5.	Water and alcohol (2 lit) (1/2 lit)	Alcohol (liquid)	Water (liquid)
6.	Atmosphere	Other gases (gas)	Nitrogen (gas)
7.	Water(1/2 lit) and Alcohol(2 lit)	Alcohol	Water

Unsaturated, Saturated and Super-saturated solutions

On the basis of the capacity of dissolving more solute in a solution, it is divided into following three types.

1. Unsaturated solution
2. Saturated solution
3. Super-saturated solution

1. Unsaturated solution

The solution that can dissolve some more solute at the given temperature is called unsaturated solution. The concentration of unsaturated solution increases with the addition of solute in it. An unsaturated solution the solution can be changed into saturated solution either by evaporating the solvent or by adding more solute.

2. Saturated solution

The solution that cannot dissolve extra solute in it at the given temperature is called saturated solution. The concentration of saturated solution does not change with the addition of extra solute to it. The additional solute remains undissolved in the saturated solution. A saturated solution becomes unsaturated either by increasing temperature or by adding solvent.

Answer it now

1. Write the differences between unsaturated solution and saturated solution.

Activity: To demonstrate saturated solution and effect of heat on it.

Materials required: Water, beakers, copper sulphate, spoon, funnel, stand with clamps glass rod, filter paper

Method:

1. Fill half a 100 ml beaker with water and dissolve some copper sulphate in it.
2. Add more salt and stir the mixture until some undissolved salt is left in the beaker.
3. Now, filter it by using a filter paper and a funnel into a dry receiver.

You have prepared saturated solution of copper sulphate at room temperature.

If the solute is heated more solute can be dissolved in it. It shows that the solution becomes unsaturated by the heating of it.

3. Super-saturated solution

A supersaturated solution is the one which contains more dissolved solute than it is expected from its solubility at that temperature. Such solution is highly unstable. The addition of even a very small amount of solid e.g. a crystal of solute or even dust or shaking of the solution causes the solid to separate from the solution. A common example of a supersaturated solution is a solution produced by gently warmed sodium thiosulphate crystals.

Answer it now

1. Suggest two methods of preparing saturated solution from supersaturated solution.

Method of preparation of supersaturated solution

Put a few crystals of sodium sulphate or sodium thiosulphate (hypo) in a conical flask and heat the flask gently. The crystals melt and form a very concentrated solution. Plug the mouth of the flask with cotton wool and leave it for cooling. The solid is not separated out even after cooling it. The solution thus formed is supersaturated solution.

Why do you need to plug the mouth of bottle? Observe the change in the solution on shaking it. Also observe the change in temperature when excess solute crystallizes out from the solution.

Activity:

Method of identifying unsaturated, saturated and supersaturated solution.

Prepare an unsaturated, saturated and supersaturated solution of a solid in water. Now, add a few crystals of solid turn by turn to each of the beakers.

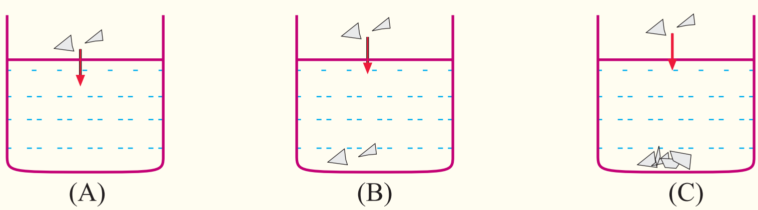


Fig.10.2: *Different types of solution*

i. The solution in beaker 'A' dissolves the solute. When it dissolves the solute, the concentration of the solution increase.

ii. The solution in beaker 'B' does not dissolve any added solute particles. As it doesn't dissolve the solute, its concentration remains unaltered.

iii. In beaker 'C' the size of the crystal grows bigger and concentration of the solution drops.

Now, identify the unsaturated, saturated and supersaturated solutions. Try to define three types of solution on the basis of the change in concentration on adding extra solute.
Yes, A is unsaturated, B is saturated and C is supersaturated solution.

Significance of solution in daily life

Solution is very important to us as they are very useful in our daily life. Some significance of them are given below-

1. Plants obtain their nutrients in the form of solution with the help of their roots.
2. The food that we eat is digested in the alimentary canal and absorbed in the intestine in the form of solution.
3. Oxygen used for respiration is found in nature in the form of solution.
4. The oxygen gas that we breathe in is absorbed in the lungs through a layer of moisture and forms a solution with it.
5. Most chemical reactions occur in the form of solution.
6. Most of the medicines, paints etc are formed in the of solution.
7. Different types of industrial products such as beverages, lotion etc. are all solution.
8. Washing up of something or removing a stain by using a solvent is also a process of making solution.

Solubility

A soluble compound when dissolved in a solvent forms a solution. The amount of different types of solute that can be dissolved in a fixed quantity of solvent is not the same. It means that one dissolves more than another even in the same quantity of solvent at the same temperature to make its saturated solution. This property of solute can be explained in terms of solubility. The weight of solute in grams necessary to dissolve in 100 g of solvent to make a saturated solution at the given temperature is called solubility of that substance at that temperature. Thus solubility is the number of grams of solute necessary to saturate the fixed amount of solvent usually 100 g at a given temperature.
Mathematically,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

For example, if at 20°C, 36 g of sodium chloride can be dissolved in 100 g of water to form its saturated solution, the solubility of sodium chloride at 20°C will be 36.

Answer it now

What do you mean by solubility of potassium nitrate at 20°C is 30?
Temperature is mentioned along with solubility, why?

Activity: Determination of solubility of sodium chloride at lab temperature.

1. Prepare a saturated solution of sodium chloride in water.
2. Weigh a small evaporating basin.
3. Pour the solution into the basin and weigh the basin with solution again.
4. Let the solution evaporate to dry carefully so that no salt is spits out due to over heating in the end.
5. Cool it and weigh it again.
6. Record your observation as below.

Observation

Weight of empty basin	= w g
Weight of basin + salt solution	= w_1g
Weight of basin + dry salt	= w_2g
∴ Weight of salt	= $(w_2\text{-}w)$g
and, weight of water	= $(w_1\text{-}w)$g

Now the solubility of sodium chloride can be calculated by using formula:

$$\text{Solubility of salt} = \frac{W_2 - W}{W_1 - W} \times 100$$

What do you mean by the value you have obtained from this experiment?

Solved numerical problems

1. Find the solubility of a solute in water at 20 °C, If 50 g of water dissolves 30 g of a solute.

Given,

weight of solute = 30 g
weight of solvent = 50 g
solubility at 20 °C = ?

We have,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

$$= \frac{30}{50} \times 100 = 60$$

∴ Solubility of potassium nitrate at 20 °C is 60.

2. 40 g of saturated solution of potassium iodide at 30 °C, when evaporated to dryness, leaves 10 g of solid residue. Calculate the solubility of potassium iodide at that temperature.

Here,

weight of solution = 40 g

weight of solute = 10 g

weight of solvent = weight of solution - weight of solute

= 30 - 10

= 20 g

Solubility at 30 °C = ?

We have,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

$$= \frac{20}{30} \times 100$$

$$= 66.6$$

∴ Solubility of potassium nitrate at 20 °C is 66.67.

3. The solubility of sugar is 220 at 25 °C. What amount of water is required to prepare a saturated solution of 500 g of sugar in water at the given temperature?

Here,

solubility of sugar at 25 °C = 220

weight of solute = 500 g

weight of solvent = ?

We have,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

$$\text{or, } 220 = \frac{500}{\text{Weight of solvent}} \times 100$$

$$\text{or, Weight of solvent} = \frac{500}{220} \times 100$$

$$= 227.2 \text{ g}$$

∴ The weight of required amount of solvent (water) is 227.2 g.

4. What grams of copper sulphate will crystallize out when 50 g of its saturated solution is cooled from 70 °C to 20 °C, if the solubility of copper sulphate at 70 °C and 20 °C is 48 and 28 respectively.

Here,

at 70 °C

The solubility of copper sulphate = 48

weight of solvent = 50 g

Let the weight of solute dissolved in the solution be = x

$\therefore$ Weight of solvent = 50 - x

We have,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

$$\text{or, } 220 = \frac{x}{50 - x} \times 100$$

or, 48 (50 - x) = 100x

or, 2400 - 48x = 100x

or, 148x = 2400

$$\text{or, } x = \frac{2400}{148} = 16.22 \text{ g}$$

Amount of solute dissolved in solution at 70 °C = 16.22 g

Hence, the amount of solvent = 50 - 16.22 = 33.78 g

Let the amount of solute dissolved at 20 °C be = y.

Calculating the amount of solute dissolved at 20 °C,

We know,

Solubility = 28

Weight of solvent = 33.78 g

We have,

$$\text{Solubility} = \frac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$$

$$\text{or, } 28 = \frac{y}{33.78} \times 100$$

$$\text{or, } 100y = 28 \times 33.78$$

$$\text{or, } y = \frac{28 \times 33.78}{100} = 9.46 \text{ g}$$

$\therefore$ The amount of solute crystalized when the solution is cooled from 70 °C to 20 °C = 16.22 - 9.46 = 6.76 g

Alternative method

Here,

Solubility at 70 °C = 48

Solubility at 20 ° = 28

Amount of solute separated by cooling the solution from 70 °C to 20 °C = ?

From the statement we know that-

At 70 °C 100 g of solvent forms 148 g of solution and

At 20 °C 100 g of solvent forms 128 g of solution

The difference in weight of solution at different temperatures is-

(148 - 128) g = 20 g

$\therefore$ By cooling 148 g of solution we can get 20 g of solute

$\therefore$ By cooling 1 g of solution we can get $\frac{20}{148}$ g of solute

$\therefore$ By cooling 50 g of solution we can get $\frac{20}{148} \times 50$ g of solute

$= 6.76$ g

Effect of heat on solubility

We know that dissolving of a solute in a solvent can be accelerated either by heating or by stirring it. Generally a larger quantity of solid cannot be dissolved in a definite quantity of solvent. The following description will enable you to explain that what is the effect of heat for dissolving a solid.

In solids, the atoms or ions are held together by a strong force of attraction and therefore there is a definite shape. The free movement of particles in a solid is relatively very

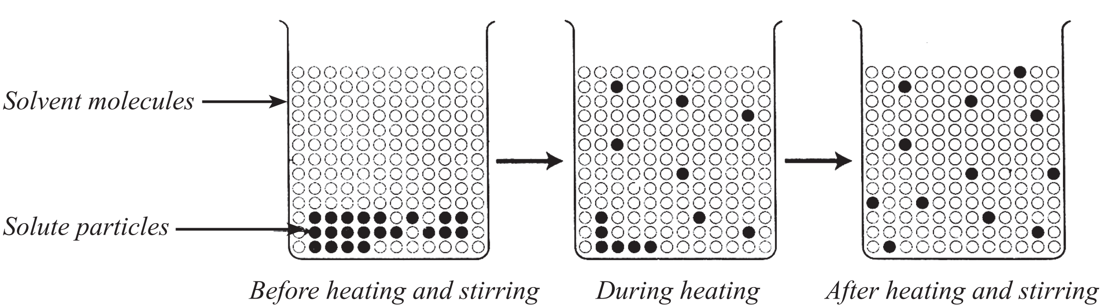


Fig.10.3: A simple model of solvation

small compared to that of liquids. In liquids atoms are loosely held and particles are in constant motion. When a liquid is heated the kinetic energy of the molecules increases and the particles move faster. Putting a solute in a liquid, weakens the bond energy between the ions or atoms of the solute and sets these particles free into the liquid effectively. When a solution is heated there is increase in the kinetic energy of the solute particles and these particles are brought closer to the solvent particles. On stirring too, the solute particles are distributed uniformly and mixed with the solvent particles.

Now try to understand how does common salt particles dissolve in water. Common salt is an ionic compound made of sodium and chloride ions. Sodium is cation and chloride is anion. In the same way, cold water is a polar solvent i.e. oxygen of them are slightly electronegative and hydrogen is slightly electropositive.

Fig.10.4:

When salt is mixed in water, the opposite charge of the molecules attract each other. It helps to distribute salt particles in between the water particles.

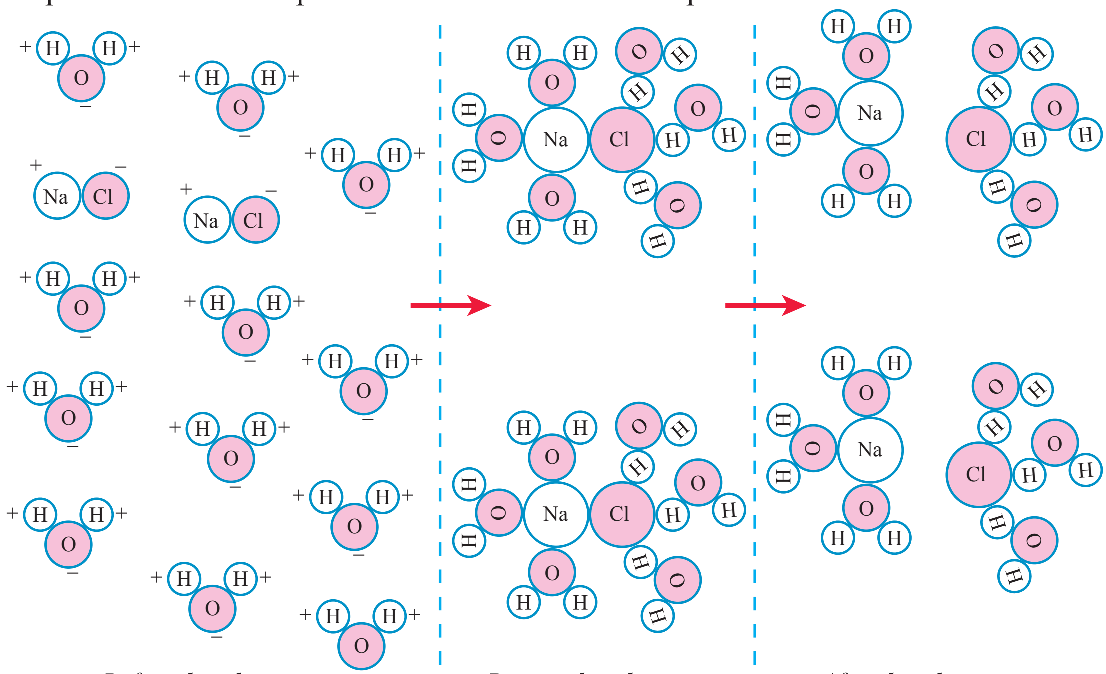


Fig.10.5: *Dissolution of electrovalent compound in water*

Similarly, dissolving of powder is faster than dissolving a larger lump of solid. When a solid is in the powdered form, water gets larger surface area to weaken the force of the atoms of solute and brings the solute particles into solvent quickly.

The vibration of solvent particles due to heat also causes the expansion of liquid. Therefore, more space which can accommodate the larger number of the solute particles between them is made available. This is the reason why the solubility of a substance increases with the increase in the temperature.

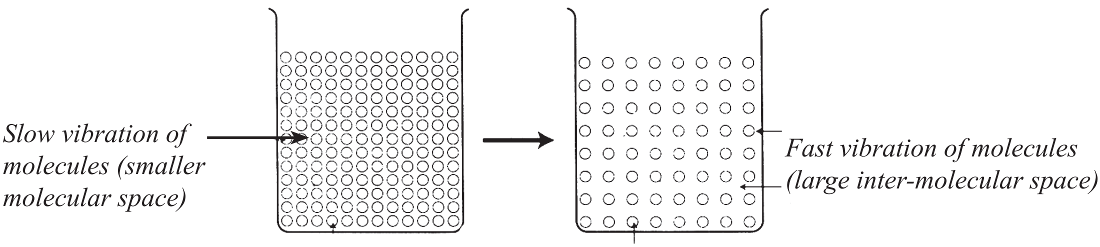


Fig.10.6: *Molecular spacing in solvent*

Solubility curve

One can express the solubility of a substance at different temperatures in two ways i.e. in the form of a table or a graph. The solubility of potassium nitrate can be given as in the table below.

Temperature °C	0	10	20	30	40	50	60
Solubility of potassium nitrate	12	20	30	44	60	85	110

If the data given in this table are plotted in graph then the following curve will be obtained. This is called solubility curve.

The graphical representation of the solubility of a substance at different temperatures by means of a curve is called solubility curve. To draw a solubility curve, temperature is plotted in x-axis and solubility in y-axis. The given graph 10.7 shows the solubility of some solids in the form of curves. In this way solubility of many substances can be plotted on the same graph too.

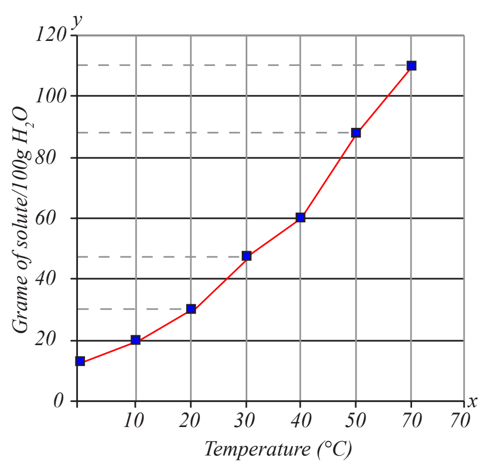


Fig.10.7: *Solubility curve*

Informations obtained from a solubility curve

1. The solubility of a substance at a particular temperature can directly be read from the curve.

2. The trend in the solubilities with the change in temperature can be studied from the curve.
3. The comparison of the solubilities of two or more substances at the same temperature can be done.
4. The solubility curves help to calculate the amount of solute crystallized out or to be added when a solution containing two or more solutes is cooled or heated to a certain degree of temperature.

Activity: Study the graph given and answer the question asked.

1. What are the solubility of potassium nitrate, sodium chloride and potassium chlorate at 10 °C?
2. Which is the most soluble salt at 40 °C?
3. At which temperature is the solubility of potassium nitrate and sodium nitrate is 100?
4. Which salt has almost constant solubility with the change in temperature?
5. What gram of potassium nitrate will crystallize from the solution prepared at 30 °C with 40 g of solvent when it is cooled down to 10 °C?

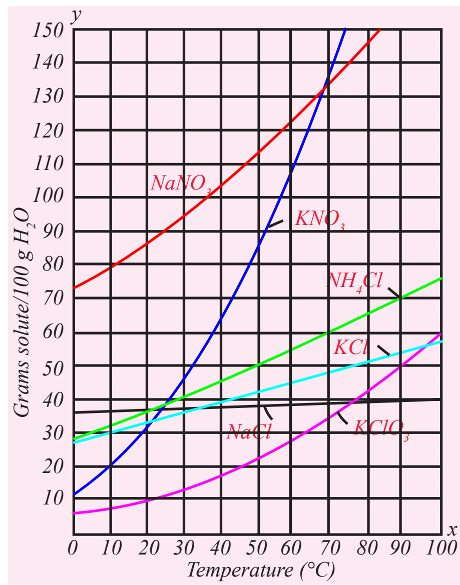


Fig.10.8: Solubility curve of some common solutes

Crystallization

We know that when the saturated solution of a solid at a higher temperature is cooled, a part of the solid held in the solution is deposited in the form of crystals. This homogeneous solid is called a crystal and the process is called crystallization.

Crystals are pure form of particles of substance with sharp edges and smooth faces having regular geometrical shapes. A crystal can be obtained from its saturated solution by allowing the liquid to evaporate from the saturated solution.

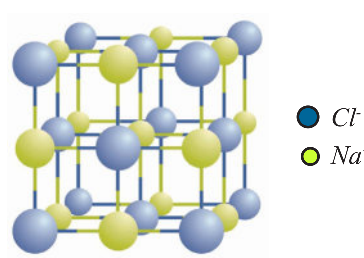


Fig.10.9: Sodium chloride crystal

Preservation of crystal

Crystal grown from aqueous solution can be preserved by immersing it into carbon tetra chloride, benzene or painting with clear varnish.

Amorphous

The particles of substance without regular geometrical shape is called Amorphous for e.g. glass, plastic, rubber, coal, charcoal etc.

Activity: Preparation of copper sulphate crystals.

Materials required: Evaporating basin, tripod stand, wire gauze, Burner, copper sulphate (blue vitrol), water, glass rod, filter paper

Method:

1. Prepare a concentrated solution of copper sulphate with water and put it in an evaporating basin.
2. Evaporate the solution to make it saturated in hot condition. Continue to heat the solution until crystals begin to appear along the inner walls of the basin.
3. Remove the source of heat and cool the solution keeping it at cold place.

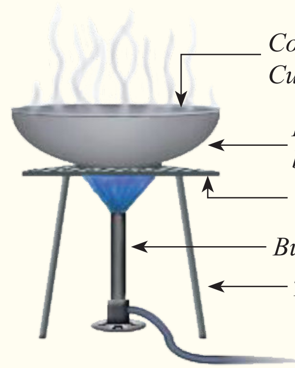


***Fig.10.10:** Crystalization*

In a moment you will able to see beautiful crystals of copper sulphate (blue vitriol) collected at the bottom of the basin. These crystals can be separated from the mother liquor by draining the liquid off. The crystals can be dried by keeping them in between the folds of a filter paper.

If one wants to prepare larger crystals, the solution is allowed to cool slowly by keeping at room temperature.

Lesson Summary

1. If two or more substances are mixed together and these substances do not undergo any chemical change, a mixture is formed.
2. Mixtures are heterogeneous or homogeneous.
3. Solution is a homogeneous mixture of a solute and a solvent.
4. The solution that can dissolve extra solute in it at the given temperature is called unsaturated solution at that temperature.
5. The solution that cannot dissolve extra solute in it at the given temperature is called saturated solution at that temperature.

6. The solution that contains the solute more than it can actually dissolve at the given temperature is called supersaturated solution.
7. Saturated solution can be changed into unsaturated by heating it or by mixing solvent in it. Unsaturated solution can be changed into saturated by evaporating the solvent or by adding more solute to the solution.
8. The weight in grams of a solute necessary to dissolve in 100 g of solvent to make a saturated solution at a given temperature is called solubility of that solute.

   or, Solubility $= \dfrac{\text{Weight of solute (g)}}{\text{Weight of solvent (g)}} \times 100$

9. There is a change in the solubility with the change in temperature.
10. The graphic representation of solubility of a substance in the form of a curve is called solubility curve.
11. The process of obtaining crystals by cooling a hot saturated solution is called crystallization.
12. Non-crystalline substances are called amorphous.

Project work

Making a sugar candy from sugar solution.

Prepare a saturated solution of sugar in water. You can dissolve roughly 220 g of sugar per 100 g of water to obtain its saturated solution at room temperature. Select a small crystal of 0.5 to 0.8 cm long sugar candy and tie it with a small piece of cotton thread around it. This small crystal which is the starting point of the crystal is called 'seed'. Hang the seed crystal about 5 cm above the base of the container with a thread as shown in the diagram.

Fill the bottle with sugar solution before you put seed crystal in position. Leave the setting for a few days. You will obtain larger crystals of sugar candy. The substances that can form crystals are called crystalline and those that cannot form crystals are called amorphous.

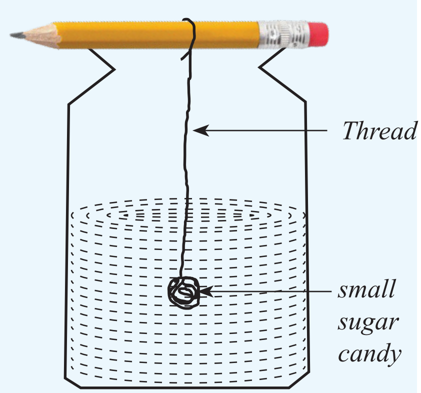


Fig.10.11: *Crystalization*

Conceptual questions with their answers

Q.1. "When a saturated solution is heated, it again becomes unsaturated." Give reason.

It is due to the fact that upon heating intermolecular spaces increase among molecules and therefore more particles (solute) can be adjusted.

Q.2. Which substance is called universal solvent? Why?

Water is also known as universal solvent as it can dissolve many different types of substances in it.

Exercise

1. Answer the following questions.

a. What is solution? Name the constituents of a solution. Write any two points of difference between unsaturated and saturated solutions.
b. What is unsaturated solution?
c. How can you change unsaturated solution into saturated solution?
d. What happens when extra solute is added to unsaturated, saturated and supersaturated solutions?
e. How do you identify whether a given solution is saturated or unsaturated?
f. What is solubility? Write the process of determining the solubility of a solute.
g. Why does the solubility of a substance increase with the increase in temperature?
h. Why is it necessary to mention the temperature while expressing the solubility of a substance?
i. What do you mean by the solubility of a salt at 20 °C is 36?
j. What is a solubility curve? What information can be obtained from it?
k. What change in the solution occurs if a hot saturated solution is cooled? Give reason.

2. From the data below plot the solubility curve.

Temperature °C	0	10	20	30	40	50	60	70
Solubility of NaCl	25	30	35	37	39	40	41	41
Solubility of NH_4Cl	28.4	32.8	37.3	41.3	46.2	50.6	55	64

3. Answer the following questions with the help of the solubility curve (Fig 10.12).

a. What is the solubility of sodium chloride at 25 °C?

b. What is the relationship between temperature and solubility?

c. What happens when saturated solution of sodium chloride at 50°C is cooled to 20°C?

d. Find the solubility of ammonium chloride at 25 °C and 50 °C.

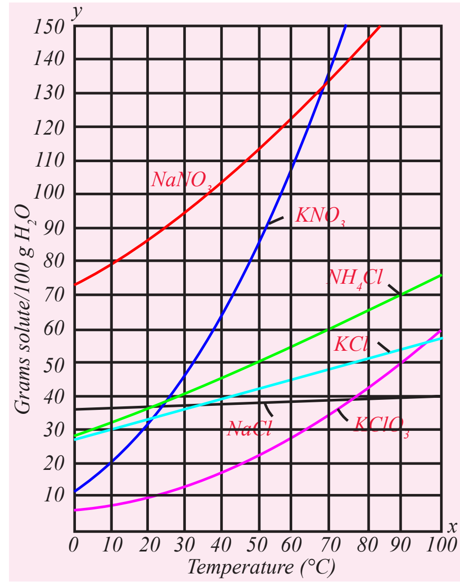


Fig.10.12:

4. Solve the following numerical problems.

a. If the solubility of a substance at a temperature is 60, calculate the weight of solvent in 200 g of saturated solution. [Ans: 125 g]

b. If 60 g of water is required to dissolve 20 g of solid at 30 °C, what is the solubility of the solid at the given temperature? [Ans: 33.33]

c. What amount of potassium chloride is required to saturate 40 g of water at 25 °C, if its solubility at the given temperature is 38? [Ans: 15.2 g]

d. 17 g potassium chlorate is left behind on drying 150 g of its saturated solution prepared at 40 °C. What is the solubility of the salt at the given temperature? [Ans: 12.78]

e. The solubility of a substance at 80 °C is 60 and at 20 °C is 40. How many grams of this substance will crystallize out when 80 g of its saturated solution at 80 °C is cooled to 20 °C? [Ans: 10 g]

f. 40 gram of saturated solution of a solute is prepared at 30 °C. The solution is heated up to 70 °C. How much extra solute is to be added so as to make the solution saturated again? Solubility of the solute at 30 °C is 22 and at 70 °C is 58)

[Ans: 11.8 g]

Multiple Choice Questions

1. Tick (√) the correct answers from the alternatives.

a. In cold drinks-

i. Liquid is dissolved in liquid
ii. Liquid is dissolved in gas
iii. Gas is dissolved in liquid
iv. Gas is dissolved in gas

b. The component of a solution which dissolves the other is called

i. Solvent
ii. Solute
iii. Crystalline
iv. Amorphous

c. Temperature .... the solubility.

i. decreases
ii. increases
iii. does not affect
iv. All of above

d. We can know from a solubility curve-

i. Solubility at that temperature
ii. Amount of solute crystallizes after cooling the solution
iii. Amount of solute can be dissolved when it is heated
iv. All of the above

Unit 11
Some Gases

Total estimated teaching hours = 8

Learning Outcomes

After the completion of this unit, students will learn:

- *preparation, properties and uses of hydrogen, oxygen and nitrogen gases.*

Lavoisier (1743AD-1794AD)

KEY WORDS

1. **Hydrogenation** : chemical reaction while manufacturing vegetable ghee
2. **Catalyst** : the chemical used to accelerate the chemical reaction
3. **Oxidation** : the process of combining oxygen
4. **Oxy-hydrogen flame** : the flame formed by burning a mixture of oxygen and hydrogen
5. **Chemical nitrogen** : pure nitrogen formed by using ammonium chloride and sodium nitrite
6. **Reduction reaction** : the chemical reaction in which oxygen is separated from a compound
7. **Oxidation reaction** : the chemical reaction in which oxygen is combined to form compound
8. **Promotor** : the chemical that activates a catalyst
9. **Hydrocarbon** : a compound consisting of hydrogen and carbon

Introduction

The earth is surrounded by a huge mass of air that consists of different gases like nitrogen, oxygen, carbon dioxide, etc. Though there is a huge mass of gases around us which we are breathing but, it is not visible. Neither has it any odour. We can only feel its presence.

Gases are the essential substances to the living beings including humans. They are not only used for breathing or photosynthesis process but also for burning of fuels, maintaining constant temperature on the earth, generating electricity, wind mill and even for enhancing the taste of soft drinks like beer, lemonade and other fizzy drinks.

Composition of Air

The atmospheric air consists of nitrogen, oxygen, carbon dioxide, argon and neon. Besides these, the air also contains other inert gases and water vapour. The major composition of dry air is as given below:

Gas	Composition by volume
Nitrogen	78.08%
Oxygen	20.95%
Argon	0.93%
Carbon dioxide	0.03%
Neon	0.0018%
Helium	0.0005%
Krypton	0.0001%
Xenon	0.00001%

Table 11.1 Composition of atmospheric air

The above stated percentage of gases varies depending on the geographical location and weather. In addition to water vapour, air in some places contains sulphur compounds, hydrogen peroxide, hydrocarbons and dust particles. In this unit we are going to study about preparation, properties and uses of hydrogen, oxygen and nitrogen gases.

Hydrogen

(A gas which burns itself)

Symbol = H
Molecular formula = H_2
Atomic number = 1
Atomic weight = 1 amu
Valency = 1
Molecular weight = 2 amu
Electronic configuration = 1 ($1s^1$)
M.P. = – 259 °C
B.P. = – 253°C

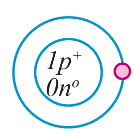


Fig.11.1: *Hydrogen atom*

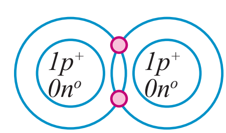


Fig.11.2: *Hydrogen molecule*

Hydrogen as a distinctive element was studied by Henry Cavendish in 1766. The gas was named as "Inflammable air" because of its burning property in air. The name Hydrogen was given by Lavoisier as it forms water (Hydro = water, gen = generator).

Hydrogen is the simplest element. In free state hydrogen exists as a diatomic molecule in which two atoms are combined together by a covalent bond. Hydrogen gas is not found in elemental form in the nature. It is found in combination with water, acids, alkalis and many plant and animal products.

General methods of preparation of hydrogen gas

Hydrogen can be prepared from the following methods.

1. From acid
2. From alkali
3. From water

1. From acid

Usually metals react with acids and form salt and hydrogen.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$
$$Mg + 2HCl \longrightarrow MgCl_2 + H_2\uparrow$$
$$2K + 2HNO_3 \longrightarrow 2KNO_3 + H_2\uparrow$$

2. From alkali

Some metals like zinc and aluminium form salt and hydrogen when heated with alkalis.

$$Zn + 2NaOH \longrightarrow \overset{\text{sodium zincate}}{Na_2ZnO_2} + H_2\uparrow$$

$$2Al + 2NaOH + 2H_2O \longrightarrow \overset{\text{sodium aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

3. From water

Very reactive metals like sodium, potassium etc. form react with water at normal temperature and form alkali and hydrogen.

$$Na + H_2O \longrightarrow NaOH + H_2\uparrow$$
$$K + H_2O \longrightarrow KOH + H_2\uparrow$$

Metals like magnesium, zinc, iron, aluminium etc react with boiling water and form alkali and hydrogen.

$$Mg + 2H_2O \xrightarrow{\Delta} Mg(OH)_2 + H_2\uparrow$$

$$Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2\uparrow$$

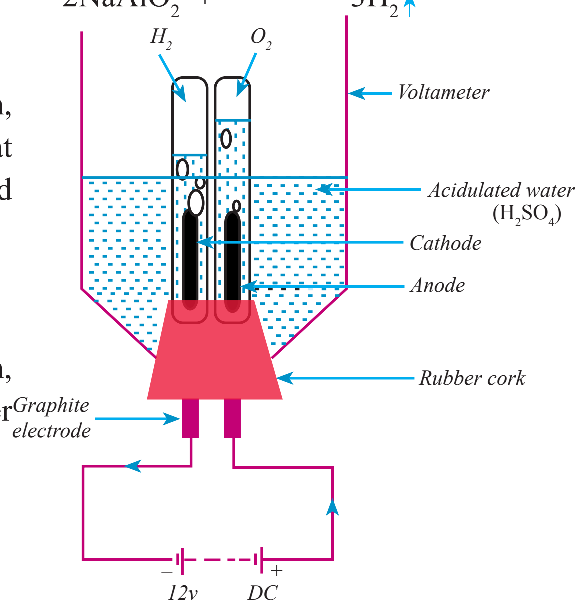


Fig.11.3: *Electrolysis of water*

When electric current is passed in acidulated water through electrodes, the water splits into hydrogen and oxygen gases.

$$2H_2O \xrightarrow{\text{electricity}} 2H_2\uparrow + O_2\uparrow$$

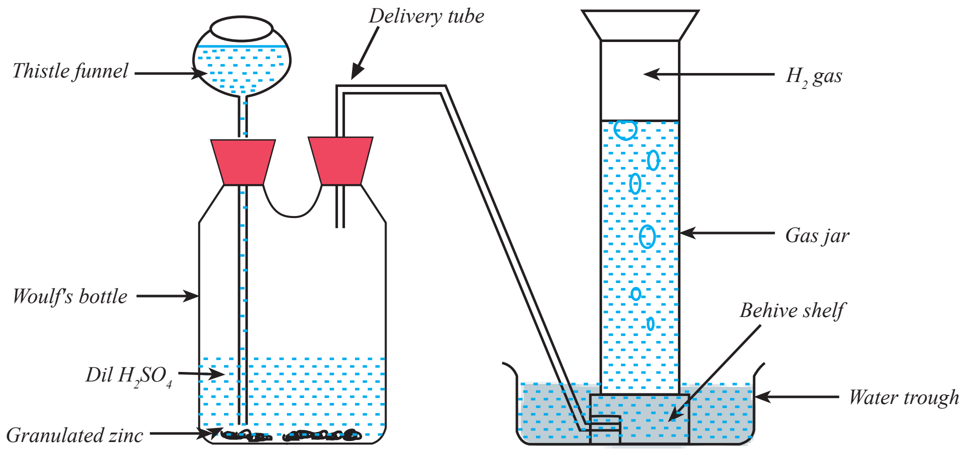
4. From alkali metals

When alkali metals (IA) react with water, it gives alkali and hydrogen gas.

$$2Na + 2H_2O \xrightarrow{\text{electricity}} 2NaOH + H_2\uparrow$$

Preparation of hydrogen gas in lab

In the laboratory, hydrogen gas can be prepared by the reaction between zinc and dilute mineral acids like hydrochloric acid or sulphuric acid.



$$Zn + \text{dil. } H_2SO_4 \longrightarrow ZnSO_4 + 2[H]$$
$$[H] + [H] \longrightarrow H_2\uparrow$$

***Fig.11.4:** Laboratory preparation of hydrogen gas*

Few pieces of granulated zinc are put into woulf's bottle which is fitted with a thistle funnel and a delivery tube. The end of the delivery tube is dipped into the trough containing water. The tube is introduced to the sideway opening of the bee hive shelf. Dilute sulphuric acid is poured into the bottle through thistle funnel. The reaction between metal and acid occurs to produce hydrogen gas. Allow the gas to escape for some time till the air from inside the bottle is completely driven away. Invert a gas jar completely filled with water over the bee-hive shelf. When the reaction between metal and acid takes place, the H_2 gas is formed which can be collected in the gas jar by the downward displacement of water.

Fact file:

Concentrated H_2SO_4 is not used in the lab preparation as it produces SO_2 gas rather than H_2 gas $Zn + conc H_2SO_4 \longrightarrow ZnSO_4 + SO_2 + H_2O$

$$Zn + conc\ 4H_2SO_4 \longrightarrow ZnSO_4 + 4H_2O + 3SO_2$$

Test of hydrogen gas

Hydrogen gas can be tested by bringing a burning matchstick or a splinter near the tube filled with hydrogen gas. As soon as it is brought to the mouth of the tube, the gas burns with a pale blue flame producing a pop sound.

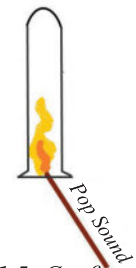


Fig.11.5: Confirmation test of H_2 gas

Precautions

Following precautionary measures have to be taken while preparing hydrogen gas in the laboratory.

1. The end of the thistle funnel must be dipped into the liquid, otherwise gas may escape through it.
2. Pure zinc should not be used as the reaction between dilute acid and pure zinc is very slow. If the reaction is very slow a small amount of $CuSO_4$ solution can be added in the bottle. $CuSO_4$ acts as a catalyst here.
3. Concentrated sulphuric acid should not be used as it produces sulphur dioxide gas with sulphuric acid.
4. The apparatus must be air-tight.
5. The gas jar should not contain any air bubble while inverting it into the water trough.
6. The gas formed at the beginning should be allowed to escape as it contains air.
7. This experiment should not be conducted near flame.

Manufacture of hydrogen gas

Hydrogen gas can be manufactured by following two methods usually.

1. By using methane (Methane-steam reforming process)
2. By electrolysis process

1. By using methane

Methane is a natural gas found in a large amount inside the earth. When the gas is heated at 900 °C to 1200 °C with steam with nickel as catalyst it forms carbon monoxide and hydrogen is called as methane-steam reforming process.

$$CH_4 + H_2O \xrightarrow[\text{Ni}]{900\text{-}1200\ ^\circ C} CO + 3H_2\uparrow$$

The prepared hydrogen is filled in cylinders and sent to market to sell.

2. By electrolysis of water

By using this method hydrogen and oxygen both gases can be manufactured. For it a special type of voltameter fitted with two iron electrodes and separated in two parts by an asbestos diaphragm is taken. The voltameter is supplied with acidulated water and the electrodes are connected in closed circuit. When electric current is passed in the water, it splits into H_2 and O_2. The gases come out from the side tubes as shown in the diagram.

$$2H_2O \xrightleftharpoons{\text{Electricity}} 2H_2 + O_2$$

The gases are filled in different cylinders to sell them.

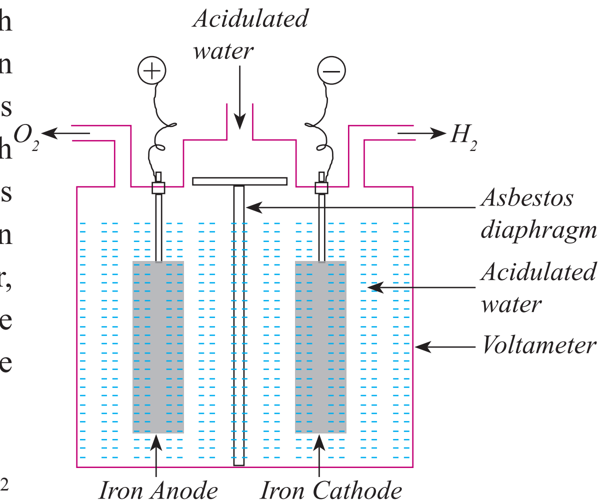


Fig.11.6: *Industrial electrolysis*

Nascent hydrogen

The newly born hydrogen atom formed as a result of the chemical reaction at its site is much more reactive than ordinary molecular hydrogen. Such a newly born atomic hydrogen is called nascent hydrogen. Nascent hydrogen combines together to give molecular hydrogen.

Properties of hydrogen

A. Physical properties

a. Hydrogen is a colourless, odourless and tasteless gas.
b. It is very slightly soluble in water.
c. It is lighter than air. It is the lightest substance.
d. Hydrogen gas can be liquidified and solidfied at a very high pressure and much less temperature. Its boiling and melting points are -253 °C and -259 °C respectively.
e. It is neutral to the litmus.
f. It is inflamable gas. It burns with blue flame

B. Chemical properties

a. Hydrogen forms water by burning with oxygen.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

b. Metals like sodium, potassium and calcium react with hydrogen to form respective metal hydrides, Which are unstable compound.

i. $Na_{(s)} + H_{2(g)} \longrightarrow 2NaH_{(s)}$ (Sodium hydride)

ii. $Ca_{(s)} + H_{2(g)} \longrightarrow CaH_{2(g)}$ (Calcium hydride)

c. When hydrogen gas is passed over hot metal oxides such as copper oxide or lead oxide, they are reduced to respective metals. This process is called reduction and hydrogen acts as a reducing agent.

i. $PbO_{(s)} + H_{2(g)} \xrightarrow{\Delta} Pb_{(s)} + H_2O_{(l)}$

ii. $Fe_3O_4 + 4H_{2(g)} \xrightarrow{\Delta} 3Fe + 4H_2O_{(l)}$

The reduction of metal oxides like PbO and CuO can be carried out the following setting of apparatus in the laboratory.

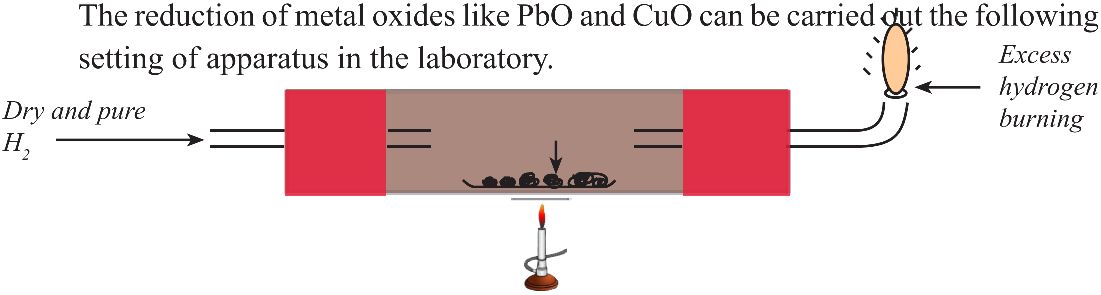


Fig.11.7: *Reduction of metallic oxide*

$$CuO_{(s)} + H_{2(g)} \xrightarrow{\Delta} Cu_{(s)} + H_2O_{(l)}$$

Answer it now

1. Why is dry and pure hydrogen needed for the above setting?
2. How is the flame produced at the mouth of the jet ?

d. Hydrogen gas combines with fluorine, chlorine, bromine and iodine like halogens and forms acids.

Hydrogen		Halogen		Acids
1. H_2	+	F_2	$\xrightarrow{\text{cold and dark}}$	$2HF_{(l)}$
2. $H_{2(g)}$	+	$Cl_{2(g)}$	$\xrightarrow{\text{light}}$	$2HCl_{(g)}$
3. $H_{2(g)}$	+	$Br_{2(g)}$	$\xrightarrow{\text{Heat}}$	$2HBr_{(g)}$
4. $H_{2(g)}$	+	$I_{2(g)}$	$\xrightarrow{\text{light}}$	$2HI_{(g)}$

e. Hydrogen reacts with nitrogen at about 250 atmospheric pressure and 500 °C temperature in the presence of catalyst iron and promoter molybdenum.

$$3H_{2(g)} + N_{2(g)} \xrightarrow[\text{250atm. pressure}]{\text{Fe, Mo 500 °C}} 2NH_{3(g)}$$

f. Hydrogen reacts with unsaturated hydrocarbon (oil) and forms saturated hydrocarbon (vegetable ghee) the process is called hydrogenation.

$$\text{Vegetable oil} + H_2 \xrightarrow[\text{Ni}]{\text{200 °C}} \text{Vegetable Ghee}$$

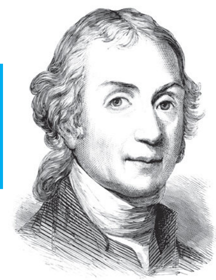
(Unsaturated Hydrocarbon) → (Saturated Hydrocarbon)

Uses of Hydrogen Gas

1. Hydrogen is the lightest gas, therefore, it is used to fill up the balloons. Being inflammable in nature hydrogen is mixed with helium for safety.
2. Hydrogen gas is used for the preparation of ammonia gas in the Haber's synthesis process.
3. Hydrogen gas is used in the manufacture of vegetable oil.
4. It is used in producing oxy-hydrogen flame which is used for high temperature welding and cutting of metals.
5. Mixture of liquid hydrogen and oxygen is used as a fuel in rockets.
6. It is used as a reducing agent in laboratories and industries.

Oxygen

(A gas which helps burning)



Joseph Priestly
(1774AD-1804AD)

Symbol = O
Molecular formula = O_2
Atomic number = 8
Atomic weight = 16 amu
Valency = 2
Molecular weight = 16 amu
Electronic configuration = 2, 6 ($1s^2$, $2s^2$, $2p^4$)
M.P. = - 219 °C
B.P. = - 183 °C

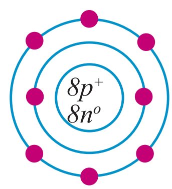


Fig.11.7: *oxygen atom*

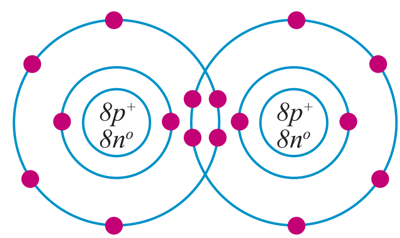


Fig.11.8: *oxygen molecule*

Oxygen gas was discovered by Joseph Priestly, and Karl Sheele independently in 1774 AD. He obtained the gas by concentrating sun's rays through a lens on red oxide of mercury. Sheele also prepared the gas independently and he called it 'Vital air' or 'fire air'. The name 'Oxygen' was given by Antony Lavoisier. Lavoisier was the scienntist to prove that atmospheric air contains $1/5^{th}$ of oxygen gas.

General method of preparing O_2 gas

Some general methods of preparing oxygen are as given below.

A. By heating metallic oxides

Heating of red mercuric oxide can give mercury and oxygen (thermally unstable).

$$2HgO \xrightarrow{\Delta} 2Hg + O_2$$

B. Electrolysis of water

Electrolysis of water can provide oxygen gas along with hydrogen gas.

$$2H_2O \xrightarrow{\text{Electricity}} 2H_2\uparrow + O_2\uparrow$$

C. By heating the salts having oxygen

If oxygen containing salts are heated strongly oxygen is separated from them.

$$2KNO_3 \longrightarrow 2KNO_2 + O_2$$
$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

D. From atmospheric air

Atmospheric air is filtered and cooled below the boiling point of oxygen i.e. below -183 °C. Now the mixture of gases is warm up to -183 °C so that complete oxygen vaporises to obtain at its pure form. It's the fractional distillation of liquidified air.

Laboratory preparation of oxygen gas

Oxygen gas can be prepared in laboratories by following two methods

A. By heating method

B. Without heating method

A. By heating method

Oxygen gas can be prepared in the laboratory by heating a mixture of potassium chlorate and manganese dioxide. In order to prepare the gas, crush 4 parts of potassium

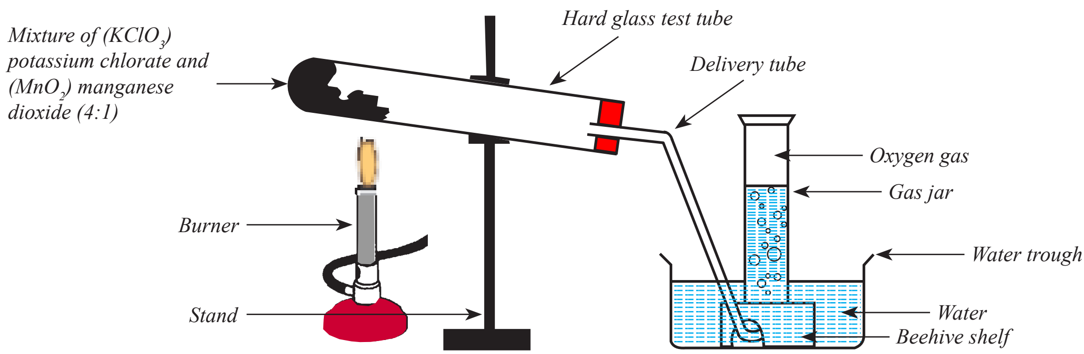


Fig.11.9: *Preparation of oxygen by heating process*

$$2KClO_3 \xrightarrow[\Delta]{MnO_2} 2KCl + 3O_2\uparrow$$

chlorate ($KClO_3$) and 1 part of mangnese dioxide (MnO_2) powder in a mortar and mix them thoroughly. Manganese dioxide acts as a catalyst in this reaction. Place the mixture in a hard glass test tube and fit up the apparatus as shown in the diagram 11.9. Heat the mixture, and the gas thus formed is collected in the jar by downward displacement of water.

Precautions

Following precautionary measures have to be taken in the preparation by the above method.

1. The apparatus must be fitted leak proof.
2. The delivery tube should be taken out of the water before the burner is removed at the end of the experiment otherwise water will be sucked in and the tube may break.
3. The test tube needs to adjust slightly in an inclined position.
4. Heating should be done in a uniform manner.

B. Without heating method

Oxygen gas can be prepared much more conveniently from hydrogen peroxide without heating process. For it small quantity of manganese dioxide powder is kept in a conical flask as the catalyst. The apparatus needed for the preparation of the gas is then fitted as shown in the diagram 11.10. Hydrogen peroxide is added drop by drop through a dropping funnel by opening the stopper. Oxygen gas evolves and it can be collected in a gas jar by downward displacement of water.

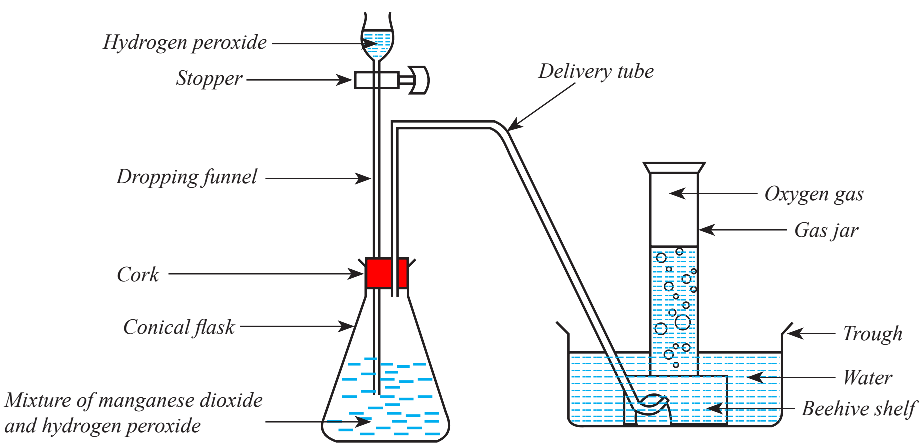


Fig.11.10: *Preparation of oxygen without heating process*

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2\uparrow$$

Manufacture of oxygen gas

Oxygen gas can also be prepared in a large scale by the electrolysis of water . About this method we have already studied in the subtopic hydrogen gas.

Precautions

The following precautions should be taken during preparation of oxygen gas without heating process-

1. The apparatus must be fitted airtight.
2. The end of dropping funnel must be immersed inside Hydrogen peroxide.
3. The beehive sheet must be immersed in water.
4. The end of delivery tube inside the flask should be above the hydrogen peroxide.

Properties of oxygen gas

A. Physical properties

a. It is a colourless, odourless and tasteless gas.
b. It is neutral to indicators.
c. It is only slightly soluble in water (3% by volume)
d. It is slightly heavier than air.
e. It does not burn itself but helps substances to burn.
f. It boils at -183 °C and freezes at -219 °C.

B. Chemical properties

a. Non-metals like carbon, phosphorus, nitrogen combine with oxygen and give their respective oxides:

i. $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$
ii. $4P_{(s)} + 5O_{2(g)} \longrightarrow 2P_2O_{5(g)}$ (Phosphorus Pentoxide)
iii. $S_{(s)} + O_{2(s)} \longrightarrow SO_{2(g)}$ (Sulphur dioxide)

b. Nitrogen reacts with oxygen at a very high temperature to form nitric oxide. Often the spark produced in lightning causes nitrogen and oxygen to combine to form nitric oxide. Nitric oxide dissolves in rainwater which increases the fertility of soil.

$N_{2(g)} + O_{2(g)} \xrightarrow{2000°C\text{-}3000°C} 2NO_{(g)}$ (Nitric oxide)

Do it now

Insert a glowing match stick inside the jar containing oxygen gas. The match stick will burn brighter than before. After the burning of the match stick, put a few drops of lime water into the jar. What do you observe now? What does it confirm? Explain.

c. Metals like sodium, potassium, calcium and magnesium burn with a bright flame in oxygen to form their respective oxides.

i. $4Na(s) + O_{2(g)} \xrightarrow{\Delta} 2Na_2O_{(s)}$
ii. $4K(s) + O_{2(g)} \xrightarrow{\Delta} 2K_2O_{(s)}$

iii. $2Mg(s) + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$

iv. $2Fe(s) + O_{2(s)} \xrightarrow{\Delta} 2FeO_{(s)}$

d. Oxygen also combines slowly without heating with metals to form their oxides. Iron surface when exposed to most air it combines with oxygen to form hydrated ferric oxide which is called rust and the surface appears tarnished.

$$4Fe + 3O_2 + 2H_2O \longrightarrow 2Fe_2O_3.2H_2O$$

e. Organic compounds like hydrocarbons, ethyl alcohol, mineral oil, petrol, wax burn in air to form carbon dioxide and water along with heat energy.

i. $CH_4 + 2O_2 \longrightarrow CO_{2(g)} + 2H_2O_{(l)} + \text{heat}$

ii. $C_2H_5OH + 3O_2 \longrightarrow 2CO_{2(g)} + 3H_2O_{(l)} + \text{heat}$

f. Oxidation of glucose occurs in the living cells due to the oxygen absorbed. The process is called as respiration.

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \longrightarrow 6CO_2 + 6H_2O + \text{heat}$$

g. Ammonia gas burns in the presence of air (Oxygen) and gives water and nitrogen gas.

$$4NH_3 + 3O_2 \longrightarrow 6H_2O + 2N_2\uparrow$$

Uses of Oxygen

1. Living organisms use oxygen for respiration. The chemical reaction occurs between glucose and oxygen and energy is released. The energy is used to maintain life processes.
2. Cylinders filled with oxygen gas are used in the hospitals for the patients with a breathing problem.
3. Mountaineers and people working in mines use oxygen cylinders for breathing as the oxygen concentration lacks there.
4. Oxygen helps to burn fuels. Fuels like fire wood, coal, L.P. gas etc burn in the presence of oxygen. Liquid oxygen is used for the burning of fuel in rockets.
5. Oxygen is used to prepare various useful compounds like oxides, sulphuric acid, chlorine, acids, bases etc.
6. Because of the solubility of oxygen in water, it is used by aquatic organism for respiration.
7. Oxygen is used by welders to produce oxy-acetylene flame and oxy-hydrogen flame.

Nitrogen

(The gas which neither burns nor helps burning)

Daniel Rutherford (1749AD-1819AD)

Symbol = N

Molecular formula = N_2

Atomic number = 7

Atomic weight = 14 amu

Valency = 3

Molecular weight = 28 amu

Electronic configuration = 2, 5 ($1s^2$, $2s^2$, $2p^3$)

M.P. = - 196 °C

B.P. = - 210 °C

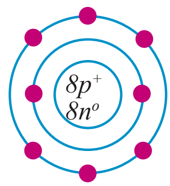


Fig.11.11: *Atomic structure*

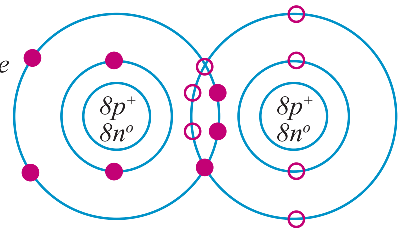


Fig.11.12: *Molecular structure*

Nitrogen was discovered by Daniel Rutherford in 1872 AD, who called it as "Poisonous air" for not supporting combustion and respiration. The name 'Nitrogen' was given by Chaptal. Lavoiser studied its properties and named it "azota" i.e. not essential for life.

Nitrogen is major constituents of air. Nitrogen occurs freely in the atmospheric air and occupies 78% by volume. It is an essential component of proteins in living organisms. In combination, it is also found as ammonia, nitrate, sodium nitrate etc.

General methods of preparation of nitrogen gas

Nitrogen gas can be prepared by using following general methods-

a. By passing air over hot copper

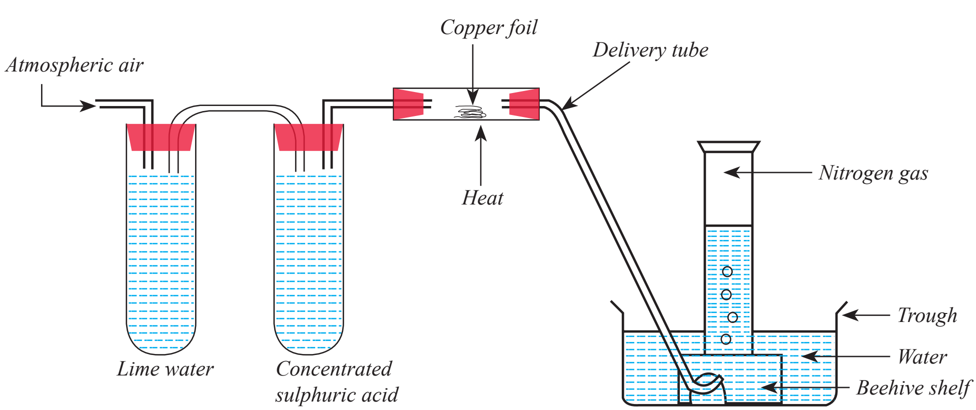


Fig.11.13: *Preparation of nitrogen passing air over hot copper*

For this method firstly the apparatus is adjusted as shown in the above diagram. Then atmospheric air is passed in a test tube containing lime water, which absorbs CO_2 from the air. Now the air is passed through concentrated sulphuric acid which absorbs moisture. Then the remaining air in passed through hot Cu foil/powder which absorb oxygen to form copper oxide.

$$2Cu + O_2 \longrightarrow 2CuO$$

The remaining nitrogen with very few impurities is collected in the gas jar by downwards displacement of water.

b. By burning phosphorus in air

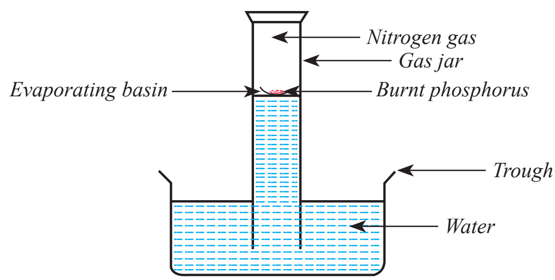


Fig.11.14: *Phosphorus burning*

For this method a trough containing water is taken. Over the water an evaporating basin with phosphorus is also placed. Now the phosphorus is burnt and immediately an empty gas jar is adjusted over the basin. The burning phosphorus reacts with oxygen of air and nitrogen gas with some impurities is remained in the gas jar.

$$4P + 5O_2 \longrightarrow \underset{\text{Phosphorus pentoxide}}{2P_2O_5}$$

Laboratory method of preparation of nitrogen gas

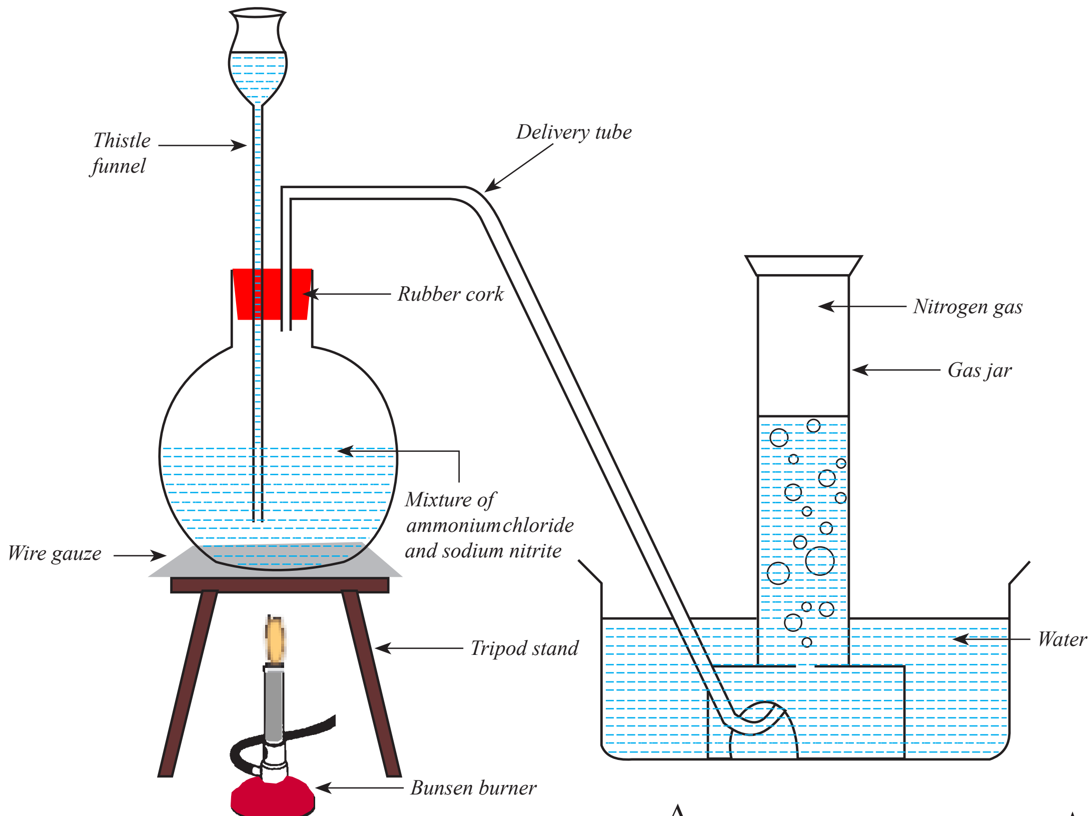
In laboratory,

$$NH_4Cl_{(aq)} + NaNO_{2(aq)} \xrightarrow{\Delta} NaCl_{(aq)} + NH_4NO_2 \text{ (amm. nitrite)}$$

$$NH_4NO_2 \xrightarrow{\Delta} N_{2(g)} + 2H_2O_{(l)}$$

The overall reaction may be written as:

$$NH_4Cl_{(aq)} + NaNO_{2(aq)} \xrightarrow{\Delta} N_{2(g)} + NaCl_{(aq)} + 2H_2O_{(l)}$$



$$NH_4Cl + NaNO_2 \xrightarrow{\Delta} NaCl + 2H_2O + N_2\uparrow$$

Fig.11.15: *Lab. preparation of nitrogen gas*

A mixture of ammonium chloride and sodium nitrite in the is kept in the form of aqueous solution is kept in a round bottom flask. The flask is fitted with a cork and a delivery tube too. The other end of the delivery two is taken into a gas jar. The gas jar is kept inverted filling with water. Then heat is applied gently. When the solution is warmed, rapid effervescence occurs and nitrogen is produced. The gas thus produced can be collected in a jar by downward displacement of water.

Precautions

Following precautionary measures have to be taken in the laboratory preparation of nitrogen gas.

i. The apparatus must be air tight.
ii. The heating should be done slowly.
iii. Only a calculated amount of ammonium nitrate and sodium nitrite should be used.
iv. The end of delivery tube inside the flask must be above the solution.
v. The beehive shelf must be immersed in water.

Test of nitrogen: Nitrogen gas can be identified by following methods-

1. When a burning splinter is taken in it, the splinter extinguishes.
2. When a burning magnesium ribbon is taken into this gas, the ribbon burns continuously and forms yellow magnesium nitride.

   $N_2 + 3Mg \longrightarrow Mg_3N_2$ (yellow)

Manufacture of nitrogen (Industrial Preparation)

i. From air: Air is the main source of nitrogen. Therefore, it can be manufactured by the fractional distillation of liquid air. Air is cooled under high pressure i.e. 200 atmosphere. Oxygen is liquidified at -183 °C, whereas nitrogen changes into liquid at -196 °C. The two gases can thus be separated and collected separately due to their different boiling points.

i. From ammonia: For commerical purpose it can be prepared by inducing a reaction between ammonia and chloride

$$8NH_3 + 3Cl_2 \longrightarrow 6NH_4Cl + N_2\uparrow$$

Properties of nitrogen

A. Physical properties

i. It is a colourless, odourless and tasteless gas.
ii. It is very little soluble in water.
iii. It is slightly lighter than air.
iv. It is neutral to the indicators.
v. It neither burns itself nor supports in burning.
vi. It boils at -196 °C and freezes at -210 °C.

B. Chemical properties

Chemically, nitrogen is a less reactive gas. As it is diatomic molecule having triple covalent bonds (N≡N). It shows some chemical combination with some elements under certain conditions.

a. Metals like magnesium, calcium and aluminium combine with nitrogen gas on heating to form their nitrides.

$$3Mg_{(s)} + N_{2(g)} \xrightarrow{\Delta} Mg_3N_{2(s)}$$
Magnesium nitride

$$3Ca_{(s)} + N_{2(g)} \xrightarrow{\Delta} Ca_3N_{2(s)}$$
Calcium nitride

$$2Al_{(s)} + N_{2(g)} \xrightarrow{\Delta} 2AlN_{(s)}$$
Aluminium nitride

When yellow coloured magnesium nitride powder formed above is heated by mixing it with water, ammonia gas evolves.

$$Mg_3N_{2(s)} + 6H_2O_{(l)} \longrightarrow 3Mg(OH)_{2(s)} + 2NH_{3(g)}\uparrow$$

b. Nitrogen and oxygen can also be combined at a very high temperature (2000-3000 °C). The combination of nitrogen and oxygen forms nitric oxide during lightening in air.

$$N_2 + O_2 \xrightarrow{2000°C\text{-}3000°C} 2NO \text{ (Nitric oxide)}$$

c. Nitrogen can combine with hydrogen at a high temperature and high pressure. In this process iron powder is used as catalyst and molybdenum powder is used as promotor.

$$3N_2 + 3H_2 \xrightarrow[\text{at the temp. of 500°C and at high pressure}]{\text{Fe \& Mo powder}} 2NH_3$$

Uses of nitrogen

i. Nitrogen is used in the manufacture of ammonia, nitric acid, fertilizers and explosives like nitronglycerine.
ii. A fuel tank of aeroplane is separated from air by nitrogen to prevent possible explosion.
iii. Being inactive in nature, nitrogen is used for filling filament bulbs to provide inner atmosphere.
iv. Nitrogen is used in packaging of food, fish, meat to keep them fresh.

Lesson Summary

1. Air is the mixture of different gases like nitrogen, oxygen, carbon dioxide and inert gases.
2. Hydrogen gas can be prepared from acid, base and water.
3. Hydrogen gas can be prepared in the laboratory by the action of granulated zinc with dilute sulphuric acid.
4. Industrially, hydrogen gas can be prepared by heating methane and by electrolysis process.
5. Hydrogen is a colourless, odourless and tasteless gas. It is a neutral gas which can be liquidified and solidified when cooled.
6. Hydrogen is a combustible gas, it burns in air to form water and produces a characteristic 'POP' sound.
7. Hydrogen gas is used in filling up balloons, hydrogenation of fat, as a fuel in producing high temperature, in fertilizer factory and as a reducing agent.
8. In laboratory, oxygen gas can be prepared by heating the mixture of potassium chlorate and manganese dioxide in the ratio of 4:1.
9. Oxygen gas can also be prepared without heating but by the decomposition of hydrogen peroxide in the presence of manganese dioxide as a catalyst.
10. Oxygen is a colourless, odourless and tasteless gas. It is slightly soluble in water.

11. Metals and non-metals combine with oxygen to form their respective oxides under different conditions.
12. Oxygen is used for respiration, burning of fuels, welding metals and manufacturing useful substances.
13. In laboratory, nitrogen gas can be prepared by heating a mixture of ammonium chloride and sodium nitrite.
14. Nitrogen gas is manufactured by the fractional distillation of liquid air.
15. Chemically, nitrogen is inert, however, it combines with certain elements under different conditions.
16. Nitrogen is used in manufacturing ammonia, nitric acid, explosives, fertilizers, filling up the filament bulbs, in the fuel tank of aeroplanes and in packaging of food.

Project work

Activity

1. Put a little potassium permanganate in a test tube and heat it. What happens if a glowing splinter is introduced to the tube? What can you conclude from it?
2. Burn sulphur powder in a steel spoon in a jar containing oxygen. Dissolve the gas thus formed in water and test the gas with a piece of blue litmus paper.
   i. What do you observe? ii. What can you conclude from it?

Conceptual questions with their answers

Q.1. Why zinc is preferred to other metals in the preparation of hydrogen gas?

Zinc reacts slowly and gradually with acid while other metals such as sodium potassium etc. react violently with acid and many lead to many hazards in a laboratory.

Q.2. Which gas is filled in electric bulb? Why?

Nitrogen gas is filled in electric bulb because it behaves as an inert gas in a diatomic form and prevents electric bulb from oxidation (burning).

Exercise

A. Hydrogen gas

1. **Describe the laboratory preparation of hydrogen gas in the laboratory.**
2. **What property of hydrogen gas makes it possible to collect by downward displacement of water?**

3. How do you test whether an unknown gas is hydrogen or not?

4. What are the physical properties of hydrogen gas?

5. What is hydrogenation? Write its importance.

6. Write three chemical properties of hydrogen with chemical equations.

7. What happens.

i. when hydrogen passes over the heated lead oxide?

ii. when steam passes over the heated iron surface?

iii. when hydrogen and chlorine are mixed in a test tube and kept in the sunlight?

iv. when hydrogen gas is burnt in air?

8. Study the given diagram 11.16 and answer the questions as listed below.

i. What mistake is made in the setting shown in the diagram?

ii. How can you overcome the problem?

iii. Write the equation to take place in the Woulfe's bottle.

iv. Why is gas collected by downward displacement of water?

v. List any three uses of the gas prepared from this setting of apparatus.

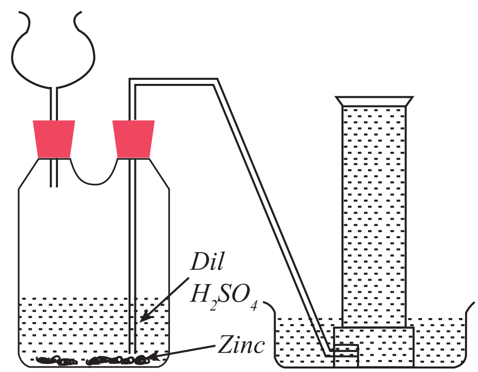


Fig.11.16:

B. Oxygen gas

1. Why is oxygen regarded an important constituent of air?

2. Describe with a diagram the laboratory perparation of oxygen gas.

i. By using heat　　　　ii. Without using heat

3. What is the role of MnO_2 in the preparation of oxygen by using potassium chlorate or hydrogen peroxide?

4. How do you test oxygen?

5. What are the physical properties of oxygen gas?

6. What happens when:

i. a burning magnesium is introduced to a jar containing oxygen gas?

ii. iron is exposed to moist air?

iii. burning phosphorus is introduced to the jar containing oxygen?

iv. the flame produced by burning sulphur is tested with a piece of wet blue litmus paper?

7. Write any three uses of oxygen gas.

C. Nitrogen gas

1. **Describe the laboratory methods of preparation of nitrogen gas with a labelled diagram.**
2. **Describe how nitrogen gas can be separated from liquid air.**
3. **Why is nitrogen gas prepared in the laboratory called chemical nitrogen?**
4. **What are the physical properties of nitrogen gas?**
5. **Describe with equation what happens in the following cases?**
   a. A mixture of ammonium chloride and sodium nitrite is heated gently.
   b. Burning magnesium is introduced to a jar containing nitrogen gas.
   c. Water is added to magnesium nitride solid.
6. **Why is nitrogen gas called an inert gas? What is its significance?**
7. **Write any three uses of nitrogen gas.**
8. **What is Haber's process?**
9. **Explain the confirmation test of nitrogen gas.**

Multiple Choice Questions

1. Tick (√) the correct answers from the alternatives.

a. Which chemical is used as cooling agent?

i. Oxygen	ii. Liquid ammonia
iii. Hydrogen	iv. None

Unit 12 Metals

Total estimated teaching hours = 5

Learning Outcomes

After the completion of this unit, students will learn:

- *properties of metals.*
- *difference between metals and non-metals.*
- *the role of metal (Zinc in enzyme, importance of sodium and potassium ions, adverse effects of Hg and Pb on body).*

Madam Curie (1867AD-1934AD)

KEY WORDS

1. **Basic oxide** : metallic oxides, which form alkali with water
2. **Acidic oxide** : non-metallic oxides, which form acid with water
3. **Cardiovascular**: related to heart and blood circulatory system
4. **Enzyme** : biological catalyst
5. **Lymph** : fluid that collects waste of the body and mixes with blood
6. **Impulse** : electrical signal
7. **Placenta** : a vascular organ connected with navel of foetus and supplies food and oxygen to them from mother's body
8. **Gasoline** : petrol
9. **Insomnia** : sleeping disorder
10. **Anaemia** : loss of RBC that reduces the carrying capacity of oxygen by blood (deficiency of Haemoglobin)
11. **Antioxidant** : any substance that acts to slow or prevent the oxidation of another chemical.

Introduction

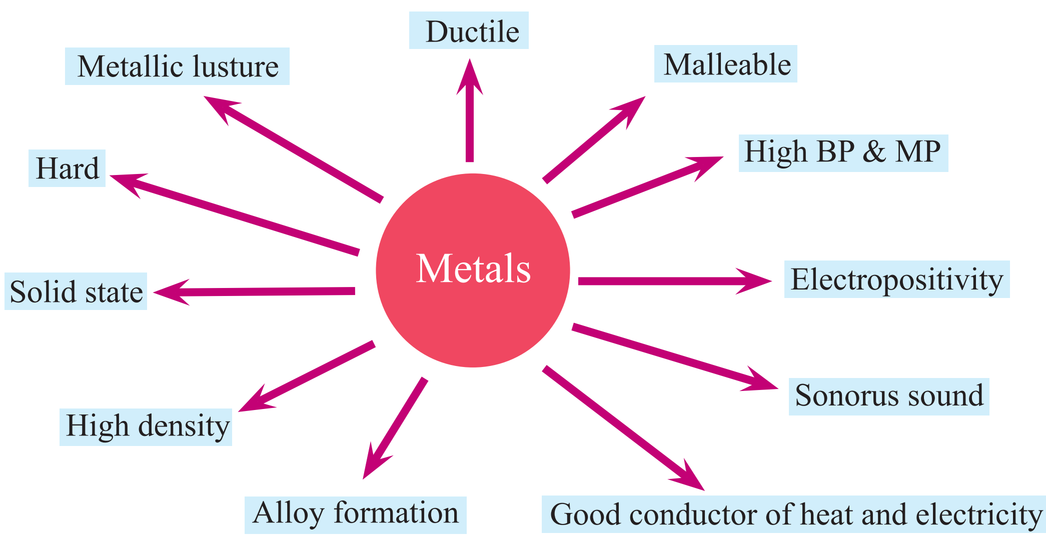
There are many types of substances around us. Some of them are metals and some are non-metals. At modern age, we heavily rely on metals. Iron or steel is used for the construction work, manufacturing weapons, machinery parts in industries, roofs, pipes, railway lines and household utensils. Metal like aluminium is used in making coins, electric cables, household utensils and many more. There are metals which are used for special purposes. Metals such as tantalum, titanium and zirconium are used in space missiles, jet aircraft and nuclear reactors. Similarly, the precious metals like silver, gold, platinum are used in jewellary because of their shiny appearance and chemical inertness. Metals like copper and aluminium are used for making household utensils. They are widely used as electrical cables to pass electricity from one place to another.

Not only metals, but also their compounds have immense importance in our daily life. You may not realize that substances like common salt, soap, various drugs, cement, glass, etc. all are metal compounds.

Metals are important inside living beings bodies also. Iron found in our blood, magnesium found in chlorophyll are very important to survive. In the same way zinc, sodium and potassium are also important for the vital functions in our body.

Properties of metals

Some characteristics which are found in metals are not in others, they are called properties of metals. Some such properties of metals are described below.



A. Physical properties

a. Hardness

Most of the metals are hard. Only some of them are soft (sodium, potassium) as excepted cases. You also should remember that diamond is the hardest which is not a metal. It is a non metal.

b. Physical state

Most of the metals are in solid state. Only mercury is found in liquid state but no metal is in gas state at normal temperature and pressure. (NTP)

c. Melting point and boiling points

Usually metals have high melting point and high boiling point. Only few metals have low melting point and low boiling point. Boiling point and melting point of some metals are given below.

S.N.	Metal	Melting pt.	Boiling pt.	Remarks
1.	Iron	1500 °C	2500 °C	High M.p. and B.p.
2.	Copper	1083 °C	2350 °C	"
3.	Silver	960 °C	1955 °C	"
4.	Gold	1063 °C	2530 °C	"
5.	Lithium	180 °C	1326 °C	Low M.p. and B.p.
6.	Sodium	97.5 °C	880 °C	"
7.	Potassium	72.5 °C	757 °C	"
8.	Caesium	28.5 °C	678 °C	"
9.	Rubidium	39 °C	688 °C	"

Table: 12.1 MP and BP of same metals

d. Metallic lustre

Metals are shiny. Some metals which have dull surface they are also seen shiny at fresh cut. The property is termed as metallic lustre.

e. Sonorous sound

Metals produce special sound when they are hit by another metal. The sound is called sonorous sound or metallic clink. Due to this property bells are made of metals.

f. Electropositivity

The property of losing electron is called as electropositivity. Metals have this property so they are electropositive in nature.

g. Relative density

The ratio of density of a substance to the density of pure water at 4 °C is called relative density of that substance. Relative density of metals is more i.e. they have high density. Alkali metals are exception of it.

h. Alloy formation

Metals can form alloy by mixing with other metal and non-metal. Brass, steel bronze, amalgam etc. are some examples of it.

i. Malleability

When metals are beaten they flatten i.e. they can be beaten into sheet. They property is called as malleability. Due to this property of metals they can be used for different purposes.

j. Ductility

Wire can be drawn from metals. The property of the metals is called as ductility. The wires made from metals are used for different purposes in our daily life.

***Fig.12.1:** Metal wire*

k. Conductivity

Energy like heat, electricity can travel easily through the metals. Due to this reason metals are good conductor of heat and electricity. Because of the property of metals their use is more to make electric goods and cooking utensils.

***Fig.12.2:** Metal utensil*

B. Chemical properties

Beside the physical properties of metals mentioned above they have some chemical properties also.

a. Reaction with acids

Generally metals form salt and hydrogen by reacting with metals.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$
$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

b. Reaction with hydrogen

Some metals form unstable hydrids by reacting with hydrogen.

$$2Na + H_2 \longrightarrow 2NaH$$
$$Ca + H_2 \longrightarrow CaH_2$$

c. Reaction with oxygen

When metals react with oxygen they form oxide or base. Thus they are basic oxides as they form alkali by reacting with water.

$$2Mg + O_2 \longrightarrow 2MgO$$
$$2Ca + O_2 \longrightarrow 2CaO$$

Some metals like iron an aluminium react with oxygen at low temperature also and form related oxides. Iron forms rust with moist air and aluminium forms aluminium oxide.

$$4Fe + 3O_2 + 2H_2O \longrightarrow \underset{\text{Rust}}{2Fe_2O_3.2H_2O}$$
$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

d. Reaction of metal with the salt of less reactive metals

There are different degree of reactivity of metals. Some metals are more reactive and some are less reactive. More reactive metals displace the metal from the salt of less reactive metals. For example when an iron nail is kept in $CuSO_4$ solution the nail is coated with Cu displaced from the solution.

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

Difference between metals and non-metals are as given below.

S.N.	Metals	S.N.	Non-metals
1.	Metals are solid at normal temperature. Mercury is an exception.	1.	Non-metals are in three states i.e. solid, liquid and gas.
2.	Freshly cut surface of a metal has a bright appearance i.e. metallic lusture.	2.	Surface of non-metallic elements looks dull i.e. has no metallic lusture.
3.	Metals have high density. Exception-alkali metals.	3.	Non-metals have generally low density.
4.	Metals are hard with varying degrees of hardness.	4.	Generally, non-metals are soft. Exception-diamond.
5.	Generally metals have high melting and boiling points. Exception-alkali metals and mercury.	5.	Non-metals have generally a low M.p. and B.p. Exception-carbon, silicon.
6.	Metals can be hammered into thin sheets i.e. they are malleable	6.	Non-metals are non-malleable i.e. non-metals are brittle. Exception-As, Sb, Bi.
7.	Metals can be drawn into wires i.e. they are ductile.	7.	Non-metals are non-ductile.
8.	Metals conduct heat and electricity i.e. they are good conductors of heat and electricity.	8.	They are poor conductors of heat and electricity. Exception-graphite.
9.	Metals dissolve in each other to form a homogeneous mixture called alloy.	9.	Non-metals alone cannot form alloy.
10.	Metals are electropositive.	10.	They are normally electronegative.
11.	Metals burn in oxygen and form basic oxides. $2Mg + O_2 \longrightarrow 2MgO$	11.	Non-metals form acidic oxides. These oxides dissolve in a base to form salt and water. Exception CO, N_2O, NO, H_2O. $C + O_2 \longrightarrow CO_2$
12.	Only some metals combine with hydrogen to form unstable hydrides e.g. NaH, CaH_2. $2Na + H_2 \longrightarrow 2NaH$ $Ca + H_2 \longrightarrow CaH_2$	12.	Non-metals form stable hydrides with hydrogen. $C + 2H_2 \longrightarrow CH_4$ $N_2 + 3H_2 \longrightarrow 2NH_3$
13.	Most metals dissolve in acid to form a salt and hydrogen.	13.	Non-metals may dissolve in acid but gas is not formed.

Table: 12.2

Role of metals on the health of human beings

Our body is made of different elements. The main elements found in our body are C, O, H, N, P and sulphur. These six elements are those elements which are required in large amount. They form different types of bio molecules like nucleic acid, protein lipids etc. Na, K, Ca, Zn, V, Ni, Mn, Mg, Fe, Cu, Co and Mo are some other elements which are also required for different vital roles in our body. The required amount of Mn, Fe, Co, Cu, Zn and Mo is very less. Metals required for our body, play vital roles in the conduction of different life processes. Some lighter and useful metals like Zn, Na and K and some heavy and harmful metals Hg and Pb are described below-

Some useful metals for our body-

a. Zinc (Zn)

Zinc is a metal. It is a white metal with density 7134 kg/m^3 which is found naturally. We have used zinc in lab preparation of hydrogen gas. We get zinc through food. Zinc is obtained from meat, sea food, whole grains, legumes, etc. A very little amount of zinc is required for our body. In an adult person's body about 2-3 g of zinc is found. 90% of zinc is found in muscles and bones. It is also found in semen, prostate gland and in retina of eye. It plays the following important roles in human body.

Fig.12.3: *Zinc nut-bolt*

1. It is important for the strength of body.
2. It supports the male and female reproductive health and fertility.
3. It boosts immune power of our body.
4. It prevents from cancer and improves cardiovascular health.
5. It prevents from diabetes.
6. It promotes brain health and works as antioxidant.
7. It improves sleep, cognition and energy level.
8. It works as co-enzyme in our body.

b. Sodium (Na)

Sodium is very active metal. It is a light metal. Its density is 970 kg/m^3. It works as a mineral and an electrolyte in our body. We get sodium from table salt. In the form of electrolyte it supports nervous system and muscular work. In the form of minerals, it maintains the balance of water in our body. In our body, sodium is mainly found in blood and lymph. Sodium ion helps in the transmission of impulses by coordinating with Ca ions.

c. Potassium (K)

Potassium is another active metal. Its density is 862 kg/m^3 equally important metal required for our body. It works by coordinating with sodium in our body. It is responsible for both cellular and electrical functions. The main sources of potassium for our body are fruits and vegetable. It destroys by ever cooking. Fruits like oranges, bananas, apples, avocado etc. and vegetables like leaf vegetable, peas, broccoli, tomato, potato etc. contain potassium. Na-K pump is a process in which when sodium ions enter inside a cell, potassium ions come out and vice versa. The pump helps in transmission of impulses through nerves, maintains muscle contraction, avoids swelling of cells, maintains heart beat etc. It is also responsible for protein synthesis. Potassium is important for glycogen-glucose metabolism also lack of potassium causes muscle spasm, high blood pressure, hypertension etc.

Some harmful metals for our body

a. Mercury (Hg)

Mercury is a liquid shiny metal. It is heavy metal as it has density 13600 kg/m^3. It is very harmful to our health. Mercury poisoning is called hydrargyria and chronic mercury poisoning is called mercurialism. Even a very less amount of mercury can harm seriously on our health. Naturally, mercury is found in air water and soil. It has toxic effect on nervous system, digestion and immune system, lungs, kidney, skin and eyes. Its poisoning may be fatal too. It also can show negative effect on the growth of womb as mercury compound can be easily passed through placenta.

b. Lead (Pb)

Fig.12.4: *Lead*

Lead is a soft metal that is used for many purposes. Its density is 11340 kg/m^3. It is used in manufacture of paints gasoline, leaded pipes, solder and ceramics. When lead is inhaled or ingested it harms our health. About all the organs of our body are affected by it. It deposits in blood and bones of human body. When it is in blood it reduces the capacity of absorbing oxygen and causes anaemia. Some major harmful effects of lead are as given below.

1. It causes loss of appetite.
2. It increases irritability.
3. It causes stomach discomfort and constipation.
4. It reduces attention span.
5. It causes insomnia (a sleeping disorder that is known for its symptoms of unrest).
6. It also affects negatively on the development of nervous system.

Lesson Summary

1. Elements found in nature can be categorized into metal and non-metal. In contrast to non-metals, metals are at a solid state. They have a high density and high M.p. and B.p. They are malleable, ductile, good conductors of heat and electricity and electropositive. They form unstable hydrides and basic oxides.
2. Metals occur in a free or native state and in the combined state as compounds.
3. Metals react with acids and form salt and hydrogen.
4. Metals react with hydrogen and form unstable hydride.
5. Metals react with oxygen and form metallic oxide.
6. Metals are very useful to us.
7. Metals help to improve our health. Some metals are very useful for our body.
8. Some metals like lead and mercury are harmful to our health.

Project work

1. Burn magnesium ribbon. Collect the ash in a test tube and dissolve it in water. Test the solution with both red and blue litmus papers. Is the product formed acidic or basic?
2. Conduct a similar test by exhaling CO_2 through a tube into pure water. What do you conclude from the two tests?

Conceptual questions with their answers

Q.1. What is metalloid? Give examples.

Metalloids are those substances which show the properties of both metal and non-metal. They are also known as semi conductors.

For example: Arsenic, Antimony, Germanium etc.

Q.2. Why are metals regarded as good conductors of heat and electricity?

Metals have free electrons (movable electrons) which enable them to transfer such energies through them.

Q.3. What is metallurgy?

Metallurgy is a Complex and Sequential process by which we can extract (obtain) particular metal from their respective ores.

Q.4. What are ores?

Ores are those minerals which contain large amount of metals. They are further used to extract metals for commercial purposes.

Exercise

1. Answer the following questions.

a. Differentiate between metal and non-metal in terms of their physical properties.

b. How do metals and non-metals differ chemically?

c. Which two properties of metal enable us to use metal as electric wire?

d. A tarnished surface of copper vessel can be cleaned up with lemon. Explain why this sour substance is effective in cleaning the metal vessels.

e. Why do metals like platinum, gold and silver glitter for ever but the surface of iron or copper gets tarnished when it is exposed to moist air?

f. What property of metal is useful to make cooking utensils? Explain.

g. Name any three metals which help improve our health condition.

h. Name any two metals which are harmful to our health.

i. How does mercury harm us?

j. How are sodium and potassium useful to us?

k. What are the advantages of zinc for our health?

2. What happens when

a. magnesium reacts with sulphuric acid?

b. sodium burns in oxygen?

c. calcium reacts with hydrogen?

d. an iron nail is kept in copper sulphate solution?

Multiple Choice Questions

1. Tick (√) the correct answer from alternatives.

a. Metals have-

i. Metallic clink | ii. Lustre
iii. Malleability | iv. All of the above

b. Which property of metals supports to use them as cooking utensils?

i. Malleability | ii. Ductility
iii. High MP | iv. All of the above

c. Which property of metal helps to make wire from them?

i. Malleability | ii. Ductility
iii. Electropositivity | iv. High density

d. Which metal is harmful to our health?

i. Calcium | ii. Iron
iii. Lead | iv. Potassium

e. Which two elements coordinate the transmission of impulse through nervous system?

i. Sodium and lead | ii. Sodium and mercury
iii. Sodium and zinc | iv. Sodium and potassium

Unit 13 Carbon and its Compounds

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *to demonstrate the presence of carbon in different substances.*
- *physical and chemical properties of carbon.*
- *differences between organic and inorganic compounds.*

R.B. Woodward (1917AD-1979AD)

KEY WORDS

1. **Charcoal** : the carbon obtained from wood and others
2. **Fullerene** : an allotrope of carbon having hollow molecules (fullerens)
3. **Bucky ball** : most common type spheroidal
4. **Graphene** : hydrocarbon having the structure of part of a layer of graphite
5. **Caramel** : a smooth thick fluid obtained by heating sugar
6. **Catenation** : capacity of forming molecules in the form of a long chain of atoms
7. **Allotropy** : the property of an atom having different physical forms
8. **Allotrops** : the different physical forms of an element

Introduction

Carbon is a unique element because of its remarkable ability to join up with other elements or with itself. The number of compounds containing carbon and hydrogen is far more than the compounds formed by all the other elements put together. The study of carbon compounds is done under a separate branch of chemistry called organic chemistry.

The term "Carbon" is derived from the Latin word 'Carbo' which means black. The compounds containing carbon are found abundantly in the nature. Mainly coal and charcoal which have been widely used for household and industrial purpose contain carbon. Carbon is a constituent of several other naturally occurring compounds such as mineral oils, carbonates, natural gas, air, etc. Carbon is a basic element of plants and animals. In present days, fullerene, buckyball, graphene etc like carbon forms are also known. It is believed that their discovery may help a lot to solve the solution of fuel. Carbon alone as an element is found as diamond, graphite, charcoal, soot and coal. If you look at the amount of carbon present in the nature, it is quite small. The earth's crust contains up to 0.02% in the form of carbonates, bicarbonates, coal and petroleum and the atmosphere contains 0.03% of carbon dioxide. But if we look at the number of compounds, it is immense. Therefore, the study of carbon chemistry has been given a special importance.

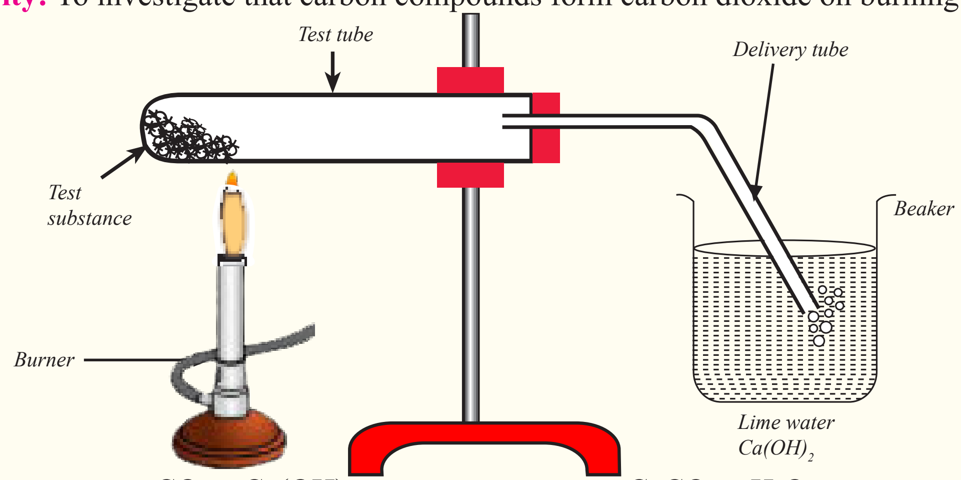
Carbon in ordinary substances

One can easily identify carbon from its appearance i.e. black colour. Carbon present in a compound can also be observed if it forms carbon dioxide gas, sooty smoke by burning or decomposing it.

Activity: To investigate the presence of carbon in everyday substances.
Materials required: burner, metal, spoon, samples
Method:

1. Collect the sample of substances of everyday use such as food grains, wood, sugar, vegetable oil, kerosene, a small flesh of meat, a piece of cloth, spirit etc.
2. Put them in a spoon turn by turn and heat over the flame.
   observe. What is left as a solid residue or released as a gas?
   What can you conclude from it? If the residue is black solid or black soot is given out, it indicates carbon in the substance.

Activity: To investigate that carbon compounds form carbon dioxide on burning.



$$\underset{\text{colourless}}{CO_2 + Ca(OH)_2} \longrightarrow \underset{\text{milky}}{CaCO_3 + H_2O}$$

Fig.13.1: *Testing the presence of carbon*

Material required: burner, hard glass test tube, stand, cork, delivery tube, beaker, saw dust

Method:

1. Arrange the apparatus as follows.
2. Put saw dust into the test tube.
3. Heat it pass the gas into a test tube containing lime water.
   Observe whether any change occurs in the colour of lime water. The lime water turns milky as carbon dioxide formed reacts with lime water and forms milky mixture of calcium carbonate and water.

Activity: Preparation of sugar charcoal

Materials required: metal spoon, sugar, burner

Method:

1. Put some sugar in a dry clean spoon and heat it. You will observe that water vapour is formed.
2. Continue the heating, the sugar melts and forms a brownish fluid at first, then changes into a black solid.

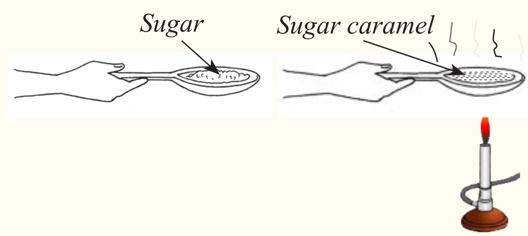


***Fig.13.2:** Formation of sugar charcoal*

The brown coloured liquid formed during the course of heating is called caramel. It has a pleasant smell and people use it to prepare caramel tea, soft drinks etc. The black stuff left on further heating in the end is carbon.

Here, sugar charcoal i.e. carbon is formed because the heat causes the loss of water from sugar ($C_{12}H_{22}O_{11}$).

$$C_{12}H_{22}O_{11} \xrightarrow[\Delta]{} 11H_2O + 12C$$

Sources of carbon

As mentioned earlier, free carbon is found in the form of coal, graphite, diamond etc. It is also found combined in large number of compounds.

The main sources of carbon are as follows.

a. All living organisms,
b. Atmospheric carbon dioxide,
c. Carbonate rocks,
d. Petroleum and natural gas,
e. Organic compounds (e.g. hydrocarbon and its

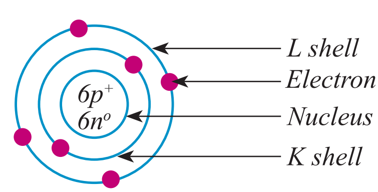


***Fig.13.3:** Atomic structure of carbon*

derivatives, carbohydrate, fats, proteins, etc).

f. As free carbon: diamond, graphite, coal, etc.

Study the following table in detail.

Free carbon	In the form of compounds	
	Inorganic compounds	Organic compounds
1. Graphite 2. Diamond 3. Coal 4. Chorcoal 5. Soot/Lamp blank 7. Graphene	1. Carbonates 2. Bicarbonates 3. Carbon dioxide 4. Carbon monooxide 5. Carbides	1. Carbohydrates 2. Protein 3. Fat 4. Petrol 5. Vitamin 6. Medicines 7. Cloths 8. Paints 9. Paper 10. Soap 11. Hydrocarbons and their derivatives 12. Bodies of living beings

Table: 13.1 Sources of carbon

Nature of carbon

Carbon is a non-metal and has been kept in group IV A and period 2 of the periodic table. Its atomic number is 6 and atomic mass is 12. The electronic configuration is as given below. i. Based on shell ii. Based on sub shell

$1s^2, 2s^2, 2p^2$

Shell	K	L
No. of electrons	2	4

The reactivity of an element is explained on the basis of its tendency to attain the stable electronic configuration i.e. the configuration of the nearest noble gas. As there are 4 electrons in the valence shell, the following two possibilities can be expected:

1. It can gain 4 electrons to give the C^{4-} neon configuration. But 6 protons in the nucleus cannot hold ten electrons in the orbit.
2. It can lose four electrons to form C^{4+} helium configuration but it requires a large amount of energy to lose 4 electrons.

Thus, carbon has to share four electrons with the other element or another carbon so that it obtains stable configuration.

A covalent bond is formed by a pair of electrons. One carbon atom has four electrons in the valence shell and 4 electrons are shared by other atoms and thus forms four covalent bonds. Therefore, carbon is termed as tetravalent element. In the formation of methane molecule, one atom of carbon combines with four atoms of hydrogen separately. In forming a molecule, carbon contributes to i.e. shares one electron each with hydrogen. The covalent bond in carbon can be represented as follows.

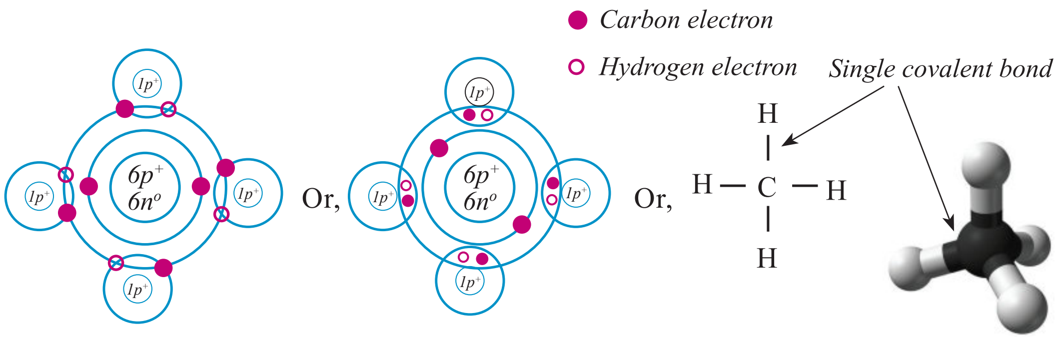
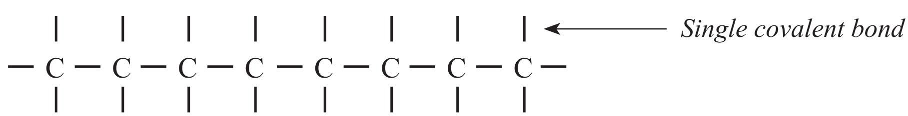


Fig.13.4: *Methane molecule*

You might be wondering how carbon alone can form such a large number of compounds. This is due to the following:

- Tetravalency of carbon: One carbon atom can combine with four different atoms or groups.
- Ability to combine with another carbon atoms to form a long chained or large ringed compounds. This property of forming chains of atoms by self linking is called catenation.



- Carbon can also form strong single, double and triple bonds to itself.

Properties of carbon

A. Physical properties

Carbon is a non-metallic element. It can occur in different forms in nature which are physically different. The existence of an element in more than two physical forms is called allotropy and these forms are called allotropes. Diamond and graphite are the allotropes of carbon.

Carbon has mainly two categories of allotropes

i. Crystalline carbon e.g. diamond and graphite.
ii. Amorphous carbon e.g. charcoal, lamp black, coal, etc.

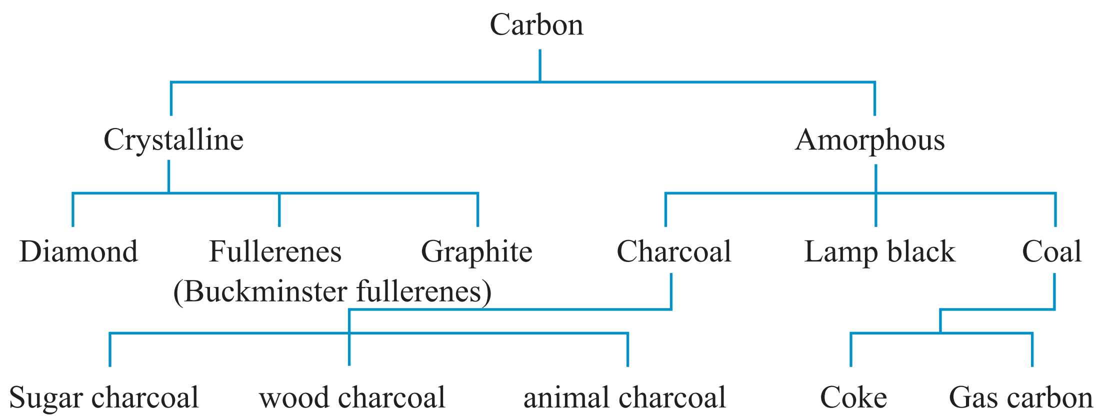


Fig.13.5: Carbon Allotropes

Diamond and graphite are two allotropes of carbon. They are crystalline and are used for many purposes in our daily life. Their short description is given below-

a. Diamond

This is the hardest naturally occurring solid. Diamond crystals may be colourless and mostly transparent. In diamond each carbon atom is bonded to four other carbon atoms. It is used as a precious gemstone in industries due to its hardness. It is the hardest substance known till now. It is insulator of electric current.

Fig.13.6: *Diamond*

All the carbon atoms are linked with covalent bond in diamond

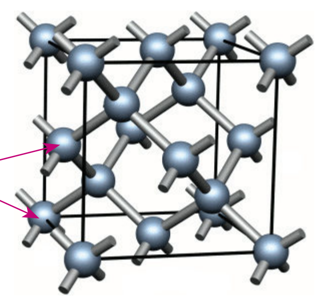


Fig.13.7: *Diamond*

b. Graphite

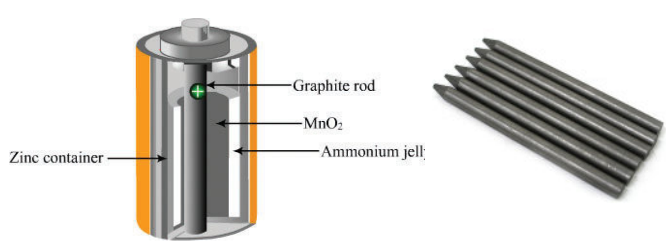


Fig.13.8: *Uses of graphite*

It is a soft black solid and sometimes called black lead. In graphite, each carbon atom is bonded to three other carbon atoms forming a layer. It is a good conductor of heat and electricity due to the non-bonded free electrons. It is slippery and soft. Graphite mixed with clay is used as lead in pencils. Graphite is also used as a lubricant due to its slippery nature and carbon rods are used in dry cells due to their conductivity.

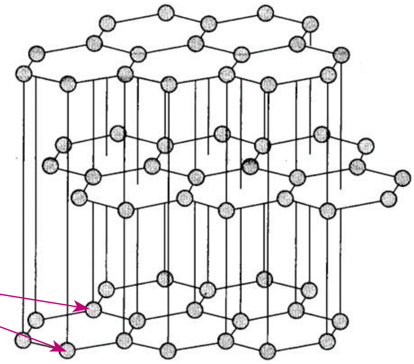


Fig.13.9: *Graphite*

Fact file:

One free valence electron (of graphite) makes graphite a conductor of electricity but diamond lacks such free valence electron to conduct electricity. So diamond is bad conductor of electricity.

B. Chemical properties

1. Carbon burns with oxygen to form carbon dioxide if there is a sufficient supply of oxygen.

   $C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$

   Hot carbon further reacts with carbon dioxide gas to give carbon monoxide

   $C + CO_2 \xrightarrow[\Delta]{900\ °C} 2CO$

   When coal burns with insufficient supply of oxygen, it gives carbon monoxide.

   $2C_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{(g)}$

2. Carbon on heating with water vapour forms mixture of carbon monoxide and hydrogen gas:

   $C_{(s)} + H_2O_{(g)} \xrightarrow{\Delta} \underbrace{CO_{(g)} + H_{2(g)}}_{\text{water gas}} + \text{Heat Energy}$

   The mixture of carbon monoxide and hydrogen is called water gas. This gas burns and gives out heat. Therefore, it is used as a fuel in many industries.

3. When carbon is heated with metal oxides like copper oxide and lead oxide, it forms metal and carbon monoxide. This behaviour of carbon by which it removes oxygen from a compound is called reducing property.

   $PbO_{(s)} + C_{(s)} \xrightarrow{\Delta} Pb + CO_{(g)}$ $SiO_2 + 3C \longrightarrow SiC$

   $CuO_{(s)} + C_{(s)} \xrightarrow{\Delta} Cu + CO_{(g)}$ [SiC is hardest manmade object]

4. Carbon reacts with quick lime to give calcium carbide and Carbon monoxide

   $3C + CaO \longrightarrow CaC_2 + CO$

Organic and Inorganic Compounds

The term 'Organic' chemistry was originally confined to the study of those compounds of carbon which occurred in living organisms. In 1828 German chemist Wohler prepared an organic compound urea, which is present in urine, from the non-living substance ammonium cyanate and the definition has been extended to include the compounds of carbon, whether or not they occur in living organisms. Few compounds that contain carbon such as carbon dioxide, carbon monoxide, cyanides, carbonates, bicarbonates, carbides are not studied under organic chemistry.

The original concept of organic chemistry has been extended to a wider number of compounds which are formed between carbon and several other elements with a few exceptions as mentioned above. Methane, ethane, propane, butane, petrol, kerosene, alcohol, wax, ether, glycerol, amide, carbohydrate, protein, napthalene etc. are some examples of organic compounds.

Inorganic compounds are obtained from minerals. They often do not contain carbon. But the carbon containing compounds such as carbon dioxide, cyanides, carbonates, bicarbonates and carbides come under inorganic compounds.

Organic Compounds	Inorganic Compounds
1. Organic compounds are in general insoluble in water. For example, wax, kerosene, ether, petrol, etc. do not dissolve in water.	1. Inorganic compounds are generally soluble in water. For example, sodium chloride, copper sulphate, potassium hydroxide, etc. dissolve in water.
2. These are generally soluble in organic solvent. Example, wax, kerosene, petrol dissolve in ether.	2. These are insoluble in inorganic solvent. For example, salt does not dissolve in kerosene.
3. Melting and boiling points of organic compounds are very less e.g. wax, ghee, sugar.	3. In general, inorganic compounds have high melting and boiling points.
4. Organic compounds burn on heating.	4. Inorganic compounds generally do not burn on heating.
5. Organic compounds are generally covalent in bonding.	5. Most of the inorganic compounds are generally electovalent in nature.
6. The reaction of organic compounds is slow.	6. Inorganic reactions are generally fast.
7. Organic compounds are generally made of smaller numbers of elements like carbon, hydrogen, oxygen, nitrogen, sulphur halogen, etc.	7. Inorganic compounds are formed by a larger number of elements.

8. There are larger numbers of organic compounds.	8. The number of inorganic compounds is less compared to inorganic compounds.
9. Organic compounds are usually more complex in their composition.	9. Inorganic compounds have simple composition.

Lesson Summary

1. Carbon is a unique element. It is the basis of life and many things we use.
2. Carbon has 4 electrons in its outermost shell and forms compound by sharing electrons.
3. Carbon forms a large number of compounds because of tetravalency and property of catenation.
4. Carbon exists in two physical forms i.e. amorphous and crystalline. Graphite and diamond are a crystalline form and coal and lamp black are amorphous form.
5. Living organisms, atmospheric CO_2, carbonate rocks, petroleum, organic compounds and free carbon as diamond, graphite, etc. are the main sources of carbon.
6. Compounds containing carbon are called organic compounds and the branch of biology that deals with organic compounds is called organic chemistry.
7. The compounds which do not have carbon are called inorganic compounds and the branch of chemistry that deals with such compounds is called inorganic compounds.
8. Carbon is found in different physical forms. The property of carbon is called allotropy.
9. Graphite and diamond are very common allotropes of carbon.
10. Graphite is a crystalline, soft, gray, opaque form of carbon. Each carbon atom is graphite and is connected with three other carbon atoms. Thus it has a free electron which makes it a good conductor of electricity.
11. Diamond is non-crystalline, the hardest, transparent form of carbon. In it each carbon atom is connected with four carbon atoms and has no free electron. It is an insulator.
12. Carbon reacts with metallic oxides and forms metal and water. The property is called reduction property.
13. Carbon reacts with steam and forms carbon monoxide and water. The formed mixture is also known as water gas.
14. Carbon reacts with lime and forms calcium carbide and carbon monooxide.
15. Organic and inorganic substances differ from each other in many aspects.

Conceptual Questions with their answers

Q.1. What is known as the hardest substance? Why?

Diamond is known as the hardest substance. It is because each carbon atom in diamond is bonded onto four other carbon atoms giving rise to a three-dimensional rigid and stable structure.

Q.2. Why is graphite unlike other non-metals a good conductor?

It is because a graphite has ore free electron out of the three bonded electrons. While other non-metals such as diamond do not contain free electrons.

Q.3. "Not all carbons containing compounds are organic compounds." Justify.

This is so because there are many compounds such as Na_2CO_3, $CaCO_3$ which are bonded electrovalently rather than covalently.

Project work

Converting a metal oxide into metal

Mix thoroughly a small amount of copper oxide with carbon (coal). Heat the mixture strongly in a crucible. What do you observe? What happens in the reaction? Which behaviour of carbon has caused this?

Exercise

1. Write four examples for each of the following.

a. Organic compounds found in solid state at room temperature.
b. Inorganic compounds found in gaseous state at ordinary temperature.
c. Organic compounds which are soluble in water.

2. Write differences between

a. Graphite and diamond
b. Inorganic and organic compounds

3. Give reasons.

a. Graphite is a good conductor of electricity
b. Carbon is a reducing agent
c. Carbon has the property of allotropy
d. Graphite is used to prepare lubricant

4. Answer the following questions.

a. What are the sources of carbon in nature?
b. How do you prove that sugar contains carbon?
c. What is sugar caramel? How do you prepare it?
d. The number of compounds formed by carbon alone is much higher than the rest of the elements. Why?
e. What is tetravelency? Define catenation.
f. What is water gas? How is it produced?
g. What do you mean by reduction of metal oxide?
h. What is allotropy? Explain with example.
i. In what respect do the organic compounds differ from inorganic compounds?

5. What happens when

a. Carbon is heated in excess oxygen?
b. Copper oxide is heated with carbon?
c. Carbon is heated with water vapour?

Multiple Choice Questions

1. Tick (√) the correct alternative.

a. Which is not considered as organic compound?
   i. Methane ii. Petrol
   iii. Limestone iv. Graphite
b. Which property is called allotropy?
   i. Capacity of forming co-valent bond
   ii. Capacity of existence in different forms
   iii. Capacity of forming a long chain of atoms
   iv. All of the above
c. Which is not the property of organic compounds?
   i. Dissolves in water
   ii. Has covalent bonding
   iii. Has low melting point and boiling point
   iv. Has presence of carbon
d. What is the product of the reaction between carbon and quick lime?
   i. CaC and CO ii. Ca_2C and CO
   iii. CaC_2 and CO_2 iv. CaC_2 and CO
e. Which mixture is water gas?
   i. A mixture of CaC_2 and CO_2 ii. A mixture of CaO and CO_2
   iii. A mixture of CO and H_2 iv. A mixture of CO and H_2O

Unit 14 Water

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *sources of water.*
- *properties of water.*
- *uses of water.*
- *removal of hardness of water*

Fritz Haber (1868AD-1934AD)

KEY WORDS

1. **Artesian well** : an aquifer in which water rises to the surface under its own hydrostatic pressure
2. **Capillary action:** drawing of liquid against gravity through a narrow tube
3. **Solvent** : the component of solution that dissolves solute
4. **Electrolyte** : the aquous solution that allows to pass solute through
5. **Amphoterric** : the compound which shows common properties of two different chemicals
6. **Hydrolytic** : the property in which compounds are broken chemically by water
7. **Slaked lime** : calcium hydroxide
8. **Sodium zeolite** : aluminosilicate of sodium ($Na_2Al_2SiO_3O_{10}2H_2O$)
9. **Brine** : thick solution of NaCl in water
10. **Heavy water** : deuterium oxide (D_2O)

Introduction

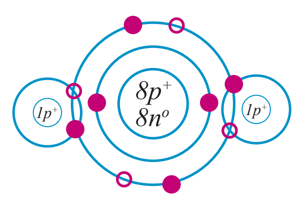


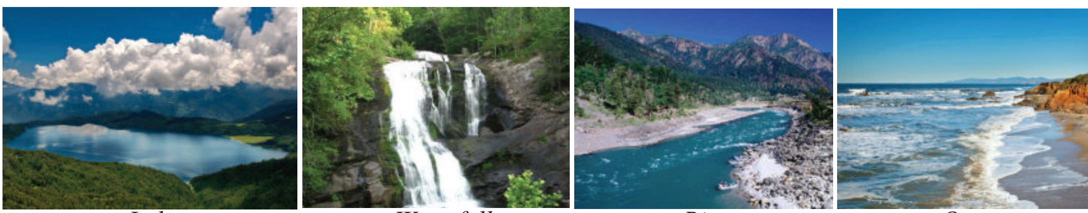
Fig.14.1: *Molecule of water*

Water is a very important compound for all the organisms. It consists of two atoms of hydrogen and one atom of oxygen. We cannot survive without water as it is needed to conduct all the life processes. The study of water is hydrology. We drink water and plants absorb it through their roots. Plants need water for photosynthesis to prepare their food in the presence of sunlight and chlorophyll. We and other organisms use water from earth's surface as well as from inside the earth. We human beings use water for other purposes like cleanliness, washing, bathing, irrigation, fish-farming, transportation, hydroelectricity, entertainment, etc.

Sources of water

The sources of water can be categorized mainly in two groups. They are surface water and ground water.

Sources of water
- Surface water
  - Snow
  - Ocean
  - River
  - Lake
  - Pond
  - Watershed
- Under ground water
  - Well
  - Hand pump
  - Artesian well
  - Roar pump



Lake *Waterfall* *River* *Ocean*

Fig.14.2: *Sources of water*

A. Surface water

The sources of water which contain water on the earth's surface are called surface water. They may be in the form of ocean, rivers, lakes, water sheds, ponds etc.

Oceans and seas contain a very large amount of water in them. They contain water in solid and liquid both the states. About 97% of water sources is stored in oceans. Ocean water is salty so it cannot be used for drinking purpose and to boil in boilers of steam engines. Tidal water of ocean can be used to generate hydroelectricity. Ships are also navigated in oceans.

Other sources of surface water are lakes, rivers, ponds, etc. Many of them are used as the source of drinking water in our country. But all the sources of water mentioned above are not safe to use as drinking water. The sources are also used for irrigation, fish farming, boiling in boilers of steam engines etc. River water is also used to generate hydroelectricity.

B. Under ground water

After rain a part of water is absorbed by the soil and rocks. The absorbed water is stored by porous rocks inside the ground. Ground water reservoir is also called as aquifer and its surface is called as water table. Due to topography when the water table exposes on hills it comes out in the form of

Under ground water

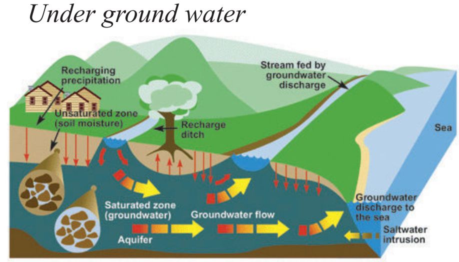


Fig.14.3: *Under ground water*

spring. Thus spring water is in fact the ground water. Ground water is also used for by different means like wells, hand pumps, roar pumps, artesian wells, etc.

Activity:

Make a report of sources of water and their use in your locality.

A. Physical properties of water

Some physical properties of water are as given below-

Properties of water: Pure water has the following properties.

1. Water is tasteless and odourless liquid, which has a very light blue colour that can be identified only at a very deep place.
2. It is found in all the three states. Liquid state of water is the heaviest and the gas state is the lightest.
3. Water can dissolve many of the solutes in it. Because of this property of water, it is used for washing and cleaning purposes. Due to it, water is popularly named as an universal solvent.
4. At standard atmospheric pressure it boils at 100 °C (212 °F or 373 K) and freezes at 0 °C (-32 °F and 273 K).
5. Pure water is insulator of electricity, thus electric current cannot flow through it.
6. It is neutral to indicators i.e. it is neither acidic nor basic in nature.
7. Water has both cohesive and adhesive properties. Cohesive property is that in which water attracts water molecule. Due to this property water appears round on corm's leaves. Adhesive property is that in which unlike molecules are attracted, that is why water remains flat on a piece of glass.
8. Water has anomalous expansion i.e. it contracts when it is heated. It contracts from 0 to 4 °C and then it expands. Due to this property of water, ice floats on water.
9. Water changes its temperature very slowly. Water has high specific heat capacity. Because of this property of water it is used for heating and cooling purposes.
10. It also shows capillary action. Due to its less density it can lift up about ten metres, high in thin tubes.

Activity:

To study adhesive property of water.

Materials required: A glass measuring cylinder, water

Method:

1. Take a measuring cylinder of glass and pour water in it.
2. Study the upper surface of water inside the cylinder.

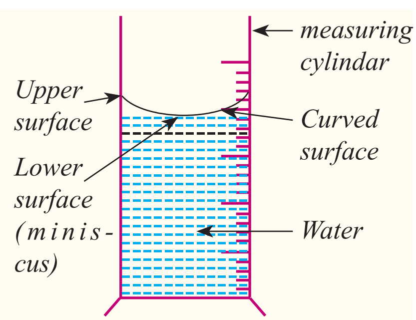


Fig.14.4: Adhesive and cohesive property of water

Why is it not parallel?
It is curved. Why? Find the cause after discussion with your friends and the science teacher.

B. Chemical properties of water

Some chemical properties of water are as given below-

1. We know that pure water is insulator of electricity. But when it is dissolved with any soluble acid, base and salt, the water becomes good conductor of electricity (electrolyte). It is because the water as well as the dissolved acid or base or salt dissociate into ions. (undergo ionization)

   $$H_2O \rightleftharpoons H^+ + OH^-$$

   The formed H^+ ion combines with another water molecule and forms hydronium ion.

   $$H^+ + H_2O \longrightarrow H_3O^+$$

2. As water contains H^+ and OH^- both in it, it shows properties of acid and base both (Amphoteric property) from above equations we can write that-

   $$H_2O + H_2O \longrightarrow H_3O^+ + OH^-$$

   In the equation given it is very clear that water can form H_3O^+ or H^+ ion as acids as well as OH^- ion as bases. This shows that water acts as acid and base both.

3. Water reacts very actively with alkali metals (Na, K, Li) and forms the related hydroxides and hydrogen gas.

   $$2Na + 2H_2O \longrightarrow 2NaOH + H_2\uparrow$$
   $$2K + 2H_2O \longrightarrow 2KOH + H_2\uparrow$$
   $$2Li + H_2O \longrightarrow 2LiOH + H_2\uparrow$$

4. Water reacts with oxides, carbides and nitrides of different metals and non-metals they decompose the water molecules.
   The process is called hydrolysis and the property of water is called hydrolytic property.

   $$Mg_3N_2 + 6H_2O \longrightarrow 3Mg(OH)_2 + 2NH_3\uparrow$$
   $$CaO + 2H_2O \longrightarrow Ca(OH)_2$$

Uses of water

Water is very useful compound. Without water no living beings can survive. Some main uses of water are mentioned below-

1. Water is used for irrigation in the field of agriculture.
2. Water is used to generate hydroelectricity.
3. As water is universal solvent it conducts about all the life processes of the living beings.
4. Water is one of the main components of photosynthesis in green plants.
5. Water is used in steam engines.

6. Water is also used in nuclear reactors to generate electricity.
7. Heavy water is a very cheap means of transportation. Ships, boats, etc. use it.
8. Water is used in many industries for different purposes.
9. Water balances and regulates suitable temperature on the earth. A huge community of living beings gets habitat in it.
10. Water is used for entertainment adventures and recreational activities.
11. It is used for cleansing work in our daily life.
12. Water is used for the preparation of our food and as a part of our food.

Hardness of water

Water of different sources may show different properties. Water of some sources form lather with soap easily but of other sources do not. The water that does not form lather with soap easily is called hard water. About hardness, its types and removal of the hardness we have studied in junior classes also.

we know that when particular type of salt like chloride, sulphate or bicarbonate of calcium or magnesium is dissolved in water, the water becomes hard. Hardness of water and their removal are described below-

Fact file:
Soap is Sodium or Potassium salt of fatty acid. Soap is Sodium or Potassium stearate/oleate/palmitate. When it soap is treated with hard water the salts present in hard water change the sodium stearate, into sodium chloride sulphate or bicarbonate which forms scum and lather is not formed. But when all the salts making the water hard are consumed in the process then only lather is formed.

A. Temporary hardness of water

The hard water that contains calcium bicarbonate or magnesium bi-carbonate is called temporary hard water. The hardness can be removed by simple methods like boiling method or by Clark's method.

1. By boiling method

Temporary hardness of water can be removed by boiling it. When temporary hard water is boiled, the calcium or magnesium bicarbonate present in the hard water decomposes in to calcium or magnesium carbonate, water and carbon dioxide. In this way temporary hardness of water is removed and the water becomes soft. Eg.

$$\underset{\text{calcium bicarbonate}}{Ca(HCO_3)_2} \xrightarrow{\Delta} \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{water}}{H_2O} + \underset{\text{carbondioxide}}{CO_2}$$

$$\underset{\text{magnesium bicarbonate}}{Mg(HCO_3)_2} \xrightarrow{\Delta} \underset{\text{magnesium carbonate}}{MgCO_3} + \underset{\text{water}}{H_2O} + \underset{\text{carbondioxide}}{CO_2}$$

2. By Clark's method

Temporary hardness of water can be removed by treating it with slaked lime [$Ca(OH)_2$]. When temporary hard water is mixed with slaked lime, the lime reacts with bicarbonates of calcium or magnesium and it forms carbonates of calcium and magnesium and carbon dioxide. It is called Clark's method. In this way the temporary hard water changes into soft water. E.g.

$$\underset{\text{calcium bicarbonate}}{Ca(HCO_3)_2} + \underset{\text{slaked lime}}{Ca(OH)_2} \longrightarrow \underset{\text{calcium carbonate}}{2CaCO_3} + \underset{\text{water}}{2H_2O}$$

$$\underset{\text{magnesium bicarbonate}}{Mg(HCO_3)_2} + \underset{\text{slaked lime}}{Ca(OH)_2} \longrightarrow \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{magnesium carbonate}}{MgCO_3} + \underset{\text{water}}{2H_2O}$$

We should be careful that, slaked lime in temporary hard water for Clark's method in large amount may form calcium bicarbonate again by using atmospheric carbon dioxide. This is results temporary hardness water again.

Fact file:
Hard water is not suitable to generated steam in boilers. It may cause the bursting of the boiler. It is because when water boils in it Ca and Mg salts form a layer at the inner surface of the boiler which causes insulation of heat. It causes over heating on boiler and the boiler may burst. Similarly, Minerals in hard water corrode the boiler and shortens its life.

B. Permanent hard water

The hard water, which contains chloride or sulphate of calcium or magnesium in it is called permanent hard water. This type of hardness cannot by removed by boiling. We have to treat the water with washing soda or use permutit process to soften the water.

a. By treating with washing soda

Washing soda is sodium carbonate. When it is mixed with permanent hard water, it reacts with the salts present in the hard water and forms those salts, which do not make water hard. Eg.

$$\underset{\text{calcium chloride}}{CaCl_2} + \underset{\text{washing soda}}{Na_2CO_3} \longrightarrow \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{sodium chloride}}{2NaCl}$$

$$\underset{\text{magnesium sulphate}}{MgSO_4} + \underset{\text{washing soda}}{Na_2CO_3} \longrightarrow \underset{\text{magnesium carbonate}}{MgCO_3} + \underset{\text{sodium sulphate}}{Na_2SO_4}$$

b. By permutit process

Zeolite is aluminosilicate ($Z = Al_2Si_2O_8.H_2O$) and permutit is of sodium, potassium, magnesium or calcium zeolite. Zeolite of sodium is used as water softener. It can soften both temporary and permanent types of hardness.

In this type of removal of hard water, the water is passed through sodium zeolite as shown in the diagram. The salts present in the water react with the zeolite and forms calcium or magnesium zeolite and hardness of the water is removed.

$CaCl_2$	+	Na_2Z	$\longrightarrow$	CaZ	+	$2NaCl$
calcium chloride		sodium zeolite		calcium zeolite		sodium chloride
$MgSO_4$	+	Na_2Z	$\longrightarrow$	MgZ	+	Na_2CO_3
magnesium sulphate		sodium zeolite		magnesium zeolite		sodium carbonate
$Ca(HCO_3)_2$	+	Na_2Z	$\longrightarrow$	CaZ	+	$2NaHCO_3$
calcium bicarbonate		sodium zeolite		calcium zeolite		sodium bicarbonate

When all the sodium zeolite changes into CaZ or MgZ, it can not soften hard water any more. In this condition a concentrated solution of Sodium Chloride is poured in the zeolite to recharge it.

CaZ	+	$2NaCl$	$\longrightarrow$	Na_2Z	+	$CaCl_2$
MgZ	+	$2NaCl$	$\longrightarrow$	Na_2Z	+	$MgCl_2$
Ca or Mg Zeolite		sodium salt		sodium zeolite		Ca or Mg salt

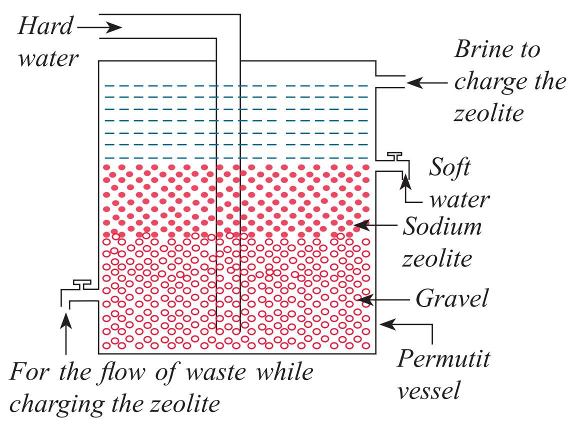


Fig.14.6: *Permutit method*

Lesson Summary

1. Water is a very useful compound and its study is called hydrology.
2. The main sources of water are surface water and underground water.
3. Animals and plants use water from both the sources for different purposes.
4. Water is a colourless and tasteless liquid-very little blue in colour.
5. Water has anomalous expansion and it changes its temperature very slowly.
6. Water has both cohesive and adhesive properties.
7. Water shows electrolytic, hydrolytic and amphoteric properties.
8. Water is used for different purposes in our daily life.
9. Water may be hard or soft.
10. Hard water is mixed with calcium or magnesium chloride/sulphate/ bicarbonate.

11. The water that contains calcium or magnesium bicarbonate in it is called temporary hard water.
12. Temporary hardness of water is removed by boiling method and Clark's method.
13. In Clark's method, slaked lime [$Ca(OH)_2$] is mixed with hard water.
14. The water mixed with calcium or magnesium chloride or sulphate is called permanent hard water.
15. Permanent hardness is removed by treating the water with washing soda and by permutit process.
16. Permutit is aluminosilicate of sodium, potassium, calcium or magnesium but sodium permutit is especially used to soften water.

Project work

Write a report on the water resources in Nepal including the following things.

1. Sources of water
2. Use of water
3. Problems in use
4. Solution to the problem

Conceptual questions with their answers

Q.1. What is Aquifer?

Aquifer means underground bed or layer yielding ground water for wells, springs, etc. (Study of water flow in aquifer is called hydro geology)

Q.2. What is holard?

The total water content of soil is called holard. Similarly the portion of water available for vegetation is chresards and the portion of water of soil not available for vegetation is echard.

Exercise

1. Answer the following questions.

a. What is surface water? Describe with examples.
b. What is ground water? Describe with examples.
c. What are the uses of water?
d. Write any five physical properties of water.
e. Write any three chemical properties of water.

f. What are hard water and soft water?
g. What are temporary hard water and permanent hard water?
h. Write the names of methods that can be used to soften temporary hard water and explain any one of them in short.
i. Write the names of methods that can be used to soften hard water and describe an easier method in short.
j. What is Clark's method? How is it done?
k. Sketch a neat and labelled diagram of permutit process.

2. Write the difference between

a. Hard water and soft water
b. Surface water and ground water
c. Temporary hardness and permanent hardness (of water)

3. Give reasons.

a. Hard water does not form lather with soap easily.
b. Hard water is not suitable for laundries.
c. Hard water is not suitable for boilers to generate steam.
d. Water is very useful for animals.
e. Water is useful for plants.
f. Hard water is good for our health.

4. Answer the following questions on the basis of the given diagram 14.7.

a. Identify temporary hard water.
b. Which one of them is not suitable to wash clothes?
c. Which of them can be softened by treating with washing soda?
d. Which of them can be softened by Clark's method?
e. For which of them only permutit process is useful to soften?

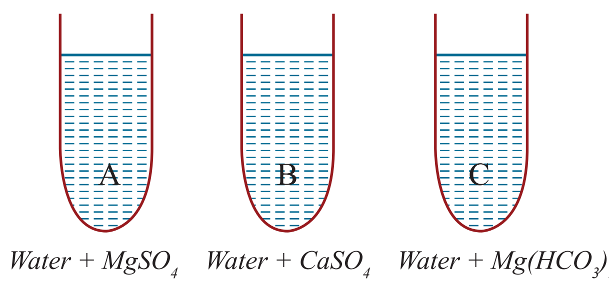


Fig.14.7:

5. Study the diagram given 14.8 and answer the following questions.

a. What is the chemical name of B?
b. What passes through 'C' and why?
c. What passes through E?
d. What comes out from D and F?

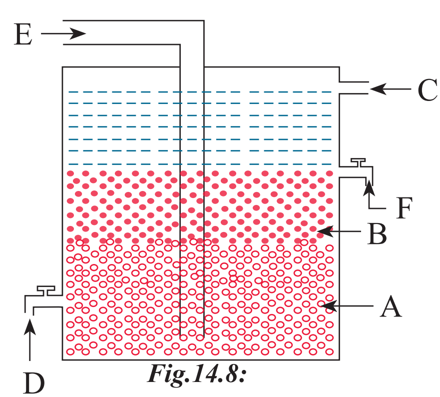


Fig.14.8:

Multiple Choice Questions

1. Tick (√) the correct answer.

a. Which one is a source of ground water?

i. Lake	ii. Snow
iii. Artesian well	iv. Stream

b. Which two of the following make water hard?

i. Calcium chloride	ii. Sodium sulphate
iii. Magnesium bicarbonate	iv. Calcium carbonate

c. Which one of the following causes temporary hardness of water?

i. Calcium nitrate	ii. Calcium bicarbonate
iii. Magnesium sulphate	iv. Sodium bicarbonate

d. Which one of the following causes permanent hardness of water?

i. Potassium sulphate	ii. Sodium sulphate
iii. Calcium sulphate	iv. Sodium chloride

e. Which one of the following is perfect for the removal of both types of hardness of water?

i. Boiling method	ii. Permutit process
iii. Treating with washing soda	iv. Treating with lime

Unit 15 Chemical Fertilizers

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *definition and examples of nitrogenous, phosphorus and potassium fertilizers and their examples.*
- *uses of different types of chemical fertilizers.*

Herman Boerhaave (1668AD-1738AD)

KEY WORDS

1. **Plant nutrients:** the elements required to keep crops healthier
2. **Deficiency** : lack
3. **Faeces** : stool
4. **Bone meal** : bone powder
5. **Eco-friendly** : do not harm environment
6. **Soil erosion** : removal of soil from any place
7. **Compost tank** : the pit or the plastic container in which compost fertilizer is prepared

Introduction

All the animals and plants need nutrients to survive and grow. Plants absorb the required elements from air and soil. Like us, plants also need different elements. Plants need different elements like C, O, H and N in the largest amount. P, K and Ca are required in a little bit less amount. The elements needed for plants in a very less amount are Zn, Mg, B, Cu, Fe, Mn, Mo and Cl. C, O and H are fulfilled from air and water. Plants have to borrow the elements from soil. If the whole plants die in the growing place the nutrients return to the environment. But different parts of crops are used as food, which removes the nutrients from the soil. It causes deficiency of nutrients in the soil. It can be fulfilled by mixing nutrients in the soil.

The things which are mixed in soil to fulfil the deficiency of nutrients for plants are called fertilizers. Plants require different 16 nutrients for their proper growth and development. There nutrients are different 16 elements. Plants require Nitrogen (N) Phosphorous (P) and Potassium (K) in large quantity, so that N, P and K is called macro nutrients. Nitrogen plant requires is maximum than Phosphorous and than Potassium. They are also called primary nutrients.

Similarly, 13 different nutrients are necessary but lesser in quantity so that they are called micro nutrients or trace nutrients. Boron (B), Zinc (Zn), Manganese (Mn), Iron (Fe), Copper (Cu), Molybdenum (Mo), Chlorine (Cl), Calcium (Ca), Sulphur (S), Nickel (Ni), Magnesium (Mg), Cobalt (Co), Chromium (Cr).

Types of fertilizers

On the basis of the source of fertilizers they are categorized into two types.

A. Organic fertilizers or manure

B. Inorganic fertilizers or chemical fertilizers

A. Organic fertilizers

Excretory materials of animals and dead and decayed bodies of different organisms and their parts also supply nutrients for plants. Cow dung and faeces of animals and decayed straw and green plants, ash, bone, food, etc. are some of their examples. All of them are obtained from different types of plants and animals.

Fig.15.1: *Mal Khaldo/Pit*

Thus, those fertilizers which are obtained from the body organisms are called organic fertilizers.

Such fertilizers contain varieties of nutrients for plant but their amount is less. Such types of fertilizers are required in large amount to be used in land. They lose their fertility by their storing for a long time. These fertilizers are cheap and eco-friendly too. They are also known as manure or natural fertilizers.

Some examples of organic fertilizers

Some major examples of organic fertilizers are described below-

a. Compost fertilizers

The organic fertilizers, which are prepared by decaying urine and faeces of animals, straw, leaves etc. are compost fertilizers. Such fertilizers are made in pits by aerobic and anaerobic method. In cities special types of plastic tanks are available to make compost fertilizers in side them. Their main supply is nitrogen.

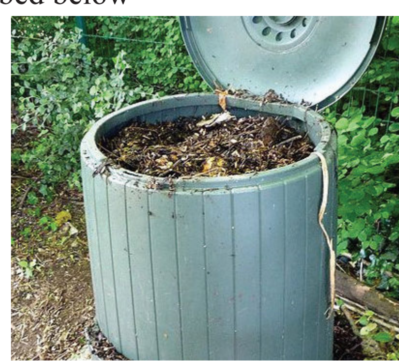


Fig.15.2: *Compost tank*

b. Green fertilizers

This types of organic fertilizer is made by decaying young green plants in field. In terai fast growing liguminous plant like hemp and Jute are used for this purpose. They mainly supply nitrogen. Decaying is made easier in damp or wet land.

c. Ash

Fig.15.3: Ash

Ash is obtained by burning different parts of plants. Such fertilizers are rich in potassium. Volcanic ash is equally enrich in potassium though it is not organic in nature.

d. Bone meal

Fig.15.4: Bone powder

Bone meal is bone powder of dead animals it mainly supplies calcium and phosphorus for the plants in the soil.

Advantages of organic fertilizers

Some main advantages of organic fertilizers are given below.

1. The crops grown by using organic fertilizers only are called organic products. They are very healthy for us.
2. It supplies all the required nutrients to the plants.
3. It does not degrade the quality of soil.
4. It increases the absorbing quality of soil.
5. Its use reduces the soil erosion.
6. It is cheap and easily available everywhere.
7. It contains varieties of nutrients required for plants.
8. It does not cause any chemical pollution.

Disadvantages of organic fertilizers

1. They contain less amount of nutrients for plants. So they need to be used in large amount.
2. They cannot be stored for long days as their fertility decreases due to the process of denitrification.
3. They need more labour to prepare, to transport and mix up with soil.
4. During their preparation they mix up bad odour with the air in the atmosphere.
5. It releases green house gases and increases green house effects.

b. Inorganic fertilizers

Inorganic fertilizers are water soluble salts artificially prepared in industries. They contain one or more nutrients required for plants. As we know that plants need C, O, H, N, K, Ca and P in a very large amount. C and O of them are fulfilled by carbon dioxide of air. Hydrogen and oxygen is supplied by water but plants have to absorb N, K, Ca and phosphorus from soil. Usually, their scarcity is found in soil. They are removed from the soil by the regular plantation of crops. Thus, N, K, Ca and P are the major elements found in chemical fertilizers. Chemical fertilizers are categorized into the following three types.

i. Nitrogeneous fertilizers (N)
ii. Phosphorous fertilizers (P)
iii. Potassium fertilizers (K)

Fact file:
As calcium is fulfilled by the use of lime. during neutralizing acidity of soil and through phosphorous fertilizers, it is not considered as a type of chemical fertilizer. The fertilizer which contains all three major nutrients i.e. nitrogen, phosphorus and potassium in them are called NPK fertilizers.

i. Nitrogenous fertilizers

Those chemical fertilizers which supply nitrogen to the plants are called nitrogenous fertilizers. Nitrogen salts like urea [$CO(NH_2)_2$], Ammonium sulphate [$(NH_4)_2SO_4$], Ammonium nitrate [NH_4NO_3], Ammonium chloride [NH_4Cl], etc. are some examples of this type of fertilizers. Such fertilizers have the following advantages to the plants.

Fig.15.5: *Urea*

1. They form chlorophyll in plants which is necessary for photosynthesis.
2. They help to form healthier seeds and fruits.
3. They effect directly on the growth of plants.
4. They also form protein and protoplasm.

Effects of deficiency of nitrogen in soil

If nitrogen is lacked in soil, it shows the following effects on plants-
1. Plants of nitrogen defficiated region are found yellowish.
2. The plants do not grow properly.
3. Fruits and seeds of the plants are unhealthier and smaller.

ii. Phosphorous fertilizers

Those chemical fertilizers which supply phosphorus element in plant are called phosphorous fertilizers. Ammonium phosphate [$(NH_4)_3PO_4$], Triple super phosphate [$3Ca(H_2PO_4)_2$], ammophos [$NH_4H_2PO_4$] and Calcium super phosphate [$Ca(H_2PO_4)_2CaSO_4$] are some salts which are used as phosphorous fertilizers. The major functions of phosphorus are.


Fig.15.6: *Phosphorous fertilizer*

1. Mainly they are responsible for the root growth. Thus, for root crops like radish, carrot, beet root, sweet potato their supply is a must.
2. They help to ripe the crop faster.
3. They form carbohydrates and other nutrients in plants.
4. They are essential for photosynthesis and transformation of genetic characters.

Effect of deficiency of phosphorus in soil

For lack of phosphorus in soil the following effects are seen on the growth of plants.

1. Plants die for lack of proper growth of roots.
2. Root crops do not yield crops.
3. Crops take a long time to be matured.

iii. Potassium fertilizers

It is defined as that type of chemical fertilizer which supplies potassium to soil. Potassium chloride (KCl), potassium sulphate (K_2SO_4), potassium nitrate (KNO_3), potassium carbonate (K_2CO_3) etc. are used as potassium fertilizer. The main functions of this fertilizer are as given below.

Fig.15.7: *Potassium*

1. It works as a disease resistant.
2. It Help in the growth of plants.
3. It forms starch protein, cellulose, etc.
4. It makes stem stout.
5. It is necessary for the development of flowers.
6. It improves the quality of fibres of cotton.

Effect of deficiency of potassium in soil

Because of the deficiency of potassium in soil, the following effects are seen on plants.

1. Plants do not grow properly and crop yielding reduces due to different diseases.
2. The stems of plants (rice) fall down to the land and harvesting of crop is affected and the crop is destroyed.
3. Leaves of plants and young plants die.

Differences between organic and inorganic fertilizers

Organic fertilizers	Inorganic fertilizers
1. They are obtained from organisms.	1. They are water soluble salts.
2. They cannot be stored for a long time.	2. They can be stored for a long time.
3. They contain many types of nutrients but in less amount.	3. They contain less types of nutrients but in a large amount.
4. They are eco-friendly. (Donot cause pollution)	4. They are not eco-friendly. (Cause pollution)
5. They do not degrade the quality of soil.	5. They degrade the quality of soil.
6. They do not harm our health.	6. They have adverse effects on our health.
7. They promote aeration and absorption capacity of soil.	7. They do not promote aeration and absorption capacity of soil.

Caring while using chemical fertilizers

We should keep the following points in mind while using chemical fertilizers.

1. Soil-test of the field is necessary before the use of chemical fertilizers in it.
2. Chemical fertilizers should be used in a required amount only.
3. The fertilizers should be used in such a way that the fertilizer is absorbed by the plants and the water of the field is not collected in nearby water resources.
4. Technicians' advice is better before the use of chemical fertilizers.
5. We should use quality chemical fertilizers produced reliable industries to avoid the cheating.
6. Use of chemical fertilizers along with the organic fertilizer is effective.

Fact file:

Calcium hydroxide [$Ca(OH)_2$] is used in soil against its acidity i.e. against acidic soil.

Calcium sulphate [$CaSO_4$], Calcium Chloride [$CaCl_2$] is used in soil against its alkalinity i.e. against Basic soil.

Impacts of using chemical fertilizers on the environment

The following impacts of using chemical fertilizers is found on the soil, air, water and human health.

1. It may cause acidity of soil.
2. Over-use of fertilizers is not absorbed by plants and it is mixed with water source and the source gets polluted for other organisms.
3. The children who drink using nitrate-mixed water do not grow properly.
4. Pond ecosystem is found imbalanced following the overgrowth of plants in the pond. It leads to scarcity of oxygen in the pond.
5. Nitrogen salts used for this purpose cause climate change and make the atmosphere unhealthier.

Answer it now

Why is the use of inorganic fertilizers increasing even if we know their adverse effects?

Lesson Summary

1. The substances which are mixed with soil to supply deficiated amount of nutrients for plants are called fertilizers.
2. Fertilizers are of two types. They are organic and inorganic.
3. Organic fertilizers are those which are obtained from different types of organisms.
4. Compost fertilizers, green fertilizers, ash and bones are some examples of organic fertilizers.

5. Water-soluble salts containing one or more nutrients for plants are called chemical fertilizers.
6. Chemical fertilizers are of mainly three types. They are nitrogenous, phosphorous and potassium.
7. Comparative study of different types of chemical fertilizer.

Chemical fertilizer / Basis of comparision	Nitrogenous	Phosphorous	Potassium
Composition	Contains nitrogen	Contains phosphorus	Contains potassium
Function	- Helps in growth - Forms in chlorophyll & helps in photosynthesis. - Makes seeds & fruits	- Forms carbohydrates - Grows roots -Promotes photosynthesis and transfers genetic characters	- Makes straw staut - Disease resistant - Causes growth
Examples	Urea, ammonium sulphate, ammonium nitrate, ammonium carbonate etc.	Ammonium phosphate, calcium super phosphate, triple super phosphate etc.	Potassium chloride, Potassium nitrate, Potassium sulphate, etc.

8. We can use chemical fertilizers but they should be mixed with organic fertilizer.

Project work

Collect transparent polythene bags and samples of different types of fertilizers with their source and display them in the class.

Conceptual questions with their answers

Q.1. "The use of chemical fertilizer has become an obligation but not a choice." Justify.

Chemical fertilizers are used widely and have become an obligation because

1. a large quantity of crops can be produced and provided to fulfill the demand of market.
2. due to the repeated cultivation, soil becomes deficient in relation to essential nutrients for the growth of crops, pulses, etc. It is necessary to replenish these deficiencies of soil.

Q.2. Why does manure regarded as superior to organic fertilizers?

It is due to following reasons:

1. Manures are bio degradable
2. Manures do not deteriorate the original quality of soil thereby maintain the originality of soil at its natural state.

Exercise

1. Write the difference between

a. Organic and inorganic fertilizers   b. Compost and green fertilizers

2. Give reasons.

a. Organic fertilizers should not be stored for a long time.
b. Organic fertilizers are eco-friendly.
c. It is better to use organic fertilizers with chemical fertilizers.
d. Soil-test is necessary before the use of chemical fertilizers.

3. Answer the following questions-

a. What is fertilizer? Mention its types.
b. What are organic fertilizers. Give examples of organic fertilizers.
c. What are chemical fertilizers? Mention its types.
d. Write two examples each of nitrogenous, phosphorous and potassium fertilizers.
e. Write any two functions each of nitrogen, phosphorus and potassium.
f. Name any three salts used to supply nitrogen, phosphorus and potassium.
g. What is the impact of using chemical fertilizers on soil and water?
h. What caring is required while using chemical fertilizers?
i. Define NPK fertilizer.
j. Write two effects of deficiency of
   i. Nitrogen in soil   ii. Phosphorus in soil   iii. Potassium in soil
k. What is NPK fertilizer? Why is it called a complete fertilizer?

Multiple Choice Questions

1. Tick (√) the correct alternatives.

a. Which one is not required in a large amount by plants?
   i. Hydrogen   ii. Nitrogen   iii. Zinc   iv. Calcium
b. Which one is not obtained from organisms?
   i. Ash   ii. Urea
   iii. Compost fertilizer   iv. Green fertilizer
c. Which one is responsible to protect the plants from diseases.
   i. Nitrogenous fertilizer   ii. Potassium fertilizer
   iii. Phosphorous fertilizer   iv. All of above
d. Which one helps to mature the crop earlier.
   i. Phosphorus fertilizer   ii. Potassium fertilizer
   iii. Nitrogenous fertilizer   iv. 1^{st} and 3^{rd}
e. Which one is responsible for green colours of leaves?.
   i. Potassium   ii. Phosphorus   iii. Nitrogen   iv. None of the above

Biology

LOUIS PASTEUR

(27 Dec 1822 – 28 Sep 1895)

Known as

a French biologist, microbiologist and chemist, renowned for his discoveries of the principles of vaccination, microbial fermentation and pasteurization

Chance favours the prepared mind.

- Louis pasteur

Chapters to study

Unit 16 Classification of animals and plants

Total estimated teaching hours = 11

Learning Outcomes

After the completion of this unit, students will learn:

- *classification of plants (up to sub-divisions) and of animals (up to class).*
- *structure, life cycle and adverse effects of mosquito.*

Carolous Linnaeus (1707AD-1778AD)

KEY WORDS

1. **Nomenclature** : Assigning name
2. **Chloroplast** : Green pigment
3. **Vascular bundle** : Xylem and phloem
4. **Trimerous** : Having three or multiple of three sepals and petals each
5. **Oviparous** : Egg laying
6. **Viviparous** : Able to give birth to young ones
7. **Histogenesis** : Forming new tissues and organs in pupal stage
8. **Moulting** : Shedding the old skin
9. **Metamorphesis** : Form adult from larval stage
10. **Histolysis** : Degenerating tissue and organs in pupal slage

A. Classification of living beings

This world comprises a great number of living and non-living things. The group of living organisms of the world exhibits a great diversity and variations. Each one is different from the other in single or many ways. The variations in plants and animals have posed a great problem to human beings for their study i.e. how to recognize them with their similarities and differences. Therefore, from the beginning of human civilization people felt the necessity of arranging them by studying not only morphological aspects but, to some extent, also their anatomy. This is because it is very difficult to remember the names, characters and uses of about 1.5 million living organisms of different varieties. Scientists made many attempts to classify these vast varieties of living organisms on the basis of their similarities and dissimilarities. This to classify is called classification of living beings.

Some terminologies used in classification

i. Taxonomy (Taxis-arrangement, nomos-law): It is the branch of biology which deals with identification, nomenclature and classification of different kinds of organisms existed in the world.

ii. Identification: Identification is the determination of a particular plant or animal similar to the other known as an individual.

iii. Nomenclature: It is the application of correct names of those individuals or groups of individual organisms which have no names of their own.

iv. Classification: It is the process of placing an organism in a certain group according to a particular plan or sequence based on similarities and dissimilarities in its characters.

History of the classification of living beings

Classification of living beings started in the ancient time. The history of classification of living beings is introduced as follows.

1. In 384-322 BC Greek philosopher Aristotle classified the organisms into animals and plants.
2. In 1735 AD Swedish naturalist Carolus Linnaeus added Binomial System of Nomenclature by dividing the animals and plants into kingdom, phylum, class, order, family, genus and species.
3. In 1866 AD German biologist Ernst Haeckel proposed protista as a third kingdom.
4. In 1938 AD American biologist Herbert Copeland proposed Monera as a fourth kingdom by dividing the total organisms into prokaryotes and eukaryotes.
5. In 1969 AD American biologist Robert H. Whittakar proposed Fungi as the fifth kingdom. We will study this type of classification in this unit.
6. In 1990 AD American molecular biologist Carl Woese proposed three-domain and six-kingdom method of classification.

Classification of living beings [Five-kingdom method]

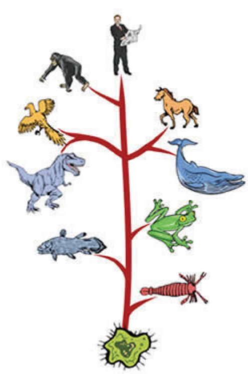
American biologist Robert H. Whittakar is the founder of this method of classification. It was proposed in 1969 AD. According to this system the five kingdoms of classification are Monera, Protista, Fungi, Plantae and Animalia. A short description of these kingdoms and their divisions is given below-

An outline classification of plants and animals- (Five-kingdom classification)

Living beings

Kingdom

- Monera eg. Bacteria
- Protista eg. Amoeba
- Fungi eg. Mushroom
- Plantae
  - **Divisions**
    - Algae eg. Chlamydomonas
    - Bryophyta eg. moss
    - Tracheophyta
      - **Sub-division**
        - Pteridophyta eg. fern
        - Gymnosperms eg. cycas
        - Angiosperms
          - **Classes**
            - Monocotyledons eg. Maize
            - Dicotyledons eg. Pea
- Animalia
  - **phylum**
    - Porifera e.g. sponge
    - Coelenterata e.g. hydra
    - Platyhelminthes e.g. tapeworm
    - Aschelminthes e.g. ascaric
    - Annelida e.g. earthworm
    - Arthropoda e.g. butterfly
    - Mollusca e.g. snail
    - Echinodermata e.g. starfish
    - Chordata
      - **Sub-phylum**
        - Hemichordata
        - Urochordata
        - Cephalochordata
        - Vertebrata
          - **Classes**
            - Pisces eg. fish
            - Amphibia eg. frog
            - Reptilia eg. lizard
            - Aves eg. sparrow
            - Mammalia eg. man



Binomial nomenclature: The way of naming living things on the basis of two names genus (generic name) and species (specific name) is called the binomial nomenclature. It was suggested by a Swedish naturalist named Carolus Linnaeus, who is also known as the father of taxonomy.

Example: man is the common name. Its generic name is Homo and specific name is sapiens. Thus, scientific name of human being is Homo sapiens. See more examples in the given table-

Common and scientific names of some plants and animals

S.N.	Common name	Scientific name	S.N.	Common name	Scientific name
1.	Tiger	*Panthera tigris*	5.	Cat	*Felis domesticus*
2.	Leopard	*Panthera pardus*	6.	Rice	*Oryza sativa*
3.	Frog	*Rana tigrina*	7.	Maize	*Zea mays*
4.	Wild buffalo	*Bubalus bubalis*	8.	Mustard	*Brassica campestris*

Remember that while writing scientific name of organism, generic name starts with capital letter and specific name starts with small letter and both of them are printed in italics.

1. Kingdom monera

Distinguishing character - Prokaryotic single cell body.

Prokaryotic unicellular organisms are kept in this group. They may or may not move. They have cell wall but no chloroplast and other organelles. They may be autotrophic or heterotropic. eg. bacteria; cyanobacteria (Blue-green algae).

Fig.16.1: *Bacteria*

2. Kingdom Protista

Distinguishing character - Eukaryotic single cell body.

Eukaryotic unicellular organisms are kept in this group. They may or may not have chloroplast. They may be autotrophic or heterotrophic. They have special structures like cilia, flagellum and pseudepodia-like structures for locomotion. They may be aquatic or terrestrial. Some of them live in other organism's bodies as parasite. eg. amoeba,

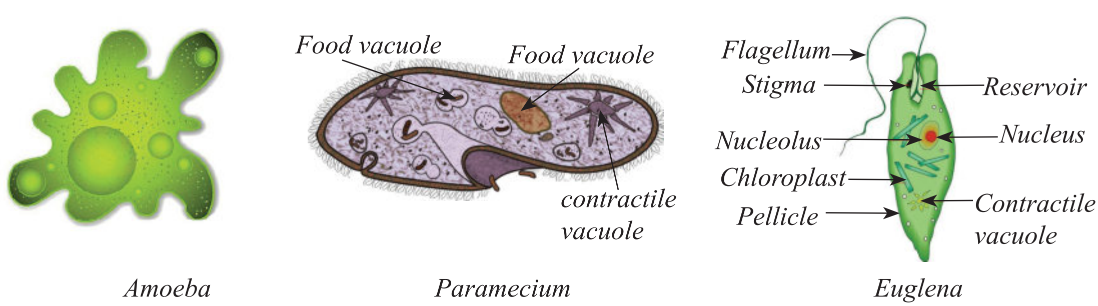


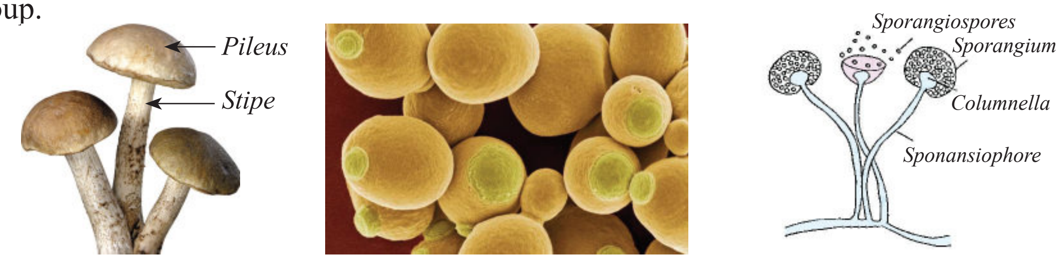
Fig.16.2: *Prorotista*

paramecium, euglena, trypanosoma, giardia, unicellular algae like chlamydomonas etc.

3. Kingdom Fungi

Distinguishing character - underdeveloped saprophytic thallophytes.

The organisms kept in this kingdom are unicellular or multicellular but they do not contain chloroplast in them. They are saprophyte in the mode of nutrition i.e. they absorb their food from decaying materials. Their body is thalloid. They store their food in the form of glycogen. Mushroom, Yeast, Mucor, etc are some examples of this group.



Mushroom *Yeast* *Mucor*

Fig.16.3: *Fungi*

4. Kingdom Plantae

Distinguishing character - autotropic (green plants).

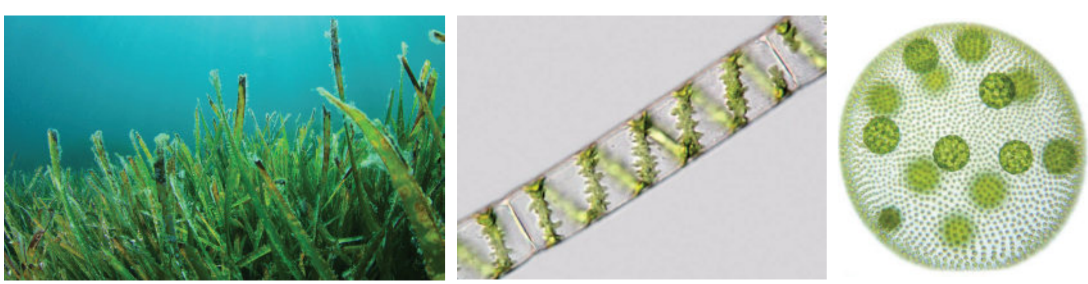
All the multicellular green plants are kept in this kingdom. All of them are autotroph. They are aquatic or terrestrial. They are autotrophs and their cell wall is made of cellulose. They store their food in the form of starch. They may be flowering or non-flowering. Some of them have thallus body. It includes primitive algae to advanced angiosperms. This kingdom is divided into the following three divisions.

A. Algae
B. Bryophyta
C. Tracheophyta

A. Division Algae

Distinguishing character - green thallophytes.

1. They are aquatic by habitat.
2. They bear chlorophyll.



Sea weed *Spirogyra* *Volvox*

Fig.16.4: *Algae*

3. Their cell wall is made of cellulose and usually they are multicellular.
4. They have thalloid body (indifferentiated into root, stem and leaves).
5. They store food in the form of starch.
6. They reproduce by asexual and sexual methods.
7. They have autotrophic mode of nutrition.

eg. Spirogyra, Ulothrix, Volvox, Chara, etc.

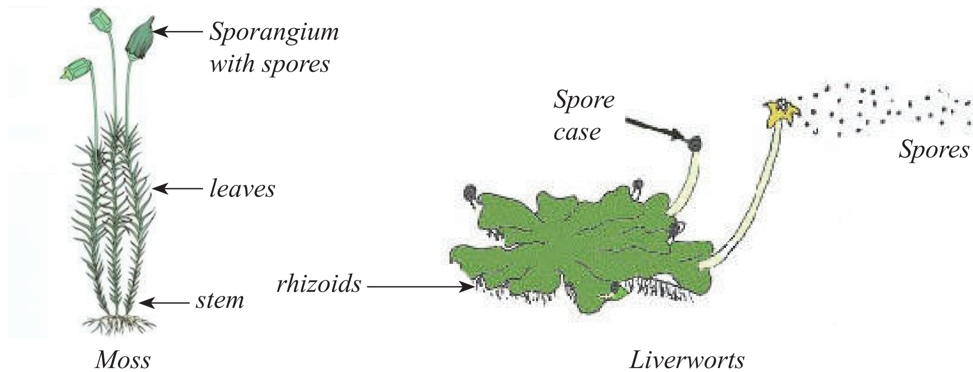


Fig.16.5: *Bryophytes*

B. Division Broyophyta

Distinguishing character - moderately developed green plants.

(Bryon = mass, Phyton = plant)

1. The plants of this division are found in moist and damp places and they are terrestrial.
2. They posses chlorophyll, and they are autotrophs.
3. During rainy season, they form a kind of green carpet (mat) on damp soil, rocks or on the bank of pond, etc.
4. They are also called amphibian plants as they require water for fertilization.
5. They have alternation of generations on which gametophytic generation is dominant over sporophytic generation.

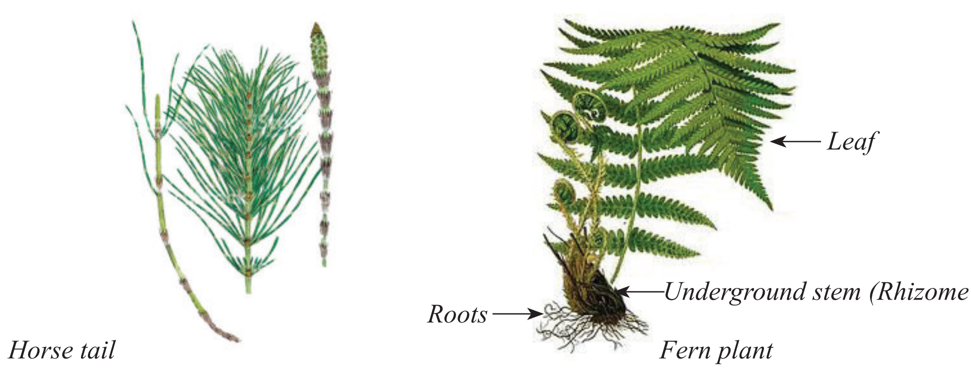


Fig.16.6: *Pteridophytes*

6. They may be simple or be differentiated into rhizoids, short stem and leaves.
7. Bryophytes do not have vascular tissues i.e. xylem and phloem, water and food are transported from cell to cell.

Examples: Liverworts (marchantia, Riccia) and Moss (funaria)

C. Division Tracheophyta

Distinguishing character - developed flowerless plants.

The developed plants are kept under this division. They have conducting tissues like xylem and phloem in them. The division includes fern-like non-flowering plants. They are green and autotrophs. This division is further divided into the following sub-divisions.

i. Pteridophyta
ii. Gymnosperms
iii. Angiosperms

i. Sub-division pteridophyta

Distinguishing character - flowerless feathery land plants.

[pteridon-feather phyton-plant]

1. They are the most primitive vascular plants.
2. They are truly land plants that grow well in moist, shady and cool places. Some of them are aquatic and few of them are epiphytes.
3. They reproduce by spores which are produced in sporangia.
4. They show a clear alternation of generations.
5. The leaves also called fronds, arise from rhizomes.
6. Sporophytic generation is more developed than gametophytic generation.

Examples: fern, horsetail, lycopodium, selaginella, tree ferns, etc.

ii. Sub-division Gymnosperms

Distinguishing character - open seeded plants.

1. Plants of this sub-division are less developed flowering plants.
2. They have undeveloped unisexual flowers called cones.
3. They bear naked seeds as they lack true fruit.
4. Their leaves are thick and pointed.
5. They have cross pollination by wind.
6. They are terrestrial, green and autotrophic.
7. They have needle-shaped leaves.

eg: cycas, cedrus, fir, ephedra, pinus, etc.

Cycas

Pinus

Fig.16.7: *Gymnosperms*

iii. Sub-division Angiosperms

Distinguishing character - close seeded plants.

1. The plants of this group are the most developed as they bear true flowers.
2. Their flowers may be unisexual or bisexual.
3. They may have self or cross pollination.
4. They have their seeds enclosed inside the fruit.
5. There is double fertilization in their flowers.
6. Usually, they reproduce by sexual method but some of them can reproduce by asexual (vegetative) method also.
7. These types of plants are aquatic or terrestrial.

This sub-division is further divided into the following two classes.

a. Monocotyledons
b. Dicotyledons

a. Class Monocotyledons

Distinguishing character - plant with single seed leaf.

1. They have single catyledon in their seeds.
2. They have fibrous root system.
3. They have parallel venation in their leaves.

Fig.16.8: *Bamboo*

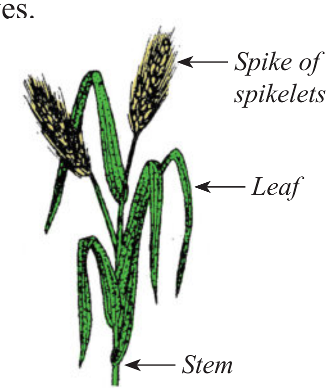


Fig.16.9: *Wheat*

4. They have narrow and long leaves.
5. They have distinct nodes and internodes on their stem and have no wood at all.
6. Usually, they have hollow and weaker stem.
7. They have scattered vascular bundle in their stem.
8. They have mostly unbranched stem.

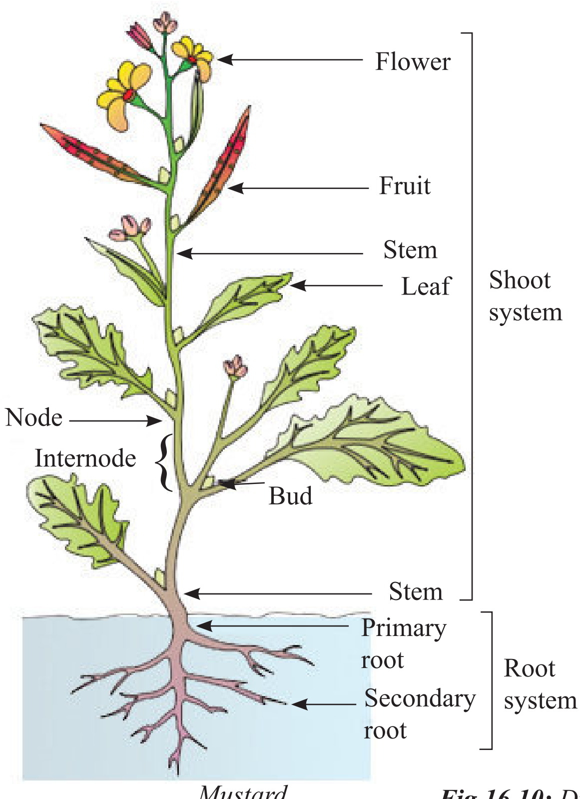
eg: maize, wheat, rice, bamboo, banana, lotus, water lily, lemna, water hyacinth, etc.

b. Class Dicotyledons

Distinguishing character - plant with two-seed leaves.

1. They have 2 cotyledons in their seeds.
2. They have tap root system.
3. They have reticulate venation in their leaves.
4. They have short and wider leaves.
5. They do not have distinct nodes and internodes on their stem.
6. They mostly have compact and strong stem.
7. They have vascular bundle in the form of ring in stem.
8. They are mostly well-branched.

eg: mustard, pea, mango, neem, bean, gram, etc.



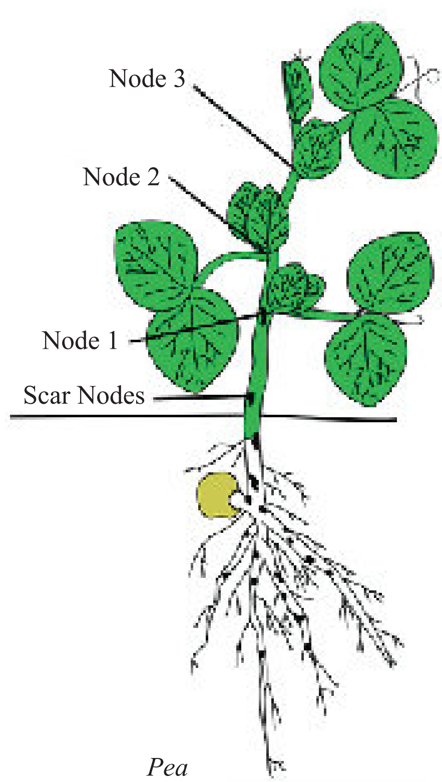


Fig.16.10: *Dicotyledons*

Difference between monocotyledons and dicotyledons

Monocotyledon	Dicotyledon
1. They have a single colytedon in their seeds.	1. They have two colyledons in their seeds.
2. Leaves are with parallel venation.	2. Leaves are with reticulate venation.
3. Root system is fibrous.	3. Root system is tap
4. Floral parts are three or multiple of three i.e. flowers are trimerous.	4. The floral parts are four (mustard) or five (hibiscus) or multiples of 4 or 5.
5. Secondary growth in stem is usually absent.	5. Stem shows secondary growth.
6. Stems are mostly hollow and weaker.	6. Most of them have compact and strong stem.
7. They have scattered vascular bundle (open vascular bundle.) e.g. Paddy, maize, etc.	7. They have vascular bundles in a ring (closed vascular bundle). e.g. Mustard, pea etc.

Classification of some plants

1. Maize - Classification
   Kingdom - Plantae
   Division - Tracheophyta
   Sub-division - Angiosperm
   Class - Monocotyledon
   Type/class - Maize

2. Cycas - Classification
   Kingdom - Plantae
   Division - Tracheophyta
   Sub-division - Gymnosperm
   Type/Example - Cycas

3. Lycopodium - Classification
   Kingdom - Plantae
   Division - Tracheophyta
   Sub-division - Pteridophyta
   Type/Example - lycopodium

4. Pea - Classification
   Kingdom - Plantae
   Division - Tracheophyta
   Sub-division - Angiosperm
   Class - Dicotyledons
   Type/Example - pea

5. Kingdom animalia

All the multicellular animals are placed in this kingdom. They may vary in shape and size. Sponge-like simple and whale-like giant and complex animals are kept in this kingdom. They may or may not have bone in their body. Some of them have vertebral column or back bone also. Their habitat is also of different types. The kingdom is further divided into the following nine phyla.

A. Porifera
B. Coelenterata
C. Platyhelminthes
D. Aschelminthes

E. Annelida
F. Arthropoda
G. Mollusca
H. Echinodermata
I. Chordata

A. Phylum Porifera (GK- porous = pore, ferre = to bear)

Distinguishing character - lower animal with pores in body.

1. They are fixed, aquatic and dipoblastic animals.
2. They have many minute pores on the surface of their body called ostia and large pore called osculum at their free end.
3. Their nutrition is holozoic with intra-cellular digestion.
4. Their excretion and respiration are performed by cell-surface.
5. They have a space in the middle called spongocoal.
6. They have diploblastic body.
7. They may be vase-like, cylindrical, tubular or cushion-like.

Examples: Sycon, spongilla, euspongia, glass rope sponge, hylonema, etc.

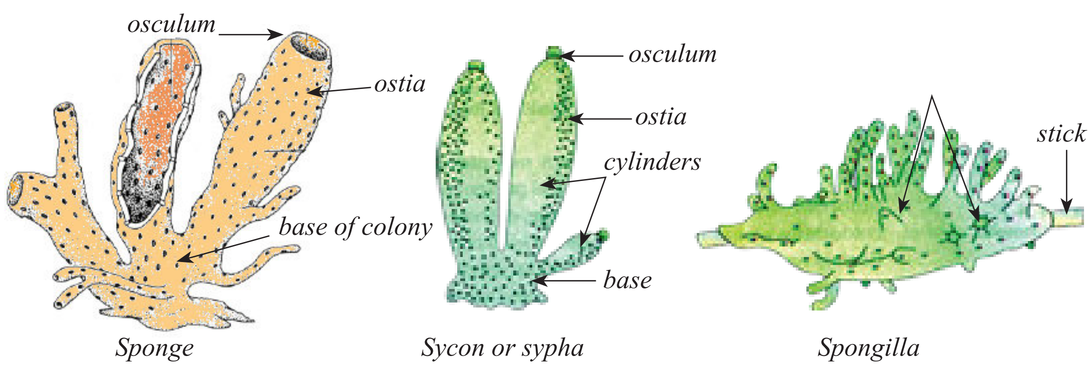


Fig.16.11: *Some poriferons*

B. Phylum Coelenterata (GK- Koilos = Hollow, enteror = gnt)

Distinguishing character - lower animal with coelenterata in body.

1. They are aquatic, occurring in fresh water or sea, attached or freely moving, solitary or colonial animals.
2. They are diploblasitc animals.
3. Most of them possess tentacles around their mouths.
4. They are bilaterally symmetrical and have no distinct heads or segmentation.
5. They have incomplete digestive system.
6. Reproduction takes place both asexually by budding and sexually by gametes. Respiratory organs are absent.
7. They have pseudo-alternation of generation.

Examples: hydra, obelia, coral, jellyfish, sea anemone etc.

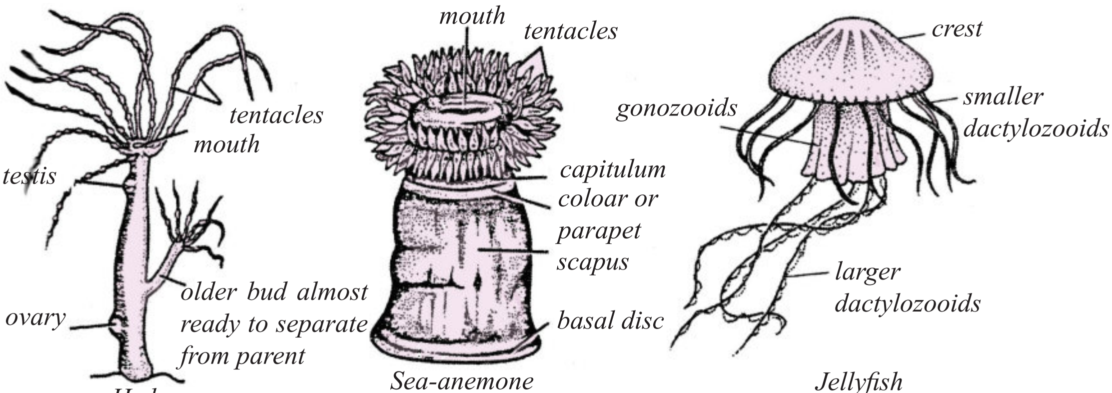


Fig.16.12: *Some coelenterates*

C. Phylum Platyhelminthes (GK- platys = flat, helminthes = worm)

Distinguishing character - flat bodies worms.

1. They are flat worms. Their body is dorsoventrally flattened and very thin.
2. They are mostly parasites but some species are living freely in sea water, fresh water or moist soil.
3. Their body is bilaterally symmetrical.
4. They may or may not have alimentary canal.
5. They have developed nervous system.
6. They are hermaphrodite and possess one or more sets of male and female reproductive organs.
7. Circulatory and respiratory systems are absent. Oxygen is absorbed through the body wall.

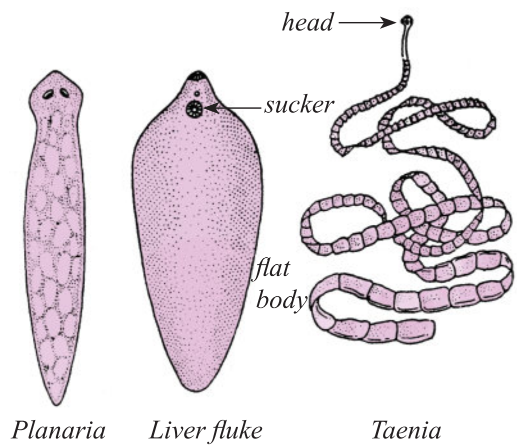


Fig.16.13: *Some platyhelminthes*

Examples: liverfluke, planaria, taenia (tapeworm).

D. Phylum Aschelminthes (GK- Assus = a bladder, helmin = worm)

Distinguishing character - ring worms with unsegmented body.

1. They are aquatic, terrestrial or parasitic elongated, cylindrical and unsegmented round worms.
2. Their body is covered with thick cuticle.
3. They possess a well-developed digestive system with mouth, pharynx, intestine and anus.

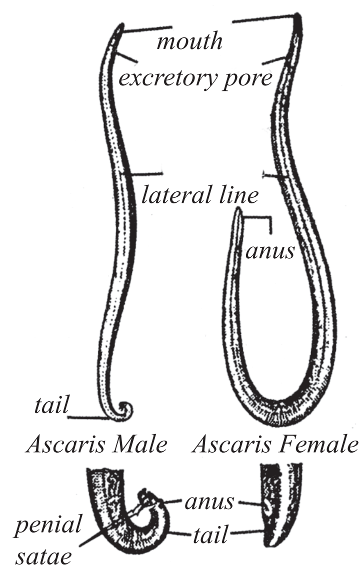


Fig.16.14: *Ascaris*

4. They have common circulatory and respiratory systems.
5. They are dioecious (unisexual) i.e. the male and female sexes develop on separate individuals. The male is often smaller than female.
6. Their fertilization is internal.
7. Their body is triploblasitc and bilaterally symmetrical.

Examples: Ascaris, pin-worm, *Wucheria bancrofti* (filarial worm), hookworm, etc.

E. Phylum Annelida (Latin = Annulus = ring, segmented worms)

Distinguishing character - segmented bodies animal.

1. These are triploblastic, bilaterally symmetrial and segmented animals.
2. Their body is elongated and vermiform with true coelom.

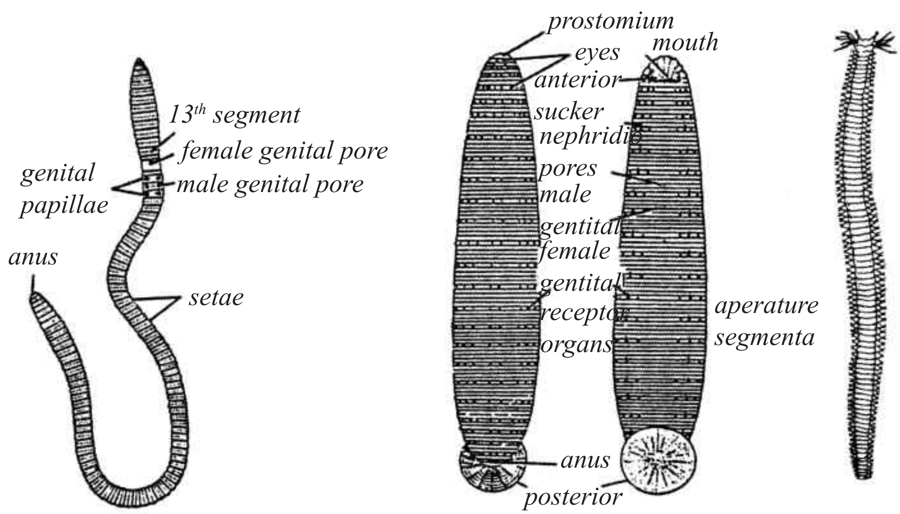


Fig.16.15: *Some annelids*

3. Locomotary organs are mainly setae.
4. They are mostly hermaphrodite but some are unisexual.
5. Excretion occurs by nephridia present in each segment.
6. They have well-developed alimentary canal with mouth and anus at opposite ends.
7. Respiration takes place through general body surface or by gills.

Examples: Earthworm, nereis (sandworm), leech etc.

F. Phylum Arthropoda (Arthro = joint, poda = leg)

Distinguishing character - animal with jointed legs.

1. They are triploblastic and bilaterally symmetrical.
2. Their body is covered with a thick chitinous cuticle forming an exoskeleton.

3. Body is often divided into head, thorax and abdomen. Head and thorax may be fused to form cephalothorax.
4. Fertilization is generally internal.
5. They have mostly compound eyes.
6. The respiration is performed by the general body surface, gills, trachea or lungs.
7. They have a pair of antennae on their head.

Examples: Prawn, lobster, crab, centipede, millipede, cockroach, flies, mosquitoes, silkworm, bee, spider, scorpion, tick, etc.

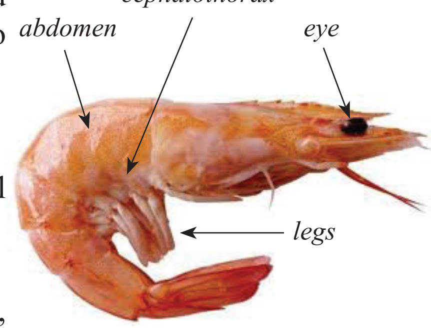


Fig.16.16: *Prawn*

G. Phylum Mollusca (L = molluscus = sort)

Distinguishing character - animals with soft body.

1. They are soft and unsegemented animals.
2. They are found mostly in marine and fresh water but some are terrestrial as well.

Snail *Limax* *Octopus*

Fig.16.17: *Some molluscans*

3. Their body is mostly covered with external or internal shell. Some species do not have shells.
4. The male and female moulluscans are separate and the fertilization is either external or internal.
5. They are triploblastic animals and have single muscular foot.
6. The alimentary canal is complete.
7. The respiratory structures include gills, lungs and mantle.

Examples: octopus, unio, slug, mussel, snail (pila), oyster, etc.

H. Phylum Echinodermata (GK- echinos = spiny, derma = skin)

Distinguishing character - animals with spines in body.

1. These are found living freely in marine, therefore they are not found in Nepal.
2. Body possesses numerous spines of calcium carbonate.
3. Body is radially symmetrical.
4. Distinct head is absent.

5. Sexes are separate and fertilization is external.
6. They are triploblastic and coelomatic animals.
7. They have tube feet to move.

Examples: brittle star, seaurchin, seacucumber, sealily, star fish, etc.

Star fish

Brittle star

Sea urchin

Fig.16.18: *Some echinodermata*

Diploblastic = The body possesses two layersn(ectoderm and endoderm)

Triploblastic = Body covered with layers (ectoderm mesoderm and endoderm)

Bilateral symmetery = When body is cut the left part is the mirror image of right part such symmetery is bilateral symmetery. e.g. Human

I. Phylum Chordata/Craniata

Distinguishing character - developed animals with back bones.

1. They develop dorsal notocord below the spinal cord at any stage of their life.
2. They develop gills cleft around the pharyngeal region at any stage of their life.
3. They have nerve cord which may grow into spinal cord.
4. Blood circulation is of closed type.
5. They have endoskeleton (skeleton is covered with muscles).
6. Eye originates from brain.
7. Brain is protected inside cranium.

   Phylum chordata is further divided into four sub-phyla. They are hemichordata, urochordata, cephalochordata and vertebrata. Only sub-phylum vertebrata is described below.

Fig.16.19: *Sea horse (Hippocampus)*

Sub-phylum Vertebrate

1. They have vertebral column or back bone inside which spinal cord is proluted.
2. They are bilaterally symetrical.
3. They have gill slits and post-anal tail.
4. They may be warm blooded or cold blooded.
5. They may be oviparous or viviparous.

This sub phylum is divided into, the following five classes.

i. Class Pisces

Distinguishing character - fish with scales in body.

1. They are completly aquatic and found in freshwater and marine water.
2. Body is straemlined or boat-shaped which is usually covered with smooth scales.
3. They are cold blooded animals. (Poikilothermic)

Fig.16.20: *Fish*

4. Respiration takes place in gills and locomotion is done by fins.
5. Heart is two-chambered (one auricle and other one is ventricle).
6. Fertilization is external.
7. They are oviporous.

Examples: Varieties of fishes, torpedo (electric ray), eel, hippocampus (Sea horse), etc.

ii. Class Amphibia

Distinguishing character - animal able to live in water and on land.

1. They can live both in water and on land.
2. Their skin is moist, scaleless and usually slippery.
3. They have three-chambered heart (two auricles and one ventrcle).
4. They are oviparous i.e. they lay eggs.
5. They are cold-blooded or poikilothermic animals.
6. Fertilization is mostly external.
7. They respire through porous, moist skin in water and through lungs on land.

Fig.16.21: *Toad*

Fig.16.22: *Salamander*

Examples: frog, toad, newt, salamander.

iii. Class Reptilia

Distinguishing character - crawling animals.

1. They move by crawling.
2. Skin is dry and rough-covered with hard scales.
3. Respiration takes place in lungs.
4. Heart is three-chambered.
5. Fertilization is internal.
6. They are poilkilothermic (cold-blooded).
7. They are oviparous and lay calcereous eggs.

Examples: turtle, wall-lizard, cobra, crocodile, chameleon, etc.

Fig.16.23: *Reptilia*

iv. Class Aves

Distinguishing character - birds with hollow bones.

1. Body is covered with feather and bones are hollow.
2. Body is streamlined i.e. boat-shaped and they have beak as mouth.
3. They are warm-blooded animals (Homeothermic).
4. Heart is four-chambered (2 auricles and 2 venticles).
5. They are oviparous and fertilization is internal.
6. Forelimb is modified into wings.
7. They have sharp eyes.

Examples: kiwi, penguin, ostrich, parrot, crow, owl, etc.

Fig.16.24: *Aves*

v. Class Mammalia

Distinguishing character - child bearing (viviparous) animal.

1. Presence of mammary glands and suckling the young ones are the main features of the animals belonging to this class.
2. Body is usually covered with hair.
3. Give direct birth to their offspring (viviparous).

4. Respire through lungs.
5. Body is divided into head, neck, trunk and tail.
6. They have sebaceous gland in their skin.
7. They have external ear called pinnae.

Examples: bat, whale, dolphin, squirrel, rhinoceros, hippopotamus, etc.

Fig.16.25: *Mammals*

Classification of some animals

Earthworm
Kingdom - Animalia
Sub-kingdom - Invertebrates
Phylum - Annelida
Class - Oligochaeta
Type - Earthworm

Octopus
Kingdom - Animalia
Sub-kingdom-Vertebrates
Phylum - Echinodermata
Class - Cephalopoda
Type - Octopus

Sea horse
Kingdom - Animalia
Phylum - Chordata
Sub-phylum - Vertebrata
Class - Pisces
Type - Sea horse

Snake
Kingdom - Animalia
Phylum - Chordata
Sub-phylum - Vertebrata
Class - Reptilia
Type - Snake

B. Mosquito

Mosquitoes are insects in arthropoda phylum. They possess short, elongated and slender body, segemented antenae, long slender legs and elongated proboscis with piercing and sucking mouth parts. Mosquitoes are mainly of two types. They are Culex and Anopheles.

Classification

Kingdom	- Animalia
Sub-kingdom	- Vertebrates
Phylum	- Arthopoda
Class	- Insecta
Type	- Mosquito

Habit and Habitat: Mosquitoes are found in tropical, sub-tropical and temperate climate. They live in houses, farms and are abundantly found in rural areas. They are most active during spring. The life span of male mosquitoes is seldom more than three weeks. They die after copulating with females. The females live for several weeks months.

External features: Mosquito (Culex) has slender body which is divided into three distinct parts-head, thorax and abdomen.

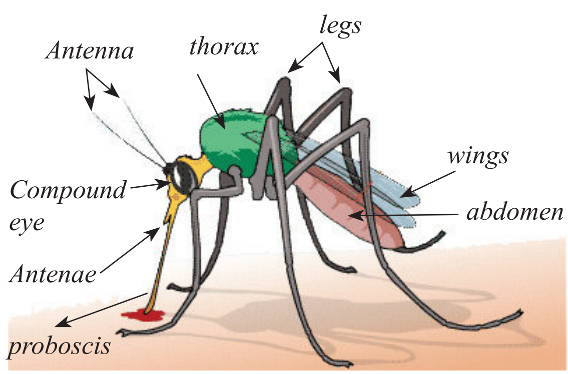


Fig.16.26: *Mosquito*

Head: Its head is almost spherical with very small neck to connect thorax. There are two very large black compound eyes. There are two long and conspicuous antennae or feelers.

The head bears two maxillary palps and a proboscis. Males have the palps as long as proboscis but females have much shorter palps. The proboscis of a female mosquito consist of a pair of mandibles and a pair of maxillae. A male mosquito does not have mandibles. As females have both sucking and piercing organs in the mouth parts, they can suck blood after piercing the skin. But males do not have piercing organs. Their mouth parts are of sucking type. They suck the nectar of flowers and fruit juices for their survival.

Thorax: The thorax of mosquito bears three pairs of jointed legs and a pair of wings. There are two pairs of spiracles on their thorax. They respire through these spiracles.

Abdomen: The abdomen of a mosquito is long, slender and narrow. There are altogether nine segments and they bear no true appendages in the abdomen. The anus lies at the end of the eighth segment and the genital aperture lies at the end of the last segment.

Life-Cycle of a mosquito

Although a female mosquito can live on a purely vegetarian diet, it appears that it must suck blood before it lays eggs. The life cycle of a mosquito is completed through four sequential stages, namely egg, larva, pupa and adult.

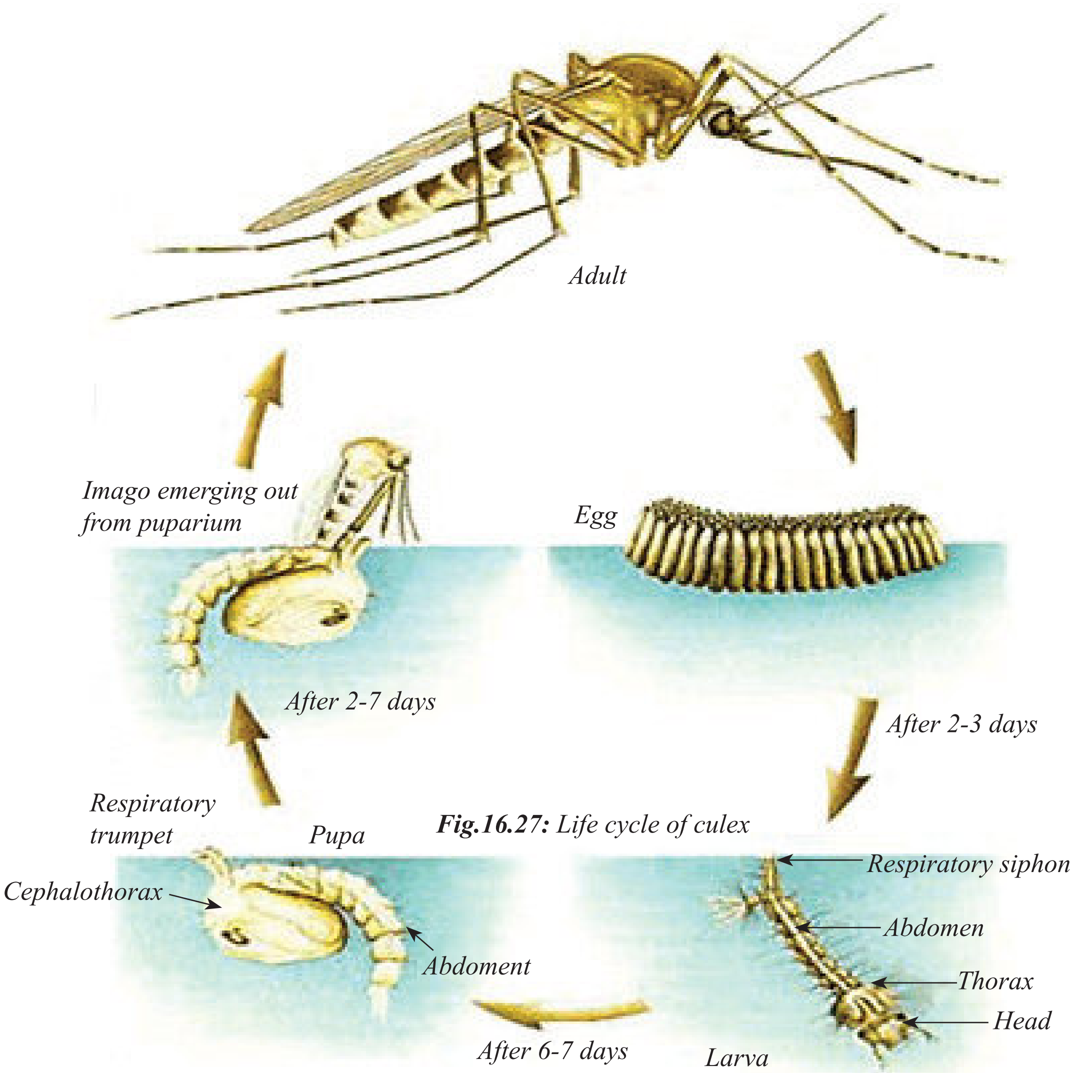
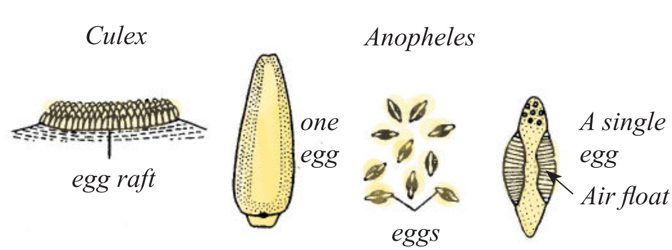


Fig.16.27: *Life cycle of culex*



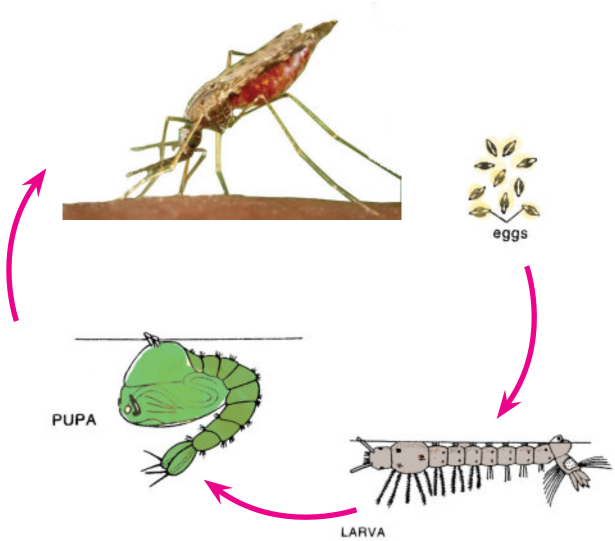


Fig.16.28: *Life cycle of anopheles*

1. Eggs: After mating, a female mosquito lays eggs on still water, ditch, tank, pond, swamp, etc. The water level must not be deep. One female culex may lay up to 300 eggs. The eggs are laid side by side making a little floating raft. A female anopheles lays 40-100 eggs separately with air floats in them. The eggs are hatched in 2 to 3 days and a larva emerges from the lower end of the egg.

2. Larvae: The newly hatched larva measures 1 mm in length. The larvae is popularly called 'wrigler' because of its wrigling movement. The larva leads an active life. It swims about, feeds and grows. Like adults, its body is distinctly divided into three regions-head, thorax and abdomen. Eye, a pair of antennae, feeding brushes, a pair of jaws and a pair of maxillae are present in the head. The thorax of a larva is broader than its head and much broader than its abdomen.

The abdomen is long and slender and it bears paired tufts of bristles. The eighth segment carries a long conical respiratory siphon. Larvae of culex makes angle with water surface but that of anopheles remains parallel angle inside water. During larval stage, it sheds its skin (the process called moulting) three to four times. The larval life completes in 6 to 7 days depending on temperature and food.

3. Pupa: The pupa is comma-shaped and is called a "tumbler". Unlike the pupal stage in the life history of a housefly or a butterfly, the mosquito pupa is as active as larva. It is able to swim vigorously but eats no food. It has a large cephalothorax on the back of which there are two little respiratory trumpets. It lasts from two to five to seven days depending upon temperature.

4. Adult: After 5 to 7 days from pupal stage, remarkable changes occur in pupa and the adult insect imago is formed. When the imago is completed, the pupal skin spurts and the imago emerges out from the upper surface. The imago rests for some time on the pupal skin-puparium. It stretches and dries its wings and then flies off. It can start laying eggs in a week's time.

Difference between Anopheles and Culex

Anopheles	Culex
A. Eggs 1. They are boat-shaped. 2. They are laid singly. 3. They are usually laid in clean water. 4. They have wings to float.	1. They are cigar-shaped. 2. They are laid in group as floating rafts 3. They are usually laid in dirty water. 4. They have air space to remain floated.
B. Larvae 5. They float parallel to the surface inside water. 6. Respiratory siphon is excessively short.	5. They hang with head downwards inclined with acute angle with the surface of water. 6. Respiratory siphon is long and conical in shape.
C. Pupae 7. Pupa is green with short respiratory trumpets.	7. Pupa is colourless and has longer respiratory trumpets.
D. Adults 8. Body is slender with delicate legs.	8. Body is broad with stouter legs.
9. Wings are spotted.	9. Wings are of uniform colour.
10. Body is at acute angle with the surface on which it rests.	10. Body is more or less parallel to the surface on which it rests.

Harmful effects of Mosquitoes

1. Mosquitoes transfer to human beings different types of diseases like malaria, yellow fever, dengue, filaria, encephalitis, etc. Details are given in the following table.

S.N.	Diseases	Carrier type	Causative agent
1.	Malaria	Female Anopheles	Plasmodium
2.	Filaria	Female Culex	*Wuchereria bancrofti*
3.	Yellow fever	Female Aedes	Virus
4.	Dengue	Female Culex and Female Aedes	Virus
5.	Encephalitis	Female Culex and Female Aedes	Virus

2. Mosquitoes produce irritating sound and disturb our sleep.
3. Mosquitoes bite painfully and cause itching and swelling in the skin. Mosquitoes are harmful to domestic animals.

Malaria

Malaria is an infectious disease characterized by chills, shaking and periodic bouts of intense fever. Malaria is transmitted from person to person by the bite of female anopheles mosquito. It is caused by the single celled parasite called "plasmodium".

Malaria transmission begins when a female mosquito bites a human with the malarial parasite. The mosquito injects into its own body, the blood containing immature male and female gametes of the malaria parasite. The life cycle of the parasite begins at the gut and finally moves the mosquito's salivary glands as sporozoites. When the infected mosquito bites a healthy human, sporozoites in the mosquito's saliva is transferred to the blood of the human. Mosquito sporozoites remain in blood RBC for 24 hours and travel to the liver and form metazoites. The metazoites then leave the liver and enter the blood stream where they invade red blood cells. They multiply in these blood cells, and finally burst the red blood cells. In this way a person suffers from malaria.

Fact file:
Histolysis: The scrapping of the larval organs is known as histolysis.
Histogenesis: It is the rebuilding of the organs to give rise to pupa.
Metamorphosis: The phenomenon of conversion of pupal stage of insects to produce an imago in succession is called metamorphosis.

Prevention and control of mosquitoes

Mosquitoes are the deadly enemies of mankind as they transmit diseases. Therefore steps have to be taken for their destruction. The general measures that can be adopted to eradicate and destroy mosquitoes are given below.

a. Removal of swamps and stagnant water which are the breeding place of mosquitoes.
b. Spraying paraffin oil, kerosene on the surface of water.
c. Ducks and fishes like gambusia which are specially fond of larvae and pupae should be farmed.
d. Mustard oil and anti-mosquito creams can be used on the exposed parts of our body to prevent mosquito bite.
e. Mosquito nets should be used to prevent their bite.
f. Destruction of adults by spraying insecticides.

Activity

To find ways to drive mosquito away

Materials required: Plate, petridish, water, oil or kerosene, larvae and pupae of mosquito.

Method:

1. Put a few larvae or pupae in a petridish containing some water.
2. Observe the larvae or pupae suspended from water surface.
3. Wait until the larvae or pupae come to the water surface. Put a few drops of oil or kerosene into the water.
4. What happens to the larvae or pupae? Observe it.
5. Think how effective this method can be to control mosquitoes.

Lesson Summary

1. The branch of biology that deals with the nomenclature and identification of various plants and animals is called taxonomy.
2. Classification is important for the systematic study of various plants and animals on the basis of their resemblances and differences.
3. Nomenclature of an organism on the basis of its specific name (Species) and generic name (Genus) is called the binomial system of nomenclature.
4. Living beings are divided into five classes. They are Monera, Protista, Fungi, Plantae and Animalia.
5. Kingdom Monera contains Prokaryotic unicellular organisms and Kingdom Protista contains Eukaryotic unicellular organisms.
6. Kingdom Fungi contains non-green unicellular and multicellular organisms.
7. Kingdom plantae contains green multicellular organisms which are autotrophic. It is divided into three divisions. They are Algae, Bryophyta and Tracheophyta.
8. Division Algae contains those green plants which have thalloid body and are aquatic.
9. Division Bryophyta contains green multicellular plants which have root, stem and leaf- like structures but there is no vascular bundle in them.
10. Division Tracheophyta contains those plants which have vascular bundles in them.
11. Division Tracheophyta is further divided into three sub-divisions. They are Pteridophyta, Gymnosperms and Angiosperms.
12. Sub-division Pteridophyta contains those plants which have featherlike leaves.

13. Sub-division Gymnosperms have naked seed and sub-division Angiosperms have seed enclosed in fruits.
14. Monocotyledons have single cotyledon and dicotyledons have two cotyledons.
15. Kingdom Animalia contains all the multicellular animals and it is further divided into nine phyla. They are Porifera, Coelenterata, Platyhelminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata and Chordata.
16. Phylum Chordata has notochord and is nerve cord and further divided into four sub-phylums. They are Hemichordata, Urochordata, Cephalochordata and Vertebrata.
17. Sub-phylum vertebrata has backbone and is further divided into five classes. They are Pisces, Amphibia, Reptilia, Aves and Mammalia.
18. Mosquito is a harmful insect and it is of many types but Culex and Anopheles are very common in Nepal.
19. Life cycle of mosquito completes at four stages. They are Eggs, Larvae, Pupae and Adults.
20. Mosquitoes spread many diseases like malaria, filaria, yellow fever, dengue, etc.
21. Mosquitoes feed on blood and nectar of plants.
22. Only female mosquitoes suck blood.
23. Mosquito net, anti-mosquito cream and oil, etc. should be applied to prevent from mosquito bite.

Project work

1. Show on a piece of cardboard paper classification of plants and animals and display the best one in your class.
2. Put a can of water on a dark corner of your house for about one week. Then study the creatures you find in the water. What are they? Study, discuss and write a report on your project work.

Conceptual questions with their answers

Q.1. What is pentadactyl?

The animal having five digits in a limb.

Q.2. What do you mean by monoecious?

The organism having both male and female structures in them.

Q.3. "Spraying kerosene on water reduces the control mosquitoes." How?

Spraying kerosene on water reduces the surface tension of water and makes it difficult for mosquitoes to respire.

Exercise

1. Answer the following questions.

a. Define the terms 'taxonomy' and 'classification'.
b. Write two major advantages of classification.
c. Why is bryophyta called amphibious plant?
d. Why is fern plant kept under the division tracheophyta?
e. Draw a neat and labelled diagram of a mosquito.
f. Where are mosquitoes found and where do they lay eggs?
g. What types of mosquitoe transmit disease? Name some of the diseases transmitted by mosquitoes.
h. Why are mosquitoes harmful? How can we use the knowledge of the life cycle of a mosquito as a control measure? Explain.
i. How does mosquito transmit malaria? Explain.
j. Mosquitoes are vectors of diseases. Justify the statement.
k. Write some of the preventive measures of mosquito bite.
l. What is the main food of mosquitoes?
m. Why is pupa of mosquito 'coma' in shape?
n. In what respects does a mosquito pupa differ from the pupa of other insects?
o. What is moulting?
p. What is cephalothorax?
q. How does a mosquito transmit malaria?

2. Draw a chart showing the classification of organisms.

3. Write the difference between

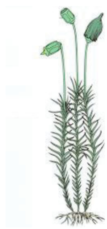
a. Monera and Protista
b. Algae and Fungi
c. Angiosperms and Gymnospems
d. Monocotyledons and Dicotyledons
e. Vertebrates and invertebrates

f. Chordates and non-chordates
g. Larva of culex and larva of anopheles
h. Adult annopheles and adult culex
i. Pupa of culex and pupa of anopheles

4. Classify the following organisms giving two main special features of each.

a. Chlamydomonas	b. Bacteria	c. Amoeba	d. Fern
e. Dolphin	f. Moss	g. Ascarics	h. Mould
i. Sea horse	j. Slug	k. Sea lily	l. Cobra

5. Classify the following giving two characteristics of each.



a. b. c. d. e. f.

6. Give reasons.

a. Cray fish cannot be grouped into class pisces.
b. Pteridophytes are more developed than bryophytes.
c. Male mosquitoes cannot suck our blood.
d. Mosquitoes lay eggs in water.
e. Mosquito is harmful to us.
f. Sea-horse is categorized as class pisces.

7. Identify the organism and write the class they belong to.

a. Body is covered with rough scale, have no legs.
b. Body is covered with smooth scales and respire through gills.
c. Body is covered with feathers, have flat beak, have waved legs.
d. Body is covered with hairs, have patagium.
e. Skin is naked and soft, have three-chambered heart.

8. Sketch neat and labelled diagrams of

a. Adult culex and adult anopheles.
b. Larva of culex.
c. Pupae of culex and anopheles.

Multiple Choice Questions

1. Circle the correct alternatives.

a. What types of organisms are kept in Kingdom Monera?
   i. Eukaryotic green organisms
   ii. Prokaryotic organisms
   iii. Prokaryotic green organisms
   iv. Eukaryotic organisms

b. An organisms is non-green but multicellular. In which kingdom can it be placed?
   i. Monera
   ii. Protista
   iii. Fungi
   iv. Plantae

c. Animals of which phylum have nerve cord?
   i. Chordata
   ii. Echinodermata
   iii. Arthropoda
   iv. Mollusca

d. Which stage of the following moults?
   i. Egg
   ii. Larva
   iii. Pupa
   iv. Adult

e. At which stage of life does a mosquito respire through respiratory trumpet?
   i. Egg
   ii. Larva
   iii. Pupa
   iv. Adult

Unit 17 Adaptation of living beings

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *concept of adaptation of living beings.*
- *adaptive features of different plants and animals that live on land and in water.*
- *introduction to micro-organisms (Bacteria, Fungi, Virus and Protists and common diseases caused by them.*

Ivanovski

KEY WORDS

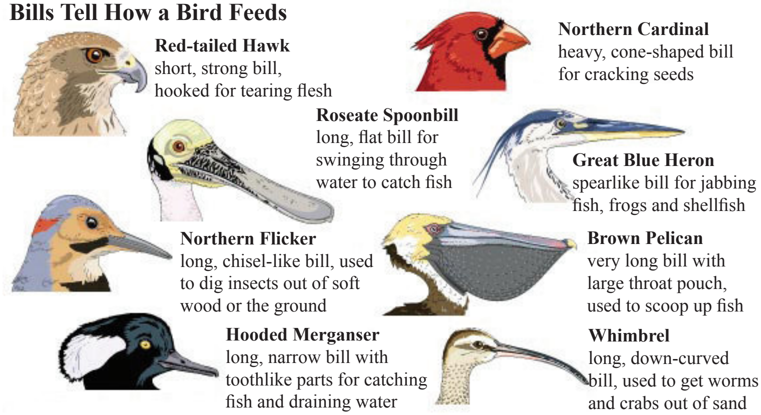
1. **Inherited** : transferred from parents into offspring
2. **Climbers** : those plants which need support to grow up
3. **Streamlined** : having tappered ends
4. **Poikilothermic** : animals changing body temperature according to surrounding
5. **Adhesive** : sticky
6. **Hump** : projection on camel's back
7. **Sessile** : unable to move from place to place
8. **Motile** : able to move from place to place
9. **Antibiotics** : the drugs used against bacteria
10. **Nucleic acid** : the acid found in nucleus

A. Adaptation

Adaptation is defined as a characteristic of an organism which makes it better suited to its environment due to structural and functional modifications in it. An organism is best adapted to a given environment when it possesses inherited features which promote its survival and ability to reproduce in that environment. Adaptation is an important result of natural selection. An individual becomes better adjusted to survive in its environment through changes in genetic make-up. When the environment changes, the direction of adaptation also changes. Adaptations may be expressed as changes in body structure, body function, colouration or behaviour.

- Adaptations may be short term and long term, suspending most of the metabolic activities by the hibernating animals during the winter.

- The claws of the various birds are adapted as per their requirements and the forms of beaks in birds are adapted for specific feeding habits. It is a long term adaptation.



Adaptations. The forms of beaks in various birds.

Adaptations. In kangaroo, the thick tail acts as fifth limb

***Fig.17.1:** Different modes of adaptation in animals*

Aquatic adaptation

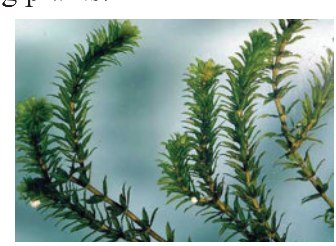
Different types of animals and plants are found in water. They have some special characters, which help them to get their food and protect themselves. Plants found in water are hydrophytes and animals found in water are called aquatic animals.

a. Hydrophytes-

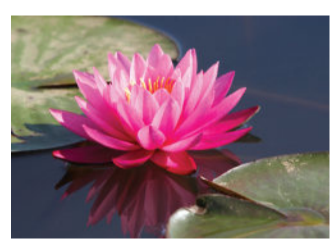
The plants found in water are called hydrophytes. They have the following adaptational characters to survive in water.

1. Roots are generally reduced in size, usually unbranched. There may not be roots in freely floating plants like wolfia. Roots are well developed in fixed plants. Floating plants show amphibian characteristics eg. water lily.
2. The stem is thin and delicate in submerged plants while the stem is extremely reduced in freely floating plants.

Water hyacinth



Hydrilla



Lotus

***Fig.17.2:** Hydrophytes*

3. Leaves are reduced in size and thickened in sub-merged plants. The leaves are longer and spongy in freely floating and amphibian plants.
4. Thin leaves contain wax or mucilage to prevent rotting and decaying.

5. Stomata are found on the upper surface of leaves.
6. They have aeronchyma tissue (Air-filled tissue) that makes them soft and flexible.

Hydrophyte is generally divided into four groups.

a. Submerged - e.g. hydrilla, vallisnaria
b. Free floating - e.g. jussiaea, wolfia, lemna
c. Fixed floating - e.g. water lily, lotus
d. Amphibious - e.g. jagittaria, typha, rumex, sagittaria, ranunculus

b. Aquatic animals

The animals which grow, multiply and adjust themselves inside water are called aquatic animals. Their adaptational characters are as given below.

1. Body of aquatic animals is streamlined, their outer surface is smoothed and thin.
2. Their body is covered with smooth scales coated with waxy material that reduces water pressure and protects from getting rotted.
3. Presence of air sacs in their body helps them to float on water.
4. The fins present in their bodies help them in swimming, and changing directions.
5. Oxygen dissolved in water is separated by gills for respiration.
6. They are poikilothermic. That is, their body temperature changes according to the change of temperature in the environment.

Eg. fish, sea horse, sea urchin, etc.

Terrestrial Adaptation

The word terrestrial indicates the land. Many types of animals and plants are found on and in land, they are called terrestrial plants and animals. Some adaptational features of such types of plants and animals are described below.

a. Mesophytes

Those plants which are found in moist soil are called mesophytes. Their adaptation characters are given below.

1. Stem is rigid and stout.
2. Leaves are generally large, broad with a moderate thickness.
3. Stomata are found on both the surfaces of leaves.
4. Roots are generally well-developed.
5. They mainly grow in normal condition of temperature and water.

Eg. Mango, mustard, wheat, peepal, neem, etc.

b. Xerophytes

Those plants which are found in dry land are called xerophytes. They have the following adaptational characters to survive there.

1. They have long tap roots which go deep into the sub-soil in search of moisture. These roots are fleshy and contain plenty of mucilage.
2. Stems are very thick and fleshy. Stems have cuticle to prevent loss of water by traspiration.
3. Under the condition of extreme dryness, leaves of most xerophytic plants roll up into thorns, considerably reducing their evaporating surfaces.
4. Most of the xerophytes have leaves modified into thorns while some have leaves in light green colour to enhance photosynthesis.
5. Some desert plant leaves are fleshy containing aqueous tissue and mucilage.
6. They have fleshy stems to store water and green stems (in those which lack leaves) to perform photosynthesis.

Eg. Aloe, cactus, etc.

Finger cactus

Barrel cactus

Jade cactus

Aloe vera

Fig.17.3: *Xerophytes*

Fact file:

Besides hydrophyte, mesophyte, xerophyte, there are some other groups of plants on the earth. They are grouped as follows.
Halophyte - saline water plant
Lithophyte - plants on the surface of rocks
Oxylophyte - plants in acidic soil
Plants found in temperate climate are well-branched and with sufficient leaves. They have strong stem to hold the load of rest of the plant body. Climbers have soft stem or vine and tendrils to support them on the wall or other supporting factors. Plants in alpine region have needle-shaped leaves and coniferous shape.

c. Terrestrial adaptation of animals

Terrestrial animals are the animals living on land. On the basis of adaptational characters we can divide the animals into-

a. Fossorial   b. Cursorial   c. Arboreal   d. Aerial   e. Desert

Adaptational characters of terresterial animals are given below.

1. The legs and phalanges of terrestrial animals are modified according to their feeding habit, habitat and climate. Some of them have single hoof while others have double hooves. The legs of cursorial animals such as tigers, bears, bats, dogs etc. have paws.

2. Rat and mole like fossorial animals have tapering head with strong snout and sharp claws in their legs. The characters help them to make holes and crawl in the holes.

Tiger

Cobra

Rat

Fig.17.4:

3. Birds have streamlined body, hollow and strong bones, strong chest muscle, presence of air sac in their body, their forelimbs are modified into wings. Body is covered with feathers that make them lighter to fly.

Fig.17.5: *Bird*

4. The teeth in birds are modified into beaks. The shape of beak is based on their feeding habit. For example, ducks have spoon-shaped beaks, woodpeckers have sharp and short beaks.

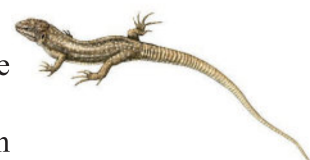


Fig.17.6: *Lizard*

5. Some animals have climbing capacity. They have adhesive pads in their legs as in lizards. (Arborial)
6. Monkeys have prehensile tails that help to balance in trees and help to grasp in the branches in trees. They bear long and flexible limbs and phalanges to grasp the trees.

Fig.17.7: *Camel*

7. The animals found in deserts possess water pouches to store water for many days. (Desert animals or xeric animals)
8. Desert animals like camels have flat hooves, water storing pouches and fat store in their hump. Reduced perspiration, less hair and concentrated urination also supports them to survive in deserts.

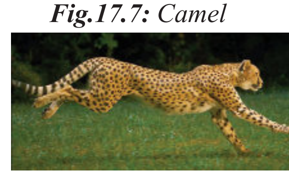


Fig.17.8: *Leopard*

9. Carnivores have sharp canine teeth, strong paws to grasp the prey. These animals have much flexible vertebrae and strong limbs to run while chasing prey.
10. Animals in Himali region have thick fur or hair in their body. They have deposited fat below the skin. They have shorter and strong legs that balance gravity during climbing up and down the hills.

Fig.17.9: *Yak*

B. Some microorganisms

Microorganisms are those which need microscope to be seen. Bacteria, fungi, virus and protozoans are some examples of such organisms. Most of them cause different types of diseases in our body and called as pathogens. Although mushrooms are non-micro organisms but they are kept under fungi. Introduction, properties, importance and disadvantages of bacteria, fungi, virus and protozoans are described below-

a. Bacteria

Bacteria are very simple and the first organism on the earth. They were formed about 3800 million years ago on the earth. Its singular form is bacterium and it is studied under the branch of biology called Bacteriology.

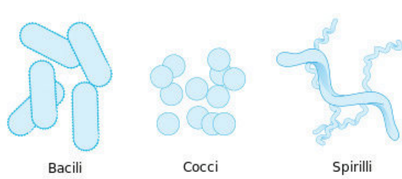
> ***Fact file:***
>
> *Bacteria are discovered by Antony Van Leeuwenhoek in 1676 AD. He observed the bacteria in water drops under his own made microscope and named micro animal. In 1828 AD Christian Gottfried Ehrenberg named it bacterium as singular form of bacteria.*

A bacterium is unicellular prokaryotic organism. It is made of cytoplasm surrounded with plasma membrane. Most of the bacteria have cell wall at the outer surface.

They do not have nuclear membrane and organelles inside their cell, ie. they have prokariotic cell.

Bacteria are found anywhere in water, air, soil, etc. Size of most of the bacteria varies in between 0.5 μm to 5 μm. On the basis of the shape of bacteria, they are classified in following types.

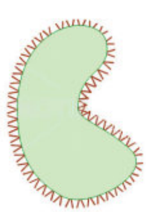
1. Coccus (Plural Cocci) - They are spherical bacteria. They are found single or connected in series.



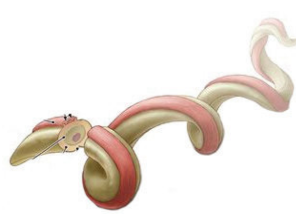
Coccus

Bacillus

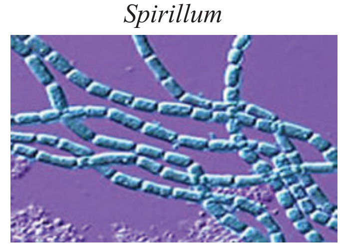
Spirillum



Vibrio



Spirochete



Filamentous

Fig.17.10: *Different types of bacteria*

2. Bacillus (Plural Bacilli) - They are rod-shaped bacteria. They also may form a series.
3. Spirillum (Plural-Spirilla) - They are spiral in shape and have flagellum for locomotion.
4. Vibrio - They are comma-shaped or curved bacterica.
5. Spirochete - They are tightly coiled bacteria.
6. Filamentous - They are found in threadlike structure.

Characteristics of bacteria

The main characteristics of bacteria are given below.

1. They are prokaryotes, unicellular and micro organisms.
2. They may be found single or in colonies. (grouped)
3. Most of them have rigid cell wall at the surface.
4. The DNA is not surrounded by a membrane, inside their cell.
5. RNA is found scattered in cytoplasm.
6. Most of them are heterotrophic but some are autotrophic.
7. Most of them are sessile but some are motile and use flagellum/flagella as locomotory organ.
8. Reproduce by asexual reproduction ie. binary fission but some of them reproduce by very simple type of sexual reproduction called conjugation.

Importance of bacteria

Bacteria are very useful to human beings. Some advantages of bacteria are given below.

1. They help to form curd from milk. *Lactobacillus acidophillus* bacterium supports the process.
2. They improve the quality of soil by conducting nitrogen fixation, nitrification and ammonification to enrich the fertility of soil.
3. They help to balance nature by conducting denitrification. It helps to return nitrogen into the atmosphere.
4. Bacteria are used to manufacture vineger, butyle alcohol and acetone.
5. They are used to manufacture vitamin B^{12}.
6. Some bacteria are used to manufacture antibiotics.
7. Some bacteria produce enzymes inside our body that help digestion.
8. Some bacteria conserve our food when they are preserved by pickling.

Disadvantages of bacteria

Bacteria are not only useful but also harmful to us. They harm us in the following ways.

1. Bacteria cause different types of diseases such as bacillary dysentery, diarrhoea, cholera, pneumonia, tuberculosis, meningities, tetanus, leprosy, siphilis, gonorrhoea, plague, etc.

2. Denitrifying bacteria like pseudomonas decrease the fertility of soil.
3. They cause the decaying of stored vegetables, fruits and other food.
4. Some bacteria cause diseases also in plants.

Control measures of bacterial disease

The following measures can be followed to control bacteria and diseases caused by them.

1. Antibiotics are used to control the bacteria in human beings and other animals.
2. For the control of bacteria in plants, healthy seeds should be used in farming.
3. Vaccination of animals is also a way of controlling bacterial infection.
4. Keeping the infected person or animal separately also the spread of bacteria in other people can be controlled.
5. Safe disposal of mucus, and other wastes of infected people.
6. By controlling temperature, rotting of vegetables, fruits and other food products can be controlled.

b. Fungi

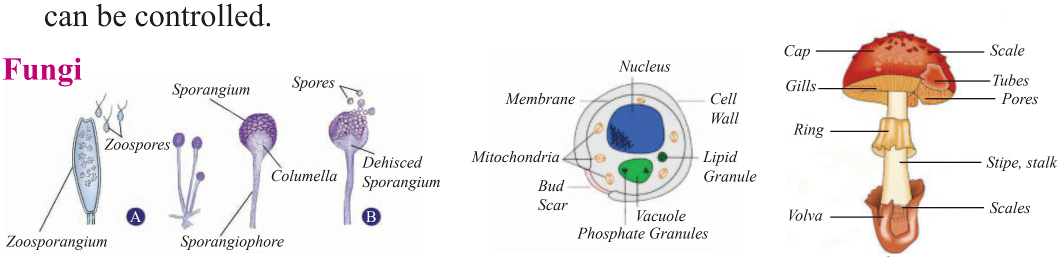


Fig.17.11: *Fungi*

Fungi is a kingdom of those type of plants which have no chlorophyll, unicellular or multicellular and heterotrophic. Their mode of nutrition is saprophytic. They may be unicellular or multicellular with thalloid body. Thus, all the members of this group are not micro organisms eg. mushroom. They grow and develop on rotting things. Some types of mushrooms are edible and they can supply protein, vitamins and minerals. Singular form of a fungi is fungus and it is studied as a branch of biology called as mycology. They reproduce by asexual methods like budding, sporulation etc. They are both advantageous and disadvantageous for us.

Characteristics of fungi

Some main characteristics of fungi are as follows.

1. They may be unicellular or multicellular.
2. They are non-green plants, thus they are heterotrophic.
3. They are saprophyte i.e. they absorb their food from decaying matters.
4. They store the excess food in their body in the form of glycogen.
5. Their cell wall is made of fungus cellulose.
6. They reproduce by asexul methods like budding, sporulation, etc.

Importance of fungi

Fungi are advantageous to us in the following ways.

1. Some fungi like mushrooms are used as food as they are rich in protein, minerals and vitamins.
2. Yeast is used in fermentation process to prepare alcohol.
3. Some fungi are used as medicine. Antibiotics like Penicillin are made from fungus penicillium.
4. Yeast is also used in bakeries and in our kitchen for baking purpose.
5. Fungi help to decay the dead bodies of plants and animals. It is very important for environmental balance.
6. Fungi are used to manufacture organic acid like lactic acid, citric acid, oxalic acid and gluconic acid, etc.

Disadvantages of fungi

Some disadvantages of fungi are mentioned below.

1. The growth of fungi on leather goods destroys the goods.
2. They promote the decaying of fruits, vegetables and spoil other food products too.
3. Fungi cause different types of diseases in potatoes, wheat, etc.
4. They cause skin diseases like ring worms itching, etc.
5. They spoil clothes and electronics specially in rainy season.
6. Some poisonous mushrooms if eaten as food can be the cause of death. Some mushrooms cause diseases and some are hallucinogenic.

Control measures of fungi

Fungi can be controlled in the following ways.

1. Fruits, vegetables, meat, etc. can be protected from rot due to fungi by controlling the temperature in the storeroom.
2. Fungal growth and diseases of plants can be controlled by using fungicides.
3. Anti-fungal ointments can be used to cure ring worms, skin rashes and itching caused by fungi.
4. Only known and edible mushrooms should be eaten as food. It is no good eating mushroom in the evening.
5. Sometimes oil, salt and sugar are also used to protect food from fungal infections.

c. Virus

Virus is a particle made of nucleic acid and protein, which is infectious and able to reproduce only inside the host cell. The word virus is derived from the latin word virion a matured virus. They are found in different shapes and sizes. The branch of biology that deals about virus is called "virology".

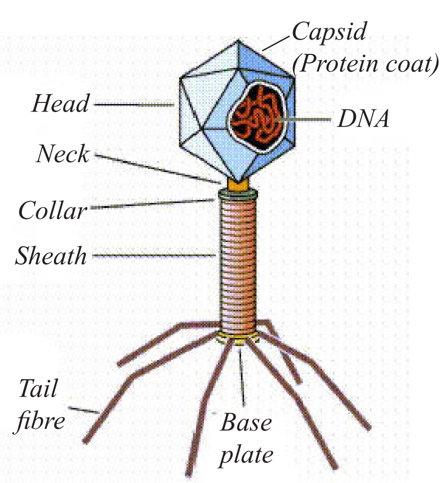


Fig.17.12: *Bacteriophage*

As they show common characters of living and non living-beings, they are called a connecting link between living and non-living beings. The size of virus varies in between 25 nm to 250 nm in diameter. Therefore, a virus is an ultra microscopic, potentially pathogenic higher nucleo protein entity that can servive in a particular living host cell. They are host specific that is animal viruses do not attack plants and bacteria cells. Similarly plant viruses do not attack animal and bacteria cells. Viruses cause different types of diseases in human beings and in other organisms. They can be classified as follows.

i. On the basis of type of nucleic acid present in them:

a. DNA virus (eg. small pox virus)(varicella, iterpes virus)

b. RNA virus (eg. Rhino virus, Retro virus, Polio virus, etc.)

ii. On the basis of host they attack on:

a. Animal virus (eg. Rhino virus, Retrovirus, small pox virus)

b. Plant virus (eg. TMV (Tobacco mosaic virus)

c. Bacteriophase (The virus that attacks bacteria cell)

Fact file:

Viruses were discovered by a Russian botanist Ivonovsky in 1892 AD from tobacco plants leaves. Later Martinus Beijerinck named it virus. Viruses are so small that they can pass through the fine pores of filter paper.

Characteristics of virus

Some major characteristics of viruses are given below.

1. Virus is a very minute particle of nucleoproteins which can be seen only with the help of electron micorscope, i.e. viruses are ultramicroscopic.
2. They lack cellular structure, (acellular).
3. They are composed of DNA or RNA, single or double stranded protein sheath called capsid.
4. They do not have cytoplasm and plasma membranes.
5. They do not have protein synthesizing machinery.
6. They do not respire.
7. They do not ingest and absorb nutrient.
8. They can be crystallized and stored for years without loss of their injective quantity.
9. They remain inactive or inert outside the cells but become alive within them.
10. They can cause disease (pathogenic).
11. They can multiply their number.

Importance of virus

The main two advantages of virus are mentioned below.

1. As they are acellular, their body can be used for the study of fundamental cells.
2. By using viruses, vaccines can be manufactured.
3. We can extract vitamins like Biotin (B_7), Riboflavin (B_2) from virus.

Disadvantage of virus

Some disadvantages of viruses are given below.

1. They cause different types of diseases in our body (Common cold, Rabies, Polio, AIDS, Mumps, Dengue, Measles, etc.)

Mode of transmission of viruses

Viruses are transmitted from person to person and plant to plant in the following ways.

1. They transmit through faeces, mucus and droplets of infected people.
2. They transmit through air, food and water.
3. They transmit from an infected plant to a healthy plant.
4. They transmit through blood and surgical instruments and skin piercing tools.
5. They transmit through sex fluid.
6. They transmit from mothers to their babies.
7. In plants viruses are transmitted through soil pollens, insects, birds and grafting too.

Control measures of viruses

Viruses and diseases caused by them can be controlled by the following method.

1. Sanitation and personal hygiene is the best way to control the diseases caused by virus.
2. Unsafe sex and infected blood should be avoided.
3. We should cover our mouth and nose using handkerchief to avoid the spreading of droplets.
4. Proper vaccination and immunization.
5. Infected plants and their parts should be burnt or burried deeply under the earth.
6. Medical precautions should be taken during injecting medicine, surgery or treatment.

d. Protozoa

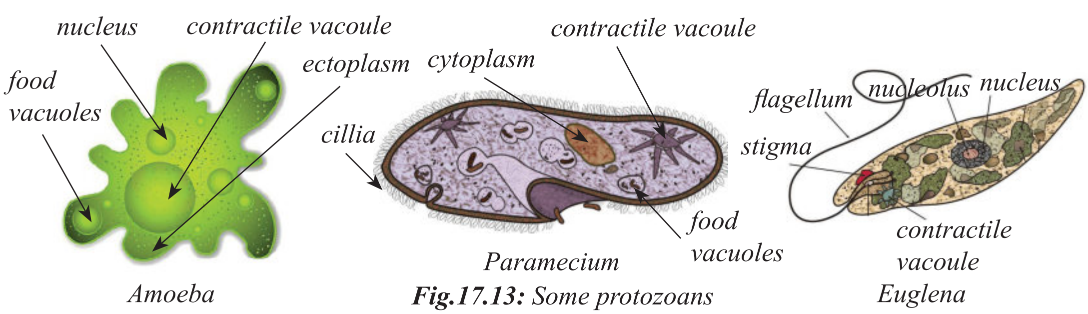


Fig.17.13: *Some protozoans*

Those animals which have single eukaryotic cell in their body are called protozoans. They are micro-organisms and the size of most of them is 10 µm - 50 µm. They may be autotrophs, or parasite. Some of them are found inside our body as parasite and cause different types of diseases like malaria, amoebiasis, giardiasis, sleeping sickness, toxoplasmosis, amoebic dysentry, etc.

Characteristics of protozoans

The main characteristics of protozoans are given below.

1. They are unicellular and micro organisms. Their cells are eukaryotic.
2. Some of them are sessile but motile protozoans have special locomotory structures like flagellum in euglena, cilia in paramecium and pseudopodia in amoebae and plasmodia.
3. They show different modes of nutrition. Some are autotrophic, some are holozoic and others are parasitic.
4. Most of them have a thin layer around cell membrane called pelicle which supports the cell membrane.
5. They reproduce by fission (asexual methods) and conjugation methods (sexual).
6. They cause different types of diseases in our bodies.

Control measures of protozoans

To control protozoans and diseases caused by them we have to follow the following measures.

1. We should follow the rules of personal hygeine properly.
2. We should not use polluted water to drink. The water should be boiled or treated with different types of chemicals to sterlize it.
3. We must be careful of our eating habit. We should avoid the open and stale food.
4. We should avoid mosquito bite as they also transfer protozoans from person to person.

Lesson Summary

1. The ability of an organism to adjust itself in a particular environment so that it can reproduce, escape from enemy, procure food, shelter, etc. is called adaptation.
2. As nature is dynamic, the adaptive features of individuals must also change with time.
3. The structures of roots, stem and leaves help plants to adjust in aquatic and terrestrial habitats.
4. The structures of an animal's body, its colour and modified organs help the animal to cope with the changeable environment.
5. Mesophytes have well-developed root and shoot system.
6. Xerpophytes have well-developed root and shoot system with thick and fleshy leaves or modification of leaves into spines.
7. Birds have sharp eyes, pneumatic and light bones, wings and special shapes of their beaks according to their food.

8. Xerophytic animals like camels have wide hoofs with pads, thick skin, hump and valves in nostrils for adaptation in the desert.
9. The harmful unicellular and micro-organisms are called pathogens.
10. Bacteria are bigger than viruses and they are both useful and harmful to us.
11. Fungi are non-green unicellular and multicellular plants and they both are advantageous and disadvantageous to us.
12. Viruses are the chain between living and non-living beings.
13. Protozoans are single-celled organisms which may be autotrophic, parasite or holozoic.

Project work

Select any five animals and plants available in your locality and analyze the changes that take place in them and help them to adjust in the environment. Note down how you helped them and share with your friends in the class

Conceptual questions with their answers

Q.1. "Viruses are known as obligatory parasites." Justify.

It is because they can survive only in the host (living body). They behave as non-living outside the host.

Q.2. "Viruses are host specific." Give reason.

Viruses are host specific as they affect only particular organism which means a virus which is pathogenic to plant may or they not be pathogenic to animals.

Q.3. What is Lichen?

The association between algae and fungi is called Lichen.

Exercise

1. Answer the following questions.

a. What is adaptation? Why is it important?
b. Write down four adaptational features of terrestrial plants and terrestrial animals.
c. Write down four adaptational features of aquatic plants and aquatic animals.
d. What are the modifications found in the desert plants?
e. What is the advantage of stomata at the upper part of a lotus leaf? Explain.

f. Write the advantages of soft stem of hydrilla.
g. Write the advantages of green and fleshy stem of cactus.
h. Write any three characteristics of
   i. Virus   ii. Bacteria
   iii. Fungi   iv. Protozoa
i. Write any three advantages each of bacteria and fungi.
j. Write any two harmful effects each of virus and protozoans.
k. Write any three preventive measures each of
   i. Virus   ii. Bacteria
   iii. Fungi   iv. Protozoa

2. Sketch labelled diagrams of

a. Bacteria
b. Mushroom
c. Bacteriophage
d. Amoeba

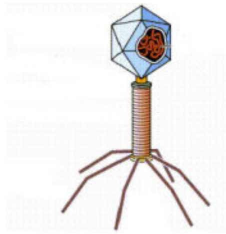
3. Write the differences between

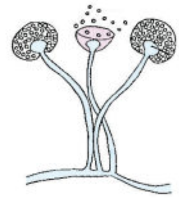
a. Terrestrial and aquatic animals
b. Terrestrial and aquatic plants
c. Virus and bacteria
d. Euglena and mushroom
e. Mesophytes and xerophytes

4. Give reasons.

a. Bones of birds are light and hollow.
b. Aloe has thick and fleshy leaves.
c. Camels have humps.
d. Camels' urine is highly concentrated.
e. Desert plants are often bushy and have thorns in them.
f. Camels have flat and wide hooves.
g. Eagles have good eyesight and strong claws in their legs.
h. Moles have strong claws and snouts.
i. A hare is sensitive to sound.
j. Bacteria are advantageous as well as disadvantageous.
k. Mushrooms are harmful too.
l. Viruses are a chain between living and non living beings.
m. Viruses are obligatory parasites.

5. Identify the organisms given and write diseases caused by them.





a. b. c. d.

Multiple Choice Questions

1. Tick (√) the correct answers.

a. How does adaptation help organisms to survive longer?
   i. By helping to catch their prey
   ii. By protecting from enimies
   iii. (i) and (ii) both
   iv. None of the above

b. Which one is not the way of adaptation?
   i. Colouration
   ii. Gaining and lossing organs
   iii. Modification in organs
   iv. Changing habitat of organism

c. An Euglena is an example of
   i. Protozoan
   ii. Bacteria
   iii. Fungi
   iv. Virus

d. Bacteriophage is a type of
   i. Virus
   ii. Bacteria
   iii. Fungi
   iv. Protozoan

e. Virus is
   i. Eukaryotic
   ii. Prokaryotic
   iii. Acellular
   iv. Unicellular

Unit 18 Cells, Tissues and Organs

Total estimated teaching hours = 6

Learning Outcomes

After the completion of this unit, students will learn:

- *cells, tissues, organs, systems and their interrelationships.*
- *different types of plant tissues with their locations and functions in plants.*

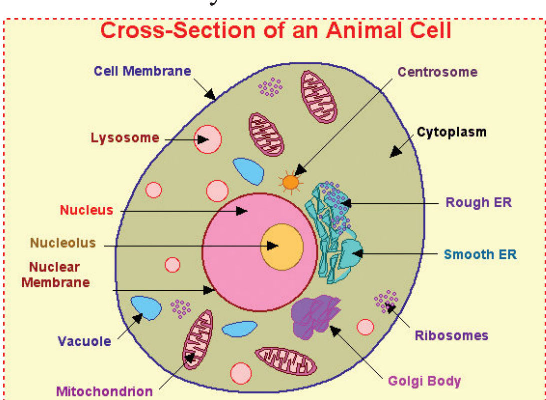
Robert hooke (1635AD-1703AD)

KEY WORDS

1. **Pre-existing** : remaining from before
2. **Cardiac muscle** : heart forming muscles
3. **Alimentary canal** : the tube that extends from mouth to anus
4. **Digestive glands** : the glands which produce digestive juices
5. **Gonads** : reproductive organs
6. **Stone cell** : hard structure found in the central part of pears
7. **Rigidness** : hardness

A. Cell

Every living being is composed of very minute units called cells. A cell is the simplest and smallest unit capable of carrying all life activities. The study of cell and its behaviour is called cytology. It was Robert Hooke who studied and explained cells for the first time with the help of a microscope prepared by himself in 1665 AD. He observed the layers of cork and detected small rooms as in bee-hive. He named



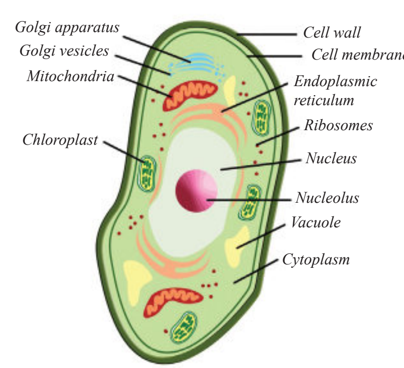


Fig.18.1: Animal and plant cells

them cells. Though the layers of the cork were non-living, scientists later on proved that the body is composed of such smaller units. In 1838, German botanist Mathias Schileden proposed that every plant is composed of numerous cells. After one year, German Zoologist Theodor Schwann made it clear that every plant and animal body is composed of cells as basic units of life.

Cell Theory

The cell theory statement was proposed by Schleiden and Schwann and was corrected and modified latorn. Then a common cell theory was proposed by Schleiden, Schwann and Rudolf Virchow. The cell theory states that:

1. All living organisms are composed of small living units called 'cells'.
2. All cells are fundamentally similar in chemical composition and metabolic activities.
3. The functions of an organism as a whole are the outcome of the activities and interactions of the cells constituting the body of that organism.
4. All cells arise from pre-existing cells.
5. The cells are the structural and functional unit of life.

B. Tissues and organs

A cell is the basic unit of life. All living organisms have cells. Some organisms are composed of only one cell. Such organisms are called unicellular organisms. All the activities of life processes such as digestion, respiration, excretion, reproduction etc. are carried out in one cell. Some other organisms are composed of two ore more cells. Such organisms are called multicellular organisms. Unlike unicellular organisms, all functions of life processes are not carried out by one type of cells in multicellular organisms but different groups of cells perform different functions. In such organisms, a group of similar cells performing a particular function is called tissue. Epithelium, muscle, bone, blood, nerve etc. are some examples of animal tissue. Meristem, parenchyma, xylem, phloem etc. are some plant tissues.

Generally an organ is responsible for one particular function. However, there are organs which are responsible for more than one function. They carry out more than one function in the body. For example, cardiac muscle of heart is responsible for circulation of blood throughout the body. It carries out one type of function. Tissues of kidney carry out more than one function of the body. They control the amount of water in the body and also help to remove the excretory materials from the body. Liver is another example of organs that has number of functions as given below-

Main function of the liver

1. The bile produced by liver helps in digestion of the fatty substances.
2. Heat is produced by chemical reaction taking place in liver which helps blood become hot when blood flows through it. It maintains body temperature.

3. It produces urea and uric acid which passes out with urine.
4. It helps to destroy the old red blood cells.
5. The excess glucose present in food is stored in the liver as glycogen.
6. It helps to maintain sugar in blood.
7. Bile from gull bladder in liver helps in imulsification of fat.

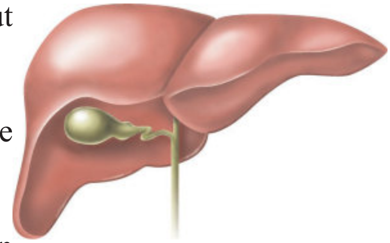


***Fig.18.2:** Liver*

C. Body System

Different organs in our body work collectively to complete a definite function. The organs in the group form a system called body system. In such a system, all organs work together to carry out a definite task.

There are different systems in our body. These are digestive system, circulatory system, respiratory system, nervous system, excretory system, endocrine system, reproductive system etc. In all of the above mentioned systems different organs work together in a group to carry out a particular life process. Let us take an example of digestive system. The digestive system helps in the digestion and in absorption of food and is concerned with nutrition in animals. Alimentary canal and various digestive glands take part in the digestive system. The part of alimentary canal like mouth, pharynx, oesophagus, stomach, small intestine and large intestine and glands-like salivary glands, gastric glands, liver, pancreas and intestinal glands take part in digestion. Digested food is absorbed by the blood to carry up to different cells and tissues.

Human body systems, their organs and functions			
Body system	Organs of the system	Kinds of tissues	Main function
a. Digestive system	Stomach, liver, pancreas, voluntary muscle	Columnar and epithelium	Digestion and absorption of food materials
b. Respiratory system	Wind pipe (Trachea), lungs	Pavement and cubical epithelium	Exchange of oxygen and carbon dioxide
c. Circulatory system	Heart, blood vessels and blood	Pavement epithelium, connective tissue and muscle	To transport oxygen and digested food throughout the body
d. Excretory system	Kidney, liver, urinary bladder	Pavement and cubical epithelium	To excrete waste substances
e. Nervous system	Brain, spinal cord	Nerves	Transmission of impulses

f. Muscular and skeletal system	Muscles and bones	Muscles, connective tissue	To support weight and help in movement of the body, locomotion
g. Reproductive system	Gonads (Testes and ovary)	Cubical, columnar epithelium and germinal epithelium	Help to reproduce new organism

Plants also have systems of organs to carry out different functions of their body. There are two organ systems in plants. They are (i) Root system (ii) Shoot system.

Interrelationship in cell, tissue, organ and system

In unicellular organisms all vital functions like respiration, digestion, reproduction, nutrition etc. are carried out by a single cell. But in multicellular organisms, these activities are carried out by various tissues in an organized way. In higher animals, several functions are carried out in the body. These functions are carried out by different types of tissues in a group. We have studied that a group of different tissues forms an organ. Eyes, nose, tongue, liver, kidney, lungs etc are some organs. Several organs work together or coordinate to form a system in order to complete a specific function. This is called the system. Different systems constitute an organism.

Cell ⟶ Tissue ⟶ Organ ⟶ Body System ⟶ Organism

Tissues are formed by the collection of similar types of cells. Different types of tissues form organs. Many organs arranged in a fixed pattern form systems. A body is composed of cells, tissues, organs and systems in a definite pattern. The organs of digestive system are mouth, tongue, throat, oesophagus, stomach, small intestine, large intestine, salivary gland, liver and pancreas. The main function of digestive system is to digest the food material and to absorb the nutrient material present in the foods. This whole activity is carried out in coordination with cells, tissues and organs in a systematic way. Liver is one of the most important organs of digestive system.

Plant tissue and its types

The tissues which consists of plant cells and form plant bodies are called as plant tissues. They contain both living or dead types of cells. On the basis of the capacity of division, the plant tissues have been classified into two fundamental types.

A. Meristematic tissue
B. Permanent tissue

A. Meristematic tissue (Meristem)

These are composed of cells that are in a state of division or retain the power of dividing. The cells are

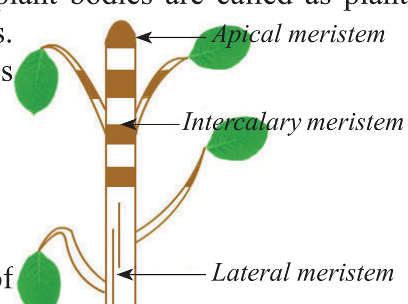


Fig.18.3: *Meristematic tissue*

alike, spherical, oval or polygonal in shape without any inter celluar spaces. Their walls are thin and homogeneous. Vacuoles are small or absent but the nuclei are large. Meristematic tissues may be apical, lateral and intercalary. The apical meristem lies at the tip of the stem and the root. They are responsible for the growth of height of plant. The lateral meristematic tissue lies among masses of permanent tissues. They are responsible for the thickness of plant. Intercalary meristem is responsible for the growth of internodal region.

B. Permanent tissues

These are composed of the cells that have lost the power of dividing. They have definite form, size and thickness. They may be living or dead and have thin-walled or thick-walled. Permanent tissues are classified into simple, complex and special.

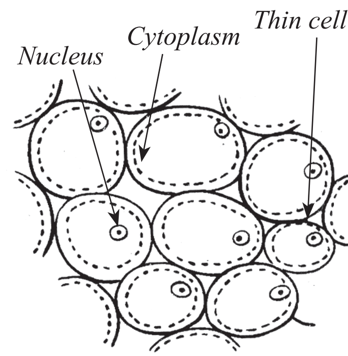


Fig.18.4: *Parenchyma*

a. Simple permanent tissue

Simple permanent tissues are those which are made of single type of cells. They are further divided into following three types:

i. Parenchyma
ii. Collenchyma
iii. Sclerenchyma

i. Parenchyma

Parenchyma consists of a collection of cells which are more or less isodiametric i.e. equally expanded on all sides. They are oval, spherical or polygonal in shape. Their walls are thin and made of cellulose. They are usually living. They are found in all soft parts of plants.

Functions

1. Their main function is the storage of food materials.
2. Chlorenchyma is the parenchyma with chloroplast that manufactures starch and sugar by the process of photosynthesis.
3. Aeronchyma is the parenchyma with large air spaces that makes the body of aquatic plants soft to be able to float.

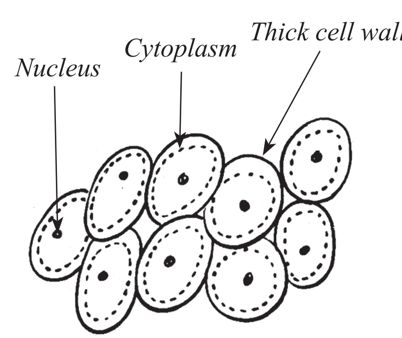


Fig.18.5: *Collenchyma*

ii. Collenchyma

These tissues consist of somewhat elongated cells with the intercellular spaces. They are living. They are circular, oval or annular in shape. Their walls are thicker and have with simple pits here and there. They are in a few layers under the skin (epidermis) of herbaceous dicotyledons e.g. sunflower.

Function

1. Being flexible in nature collenchyma gives mechanical strength to the stem.
2. It acts as a storage tissue.
3. Due to the presence of chloroplasts (though less in amount), it helps to manufacture sugar and starch.

iii. Sclerenchyma

They consist of very strong, narrow, thick-walled and lignified cells. The cells are usually pointed at both ends. They are fibre like in appearance and hence they are also called fibres. They have simple, often oblique, pits in their walls, They are found excessively patched in almost all parts of the plants. They are dead cells. Sclerenchyma is of two types they are fibres and stone cells (sclereids).

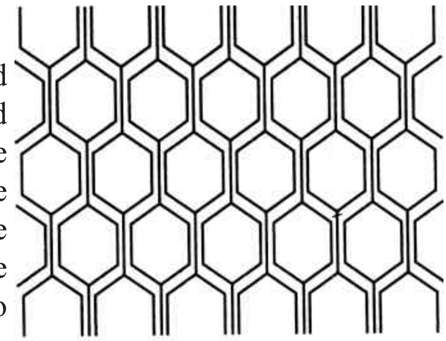


Fig.18.6: *Sclerenchyma*

Function

Their main function is to provide the mechanical strength and rigidness to plants. So the plants can withstand various types of strains.

Difference between Meristematic tissue and Permanent tissue

Meristematic tissue	Permanent tissue
1. It is a simple tissue.	1. It may be simple or complex.
2. Intercellular spaces are either absent or very small.	2. Intercelluar spaces are often persent.
3. The cell walls are thin.	3. The cell walls may be thin or thick.
4. The cells have the capacity to undergo repeated divisions.	4. The cells normally do not undergo division.

b. Complex permanent tissues

A complex permanent tissue can be defined as that type of plant tissue, which consists of many types of cells. They are found in all vascular plants.

They provide mechanical support and help in internal transportation in plants. There are two types of complex permanent tissues. They are xylem and phloem.

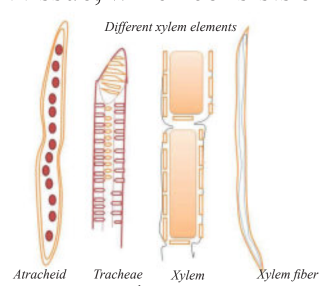


Fig.18.7: *Xylem tissue*

i. Xylem

It is a conduction tissue which is composed of (tracheids), vessels trachea wood fibres and wood parenchyma. Wood parenchyma are the living cells and the rest (tracheids, vessels and wood fibres) are all dead cells. Thus, the major cells of this tissue are dead.

Function of Xylem

1. Xylem conducts water and minerals upward from root to leaf.
2. It provides mechanical strength in the plant body.

ii. Phloem

Phloem is a living, non-lignified tissue. It is also a conducting tissue composed of sieve tube cells, companion cells, phloem parenchyma and phloem fibres. The major cells of this tissue are alive. Phloem fiber is only non living cell in phloem.

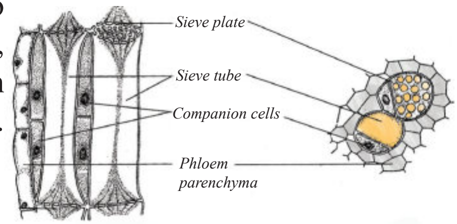


Fig.18.8: *Phloem tissue*

Function

Phloem tissue conducts prepared food materials from leaf to other organs of the plant.

Difference between xylem and phloem

Xylem	Phloem
1. Xylem is composed of wood fibre, wood parenchyma, trachea and tracheids.	1. Phloem is composed of sieve tube cells, companion cells, phloem parenchyma and phloem fibres.
2. It is found deep in the plant.	2. It is found superficial in the plant.
3. It conducts the flow of water and minerals from root to leaves.	3. It conducts the flow of organic food from leaves to other parts.
4. It provides the plant body with mechanical strength.	4. It does not provide the plant body with mechanical strength.
5. It is also called wood of plant.	5. It is also called bast of plant.

c. Special permanent tissue

Special permanent tissues are made of special types of cells. These tissues have nature of secretion. The tissues that are concerned with the secretion of gum, resins, volatile oils, latex and other substances. They are thin-walled, greatly elongated and much branched ducts. They are divided into two groups:

1. Lactiferous tissues
2. Glandular tissues


Fig.18.9: *Rubber plant*

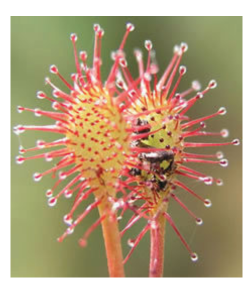


Fig.18.10: *Sundew plant*

Lesson Summary

1. Cell is a structural and functional unit of life.
2. Tissue is a group of similar cells which performs a particular function.
3. An organ is a combination of tissues to perform a definite function.
4. A body system is a group of organs speciliazed for a particular life process.
5. Plant tissues are made of plant cells and form plant bodies.
6. Plant tissues are of two types-meristematic and permanent.
7. Meristematic tissues are found in the root, stem and leaf. These tissues cause the plants to grow to length and thickness.
8. Permanent tissues are classified as simple, complex and special.
9. Simple permanent tissues are responsible for preparation and storage of food and provide mechanical support as well.
10. Simple permanent tissue is of three types- parenchyma, collenchyma and sclerenchyma.
11. Permanent tissues are made of many types of cells. It is of two types. They are xylem and phloem.
12. Phloem conducts the flow of food from leaves to other parts.
13. Xylem conducts minerals and water from soil to leaves.

Project work

Observation of plant tissues

1. You need a thin transverse section of the root of a gram (chick pea) plant or stem of a maize plant on a watch-glass with little water in it. Select the thin and complete section and place it on another watch-glass. Add a drop of safranine and stain the cut piece properly. Add a drop of glycerine and cover it with a cover slip.
3. Observe epidermis, cortex, xylem and phloem on the slide under the microscope.

Conceptual questions with their answers

Q.1. What is Lactiferous tissue?

Lactiferous tissues are the special types of tissue present in plant which have seeretory functions. They produce milky fluid known as latex.

Q.2. What do you mean by vascular tissue?

The conducting tissues of plant namely xylem and phloem are called vascular tissues.

Q.3. Which is the largest gland of our body?

Liver is the largest gland of our body.

Q.4. What are the types of pharynx present in human beings?

There are three types of pharynx. They are:

a. Naso pharynx

b. Oro pharynx

c. Laryngo pharynx

Exercise

1. Answer the following questions.

a. Define tissue, organ and system with an example of each.

b. Write the types of permanent tissues in short.

c. What happens if all the meristems are removed from a plant? Why?

d. How are cell, tissue, organ and system interrelated?

e. Write any four functions of liver.

f. What is meristematic tissue? Also write its types with examples.

g. What is permanent tissue? Mention its three types with their functions.

h. Mention different types of simple permanent tissue with one character and one function each.

i. What is a complex permanent tissue? Also write its types and functions.

2. Write the difference between

a. Permanent and meristematic tissues

b. Simple and complex permanent tissues

c. Xylem and phloem

d. Parenchyma and scelrenchyma

3. Give reasons.

a. A plant dies when phloem is removed from its stem in the form of a ring.

b. Parenchyma is a simple permanent tissue.

c. Xylem is a complex permanent tissue.

d. The height of a plant does not grow when its tip is cut.

e. Liver is an organ.

f. Respiratory system is a body system.

4. Sketch neat and labelled diagrams of

a. Meristematic tissue

b. Parenchyma

c. Phloem

Multiple Choice Questions

1. Tick the correct answer.

a. A group of similar cells that has common function is called

i. Tissue
ii. Cell
iii. Organ
iv. System

b. The tissue that conducts the flow of food from leaves to other parts is called

i. Xylum
ii. Collenchyma
iii. Phloem
iv. Parenchyma

c. An example of tissue is

i. Leaf
ii. Bone
iii. Eye
iv. Lung

d. Which one is made of mainly dead cells?

i. Xylem
ii. Phloem
iii. Glandular tissue
iv. Lactiferous tissue

e. Which one has the capacity of cell division?

i. Simple permanent tissue
ii. Meristematic tissue
iii. Complex permanent tissue
iv. Special permanent tissue

Unit 19 Sense Organs

Total estimated teaching hours = 2

Learning Outcomes

After the completion of this unit, students will learn:

- *the meaning and importance of sense organs.*
- *the structure and function of different types of sense organs of human beings.*

Bartolomeo Eustachio (1514AD-1574AD)

KEY WORDS

1. **Impulse** : electrical signals-formed stimuli
2. **Pinna** : external ear/auricle/ear lobe
3. **Ear ossicles** : bones found inside ear
4. **Chemoreceptors** : the nerves which can feel chemicals dissolved in mucus
5. **Inflammation** : swelling
6. **Dermatologist** : skin specialist (doctor)
7. **Near point** : the closest distance at which objects can be seen clearly
8. **Far point** : the farthest distance at which objects can be seen clearly

Introduction

Sense organs are the sense receptors of the body. They receive information about the conditions inside their body and in the world around them. This information is known as stimulus because it stimulates the sense organs. But no matter how the sense organs are stimulated, the stimulus is turned into only one thing. That is a pattern of nerve impulses that speed down sensory nerves to the brain. Here, the patterns of impulses are interpreted and transformed into specific sensations such as sight, hearing, taste, touch, smell, etc. The sense organs in a human body are ear, eye, nose, tongue and skin. Structure and function of some sense organs are described below.

1. Ears

Ears are the organs of hearing. Ear consists of two sets of organs, each with distinctly separate functions. One set, called the semi-circular canals, is concerned with the sense of balance. The other set transforms vibrations in the air into nerve impulses which are interpreted as sound in the brain. On the basis of hearing mechanism, ears are divided into three distinct parts:

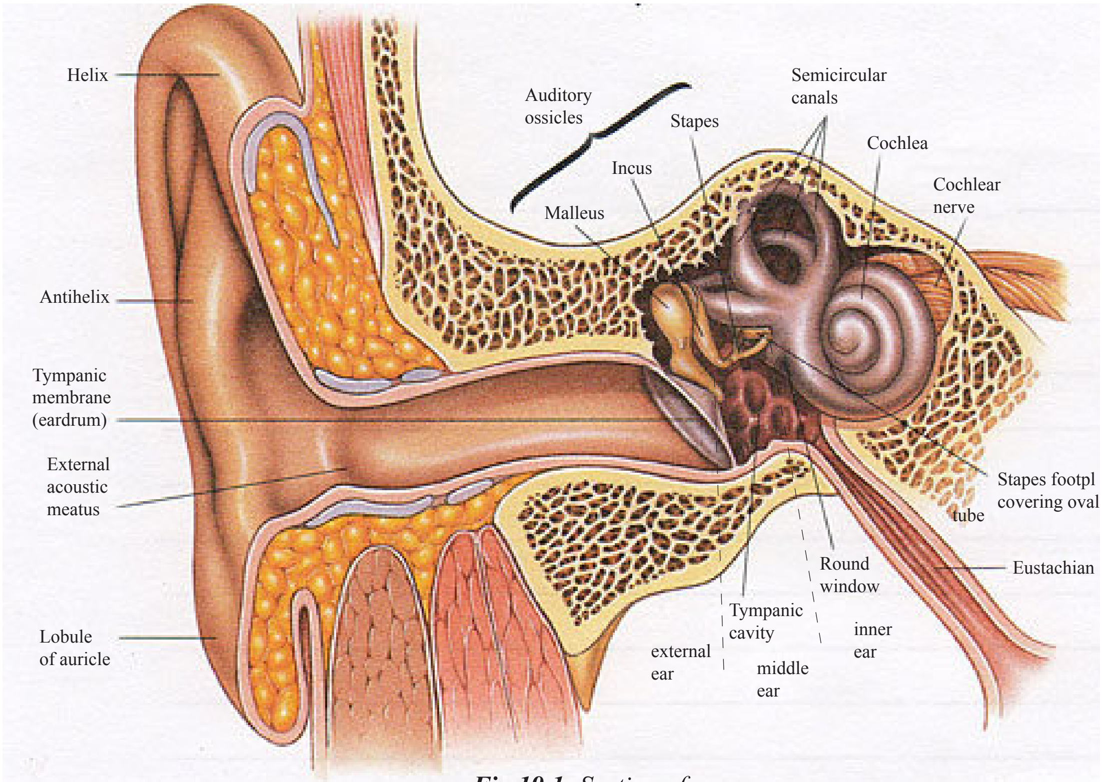


Fig.19.1: *Section of ear*

a. External ear b. Middle ear (Tympanic cavity) c. Internal ear

a. External ear

The external ear consists of pinna (auricle) and the external acoustic meatus. The pinna is funnel-shaped, made of flexible cartilage covered with skin. Pinna collects sound waves and helps in directing sound waves into the external acoustic meatus which is about 2.5 cm long S-shaped extending from the air to the tympanic membrane i.e. ear drum.

b. Middle ear

Across the cavity of the middle ear, opposite to the ear drum, there is a membrane called the oval window (part of inner ear). The ear drum and oval window are connected by a chain of three tiny bones called ear ossicles held in position by muscles and fine ligaments. They are malleus, incus and stapes. The ossicles transmit sound waves from the outer to the inner ear. Sound waves in the air cause the ear drum to vibrate which causes the ear ossicles to move against each other. They move in such a way that they cause the innermost ossicles and the stapes to be levered in and out like a piston. The stapes is attached to the oval window. So, when the stapes moves in and out, It moves the oval window in and out and this sends vibrations to the inner ear. The ossicles also magnify the sound waves about 20 times and reach the oval window.

c. Inner ear

The coiled fluid filled tube called cochlea and semi circular canals are the main parts of the inner ear. Cochlea is the combination of three tubes. The middle tube contains endolymph i.e. fluid filled tube and the outer tube contains perilymph (another fluid filled tube) and the floor contains nerve cells of hair cells. The stapes moves against the oval window and causes vibrations in the perilymph of cochlea. The vibrations spread in to the endolymph and finally cause the sensory hair cells to vibrate up and down. The sensory hair cells then send the impulses to the brain along the auditory nerve and finally sound is heard.

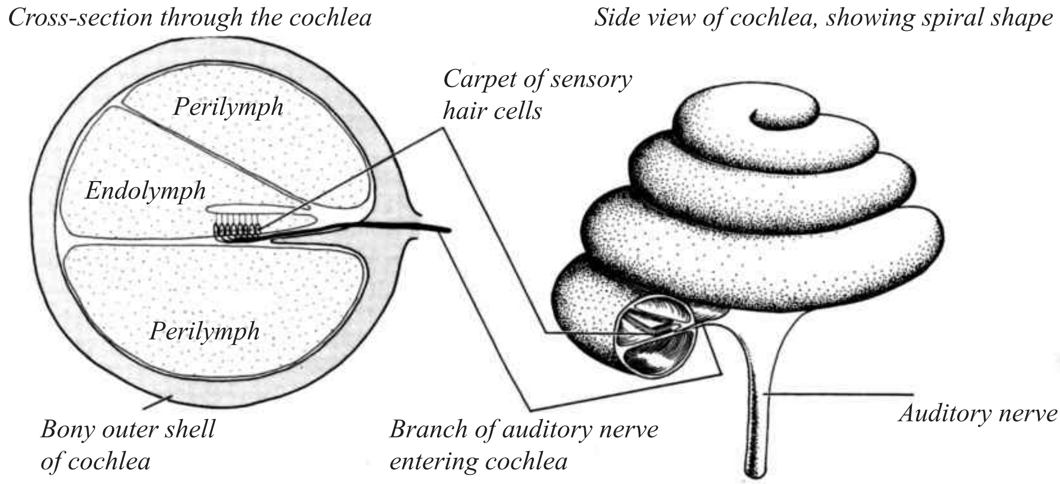


Fig.19.2: *Structure of cochlea*

Semi-circular canals

The semi-circular canals have no auditory functions although they are closely associated with the cochlea. There are three semi-circular canals.

The major function of semi-circular canals is to provide information about the position of the head in space, contributing to maintenance of equilibrium and balance.

Eustachian tube

It is an air-filled canal which connects the middle ear with the pharynx. The air pressure in the external ear and the middle ear is normally the same. If there is suddenly a large increase in external air pressure, there is a possibility that the eardrum will brust. However, this danger is prevented when air taken in from outside enters the eustachian tube during swallowing. In this way, air pressure on either side of the eardrum is equalized.

Care of ears

As ear is the sound sensitive sense organ, it may not work properly if it develops any defect in it. Ear infection, collection of wax or jammed stony wax, defect in the eardrum (tympanic membrane) damage of auditory nerve etc. can cause the loss of hearing in the people.

It is necessary to pay attention to following points to care the ears.

1. We should not expose ourself to very loud sound.
2. Improper use of cotton buds, use of sharp objects to remove wax can cause loss of hearing capacity of ears.
3. We must not drop oil, water or any thing inside the ears.
4. In the case of other problems of ears physician's suggestion (ENT specialist) should be taken.

2. Nose

Nose is responsible for two functions-sense of smell and respiration. Smell receptors, or olfactory organs, are the main parts for the detection of snells, in nose. They are situated high inside the nasal cavities. Nose contains more than 20 million mucus coated olfactory receptors. The sense of smell is perceived by chemoreceptors in nose which get stimulated by different chemicals. The chemicals must dissolve in the layer of mucus before they can be detected. The receptor cells send the impulses to the olfactory region of brain. Odours are detected by the olfactory hairs that emerge from the receptors. When a person inhales a substance with a strong smell again and again, the sensation of smell for that substance weakens gradually and may disappear altogether.

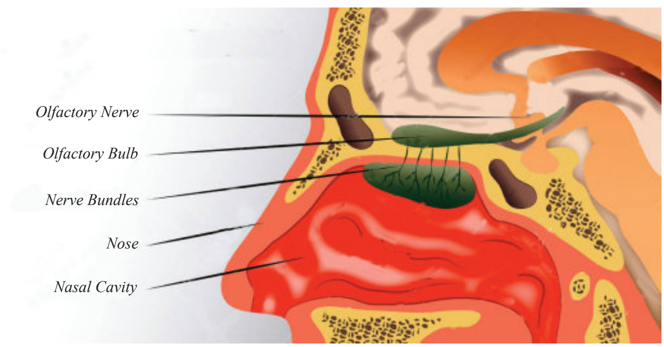


Fig.19.3: *Olfactory structures*

Care of nose

Rhino viral infection in the nasal cavity and respiratory tract causes common cold. It causes the collection of large amount of mucus around the olfactory nerve. It does not only hinder the smelling but can create the infection due to bacteria. The bacterial infection can cause inflammation of sinus chamber called sinusitis.

We should follow the following measures to care our nose.

1. We should use mask properly, use of hanky during sneezing and coughing can help to check the spreading of this virus.
2. We should not blow our nose hard. It can equally damage the nose and ears as well.
3. We should keep our nose clean.
4. We should not put our finger in nostrils.
5. In case of any major problem of nose, we should consult ENT specialist.

3. Tongue

Tongue is the main organ to feel the sense of taste. Taste receptors, or taste buds are the main part of tongue to distinguish the taste. They are situated around the walls of papillae, on the upper surface of the tongue. There are four types of taste receptors. Separate receptors detect salt, sweet, sour and bitter tastes. The countless different flavours present in food and drink are identified according to the level of stimulation which they produce in each type of taste receptor. The taste buds stimulated in different parts of tongue are as:

Sweet and salty - mainly at the tip
Sour - at the sides
Bitter - at the back

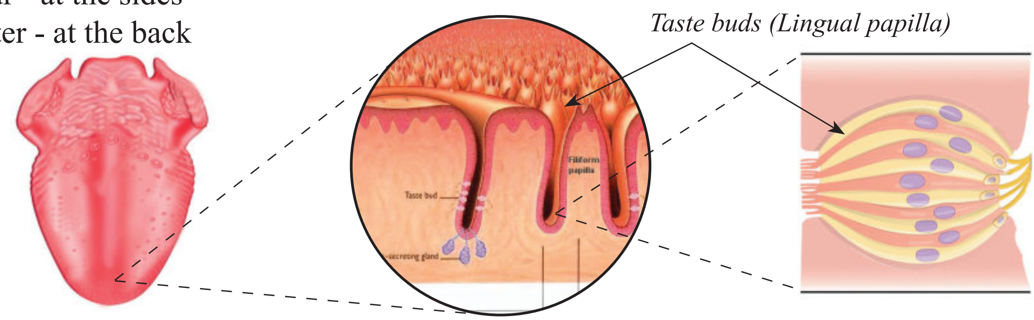


Fig.19.4: *Tongue*

Care of tongue

In following ways we should care our tongue-

1. While brushing the teeth, tongue also should be cleaned properly.
2. Some times rashes are seen on tongue due to deficiency of vitamin B. Vitamin B complex tablets and capsules are used to relief from it.
3. In the case of wound on tongue we should consult the physician.

4. Skin

The skin contains millions of separate tiny sensory nerves with several different functions. Microscopic examination of the human skin shows that it contains at least five different types of sensory nerves. Skin receptors are the main part of skin that cause to distinguish the sense of touch.

Skin receptors have the following functions.

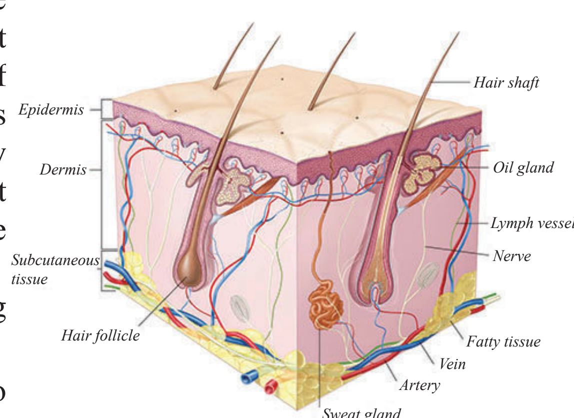


Fig.19.5: *Skin section*

a. Sense of touch: It enables person to distinguish a variety of texture-hard, soft and liquid. Blind people can read with the sense of touch through Braille. Touch receptors are found most concentrated in tongue and finger tips.

b. Sense of pressure: Pressure receptors are also concentrated on the skin of tongue and finger tips where pressure differences as small as 2 g/mm^2 can be detected.

c. Temperature sense: There are separate 'hot' and 'cold' receptors in fingers which can distinguish differences as small as 0.5°C.

d. Sense of pain: Pain receptors are distributed throughout the skin, muscles, tendons and wall of digestive system, in fact, everywhere except brain. Pain gives warning that something is going wrong in body.

e. Hair plexus: Most hair plexus have their sensory nerve endings attached to the skin. These receptors are stimulated when the hair is moved by objects close to the skin or by air movements.

Care of skin

Skin covers our body. It equally protects our body. It encounters several problems, diseases, and effects of heat, light, coldness etc.

Skin has three different layers epidermis, dermis and hypodermis. epidermis does not have blood vessels and it is non living skin layer. A living skin layer lies just below the epodermis with sufficient blood circulation called dermis. Dermis contains nerve endings sweat glands and hair follicles. Sebaceous gland lies at this layer of skin. This helps to keep the skin miost.

Skin suffers from severals problems. leucoderma (Dubi), scabies and ringworms are some diseases related to skin. Several disease worms can easily penetrate through the skin and reach up to the blood streams. Hence we should always keep skin clean and healthy. We should visit to the doctor (Dermatologist) to solve the problem if we suffer from skin problem.

5. Eyes

The eyes are the organs of the sense of sight situated in the orbital cavities and are supplied with optic nerves. Human eye is almost spherical in shape and is about 2.5 cm. in diameter. There are three layers of tissue in the walls of eye. They are:

a. The outer fibrous layer: sclera and cornea
b. The middle vascular layer: choroids, ciliary muscle and iris.
c. The inner nervous tissue layer ie. retina.

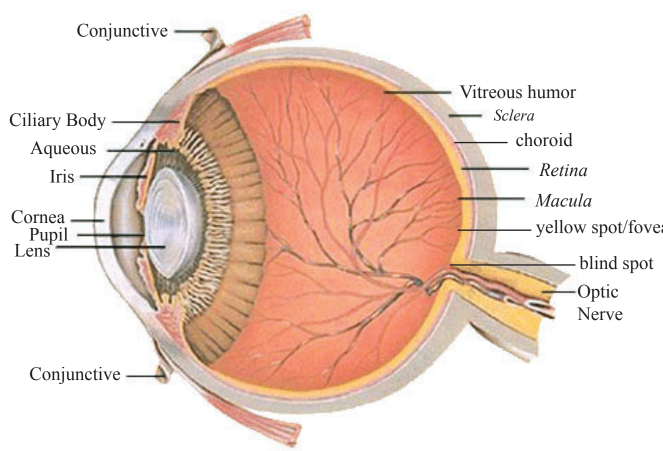


Fig.19.6: Section of eye

Function of different parts of human eyes

1. Sclera and Cornea

The sclera is a tough fibrous coating outermost layer of the eye ball which is white in appearance. It maintains the shape of eye and protects the delicate inner layers. It is continuous to cornea. Cornea is the clear transparent membrane. Light rays pass through cornea to reach retina. There is no any blood circulation in cornea.

2.Conjuctiva

It covers the entire front part of eyes including the inner lining of the eyelids.

3. Choroid

It is very rich in blood vessels and is deep chocolate brown in colour. Light enters eyes through pupil, stimulates the nerve endings in retina, then is absorbed by choroids.

4. Ciliary muscle

The ciliary muscle is the anterior continuation of choroids consisting of muscles fibres and secretory epithelial cell. It gives attachment to the suspensory ligaments. The other end of the suspensory ligaments is attached to the capsule enclosing lens. Contraction and relaxation of the ciliary muscle changes the thickness of crystalline the lens.

5. Iris

Iris is the colourful membrane of eyes and has a round hole in its centre called pupil. It extends anteriorly from the ciliary body and lies behind cornea in front of lens. Iris consists of radial muscles which contracts to enlarge the size of pupil and circular muscles which make it smaller in size. Iris regulates the amount of light which reaches retina by opening pupil in dim light and reducing it to a pin hole size in bright light.

6. Crystalline lens

Lens is a highly elastic circular biconvex transparent body, lying immediately behind increases its thickness. It is suspended from the ciliary body by the suspensory ligament and enclosed within a transparent capsule. It is the only structure in eyes that can vary its refractive power by changing its thickness.

7. Aqueous humor

There is a watery fluid called aqueous humor between the cornea and lens. It is a medium to provide oxygen and food from blood vessels to cornea and lens. It gives the anterior buldging of eye and helps to refract light up to the lens.

8. Vitreous humor

At the back of eyes between lens and retina there is a jelly transparent gelatinous protein called vitreous humor. It provides the shape of eye and helps to refract light up to the retina.

9. Pupil

Pupil is an opening surrounded by iris. It controls the passes of light inside eye. Its size is controlled by iris. It is larger in dark and smaller in bright.

10. Retina

It is the main part of eyes that cause to distinguish the sense of sight. Retina is the innermost layer of the walls of eyes. It is an extremely delicate structure and is especially stimulated by light rays. The retina consists of 126 million light-sensitive receptors, which are in the shape of rods and cones. Rods and cones convert light rays into nerve impulses. There is a small area in retina consisting of blood vessels and nerve fibres which leads to the optic nerve called blind spot. This (blind spot) is entirely insensitive to light.

Care of eyes

The eye is a delicate light sensitive sense organ. It helps us to see the things around in the presence if light. A normal eye can see from 25 cm (Near point) to upto infinity (far point). In following ways we should keep our eyes healthy-

1. We should always keep our eyes clean and healthy.
2. We should not rub our eyes long.
3. We should wash our eyes with clean water for 2 to 3 times a day.
4. We must rinse our eyes with cool water if anything enters our eyes.
5. We should not directly look at very bright light and the sun with our naked eyes.
6. We should let light fall on our books and other study materials from right side and from back during reading.
7. We should not read in dim light.
8. We should not watch TV from a short distance.
9. We must include sufficient vitamin 'A' rich food items like green leafy vegetables, yellow fruits and vegetables in our food.
10. We must visit a doctor (Opthalmologist) if we get any problem in our eyes.

Lesson Summary

1. Sense organs play very important roles in sensitivity.
2. Ears, nose, tongue, skin and eyes are called sense organs.
3. Nose is the sense organ for smell. The sense of smell is perceived by chemoreceptors in nose.
4. Ears are the sense organs of hearing. Ear is divided into external ear, middle ear and inner ear.
5. Semi-circular canals help in balancing body.
6. Tongue gives the sense of taste. It consists of taste buds to detect various tastes.
7. Skin covers body and it contains nerve endings of pain, temperature and touch.

8. Eyes give the sense of sight. Pupil allows the light rays to pass through it and ciliary muscles change the thickness of eye lens.
9. Optic nerves carry impulses from retina to brain.
10. Rods and cones cells convert light rays into nerve impulses.
11. We must care our sense organs to make them work properly.

Project work

Locating source of sound

1. Ask a student in the class to cover his/her eyes by using a clean handkerchief.
2. A ticking clock is placed somewhere in the class.
3. Let the blindfolded student find the clock (one student should accompany the blind- folded student in order to prevent him/her from accident).
4. Observe the head movement of the blind-folded student. (What do you think about the movement of the blind-folded student if he/she closes his/her ears with with a piece of cotton. It is better to carry out this activity in an open ground of your school).

Conceptual Questions with their answers

Q.1. Which part of eye is avascular?

It is the cornea which is avascular. (Remember donation of eye means donation of cornea)

Q.2. What are the two main functions of ear?

They are: a. hearing and b. balance (i.e. equilibrium)

Q.3. Which taste bud is most numerous?

Filiform papilla (bud) is the most numerous. People feel burning sensation when they get lost.

Exercise

1. Answer the following questions.

a. Define sense organs with examples.
b. How many types of receptors are found in the skin?
c. What are ossicles? Write the functions of ossicles.
d. Write the function of eustachian tube.
e. Define sense organ, stimulus, stimulation and reaction.
f. Describe the middle part of ear in short.
g. Describe different parts of nose in short.

h. Write any two methods of caring

i. eyes ii. nose iii. ears iv. skin v. tongue

i. How do ears work?

j. How does an eye work?

2. Write the difference between

a. Outer and inner ears b. Retina and eye lens

3. Give reasons.

a. Colour is not seen distinctly in the moon light.

b. A person cannot balance bodies after spinning sometimes.

c. When a person moves from a bright place to a dark place (eg. cinema hall) things are not seen distinctly.

d. Sweet taste is detected right after putting the sweet in our mouth but a bitter taste is experienced only at the time of swallowing.

e. Sweets are served to the air passengers.

f. A person suffering from cold does not get proper taste.

4. Draw neat and labelled diagram of

a. Human eye b. Human ear

c. Skin d. Nose section

5. Label the different parts of skin given aside.

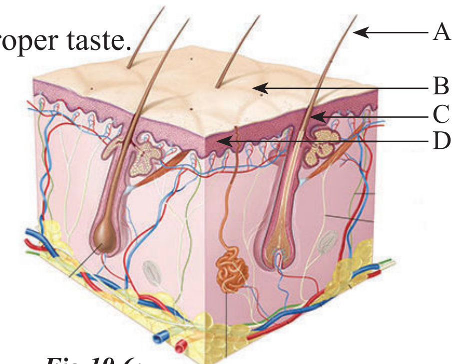


Fig.19.6:

Multiple Choice Questions

1. Tick the correct answer.

a. Which one balances air pressure in middle and internal parts of ear?

i. Oval window ii. Stapes

iii. Eustachean tube iv. Semi-circular canal

b. Which one is responsible for smelling?

i. Phonoreceptors ii. Thermoreceptors

iii. Auditory nerves iv. Olfactory organs

c. Which one is responsible for the change in focal length of the eye lens?

i. Ciliary muscle ii. Iris

iii. Cornea iv. Ligament

d. Which of the following is related to the balance of our body?

i. Auditory canal ii. Semi circular canal

iii. Cochlea iv. Eustachean tube

e. Which part of tongue gives the sense of bitter taste?

i. Tip ii. Central iii. Back iv. Sides

Unit 20 Human Body Systems

Total estimated teaching hours = 5

Learning Outcomes

After the completion of this unit, students will learn:

- *functions of skeletal system.*
- *classification of bones.*
- *human digestive system.*
- *teeth.*
- *respiratory system.*
- *transpiration, introduction and importance.*

William Beaumon (1785AD-1853AD)

KEY WORDS

1. **Transpiration** : the process of losing of water vapour from aerial parts of plants
2. **Articulation** : movement
3. **Vertebrae** : bone of vertebral column
4. **Duodenum** : bend at the beginning of small intestine
5. **Bile juice** : secretion of liver that emulsifies fat and neutralizes acid
6. **Oesophagus** : food pipe
7. **Catalyst** : the chemical which accelerates the rate of chemical reaction
8. **Villi** : fingers-like projections at inner surface of small intestine
9. **Capillaries** : very fine blood vessels which connect veins and arteries
10. **Diffusion** : a process in which substances flow from their higher concentration to lower concentration

Introduction

We have just studied that the union of different types of organs which conducts a particular life process is called body system. In our body many such systems are found. In this unit we will study skeletal system, digestive system and respiratory system. We will also discuss a life process called transpiration in plants.

A. Skeletal System

Skeleton is the bony framework of our body. Bone contains a lot of minerals such as calcium and phosphorus deposited in the intercellular space of bone cells (osteocytes), which make bones hard and strong enough to support the body. Bones look dead but bones contain blood vessels and nerve cells. Besides this, bones contain special type of bone cells which make new bones and repair the damaged ones. Cartilage is present between the two bones. Cartilage prevents the bones from shock during the movement, walking and running. The cartilage situated in between the vertebral columns helps bones to move side ways. Cartilage also helps to make our work smooth. Cartilage forms the bridge of nose and pinnae of our body.

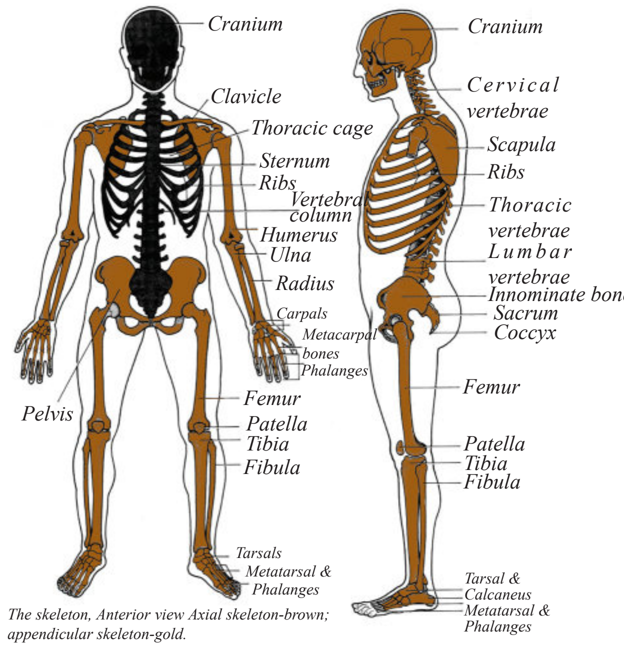


Fig.20.1: *Human Skeleton*

Skeleton provides a definite shape by maintaining the topography of various parts and organs. It provides physical support and protection to the body and also provides place for the attachment of muscles. It protects and supports the delicate organs like brains, lungs heart etc.

According to shape and size, bones are long, short, flat and irregular. The bones of thigh (femur) and upper arm (humerus) are long. The breast bone (sternum) and the shoulder bone (scapula of pectoral girdle) are flat. The bones of digits (carples and metacarples) and skull are short. The vertebrae of vertebral column are the irregular bones.

Humans have 206 bones in the adult's body. There are 22 bones in the skull, 6 in ear ossicles, 33 in vertebral column and 1 hyoid, similarly 60 bones in arms and 60 in legs, 4 in pectoral girdle and 2 in pelvic girdle. Besides these, there are 12 pairs of ribs and 1 sternum in the thoracic cage. The longest bone is femur and the smallest is stapes (found in middle ear).

A bone is the hardest connective tissue in the body. It is so due to excessive deposition of calcium and phosphorus minerals. It is composed of 20% water, 30% to 40% organic materials and 40% to 50% inorganic materials.

The skeleton is divided into two types (on the basis of position).

1. Axial skeleton (80)
2. Appendicular skeleton (126)

1. Axial skeleton (total no. of bones are 80)

The bones found at central region of our body are called axial skeleton. The axial skeleton consists of skull, ear ossicles, hyoid, vertebral column, ribs and sternum. They form the central bony core of the body and protect the internal delicate organs.

A. Skull: It is the bony framework of head which rests on the upper end of vertebral column and this bony part is divided into two segments.

Fact file:
In cranium parietal and temporal bones are paired. The rest are unpaired. Similarly in facial region vomer and mandible are only unpaired. The rest are paired.

i. Cranium (8 bones)
ii. Facial bones (14 bones = face = fourteen)

i. Cranium: It is formed by eight flat irregular bones that provides a bony protection to the brain. The bones of cranium are-

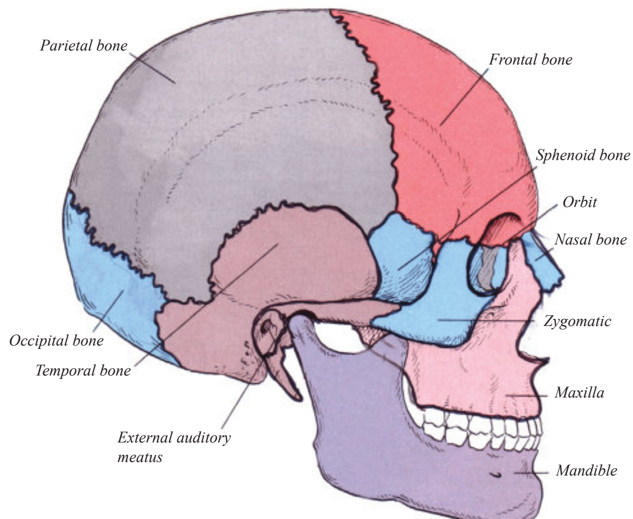


Fig.20.2: *Side view of skull*

a. **Frontal (1):** This is the bone of our forehead. It forms a part of the orbital cavities and the prominent ridges above the eyes. It helps to form the roof of orbital and nasal cavities.

b. **Parietal bones (2):** These bones form the sides and roof of our skull. Its inner surface is concave and is grooved by the brain and blood vessels.

c. **Temporal (2):** These bones lie one on each side of our head and form immovable joints with the parietal, occipital, sphenoid and zygomatic bones.

d. **Occipital bone (1):** This bone forms the back of the head and part of the base of the skull. It has immovable joints with the parietal, temporal and sphenoid bones.

e. **Sphenoid (1):** This bone occupies the base of cranium and side of skull helps to form the orbital cavity and nasal septum of nasal cavity.

f. **Ethmoid bone (1):** It lies infront of sphenoid bone. It occupies the middle portion of the wall of the orbit and helps to form the orbital cavity and nasal septum of nasal cavity.

ii. Facial bones: The skeleton of our face is mainly formed by 14 bones. They are as given below:

Mandible (The only movable bones in skull) (1), Maxillae (2), Zygomatic or cheek bones (2), vomer (1), Nasal bones (2), Lacrimal bones (2), Palatine bones (2), Inferior nasal conchae (2)

Hyoid bone (lingual bone) is a horse shoe shaped bone that lie in the anterior part of the neck, at the base of the tongue and above larynx. It is not in connection with other bones but articulated by muscles and ligaments. It helps in movement of tongue and swallowing. Three ear ossicles are also found in each ears. They are malleus, incus and stapes. Stapes is the smallest bone in our body.

B. Vertebral column

The bones of vertebral column are called as vertebra (plu-vertebrae). The vertebral column consists of 24 separate movable, irregular vertebral (five fixed bones) and the coccyx (four fused bones). The 24 separate bones are in three groups. They are 7 cervical vertebral, 12 thoracic vertebra and 5 lumbar vertebrae. The body of each vertebral is situated anteriorly. In adults the 5 sacral vertebrae are fused in 1 and the rest 4 caudal vertebrae are fused in 1. In this way inside an adults body there are 26 vertebral. The size varies with location. They are the smallest in the cervical region and they become larger towards the lumbar region.

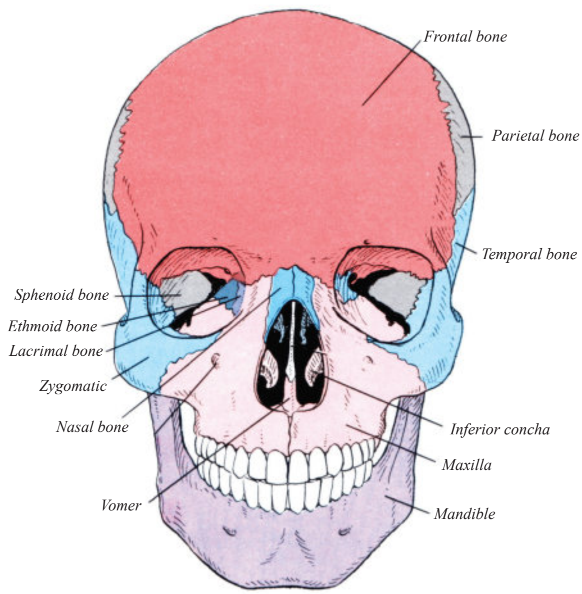


Fig.20.3: *Facial bones*

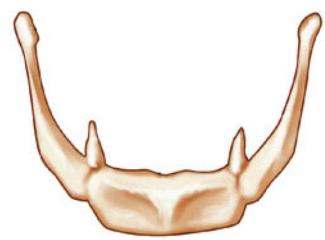


Fig.20.4: *Hyoid bone (unsocial bone)*

a. Cervical vertebrae: It is located in the neck and is divided as Atlas-first cervical vertebrae which supports head and its movement. Axis is the second cervical vertebrae which serves as a pivot when head is turned from one side to another.

b. Thoracic vertebrae: The posterior ends of the 12 pairs of ribs are attached to the thoracic vertebrae.

c. Lumbar vertebrae: There are five lumber vertebrae. They are the biggest vertebrae and they support the weight of body.

d. Sacrum: This consists of 5 rudimentary vertebrae fused to form a wedge shaped bone with a concave anterior surface.

e. Coccyx (tail bone): It consists of four terminal vertebrae fused to form a very small triangular bone. It forms a tail like structure inside the body.

Atlas = 'Yes' bone (when we node our head to say 'Yes'
Axis = 'No' bone (when we node our head to say 'No')

Functions of the vertebral column

The main functions of the vertebral column are given below.

1. It provides a strong bony protection for the delicate spinal cord lying within it.
2. Because of the numerous individual bones, slight movement is possible i.e. the joints are partially moveable.
3. It supports the skull.
4. The intervertebral discs act as shock absorbers and protect the brain.
5. It forms the axis of trunk, giving attachment to ribs, shoulder girdle, pelvic girdle, lower and upper limbs.

C. Thoracic cage

There are 25 bones in thoracic cage. The bones of thoracic cage (thorax) are: 1 sternum, 12 pairs (24) of ribs.

a. Sternum (breast bone): This flat bone can be felt just under the skin in the middle of the front at the chest. It is sternum. It supports the ribs to form the cage.

b. Ribs: There are 12 pairs (24) of ribs which form the bony lateral walls of the thoracic cage and articulate posteriorly with the thoracic vertebrae. The first 10 pairs are attached anteriorly to the sternum. The last two pairs have no anterior attachment. The spaces between the ribs are occupied by inter coastal muscles. During inspiration, when these muscles contract, the ribs and sternum are lifted upwards and outwards increasing the space of thoracic cavity.

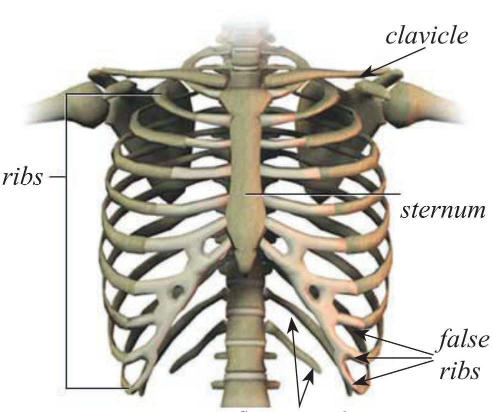


Fig.20.5: *Ribs*

There are three types of ribs- true ribs, false ribs and floating ribs.

True ribs are the first seven pairs (14) directly attached to the sternum.

False ribs are the next 3 pairs (6) of ribs which are connected between the backbone and seventh ribs. Floating ribs are the 11 and 12 pairs of ribs, which are found originated from vertebral column but the other ends are free.

2. Appendicular skeleton

It consists of the shoulder girdle with upper limbs and the pelvic girdle with lower limbs. There are 126 bones in this skeleton.

A. Shoulder girdle and upper limb

a. Shoulder girdle: Each shoulder girdle consists of 1 clavicle and 1 scapula.

i. Calvicles or collar bones: They are the long bones which have a double curve. A calvicle provides the only bony link between the upper extremity and the axial skeleton.

ii. Scapula or shoulder blade: It is a flat triangular shaped bone lying on the posterior chest wall. It remains superficial to the ribs and is separated from them by muscles. It articulates the head of humerous and forms shoulder joint. This bone is also known as "Funny bone".

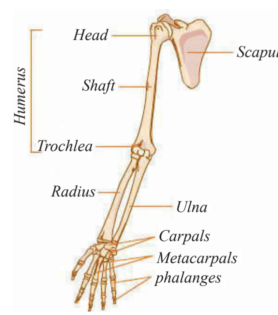


Fig.20.6: *Forelimbs*

b Upper limbs: They consist of 60 bones. Each upper limb consists of 1 humerus, 1 radius, 1 ulna, 8 carpals, 5 metacarpals, 14 phalanges.

i. Humerus: It is the bone of the upper arm. Its head articulates with the cavity of scapula, forming shoulder joint. The distal end of the bone presents two surfaces that articulate with the radius and ulna forms elbow joint.

ii. Ulna and Radius: These are the two bones of fore arm. They articulate with the humerus at the elbow joint and the carpel bones at the wrist joint etc.

iii. Carpals or wrist bones: There are eight carpels arranged in two rows of four.

iv. Metacarpals or the bones of palm: These five bones form the palm of hand. They are numbered from the thumb side inwards.

v. Phalanges or finger bones: There are 14 phalanges- three in each finger and two in thumb. They articulate with the metacarpals and with each other.

B. Pelvic Girdle and Lower Limb

Each pelvic gridle consists of one hip bone. The bones of pelvic gridle are jointly called as pelvis.

a. The pelvis

The pelvis is formed by the two hip bones which articulate interiorly at the pubis and posterior with the sacrum at synovial joints. The bony pelvis supports trunk and the organs such as urinary bladder, reproductive organs and some

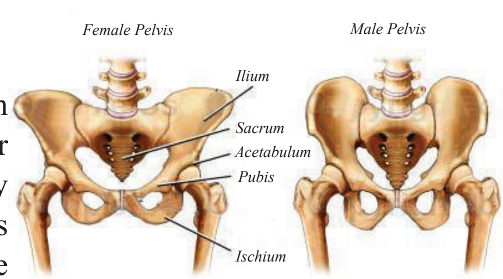


Fig.20.7: *Pelvis*

parts of intestine. The shape of the female pelvis fits the passage of the body during childbirth. In comparison with the male pelvis, the female pelvis has lighter bones, move shallow and rounded and is generally more roomy.

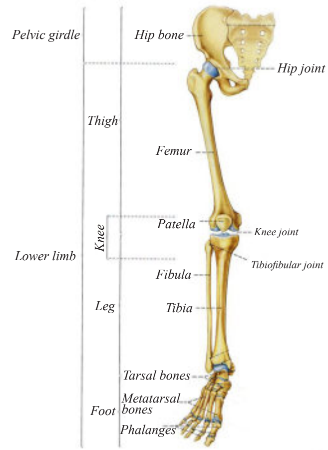


Fig.20.8: *Hindlimbs*

b. Lower limbs (30×2=60)

They consist of 60 bones. Each lower limb consists of femur, tibia, fibula, patella, tarsals metatarsals and phalanges.

i. Femur (thigh bone)

It is the longest and strongest bone of the body. The head is almost spherical and fits into the hip bone to from the hip joint. The posterior surface of the lower part forms a flat triangular area. The distal extremity articulates with the tibia and patella to form the knee joint.

ii. Tibia and Fibula

The lower part of the leg has two long bones called tibia and fibula. The tibia is the main bone in the lower limb. It lies an inner side of the legs towards the toe. It is thicker and stronger. So, it bears the weight of the body. The upper end of tibia meets femur in the knee joint. The fibula lies on the side of little finger of the leg. It runs along tibia. It is the long, slender, weak lateral bone, so it is unable to support the weight of the body. Both tibia and fibula are held together throughout their length by a strong membrane.

iii. Patella or knee cap

This is roughly triangular bone associated with the knee joint.

iv. Tarsals or Ankle bones

There are seven tarsals in each hind limb which form posterior part of the foot.

v. Metatarsals

There are five metatarsals in each leg. They form the great part of the dorsum of the foot. They are associated with the tarsals and with phalanges.

vi. Phalanges

There are 14 phalanges in each leg arranged in a similar manner in the fingers two in the great toe and three in each of other toes.

Importance of skeleton

1. It protects the delicate organs.
2. It provides mechanical support.

3. Bone forms the framework of our body.
4. It works as a reservoir of calcium.
5. It helps to form blood cells.
6. It allows the movement of our body as a whole and of parts of our body by forming joints that are moved by muscles.

B. Human Digestive System: includes Ingestion, propulsion, digestion, absorption, assimilation and elimination (egestion)

We eat different types of food. We can get energy only after the digestion of food. The energy is used to conduct different life processes and other mechanical work. Digestion is a biological process in which the complex molecules present in food is broken down into simpler molecules. The group of organs which help in digestion of food is called as digestive system.

Digestive system consists of alimentary canal and digestive glands.

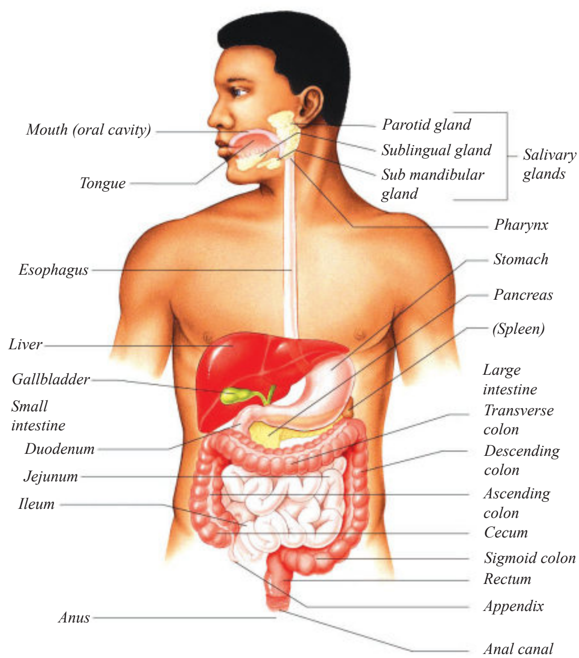


Fig.20.9: *Digestive system*

a. Alimentary canal

Alimentary canal is a tube that is extended from mouth to anus. It is about 10 m in length and is extended, from mouth to anus. Alimentary canal provides the space for digestion and absorption of the food. It forms different organs like mouth, oesophagus, stomach, duodenum small intestine and large intestine. Study and identify the parts in the given diagram. Digested food is absorbed in small intestine and the indigested and remaining materials are expelled out through anus (egestion).

b. Digestive glands

Digestive glands are those which produce different types of digestive juices. The digestive juices help in the digestion of food. The juices also have enzymes which are biological catalysts. The digestive glands and their secretion are as given below.

Digestion Chart

Parts of alimentary canal	Digestive glands	Secretion	Enzyme	Food acted upon	Food converted into
Mouth	Salivary glands	Saliva	Ptyalin (amylase)	Starch	Maltose
Stomach	Gastric glands	Gastric juice	pepsin	Protein	Peptones
			Rennin	Milk protein (Caesin)	Insoluble curd (Paracaesin)
		Hydrochloric acid	No enzyme	Provides acid environment to pepsin and kills bacteria	
small intestine	Liver	Bile juice	Bile salt	Divides fat globules into tiny droplets to be acted upon by lipase	
	Pancreas	Pancreatic	Trypsin	Proteins	Peptides and peptones
			$\propto$-Amylase	Starch	Maltose (disaccharides)
			Lipase	Fats	Fatty acid and glycerol
	Intestinal gland	Intestinal juice	Erepsin	Peptides	Amino acids
			Maltase	Maltose	Glucose
			Lactase	Lactose	Glucose and galactose
			Sucrase	Sucrose	Glucose and fructose

Digestion in human body

In alimentary canal food is digested by the help of digestive juices. The enzymes present in digestive juices play a very active role in the digestion of food. For convenient we are going to study about digestion of food in different parts of alimentary canal.

a. Digestion of food in mouth

After placing solid food in mouth it is chewed into smaller pieces. The teeth and the tongue participate in this process. Side by side the food is mixed with saliva. Saliva makes the food smooth and ptyalin (Salivary amylase) present in it digests carbohydrates. Palysaccharides like starch changes into disaccharides like maltose. After it, the chewed smooth food is passed through the food pipe or oesophagus in the form of small balls called as bolus and the process is called peristalsis.

b. Digestion of food in stomach

When the food comes in stomach it is churned with digestive juices. Now the food becomes semi-solid called as chyme. The digestive juice contains hydrochloric acid and enzymes. Hydrochloric acid kills some harmful germs and makes the medium of food acidic. Pepsin and renin like enzymes are found in the gastric juice. Pepsin breaks the protein into peptones and renin changes the milk into casein to digest it.

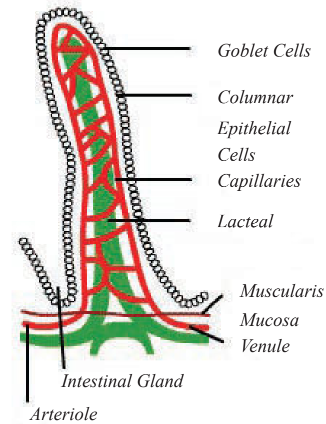


Fig.20.10: *A villus*

c. Digestion of food in duodenum

The chyme is sprayed regularly in duodenum, where it is digested by the bile juice produced by liver and pancreatic juice. Bile juice does not have any enzyme in it but helps in digestion by neutralizing the acid mixed and by emulsifying fat. Pancreatic juice contains trypsin, amylase and lipase. Trypsin changes peptones into peptides and amylase changes the remaining starch into maltose. Similarily the lipase change fat into fatty acid and glycerol.

d. Digestion of food in small intestine

In small intestine, intestinal juice is produced that contains Erepsin. Sucrase, lactase and maltase like enzymes. Erepsin digests peptides into amino acid, sucrase changes sucrose into glucose, maltase changes maltose into glucose and lactase changes lactose into glucose. In this way, food is completely digested in small intestine. The nutrients are absorbed by villi and is mixed with blood in this region. The remaining materials are passed into large intestine (colon).

Egestion

When the food comes in large intestine, it absorbs some water and important minerals. The remaining materials are pushed to rectum, which is passed out through anus. The process is called egestion.

Importance of digestive system

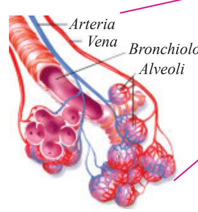
Some main importance of digestive system are as follow:

1. It helps to break complex molecules of food into simple molecules. The simple molecules are able to absorb in our body for their oxidation
2. It helps to supply raw materials for respiration to produce energy.
3. It also helps to eliminate out the unnecessary materials from our body.

C. Human Respiratory System

We need energy to survive and to conduct different other life processes inside our body. We oxidize our food inside the cell to obtain energy. The process is called as internal respiration. The group of organs which helps in internal respiration is called respiratory system. Respiratory system consists of following organs.

1. Nose
2. Trachea
3. Bronchi
4. Lungs
5. Diaphragm



Alveoli

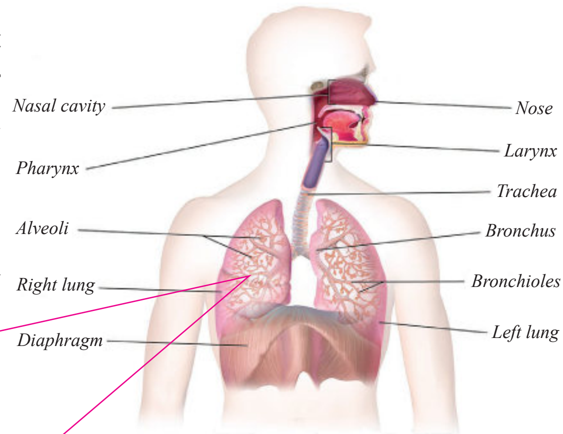


***Fig.20.11:** The Respiratory System*

1. Nose

Nose is body organ found in our face. It is mainly related with sense of smell but it also helps in respiration. It opens in two nostrils. Each nostril has its inner surface moist. It also has hairs through the nostrils. The nostril stops the entrance of dust. It also makes the air moist and at suitable temperature for the lungs; as the air has to go in the lungs.

2. Trachea

Trachea is a tube that connects the nose with bronchi. Trachea is made of rings of cartilage. It also contains pharynx and larynx also. Pharynx is that part of trachea where wind pipe and food pipe are connected. There is an epiglottis that closes wind pipe when food is swallowed after chewing. Larynx is also called as voice box. It is the part of our trachea where sound/voice is produced, when we vibrate the vocal cord. It vibrates when air is passed through it, thus it is mainly related with voice.

3. Bronchi

Bronchi are the two tubes branched from trachea and connect to lungs. They are further divided into bronchioles which form alveoli inside the lungs. Through the bronchi air passes in lungs and out from the lungs. When the passage inside the bronchi is narrowed due to infection in it is called bronchitis, which is a fatal disease.

4. Lungs

Lungs are very important organs of respiratory system. They are two sac like structures connected with bronchi and are protected in thoracic cage. The cage is made of thoracic vertebrae, ribs and sternum. In between the ribs intercoastal muscles are found. Each lung has about 350 millions very small sac like structures called as alveoli. An alveolus is connected with bronchiole and surrounded with capillaries with blood cells in it. RBCs present in capillaries exchange oxygen and carbon dioxide.

5. Diaphragm

Diaphragm is a muscular layer found in between chest and abdomen. It increases and decreases the volume of chest to inhale and exhale air. When diaphragm increases the volume of chest the lungs enlarge and air is inhaled. But when the diaphragm is pushed up the volume of the chest decreases and pressure increases. It makes the lungs contracted which exhale out the air from the lungs.

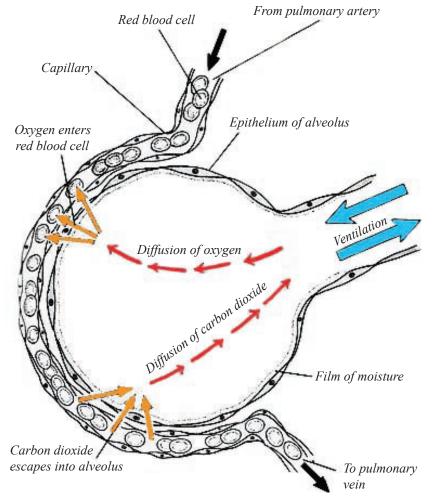


Fig.20.12: *An alveolus*

Respiration in human body

Respiration is defined as the process of oxidizing food inside the cells to release energy. For this process oxygen is required. In our body oxygen is taken from air. The process of taking oxygen and giving out carbon dioxide is called breathing. It occurs in lungs.

When diaphragm moves towards abdomen the volume of chest increases. Due to it the inhaled air reached into the alveoli of the lungs through trachea and bronchi.

The RBCs Present in capillaries absorb oxygen from the air inside alveolus and leaves carbon dioxide into the alveolus by the process of diffusion. When the diaphragm is pulled upward the volume of the chest decreases and the air with the left up carbon dioxide is pushed out from the lungs. The absorbed oxygen is taken into the cells for the oxidation of food by which energy is released.

$$\underset{\textit{Glucose}}{C_6H_{12}O_6} + 6O_2 \xrightarrow{\textit{Enzymes}} 6CO_2 + 6H_2O + \text{Energy (ATP)}$$

In this process carbondioxide and water are formed. The formed CO_2 is carried by blood into the lungs for its separation to eliminate out from the body.

Importance of respiratory system

Some main importance of respiratory system are as follow:

1. It releases energy for different purposes in our body.
2. It helps to separate carbondioxide from blood.
3. It supports the nervous system by helping in the electrochemical communication.

D. Excretory system

The group of organs which help in excretion is called excretory system. Excretion is the process of eliminating unnecessary things like sweat, CO_2, urine, undigested material after the process of digestion and absorption of food. Skin, Lungs, Liver, Kidneys and large intestine are some those organs, which help in excretion. They are excretory organs.

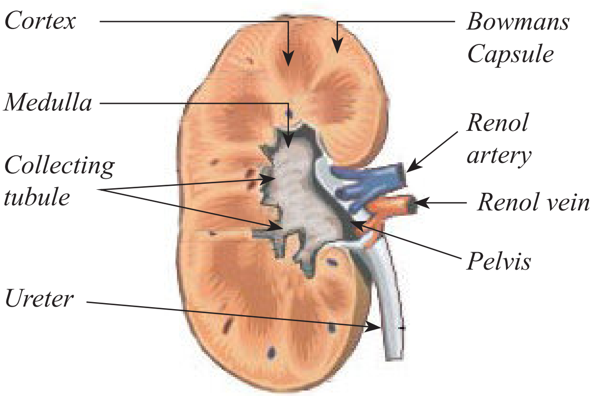


Fig.20.13: L.S. of kidney

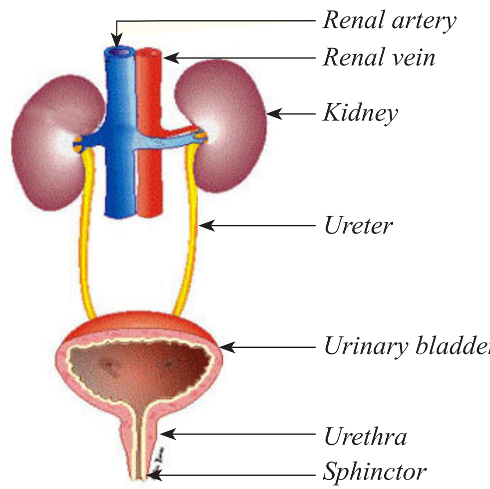


Fig.20.14: Urinary system

Skin excreates sweat and lungs separate carbon dioxide from blood. Liver changes more harmful urea into less harmful urea. Kidneys separate urine from blood. Out of them kidneys are considered as the main excretory organs. They are studied under urinary system.

Urinary system

Kidneys, ureter, urinary bladder and urethra constitute the urinary system. Kidneys are two in number. They are bean shaped and are protected by ribs. Each kidney is supplied blood by renal artery and renal vein.

The internal structure of kidney shows its three layers. Outer most layer is cortex and it is dark pink in colour. It contains Bowman's capsules in it. The middle layer is in light pink and it is called medulla. In medula tubules get connected with collecting tubule and the inner most layer is pelvis that is connected with ureter. Bowman's capsules are the free end of tubules which are cup shaped. In them, glomerulus and capillaries connecting renal artery and renal vein. The unit of kidney is nepbron. There are million of nepbron in a kidney. It consists of a collecting tubula, tubule, glomerulus. The formation of urine completes in three processes. They are ultrafiltration by glomerulus, absorption by bowmaris capsule and reabsorption by capillaries. The formed urine flows in pelvis and it is braught to to urinary bladder by ureyers where it is stored for little period. Later the urine is expelled out through urethra.

Importance of excretory system

1. It helps to separate urea and nitrogen compounds which are very harmful to our body.
2. Liver converts more harmful chemicals (NH_3) into less harmful chemicals (Urea).
3. Undigested and remaining substances after digestion and absorption of food in our intestine are eliminated.
4. Helps to maintain normal blood pressure and average sugar level in the blood.
5. Helps to eliminate CO_2 from the body.

Lesson Summary

1. Skeletal system is the bony framework of the body which helps to give definite shape and size to the body and acts as a protective cover for delicate organs like heart, brain and lever.
2. Skeletal system provides our body with shape and support, protects delicate organs, forms blood and stores minerals.
3. The human skeleton is divided into two categories. They are axial skeleton and appendicular skeleton.
4. Axial skeleton includes skull and trunk (vertebral column and thoraic cage).
5. Appendicular skeleton includes limbs and girdle.
6. Vertebral column consists of thirty-three irregular bones. (26 in adults)
7. The cranium consists of eight bones whereas the face consists of fourteen bones.
8. The process of breaking from complex particles to simple particles is called digestion.
9. The group of organs which helps in digestion is called digestive system.
10. Digestive system consists of digestive glands and alimentary canal.
11. Digestive glands such as salivery gland, pancreas, liver, gastric gland and intestinal glands produce different types of digestive juices and many of the juices contain enzyme in them.
12. Alimentary canal consists of a tube extended from mouth to anus in the form of oesophagus, stomach, small intestine, large intestine and rectum.
13. With the help of digestive juices, food is digested in alimentary canal and nutrients are absorbed in it.
14. Human beings have four types of teeth in their mouth to bite and grind food.
15. The process of oxidation of food is called respiration.
16. The group of organs, which helps in oxidation of food, is called respiratory system.
17. Respiratory system consists of nose, trachea, bronchi and lungs.
18. Exchange of oxygen and carbon dioxide takes place inside lungs.

Project work

Draw on pieces of cardboard paper coloured diagrams of digestive system and respiratory system and label their different parts. Hang them on the walls.

Conceptual questions with their answers

Q.1. Mention the smallest and largest bones of our body.

The smallest bone = stapes (present in ear)

and the longest bone = Femur (also caused thigh bone)

Q.2. Which bone is called unsocial bone and why?

Hyoid is called unsocial bone because it does not articulate with any other bone (this bone gives attachment to tongue and is horseshoe-shaped)

Exercise

1. Answer the following questions.

a. What is skeleton system? Write the major functions of skeleton system.

b. How many bones make cranium, skull and face? Write their names.

c. How many true, false and floating ribs are there in the thoracic cage of a human?

d. What are cervical vertebrae? Mention their number in human body.

e. Name the bones of forelimbs and hindlimbs.

f. What are carpals and metacarpals? Write in short with their total number.

g. Define pelvic girdle. How is it different in male and female?

h. Define digestion and digestive system.

i. Describe alimentary canal and digestive glands with their roles in digestion.

j. Explain in short.

   a. Digestion of food in stomach

   b. Digestion of food in small intestine

   c. Digestion of food in duodenum

k. Write in short about different types of milk teeth.

l. What is urinary system? Describe its different components in short.

m. What are respiration and respiratory system?
n. What organs constitute respiratory system? Explain any two of them in short.
o. Describe the process of exchanging oxygen and carbon dioxide in an alveolus in short with a diagram.
p. Write the importance of digestive system.
q. Write the importance of urinary system.
r. What is Axial skeleton? Write its function.
s. What is appendicular skeleton? Write its function.
t. Write the functions of skeleton.
u. Name the unpaired bones of facial bone.
v. Name the paired bones of cranial bone.

2. Write the difference between

a. Axial and appendicular skeleton
b. Oesophagus and digestive tract

3. Draw the following bones and label them.

a. Skull (side view)
b. Hind limb
c. Forelimb

4. Give reasons.

a. Bone softens when kept in acid for some hours.
b. Bone changes into powder when heated strongly.
c. Lungs are blood purifier.

5. Answer the following questions on the basis of the given diagram (Fig 20.15).

a. In which part is digested food absorbed?
b. Which part forms bile juice? Write the function of the juice.
c. Name the enzymes produced by C.
d. What type of food is digested in B?
e. In which part is food digested completely?
f. In which part are water and salts absorbed?

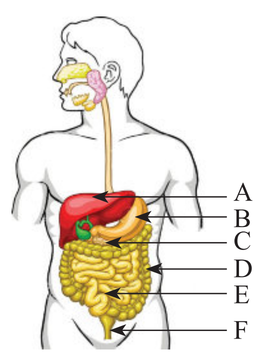


Fig.20.15:

Multiple Choice Questions

1. Tick (√) the correct answer.

a. Which digestive juice is produced by liver?
   i. Bile juice
   ii. HCl
   iii. Gastric juice
   iv. Intestinal juice

b. Which juice does not have enzyme in it?
   i. Gastric juice
   ii. Pancreatic juice
   iii. Bile juice
   iv. Saliva

c. What is peristalsis?
   i. The process of forming bolus in mouth
   ii. The process of moving bolus in oesophagus
   iii. The process of mixing bolus with gastric juice
   iv. The process of passing chyme through duodenum

d. The region where exchange of oxygen and carbon dioxide takes place is
   i. Bronchi
   ii. Trachea
   iii. Bronchus
   iv. Alveolus

e. Which part of urinary system stores urine for urination?
   i. Ureter
   ii. Pelvis
   iii. Urinary bladder
   iv. Urethra

f. What does nepbron do?
   i. Storage of urine
   ii. Separation of urine
   iii. Elimination of urine
   iv. None of them

Unit 21 Evolution

Total estimated teaching hours = 4

Learning Outcomes

After the completion of this unit, students will learn:

- *the meaning of evolution.*
- *the organic evolution and evidence in support of organic evolution.*
- *Lamarckism and its drawback.*
- *Darwinism and its drawback.*
- *mutation theory.*

J.B. De Lamarck (1744AD-1829AD)

KEY WORDS

1. **Spontaneous** : from non-living beings
2. **Putrefy** : to fill up
3. **Strata** : layer
4. **Anatomy** : study of internal structure
5. **Morphology** : study of external structure
6. **Aquired characters** : the characters obtained after birth by the use and disuse of organs
7. **Inheritance** : transmission of characters into new generation

Introduction

When one speaks of evolution, it is quite natural to ask whether the earth is created or it evolved. Similarly, The question of origin of life has remained a most complicated and puzzling problem for thinkers, philosophers and naturalists of all times. Life definitely had a beginning. Since when has life come into existence? What is the mechanism of origin of life? These questions are very difficult to answer as the life on earth has changed with time. So, history of origin and evolution of life actually comprise of two events. First, the origin of life and second, the mechanism involved in the changes of living organisms through time.

In order to explain the presence of so many different kinds of animals and plants two theories were put forward.

a) Theory of special creation: According to this theory, all forms of life were created as such by divine creation of some supernatural power, the god. The theory is based on mythology and does not have scientific evidence

b) Theory of spontaneous generation: According to this theory life originated on the earth from non-living things, inorganic materials or putrefying organic matters. Von Helmont claimed that human sweat and wheat bran when kept together for 21 days, can form mice. It was a belief that when the mud of Nile river warmed by the sun frogs, toads, snakes, crocodile etc. are formed. This theory was latter rejected by Francisco Reddi and other contemporary biologists.

c) Theory of organic evolution: organic evolution can be defined as "slow, continuous, progressive and an irreversible process, in which the simple and primitive organisms existed in the past were changed into the complex and advanced organisms of today over a long period of time". The nature is not static but dynamic. With the passage of time, as the nature undergoes gradual modification, the organisms must also undergo a gradual and orderly change form one form to another. Because of this, organisms found in present days must appear different from what they were in the past as they had to adjust themselves in the changed environment. Actually, the exiting organisms have been evolved from common ancestral plan. Evolution is a never ending process. It is proceeding gradually even now.

Some main evidences in favour of organic evolution are as given below-

1. Palaeontological evidence
2. Evidence from comparative anatomy and morphology
   a. Homologous organs
   b. Analogous organs
   c. Vestigial organs
3. Embryonic evidence
4. Evidence from bridge animals
5. Evidence from geographical distribution

1. Palaeontological evidence

Paleontological is the study of fossil. Fossil are the remains or impression of ancient plants and animals buried in mud or sand which finally hardened into rocks. Rocks formed in strata (layers) in successive geological period of the earth have been found to bear fossils of particular type of plants and animals. Fossils of older forms are found to be preserved in lower strata and those of modern forms are present in upper strata. It is remarkable that the fossils of one layer have close similarities to those of the next or the pervious layer. This leads us to conclude

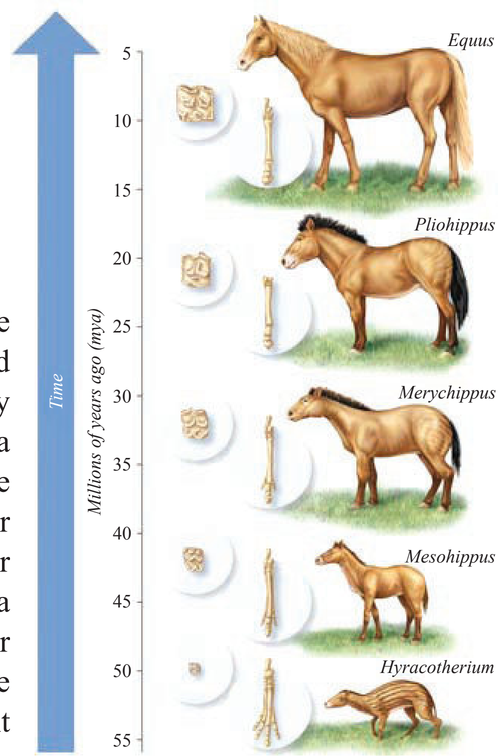


Fig.21.1: Evolution of horse

that there is a relationship between the plants or animals which appeared through the successive periods of the earth. Fossils thus help directly to know organic evolution how the evolutionary sequence changed from of lives in following ways fossils give evidence of evolution.

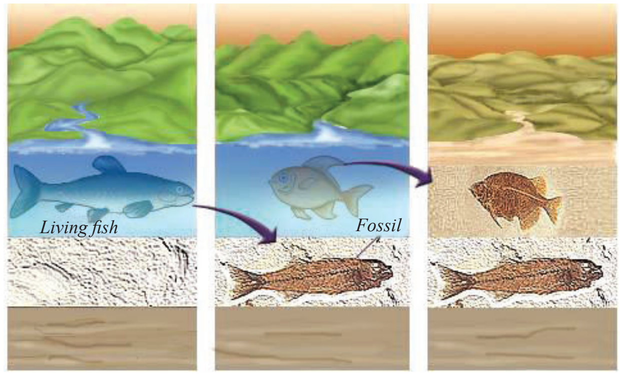


Fig.21.2: *Formation of fossil*

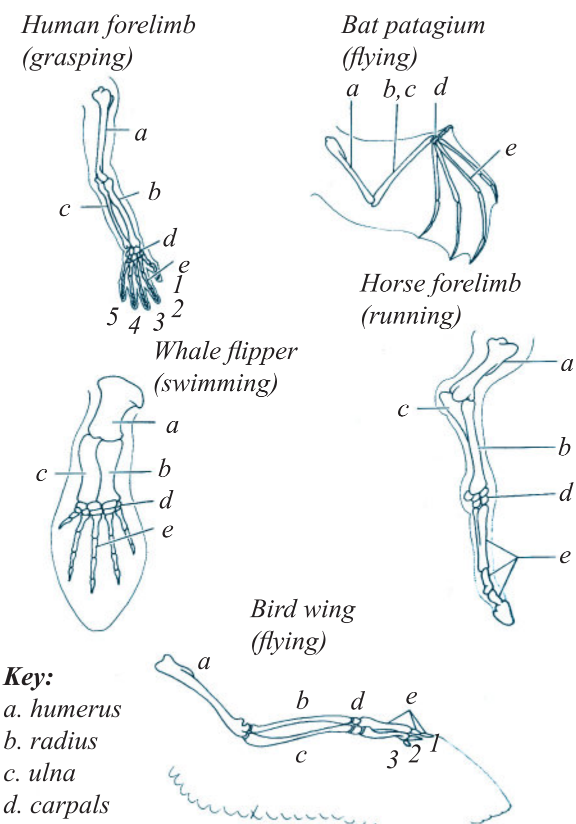
1. It suggests that the evolution has taken place from simpler to complex in a gradual way of increasing order
2. Fossils record can help to study the habits and behavior of extinct species with the help of the known climatic conditions.
3. The study of fossils can tell when and where the major groups of organisms arose, flourished, became extinct or evolved into new forms.
4. By the comparative study of fossils preserved in different strata indicate that the complex forms of life that exist today arose from simpler forms of the past.

2. Evidence from comparative anatomy and morphology

By the study of external structure (morphology) and internal structure (Anatomy) we can get evidence of evolution. On the basis of such studies the following are based-

a. Homologous organs

Homologous organs are those which have common origin and structure and usually have different appearance to perform different functions. The arms of a man, flipper of a whale, the wings of a bird, forelimbs of a horse do not resemble at first sight. But a study of their anatomy reveals a remarkable similarities. We will find



Key:
a. humerus
b. radius
c. ulna
d. carpals
e. metacarpals and phalanges

Fig.21.3:

almost the same set (arrangement) of bones, muscles and nerves. The minor variations are only because of their adaptation under different environmental conditions to perform different functions. All such examples suggest these vertebrates have inherited their main structure features from a common ancestral plan.

b. Analogous organs

Organs having similar appearance and perform similar function but are quite different in origin and development are called analogous organs. For example: the wings of an insect, the wings of a bird and bat serve the same purpose of flying but the basic structure of insets wing is totally different from the wings of birds and bats. It shows that birds and bats are evolved from one ancestral block and insect is evolved from other ancestral block.

Fig.21.4: *Analogous organs*

c. Vestigial organs

Vestigial organs are those organs which are found large, full-sized, complete and they carry out important functions in some species but in other species, they occur in very much reduced forms or some essential parts are functionless. They are also called rudimentary organs. Man possesses more than 100 vestigial organs like vermiform appendix, coccyx (fused tail vertebrae), wisdom teeth, body hair, pinnae of ears, nictitating membrane in eyes etc. Such organs clearly help us to conclude that these organs were functional and fully developed in the past. They help to know about the ancestors of organisms. From the vestigial organs of human we can say that our ancestors were herbivores with hair on their body and tail they could break nut like fruits and could move their ears or they were similar to apes.

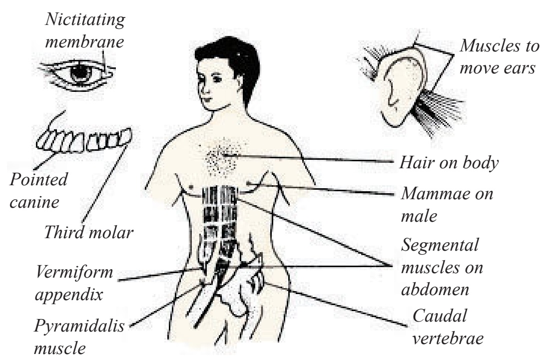


Fig.21.5: *Vestigial structures in human body*

3. Embryonic evidence

The study of embryo of living beings is called embryology. It has been observed that the embryos of different animals usually resemble one another more closely than their adult forms. For example, the embryos of mammals,

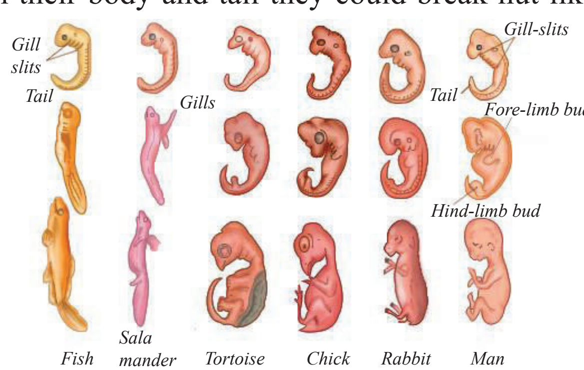


Fig.21.6: *Comparison of vertebrate embryos*

birds, reptiles, amphibians and fishes as well look alike. In course of evolution, the lower animals have passed. An embryo always develops from the egg-cell or ovum. At younger stages the embryos of different animals have similar structure. They differ only when they grow more and more. It proves that the animals shown in the diagram below are evolved from the same block of ancesters.

4. Evidence from bridge animals

There are certain animals whose features coincide partly to the lower grade animals and partly to the upper grade animals by some intermediate forms. Example: Duck- billed platypus. It has many mammalian features like hair, milk-producing glands etc. But it is oviparous and shows many anatomical features resembling those of bird. So, it is a bridge between bird and mammal. Similarly archaeopteryx seems to have developed from reptile to aves. This connecting link or bridging the lower and higher animals is of great importance in modern evolutionary theory.

Fig.21.7: *Prototheria-duck-billed Platypus*

The above examples help us to conclude that these organisms have come from the common ancestral plan.

5. Evidence from geographical distribution

Various animals and plants are available in different parts of the world. Not all the animals found in one place may be found in other places. There are some animals which are found in almost all parts of the world. In some cases same sorts of animals are found in similar climatic condition. For examples: the elephant found in Africa and Asia are not found in Brazil. Geographical distribution like oceans, rivers, plains, mountains may also bring about variations in animals and plants. When plants and animals are isolated from one region to another region for a long time, they have different forms and structure due to different climatic conditions and geographical distribution of the world. So, the diversification of animal is also due to the change brought about by different environmental and geographical conditions.

Theories of evolution

To explain the cause and mechanism of evolution, several theories have been put forward. Some main such theories and their, drawbacks are described below

1. Lamarckism
2. Darwinism
3. Mutation Theory

1. Lamarck's theory or Lamarckism

Jean Baptiste de Lamarck, a French biologist postulated the first theory of organic evolution in 1809 AD entitle "Inheritance of acquired characters" through his book 'philosophie Zoologique'. Lamarck considered that there had been a progressive development in form and structure of organisms. He believed that environment plays the most important role in the evolution of living organisms. The theory states "The gradual modifications which the living organisms acquire due to the use and disuse of the organs are automatically handed down to their descendents and so become part of heredity". Lamarckism can be described in following points-

a. Environmental effect
b. Use and disuse of organs
c. Inheritance of aquired characters

a. Environmental effect

Each organism is directly influenced by the change in environment. The environmental change effects directly on the transformation of the body structure of organisms. Eg. the sheep and yak like animals found in himalayan region have thick fur on their body due to the cold climate of that region.

b. Use and disuse of organs

As the environment is habitat of the organisms, they have to use some organs more and some organisms less in the changing environment. Those organs which are used more, they grow more and others get lost from their body. Later the changed character becomes their own. It causes modification in the body structure of that organism. For examples ironsmiths use their hand muscle more in beating of iron, their muscle of forearm are well develop.

c. Inheritance of aquired characters

Lamarck suggested that the organisms transmit the useful aquired characters in to next generation. The process continues from generation to generation and after a number of generations the organism has new look in its body structure. In this way evolution takes place.

He also explained on the basis of his theory about the elongation of neck of giraffes in following ways-

According to Lamarck, ancestors of modern giraffe were with short neck and small forelimbs. They lived in green grasslands of Africa. Gradually. The environment changed, climate became dry, grassland transformed into desert, leaving behind a few tall trees. For survival, giraffes had no alternatives to feed on the leaves of tall trees. So, the ancestors of present giraffe had to stretch their necks and forelimbs to grasp the leaves. This in each generation process continued from generation after generation.

Due to continuous stretching of necks and forelimbs the lengths of necks and forelimbs increased, now they have longest neck and and the longer forelimbs.

Criticism of Lamarckism

The drawbacks of Lamarckism are as given below-

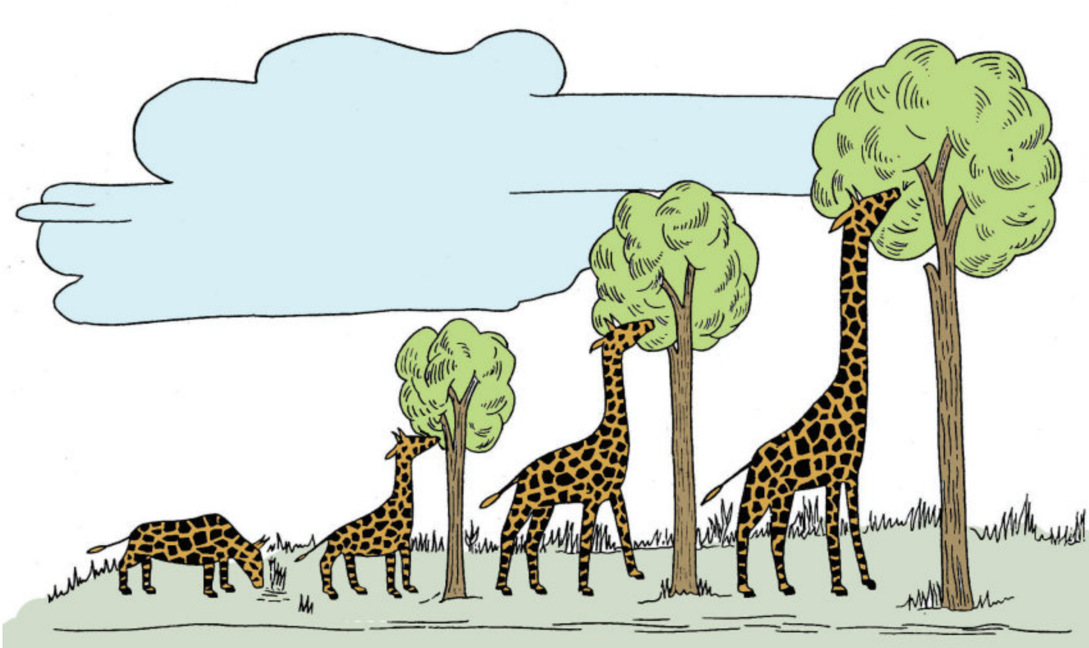


Fig.21.8: *Evolution of giraffe according to Lamarck*

1. There is no experimental proof of Lamarckism.
2. New organs are not formed in organisms by their wish or requirement.
3. It is not necessary that an the aquired characters transmit into new generation- August Weismann, a German scientist, conducted some experiments to test if characters disappear due to disuse. He cut the tails of white mice for more than 20 generations to see if this has any effect on tail length of coming generation. The measuring of tail length of the offspring of twenty successive generations showed that the tails were not shorter. It means that the acquired characters were not inherited.

2. Darwin's Theory or Darwinism

Charles Darwin, an English naturalist announced his views on evolution through, his book "Origin of Species" which was published in 1859 A. D. Before this book was published another scientist Alfred Wallace was also working independently and presented the similar ideas about the origin of species. Later they jointly presented the paper about this theory and it is also called Darwin-Wallace theory. The most reliable theory was put forward in 1859 by Charles Darwin and published to solve the theory of evolution in his book origin of species by natural selection.

Darwin's theory of natural selection, which is based on several facts and observations after a prolonged experiment for over 20 years may be concluded in the following points.

a. High tendency of reproduction: Every living organism has got a power to reproduce fast. Such a great reproduction potential in various species may be easily observed in nature. For example: under favourable conditions a house fly can lay about 6 batches in 14 days. If all house flies survive in a year, the number will be 191,000,000,000,000,000,000. Darwin calculated that even a pair of elephants, the slowest breeding animals known so far have 29 million descendants at the end of 800 years in absence of checks. In this way, the population goes on increasing geometrically.

b. Struggle for existence: There is a keen competition among individuals for food, shelter, warmth, water etc. The struggle is mainly of three types. They are Intraspecific (within species), Inter-specific (between groups of animals) and environmental (struggling with the adverse environmental conditions- heat, cold, earthquake, moisture etc). In this struggle many of the organisms die. It is struggle of existence that helps to check the number of organisms control

c. Variation and heredity: Darwin observed differences in individuals of the same species which reproduce sexually. In fact, no two individuals of the same species are alike. Darwin reasoned that certain variations, say, favourable variations help an organism survive in the struggle for existance while others, say, unfavourable variations do not. So the organisms with harmful or useless variations are unfit and get eliminated. And the organisms with useful or adaptable variations survive and reproduce efficiently. Such favourable variations are inherited in the progeny and the progeny has better chances of survival.

d. Survival of the fittest: During the struggle for existence, only such organisms can survive longer and reproduce which have favourable variations to face the changing environmental conditions. Others lacking such adjustable variations die out or are limited in number. This is called the survival of the fittest. It is also called "Natural Selection"

e. Origin of species: Due to continuous variation or modification, organisms became better adapted to their environment. The variations so obtained by natural means get inherited to its progeny in each successive generations. So by the collection and preservation or transmission of such modifications in each successive generation will finally result in the formation of species which are more adapted than the previous ones. The organisms so produced are different from their ancestors. This is what is called the origin of new species by natural selection.

Darwin explained about the mechanism of elongation of giraffes neck according to his theory as given below-

In ancient time giraffes were short and long necked both and they feed on grasses. Later when heir number was increased the food was not enough for them on the grassland. Thus they had to struggle for food. Some of them had variation of long neck and they were able to eat, shrubs and tree leaves. They were able to get food in new situation i.e they were selected by the nature. They survived and reproduced and others died. It made all the giraffes long necked.

Criticism of Darwinisms

Though Darwin's theory of origin of species of natural selection is considered to be the most reliable evolutionary theory, yet it is not completely free from controversies. Many objections were raised against this theory. They are:

1. Natural selection is not the root cause of evolution of new species. Rather, mutation is considered to be the major cause of evolution.
2. Darwin's theory failed to explain how the variations arose in the individuals.
3. Transmission of favourable variations and the loss of unfavourable variation is not always possible.
4. Darwin's theory has explained the survival of the fittest but not the arrival of the fittest.

Answer it now : Is earth created?

3. Mutation theory

Mutation theory to explain the cause of evolution was advanced by s Dutch botanist Hugo De Vries in 1901-1903. Mutation is the sudden, spontaneous and drastic heritable change in the offspring in one generation. Mutation is independent of environment. According to Hugo De-vries, small and continuous variations are only fluctuations which have no specific role in evolutionary changes. The main cause of mutation is the chemical change occurring in the DNA of gene or change in the structure (position) or number of chromosomes. Excessive use of drugs, ultraviolet rays or nature may be the causes to bring about changes in genes or chromosomes. The birth of albino baby from normal pigmented parents, six fingers in a hand or foot and any kind of disability seen during the birth are due to mutation.

Salient Features of de Vries' theory

The salient features of de Vries' mutation theory are as follows.

1. Mutations or discontinuous variations are the raw material for evolution.

2. Mutations appear all of a sudden. They become operational immediately.
3. The same type of mutations can appear in a number of individuals of a species.
4. All mutations are inheritable.
5. Mutation takes place in all directions because it means either gain or loss of any character.

Carbon Dating (A method to find the ages of prehistoric things)

Carbon dating (Radiocarbon dating):- A method of estimating the ages of archaeological specimens of biological origin. As a result of cosmic radiation. A small number of atmospheric nitrogen nuclei are continuously being transformed by neutron bombardment into radioactive nuclei of carbon.

$$^{14}_{7}N + n \longrightarrow ^{14}_{6}C + P$$

Some for these radiocarbon atoms find their way into living tress and other plants in the form of carbon di-oxides as a result of photosynthesis. When the tree is cut down, photosynthesis stops and the ratio of radiocarbon atoms to stable carbon atoms beings to full as the radio carbon decays. The ratio C_6^{14}/C_6^{12} in the specimen can be measured and enables the time that has elapsed since the tree was cut down to be calculated. The method has been shown to give consistent result for specimens up to some 40,000 years old.

Lesson Summary

1. Evolution is the modification in different forms of simpler organisms to give rise to a complex form of an organism. It is a gradual process.
2. Homologous organs, vestigial organs, analogous organs, palaeontology and embryology support modern evolutionary theory.
3. Variation is the indispensable tool for evolution.
4. Lamarck put forward the theory of evolution for the first time.
5. Lamarck's theory involves: environmental effect, use and disease of organs and inheritance of acquired characters.
6. Drawin's theory is the most reliable evolutionary theory.
7. Darwin's theory emphasizes on variation and natural selection.
8. Hugo De Vries proposed mutation theory.
9. Mutation is a sudden and drastic change in the behaviour of an organism due to the change in chromosomes.

Project work

Sketch and colour the following and display the best one in your classroom.

a. Homologous organs and vestigial organs.

b. Evolution of giraffes according to Lamarck.

Conceptual questions with their answers

Q.1. What is mutagen?

The factors (maybe physical, microbiological, chemical) that lead to mutation is known as mutagen.

Q.2. What do you mean by connecting link?

There are so many organisms which possess the common characteristics between two different phyla or group of animals, are referred to as connecting link.

For example: platypus- a link between bird and mammal

virus- a connecting link between living and non-living things etc.

Exercise

1. Answer the following questions.

a. Define organic evolution.

b. Name the hypothesis about the origin of living beings on the earth.

c. List the evidences given in support of organic evolution.

d. What are homologous and analogous organs? How do they support the organic evolution?

e. Describe in short.

  i. Palaeontological evidence

  ii. Embryological evidence

f. What are vestigial organs? How do they support the organic evolution.

g. State Lamarckism.

h. State Darwinism.

i. According to Lamarckism how did the neck of a giraffe elongate?

j. According to Darwinism, how did the neck of a giraffe elongate?

k. Define mutation and state mutation theory.

l. List the drawbacks of Lamarckism.

m. List the drawbacks of Darwinism.

2. Sketch neat and labelled diagrams of

a. Wing of bird, patagium of bat and human forelimb as homologous organs.

b. Embryoes of mammal, fish and bird showing similarities.

Multiple Choice Questions

1. Tick (√) the correct answers.

a. Which one is the evidence from fossils?
   i. Embryological evidence ii. Homologous organ
   iii. Palaeontological evidence iv. Vestigial organ

b. Which is Darwinism?
   i. Natural selection ii. Use and discuss of organs
   iii. Environmental effect iv. Inheritance of acquired character

c. A slow and progressive change in the organisms is
   i. Variation ii. Mutation
   iii. Natural selection iv. Organic evolution

d. Which hypothesis is based on the mythological evidence?
   i. Spontaneous generation ii. Special creation
   iii. Organic evolution iv. Chemical evolution

e. Lamarck and Darwin both gave examples of animals in the support of their theories. Which animal?
   i. Archaeopteryx ii. Bat
   iii. Giraffe iv. Horse

f. A sudden chromosomal change by which very new characters are seen in organisms is
   i. Mutation ii. Variation
   iii. Inheritance iv. Heredity

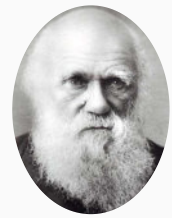
Unit 22 Nature and Environment

Total estimated teaching hours = 11

Learning Outcomes

After the completion of this unit, students will learn:

- *interrelationship between plants and animals in various aspects of life.*
- *factors influencing plants and animals, and listing the adverse effects of climate change on plants and animals.*
- *various types of ecosystem with examples.*
- *services of ecosystem.*
- *dependence of human beings on other organisms.*



Chlarls Darwin
(1809AD-1882AD)

KEY WORDS

1. **Entity** : a distinct existence as an individual unit
2. **Biosphere** : the part of the earth and its atmosphere capable of supporting life
3. **Monument** : a structure built for symbolic reasons, or as a memorial
4. **Eustary** : a wide mouth of river which ends in the sea where fresh water mixes with salty ocean water
5. **Ingestion** : the action of consuming something orally
6. **Tropism** : the movement of an organism in response to a stimulus either towards or away from the stimulus with growth
7. **Pollination** : the transfer of pollen from an anther to a stigma
8. **Synthesize** : to combine things to produce a new, more complex product

Introduction

The surface of our earth is made up of soil and stones, rivers, lakes, ponds, oceans, etc. Its surface is covered with a thick blanket of air called atmosphere. It is held closer to the surface by gravity and pressure from overlying layers of air above. All the physical environment provides suitable environment for the organisms to survive. The elements found in the physical environment influence the life processes of all the living organisms directly or indirectly. They depend upon the physical environment for gaseous exchange, soil, rocks, water, minerals, food, etc. If the condition of physical environment such as heat, light, temperature, air, water, soil, etc. degrades, then all the living organisms are adversely affected. As these substances are lost from the physical world, they are replaced by the natural processes like photosynthesis, respiration, excretion, decay, etc.

Nature consists of two very much complex, interdependent, mutually reactive interrelated entities- the organisms and the environment. The organisms can survive only in appropriate environments, interact with each other, and are influenced by the whole complex of environmental factor. Biotic and abiotic components of environment make a community where a group of interdependent organisms inhabits the same region and interacts with each other.

Factors affecting plants and animals

A biotic community which includes plants, animals and microbes lives in an environment. They get environment for their survival. The biotic community together with the physical environment forms an interacting system which is called ecosystem. An ecosystem can be defined as "a structural and functional unit of biosphere or segment of nature consisting of living beings and the physical environment both interacting and exchanging materials between them." The vast network of all interconnected ecosystems constitutes the biosphere.

An ecosystem consists of two types of components:

A. Abiotic

B. Biotic

A. Abiotic Components

Abiotic components include inorganic and organic substances and climatic factors such as air, water, soil and sunlight.

a. Inorganic substances: They include various types of nutrient elements such as phosphorous, sulphur, carbon, nitrogen, soil, water, oxygen, calcium carbonates, hydrogen, etc. These are required for the synthesis of organic substances and they are called biogenetic substances. They keep on circulating in the ecosystem.

b. Organic substances: They include proteins, lipids, carbohydrates, humic substance, etc. All these substances form the body of the organisms or by-products of metabolic activities and the product of death.

c. Climatic factors: There are two types of climatic factors

1. Atmospheric factors: They include sunlight, temperature, moisture and precipitation.
2. Edaphic factors: They include soil texture and topography. The climatic factors affect the distribution, number, metabolism and behaviour of the organisms of the ecosystem.

Some of the climatic factors are briefly described below.

i. Air: Air is an important physical factor of ecosystem. In absence of air no living organisms can survive. O_2, H_2, N_2, CO_2 etc. play very important roles in activities from feeding to breathing of all the living organisms.

ii. Water: Water plays a vital role in life processes of plants and animals. Organisms consume water from fresh water (pond, lake, river, stream, etc.) and marine water for various life processes and other purposes.

iii. Soil: Soil is formed by weathering of rock. It is very important as plants get minerals from it. It is the habitat of many types of micro organism. It is a site of decomposition of plants and animals. It provides water, mineral, fossils.

iv. Sunlight: Sun is the main source of solar energy. It is very important for all organisms. It plays a vital role in photosynthesis. Due to topography, some areas get more sunlight, some less. Temperature, climate, crop production differ and the diversity of organisms is evident.

No living organisms can survive or no food materials can be prepared in absence of these abiotic factors in good proportion in nature. The organic substances link the biotic components of the ecosystem with the abiotic components. Such abiotic components have specific functions to maintain the balance of nature.

Without abiotic components, no living organisms can survive on the earth. On the basis of the variation of these abiotic components in nature, the diversity of organism is determined.

B. Biotic Components

They include different types of organisms including plants, animals and microbes which are constantly interacting with one another for their survival. Human beings are also included in this group. On the basis of nutritional relationship, the components are classified into three types.

a. Producers

These are chlorophyll-bearing green plants and chemosynthetic bacteria which can prepare organic compounds (food) from inorganic raw materials with the help of sunlight through the process of photosynthesis and chemosynthesis respectively. As they can synthesize their own food, they are called autotrophs. All the organisms in this world are directly or indirectly, dependent on the producers for their food.

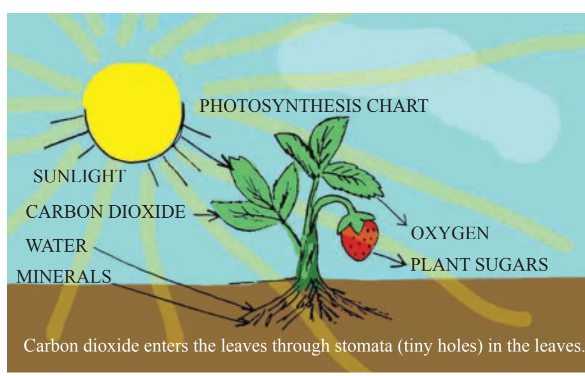


Fig.22.1: *Photosynthesis*

b. Consumers

Organisms that feed on producers or other organisms are consumers. They are mostly animals but few non-green plants can be included in this group. They are also called phagotrophs or heterotrophs. On the basis of their feeding habits and energy flow, they are categorized into the following types.

i. Primary consumers

They include herbivores which feed directly on plants or autotrophs. For example, cow, rat, rabbit, goat, deer, grasshopper etc. The producers get energy from the food they make in their body. When the primary consumers eats the producers, the energy is transferred into them. During this transfer of energy, however, about 90 percent of the energy is lost to the environment as unusable heat.

Fig.22.2: *Primary consumer*

ii. Secondary consumers

They include organisms that feed on other consumers. Usually carnivores and all the omnivores are included in this group. For example, frog, small fish, wolf, jackal, dog, cat etc. The carnivores may be either predators or parasites. As we move up, the amount of energy available declines. If primary consumers receive only 1000 units, then the secondary consumers receive only 100 units. It will be clear if we study the pyramid of energy flow below.

Fig.22.3: *Secondary consumer*

iii. Tertiary consumers

Those consumers that feed on secondary consumers are called tertiary consumers. They are the top level consumers. Usually these consumers do not become the prey of others. They die themselves and mix in the soil. For example, eagles, hawks, tigers, lions, etc. The tertiary consumers are left with just 10 units of energy.

Fact files:

Omnivores

Those consumers that feed on both plants and animals are omnivores. Secondary and tertiary consumers that eat plants as well as other organisms are omnivores. For example, bears, crows, dogs, pigs, rats, cockroaches, humans, etc.

Detritivores

These are those consumers that feed on fallen leaves, parts of dead trees and faecial wastes of animals. These consumers help to clean environment by consuming waste. Ants, termites, earthworms and crabs are the examples of detritivores.

Fig.22.4: *Cleaners*

c. Decomposers

The micro organisms like bacteria and fungi that break down dead organic materials and change them into humus are decomposers. In terrestrial ecosystem, bacteria generally act as animal tissues and digest the dead tissues and excretory materials of animals. Thus, the basic elements of the protoplasm are released in the environment which is reutilized as nutrients by the producers.

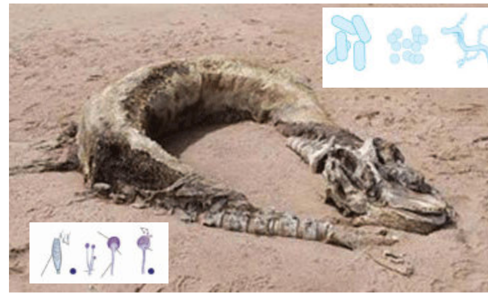


Fig.22.5: *Decomposer*

Detritivores and decomposers are essential for the long-term survival of an ecosystem.

Enormous wastes of plants and animal bodies, excreta, and garbage will be collected on the earth. Even important elements like nitrogen, phosphorus, potassium are released in the environment. The elements separated by this process are consumed by plants as minerals which have made life possible.

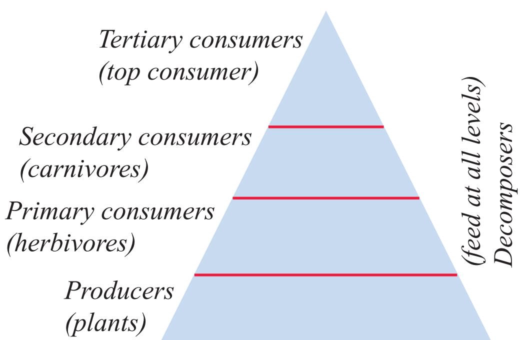


Fig.22.6: *Ecological pyramid*

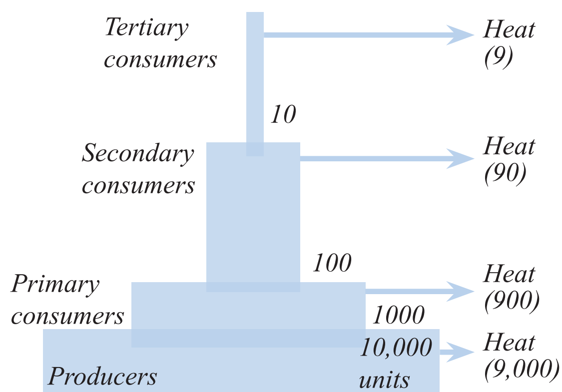


Fig.22.7: *Pyramid of energy flow*

Activity 1: Make an ecological pyramid on a piece of chartpaper and paste the picture of organisms under each category. Form a groups and present in the class.

Effect of climate change

All the organisms are affected by climate change. There are several negative effects of climate change. Some of the main effects are as follows.

a. Change in temperature of air

On the basis of 1880 AD data, the temperature of earth has increased by 0.85°c. When we compare the temperature of 1980 AD with that of 2002 AD to 2010, the world temperature has increased. One research has shown that annually the average temperature of Nepal has increased by 0.06°C. The temperature of Nepal has increased from 1977 AD to 1994 AD.

Fact file:

It is believed that the earth's temperature has increased by 1.4°C in last one century. If it continues, then the earth's temperature may rise rapidly resulting in loss of life.

b. Impact on biodiversity and ecosystem

As it is already explained in the previous lesson that because of climatic change and rise in temperature, organisms may not be able to adapt in this sudden change so they may die. The organisms which can not adapt heat die. And the organisms which adapt temperature may increase rapidly resulting in the imbalance of ecosystem. It disturbs biodiversity as well as ecosystem.

c. Impact on human health

Human are badly affected by climatic change. Rise in temperature may result in scarcity of water, loss of crop production, hot land and air around us, spread of diseases, etc. It badly affects working capacity of humans. It also increases disease in animals.

d. Impact on agriculture system and agriculture production

Due to climatic change, green house effect, excessive rain, drought, change in topography, etc. take place. It affects entire crop production. People should depend on rain water for irrigation, hilly regions face landslide and terai region flood. It degrades the fertility of soil. Which, in turn, badly affects the agriculture system as well as production.

Fig.22.8: *Impact on agriculture*

e. Disaster caused due to climate change

Climatic change promotes environmental degradation by causing disasters such as excessive rain, frequent flood and landslide, lack of rain, drought, desertification, etc. It badly affects entre organisms.

f. Negative effect in water resources

Water resources are on the most affected areas due to climatic change. Less snowfall in mountain region leads to decrease of flow of water in originated rivers. Even the melting of ice due to the rise in temperature imbalances the flow of water in rivers. It causes glacial rivers to dry. Melting of ice due to rise in temperature has increased the size of glacial lake and glacial lake outburst is likely to occur.

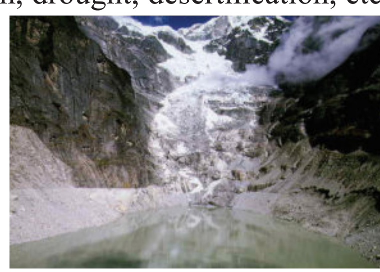


Fig.22.9: *Glacial outburst*

g. Energy crisis

Hydro electricity is generated by using the current of flowing water. Due to the imbalance in water resources, the generation of electricity is also imbalanced. Various

Fig.22.10: *Load shedding*

activities mainly industries are affected by energy cricis. It has negative impact on economic sectors. Energy crisis, is the cause of load shedding in summer and in winter.

Introduction to Ecosystem

An ecosystem is a short form of "ecological system." It consists of a dynamic set of living organisms, all interacting among themselves and with the environment. It can also be said as a region in which living organisms (plants, animals, microbes) interact with their environment. It is an ever changing system in which the living organisms and their non-living environment are interdependent and functionally integrated.

The word 'ecosystem' was coined by Sir A.G. Tansley in 1935 AD. An ecosystem may be open or closed. An open ecosystem has porous boundaries, receives input from outside and gives an output to outside. As mentioned earlier, no ecosystem exists alone. They are interconnected by inputs. One ecosystem such as nutrients, gases, water etc might be the input of another ecosystem in the same or another landscape. For example, a river receives many inputs from the terrestrial ecosystem through which it flows and in turn it provides them with many inputs such as water, sediments, nutrients, etc. An ecosystem can be as small as a pond or as large as an ocean or a small tree hole supporting grasses and small animals or an entire forest or as large as the earth itself. Biotic and abiotic components of environment play vital roles in an ecosystem

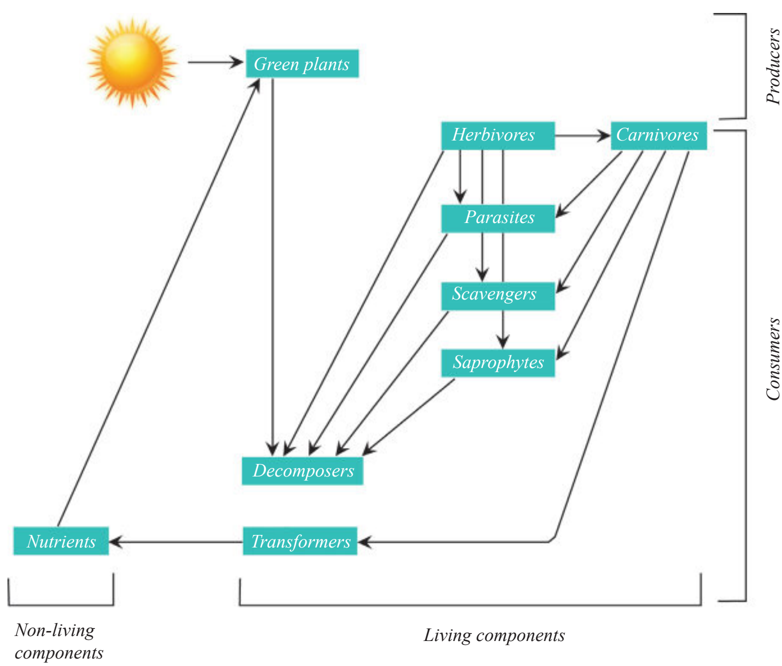


Fig.22.11: Major components in a self-sufficient ecosystem

Types of ecosystem

There are various types of ecosystem. Of them, the main ecosystems are as follows.

Ecosystem

- **Terrestrial ecosystem**
  - Forest ecosystem
  - Grassland ecosystem
  - Desert ecosystem
  - Wetland ecosystem
- **Aquatic ecosystem**
  - Marine ecosystem (eustary, ocean)
  - Fresh water ecosystem (Lake, wetland, pond, etc.)

A. Terrestrial ecosystem

The ecosystem that takes place in land is terrestrial ecosystem. In this ecosystem, there are considerable variations of climate, relief and vegetation. As a result, a number of terrestrial sub-systems exist. For example, Forest, grassland, desert, wetland and many more. These could be also called upland or lowland ecosystem depending on relief. Some terrestrial ecosystems may be called hot desert ecosystem or cold desert ecosystem based on climate.

No ecosystem starts without producers. And the energy from producers (green plants) flows to various types of consumers. Herbs, shrubs, trees act as producers in all ecosystems. But the consumers may differ in various ecosystems according to their habitat, climatic condition, soil, topography, etc.

Fact file:

Wetland ecosystem can be included in both terrestrial and aquatic ecosystems as both types of creatures play equal role in it.

B. Aquatic Ecosystem

The ecosystem that exists in water is an aquatic ecosystem. In this ecosystem, there are two main divisions. They are marine ecosystem and fresh water ecosystem. Fresh water ecosystem is a river, lake and wetland ecosystem. The marine ecosystems have also many sub-divisions. They may be again distinguished on the basis of open seas and coastal areas like eustaries, coral reef ecosystems and many more. Similarly on the basis of penetration of sunlight, the marine ecosystem can be divided into pelagic ecosystem (belonging to upper layers of the sea) and benthic ecosystem (life found on the sea floor)

Fact file:

Nepal is rich in ecosystem. Except desert and ocean ecosystems, all types of ecosystems are found in Nepal.

Energy flow through ecosystem

The organisms within an ecosystem are constantly growing, reproducing, dying and decaying. These organisms need energy for their activities. They get energy from the food that they eat. We have already discussed autotrophs and heterotrophs. Autotrophs get energy from the food they make. The energy of plant is transferred to primary consumers, secondary consumers, and tertiary consumers. When exchange of food takes place through this method, a food chain is formed.

Food chain (A process of eating and being eaten up)

An ecosystem contains many food chains. It is a sequence of species in which each is the food for the next in the chain. It is also the transfer of food energy from producers through a series of organisms (tropic level) with repeated process of eating and being eaten.

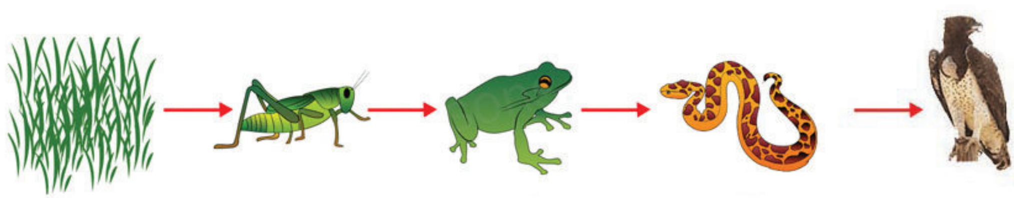


Fig.22.12: *Food chain of terrestrial ecosystem*

In the ecosystem, photosynthetic organisms utilize the radiant energy of the sun and transfer it to organic substance as carbohydrates by photosynthesis. The producers are the only link between biotic and abiotic components of ecosystem. The herbivores like grasshoppers, insects, goats, etc. consume the producers. They are, in turn, utilized by secondary consumers like birds, human beings, etc. The secondary consumers are again eaten by tertiary consumers like vulture, lion and other carnivores. After their natural death, decomposers decay them and convert them into soil with the release of energy. Again producers will produce the food materials and the process of eating and being eaten among the living things continues as a cycle.

Food web: (A complex and alternative food path)

In nature, food chains are not so simple as described before. Consumer organisms rarely depend on only one type of food. And often a particular food is eaten by more than one consumer. The feeding patterns in a community are much more complex. A food web has several alternative pathways for the flow of energy. Thus food web may be defined as a complex network of food chains in a community which forms an interlocking pattern among organisms. For example: in grazing, there is the food chain of grassland. Mouse may be eaten by hawk or snake or cat. The grass may also be eaten by rabbit. In this way, an interlocking pattern of food material formed.

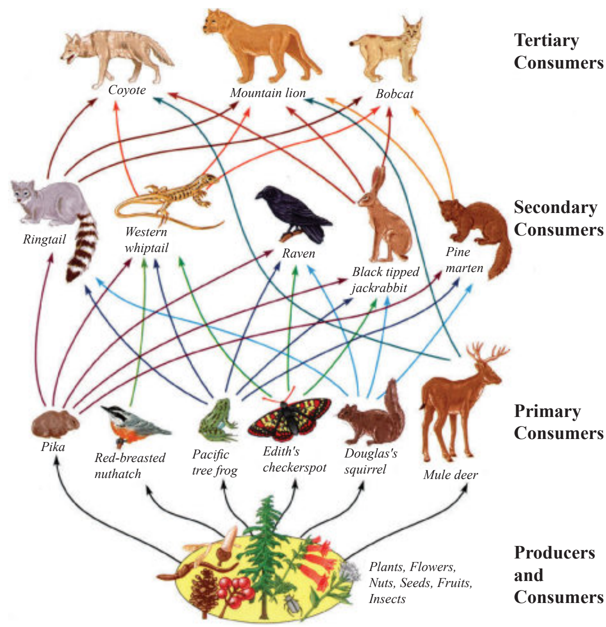


Fig.22.13: *Food web*

Difference between food chain and food web

Food chain	Food web
1. It is a much simplified form or say, a unit of food.	1. It is a very much complex network of various food chains
2. There is a linear arrangement of trophic levels which remain interconnected in food chain.	2. It depends upon alternatives at different interrelating points of consumers in a chain.

Activities 3: Make groups and take the groups to nearby grassland, garden, pond etc. Separate the organisms found there into producer, primary consumer, secondary consumer, tertiary consumer and decomposers. Prepare a report on it.

Interrelationship between plants and animals:

In an ecosystem, plants and animals are interdependent on each other. Plants use simple organic matter converted by decomposers into complex organic matter which is consumed by consumers. In this way we can say that without consumers, producers cannot survive and without producers consumers cannot survive. If there are no consumers, the energy of plants will not be transferred. Biotic factors can be divided into autotrophs and sererotrophs mainly on the basis of the way they consume food.

A. Autotrophs

Autotrophs are the organisms that can synthesize their food from inorganic substances, using sunlight as a source of energy. Green plants manufacture the complex organic matter by utilizing simple inorganic matters like water, minerals, CO_2 gas, etc. by the process of photo-synthesis. The nutrients that are pertained through solar energy, and reactions of inorganic chemical compounds are converted into energy in autotrophism.

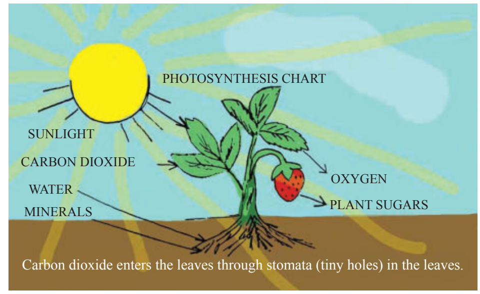


Fig.22.14: *Photosynthesis*

B. Heterotrophs

Heterotrophs are those organisms which require an external supply of energy in the form of food as it cannot synthesize in its own body. All the consumers are heterotrophs. Plants without chlorophyll are also included in this group. The way by which the organisms depend on other organisms to fulfil their requirement of food is heterotropism. Heterotrophs can be divided into the following types on the basis of the consumption of food.

Fig.22.15: *Tiger*

i. Parasites

The organisms that live on or in another organism for their food are parasites. They derive benefit from living on or in other organisms. Usually these types of organism suck food from other organisms. The organisms which supply food to parasites are called host and the one who absorb the food are parasites. For example, Ascaris, round worms, tape worms, lice, fleas, mites, ticks, etc. are parasites.

Fig.22.16: *Parasites*

ii. Saprophyte

Those organisms that live on dead organic matters are called saprophyte. They play the role of decomposers in an ecosystem. For example, yeast, bacteria. fungi etc.

Fig.22.17: *Decomposers*

iii. Holozoic

Those organisms that get their food from all types of huge or small plants and animals are holozic. All types of animals including humans are holozic as they obtain nutrition by the ingestion of organic matter. Such types of organisms digest nutrient in a simple form and the remaining undigested is excreted out of the body.

Fig.22.18: *Holozoic*

Activity:

Find out the eating habits of the animals you see in your school compound and classify them according to their mode of nutrition.

Ecosystem services: There are various services that we get from ecosystem. Some of them are mentioned below

Fig.22.19: *Services from ecosystem*

1. Provisioning services

The products that we get from an ecosystem are provisioning services.

a. Food and fibre: All the living organisms get food from ecosystem. Similarly various products such as silk, wood fire wood, jute, cotton, etc. which are consumed or used by humans are available in nature.

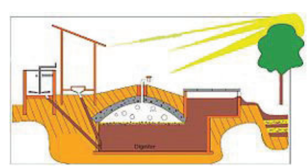


Fig.22.20: *Bio-gas*

b. Fuel: Wood, fire wood, excreta of animals (cow dung) and decaying matters can be used as fuel. Dung cakes are prepared, dried, then used as fuel mainly in villages. Nowadays biogas plants are prepared and produced by using excreta of animals. All these products are available in the environment.

Fig.22.21: *Bone ornament*

c. Ornamental resources: In some groups and castes of people animal products such as skin, bones etc. are used for making ornaments.

2. Regulating services

The services that we get from continued balanced ecosystem are the regulating services. These services are regulated in the environment and are beneficial for us all.

a. Climate Regulation: There is balance in nature following carbon cycle, nitrogen cycle, oxygen cycle, water cycle etc. These cycles are also main parts of ecosystem. Similarly forests help in balancing temperature and water cycle at local level. Ecosystem affects climatic condition of the world as well as local climate. Similarly over release of carbondioxide causes climatic change.

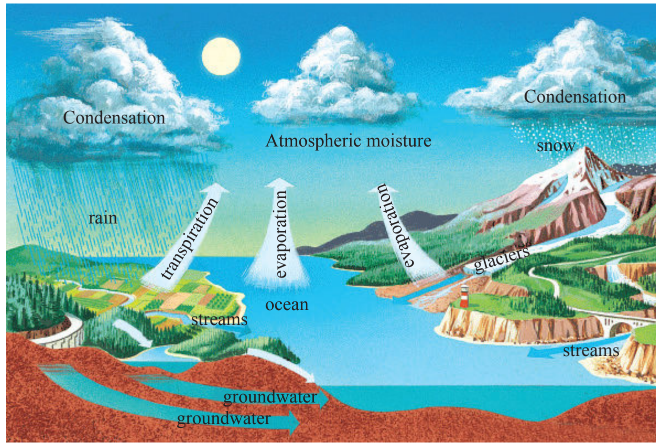


Fig.22.22: *Water cycle*

b. Water purification: Ecosystem directly or indirectly helps in purification of water in nature. It filters the impurity of water and breaks down organic harmful materials.

Similarly, the change in ecosystem affects pollination, regulation of human disease, erosion control, etc.

3. Cultural Services

When ecosystem is balanced, the whole environment becomes fresh and balanced. Natural beauty, and scenery is added to it. Animal habitat is protected. One can easily invest on and develop tourism industry. Nepal is rich in natural beauty. Those places are destinations for the people who love to relax and enjoy far away from the noisy city areas in leisure times.

Fig.22.23: *Natural beauty*

Natural beauty, relaxed environment, human culture and tradition, etc. are affected by ecosystem. Similarly religious beliefs are also affected by ecosystem. Flowers offered while praying, food consumed during festivals, etc. are determined by available nature. It differs according to a place. Ecosystem also increases norms and values of social relation, cultural heritage, etc.

Supporting services

In these types of services, nutrient recycling, primary production, soil formation, etc. are rendered. These services help plants and animals to get required food organisms which support life of all are provided with. Food regulation, water purification, etc. services.

Ecosystem services

A. Provisioning services	B. Regulating services	C. Cultural services	D. Supporting services
Food, fresh water, firewood, fibre, bio-chemicals and genetic resources	Climatic regulation, disease regulation, water regulation, water purification, pollination, N_2 cycle, C-cycle oxygen cycle	Spiritual and religious recreation, eco-tourism, aesthetic, inspirational, educational, sense of place, cultural heritage	Soil formation, nutrient cycling, primary producer

Dependence of human beings on other organisms

All the organisms including humans need food and shelter for their survival. As being a consumer, we completely depend on plants and other organisms for food. Similarly for shelter and clothes as basic needs, we depend on plants. We get food, oxygen, fibre, resins, natural colour etc. from plants. We get various products from animals too. So human beings directly depend on other organisms for their survival.

a. Food

All the organisms need food for their survival as they get energy from it. The required food for humans are cultivated on land. We use various parts of plant as food. Such as seed, leaves, fruit, root, flower etc. Some plants are consumed as whole too. Similarly we get various product such as meat, egg, milk products etc. from animals. We even get fresh air from plants. So we can say that plants and animals play a vital role in the survival of human beings.

Fig.22.24: *Food*

b. Shelter

Land provides human beings with shelter. We cultivate crop on land. We do construction work on land. We even construct our home on land.

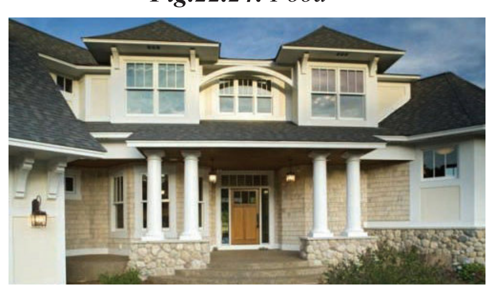


Fig.22.25: *House*

Raw materials required for construction of building such as bricks, sand, concrete, cement, metal, wood etc. are derived from nature. So we can say that humans depend on nature for their survival.

c. Clothes

We need clothes to cover our body. Clothes such as bakkhu docha, Daura-suruwal, Dhoti Kurta etc. determine people of various geographical regions. Clothes such as Hakku Patasi of Newars, Ghalek of Gurungs, Lehanga of Rajbanshis, etc. are an identity of castes in Nepal.

We get raw materials for these clothes from nature. Cotton, silk, wool, fur, etc. are used to make cloth. So we can say that plants and animals provide humans with clothes.

Fig.22.26: *Nepali costume*

Lesson Summary

1. The vast network of all interconnected ecosystems constitutes the biosphere.
2. Abiotic components include organic substances, inorganic substances and climatic factors.
3. Biotic components include producers and consumers.
4. Ecology is the branch of biology that deals with the relationship of the living organisms with their environment.
5. Ecosystem is the interrelationship between the living beings themselves and with the environment in a particular community.
6. Biotic components are the living components of an ecosystem and abiotic components are the non-living components of the ecosystem.
7. Producers, consumers and decomposers are the living components (Biotic factors) and soil, water, air, solar energy, humidity, etc. are the abiotic components of ecosystem.
8. Food chain is the process of eating and being eaten among the consumers, which is initiated from producers.
9. Food web is the complex interlocking pattern among food chains in which the same individual is consumed by many individuals and many organisms are consumed by the same consumer as its prey.
10. Heterotrophs are the organisms which depend upon others for their food.
11. Autotrophs are the organisms which do not depend upon others for their food. Rather, they manufacture their food themselves.
12. Humans depend on plants for food, shelter and clothing.

Project work

Draw and colour a grassland ecosystem and a pond ecosystem and display the best one on the wall of your classroom.

Conceptual questions with their answers

Q.1. What is symbiosis?

The association between two living partners where both of them get benefitted from each other. e.g. Lichen (The association of Algae and Fungi)

Q.2. Which living beings are kept at the first trophic level? Why?

Producers (plants) belong to the first trophic level as they produce food by themselves and become the source of food for the higher trophic level.

Exercise

1. Answer the following questions.

a. Define ecosystem and describe its components briefly.
b. Describe the terrestrial ecosystem and aquatic ecosystem.
c. Write in short about the biotic and abiotic factors in ecosystem.
d. Define food chain. Can food chain operate in isolation? Justify it.
e. How is food web important in ecosystem?
f. Write two differences between food chain and food web.
g. Describe in short the interdependence of plants and animals. Give any two points in support to your answer.
h. Write about the role of decomposers in ecosystem.
i. What adverse effect will be felt in the ecosystem if the number of producers is more than necessary? Explain.
j. Why does food chain/food web begin from producer?
k. What type of factor is mushroom in the ecosystem?
l. What are the services of ecosystem?
m. Describe briefly the regulating services of ecosystem.

2. Write the difference between

a. Autotrophs and heterotrophs
b. Abiotic factors and biotic factors
c. Food chain and food web
d. Producers and consumers

3. Write reasons.

a. Grass is a producer.
b. Mushroom is a decomposer.

c. Eagle is a top consumer. d. Green plants give us life.

e. Balanced ecosystem is a must for our survival.

4. Answer the following questions on the basis of the given diagram-

i. 

ii. 

iii. 

iv. 

v. 

a. Identify and sort out different biotic components of the ecosystem.

b. How is the ecosystem affected by the increment of (iv)?

c. Which of them is the source of food for all?

d. Which of them is a top consumer?

Multiple Choice Questions

1. Tick (√) the correct alternative.

a. Which one of the following is abiotic factor of ecosystem?
   - i. Tiger
   - ii. Water
   - iii. Yeast
   - iv. Grass

b. Fungi play the role of .... in the ecosystem.
   - i. Producer
   - ii. Top consumers
   - iii. Primary consumers
   - iv. Decomposers

c. Rice field ecosystem is an example of
   - i. Water ecosystem
   - ii. Desert ecosystem
   - iii. Land ecosystem
   - iv. Pond ecosystem

d. Which of the following help to return nutrients to producers again?
   - i. Primary consumers
   - ii. Decomposers
   - iii. Secondary consumers
   - iv. Tertiary consumers

e. The organisms which absorb their food from decaying things are the examples of
   - i. Saprophyte
   - ii. Autotrophic
   - iii. Parasite
   - iv. Holozoic

Astronomy and Geology

STEPHEN HAWKING

(8 Jan 1942 – 14 March 2018)

Known as

an English theoretical physicist and cosmologist best known for Hawking radiation, Penrose Hawking theorems, Hawking energy.

Science is not only a discipline of reason but also one of romance and passion.

- Stephen Hawking

Chapters to study

Unit 23

Natural Hazards

Total estimated teaching hours = 5

Learning Outcomes

After the completion of this unit, students will learn:

- *what natural and anthropogenic hazards are.*
- *causes, effects and control measures of avalanches, outbursting of glacial lakes and hurricane.*
- *various ways to be safe from natural hazards.*
- *various ways to be safe from manmade hazards.*

Charls R. Richter (1900AD-1985AD)

KEY WORDS

1. **Stadial** : pertaining to a glacial stade
2. **Scintillation:** a flash of light; a spark
3. **Mandatory** : compulsory
4. **Prediction** : a statement of what will happen in the future
5. **Projection** : a forecast
6. **Tributary** : a natural water stream that flows into a larger river
7. **Mapping** : the process of making maps
8. **Eerily** : in a strange manner
9. **Evacuate** : to leave a place, country, city, etc.

Introduction

Hazard or disaster is a sudden great misfortune that occurs without notice. It is a sudden calamitous event that seriously disrupts the functioning of a community or society. It causes human, material and economic or environmental losses that exceed the community's or society's ability to cope with using its own resources. It occurs suddenly and causes a great loss to life and property.

No countries are untouched by such hazards. Hazards may be natural or anthropogenic. The nature of hazard may be different in different countries. In our country such natural hazards are flood, earthquake and landslide. In Japan, Tsunami and earthquake are the main natural hazards. In some other countries they may be in the form of hurricane volcano, toranado, etc. In this lesson we will discuss avalanches, outbursting of glacial lake and hurricane as natural hazards.

Hazard

A hazard is a source of potential damage, harm or adverse health effect on something or someone under certain conditions at work. Basically a hazard can cause harm or adverse effects to individuals as health effects or to organizations as property or equipment losses. Once a hazard becomes 'active', it can create an emergency situation.

1. Natural Hazards

Natural hazard is a naturally occurring event that might have a negative effect on people or environment. It refers to all atmospheric, hydrologic, geologic (especially seismic and volcanic) and wildfire phenomena that, because of their location, severity and frequency have the potential to affect humans, their structures or their activities adversely. A hazardous event that causes unacceptably a large number of fatalities and overwhelming property damage is a natural disaster. It is important to understand that human intervention can increase the frequency and severity of natural hazards. For example, when the toe of a landslide is removed to make room for a settlement. the earth can move again and bury the settlement. We have already discussed some natural hazards in the previous classes. In this lesson, we will learn some more about other natural hazards.

Fig.23.1: *Natural hazards*

Natural hazards can be grouped into three broad categories.

a. Geological hazards -eg coastal erosion, lahar and sink holes
b. Meteorological hazards -eg Blizzard, Hailstorm, heatwave, Maels storm, Icestorm, Tornado, Geo-magnetic storm, etc.
c. Biological hazards -eg Diseases caused by virus bacteria, etc.

2. Manmade/Anthropogenic Hazards

Those hazards that are caused due to human activities are man-made hazards. It includes road accidents, war, terror attack, industrial accidents, oil spills, etc, and the nuclear-related ones are the most dreadful.

Due to carelessness, many people die unnatural death in road accidents, air accidents, ship accidents, etc. Such accidents may kill a few people or a large number of people at the same time.

Fig.23.2: *Manmade hazards*

Industrial accidents are dangerous to many people too. Many people become disabled. For example, the Bhopal Gas Tragedy of 1984 is the world's worst industrial disaster. From a pesticides factory, an extremely poisonous gas leaked and went unchecked in Bhopal. 70,000 people were evacuated from the area and 200,000 more fled in panic. More than 8000 people died and the gas poisoned more than 500,000 people leaving each of them with a lifetime illness.

Sometimes oil spills from tanker accidents and blowoots in offshore drilling rigs. In terms of quantity, however, more oil is discharged into the ocean by the normal drilling operation, cleaning of tankers and leaks from pipelines and storage tanks. Chemicals in oil kill many marine organisms. They coat the feathers of birds and fur of marine mammals and they get drown and die.

Fig.23.3: *Oil spills*

Nuclear-related disaster is more dreadful. The nuclear bomb is, no doubt, the worst invention of mankind. Waste from nuclear plants is extremely dangerous and it must be isolated for thousands of years. Still there is no proper safe method of storing radioactive waste.

Fact file:

1. *In August 1945, the US dropped nuclear bombs on the Japanese cities of Hiroshima and Nagasaki. More than 200,000 people died and many survivors suffered lifelong symptoms of the A-Bomb disease.*
2. *On 26th April 1986, the plant operators were conducting an experiment which went wrong. Then a nuclear reactor in Chernobyl, Ukraine, exploded with terrible and long lasting consequences. It remains for ever as the biggest nuclear accident in the world. It took ten days to control the fires and prevent them from spreading.*
3. *On 2001, September 11, terrorist attack in the United States by the Islamic terrorist group destroyed World Trade Center, Twin Towers, Pentagon. The attacks resulted in the deaths of 2996 people including 19 hijackers.*

Management of natural hazards

Natural hsazards cannot be stopped but we can reduce their effects. Some of the ways to manage natural hazards are as follows.

1. Pre-event measures such as prediction, emergency, preparedness (including monitoring, alert, evacuation), etc. should be taken before the disasters occur if possible.
2. Education and trainings can be given to everyone to be safe during hazards.
3. Immediate rescue and relief services should be provided during and immediately after natural disasters.
4. Rehabilitation and reconstruction should be done after the disasters.

5. An accurate and timely prediction of a hazardous event can save human lives.
6. Natural hazard assessments should be done which provide information on the probable location and severity of dangerous natural phenomena and the likelihood of their occurring within a specific time period in a given area.

Fig.23.4: *Management of natural hazards*

7. Vulnerability Assessments (VA) should be done which estimate the degree of loss or damage that would result from the occurrence of a natural phenomenon of given severity.
8. Risk Assessment (RA) which gives information from the analysis of an area's hazards and its vulnerability to them is integrated in an analysis of risk.
9. If possible, Natural Hazard Prediction (NHP) can be done. Even a short notice of the probable occurrence and effects of a natural phenomenon is of great importance in reducing loss of life and property.
10. Immediately after relief activities, post disaster rehabilitation should be carried out to restore the normal functions of public services, and businesses, to repair houses and other structures and to return production facilities to operation.

Management of manmade hazards

Man-made hazards can be managed in the following ways.

1. Criteria of age should be fixed while providing driving license of any vehicle to reduce road accidents.
2. The use of chemical industry and nuclear power plant should be reduced or high alertness should be applied to prevent from spreading in the environment.
3. Sanitation measures and rules should be applied everywhere to prevent from spreading of diseases.


Fig.23.5: *Management of manmade hazards*

4. To prevent from desertification, the fertility of soil should be balanced by promoting natural method of fertilizer such as compost manure, vermicomposting, natural pesticide and insecticide, etc.
5. The available forests should be protected and plantation programme should be promoted to be safe from disaster.

6. Unhealthy competition to use harmful chemicals among people should be reduced.
7. At local level, various programmes can be conducted by using means of communication to alert people about the ways to be applied for their safety.
8. Environment Impact Assessment (EIA) should be done before conducting any development projects to prevent from future disaster.
9. Sustainable development should be planned and applied properly.
10. While constructing buildings, earthing, retrofitting should be done to prevent building from collapsing due to various disasters.
11. These topics should be included in the school level curriculum to make students aware.

We can follow Disaster Management Cycle (DMC) mentioned below.

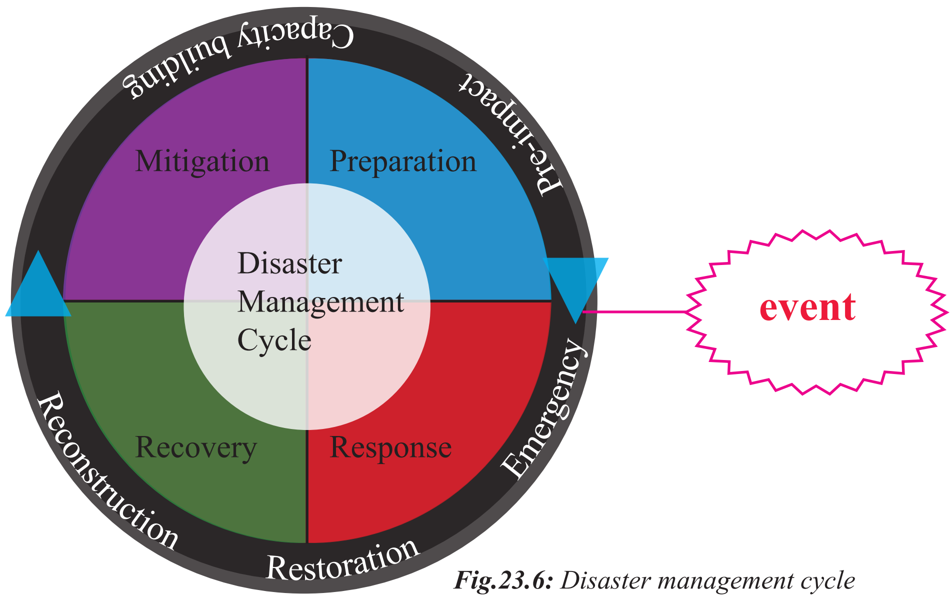


Fig.23.6: *Disaster management cycle*

The first step of disaster management cycle is usually considered to be preparedness. Projection and record of disaster, pre-planning the steps to be followed during disaster, store of rehabilitation materials, management of communication system are all for preparation.

The second stage in the disaster cycle is response. Imminently prior to a disaster, warnings should be issued. If required, evacuations or sheltering in places should be done. Necessary equipments should be placed ready.

After the immediate response phase of the disaster cycle is completed, the disaster turns towards recovery, focusing on the longer term response to the disaster. During this phase, officials and people should be interested in clean up and rebuilding. And even the learned lessons are collected and shared with the emergency response community. Distribution of required materials should be started for victims.

The mitigating phase of the disaster cycle is almost concurrent with the recovery phase. The main goal of this phase is to prevent the same disaster- caused damages from occurring again.

Fig.23.7:

Finally using the lessons learned from the response, recovery and mitigating phases of the disaster, government officials and the emergency managers return to the needs of preparedness phase again. They revise their plans and their understanding of the materials and human resources for a particular disaster in their community.

Indentification of the demand, management of temporary residence, analysis of loss, food, clothes, shelter, pure water management, rehabilitation, if required, setting new residential areas with facilities etc also help in disaster management.

Now we will study introduction, causes, effect and control measures of avalanches (snow-slide), glacier lake outburst and cyclone.

A. Avalanche (Snowslide)

Avalanche is a natural disaster in which a large snow mass slides down a mountain side. It is an example of a gravity current consisting of granular material. In an avalanche, lots of materials or mixtures of various types of materials fall or slide rapidly under the force of gravity. It is also known as snowslide.

Fig.23.8: Avalanche

Nowadays, due to global warming, avalanches frequently happen in the mountain region of Nepal.

On the 3rd of Baishakh 2071 BS. many climbers and guides lost their life.

On 12th of Baishakh 2072 BS. when earthquake took place, avalanche hit Mt. Everest killing many mountaineers, guides and local people.

Avalanches can be classified into four types such as loose snow avalanches, slab avalanches, powder snow avalanches and wet snow avalanches.

a. Cause of avalanches (Snowslide)

Some main causes of avalanche are mentioned below.

1. Naturally new snow or rain causes the accumulated snow to suddenly dislodge and cascade down the side of a mountain.
2. Due to earthquake also it may occur.

3. Sometimes, movements of animals have also been known to cause avalanches. (when mountainous areas are cleared and developed for tourist resorts).
4. Deforestation can contribute to avalanche formation. Therefore rain water cannot be trapped and held.
5. Construction of mines, roads in steep land and the big holes left behind cause avalanches.

Fig.23.9: Road on mountain

6. The use of snow vehicles creates vibrations within the snow.
7. Global warming causes changes in weather pattern which causes snow melting and increases the risk of avalanches.

b. Effects of avalanches (snowslides)

Avalanches affect in following ways.

1. If an avalanche hits a heavily populated area it will cause a huge damage to life and property.
2. People who enjoy skiing, snowboarding and snowmobiling are at a greater risk of losing their lives.
3. When an avalanche occurs, it brings down all the debris with it and can cause havoc in the low-lying areas.

Fig.23.10: Road block due to snow

4. They can also change weather patterns and cause crop failure in farms on the lower fields.
5. An avalanche can block anything on its path and even restricts the normal movement of traffic.
6. Various tourist resorts may go for loss due to lack of tourists because of avalanches.

c. Measures to prevent avalanches (snowslides)

Some preventive measures of avalanches are given below.

1. Physical construction should be discouraged in such regions.
2. Disposing the avalanche potential snow packs by artificial triggering.
3. Through stability analysis, prediction of the occurrence of avalanche can be done and warning of impending avalanche can be issued.

Fig.23.11: Afforestation

4. Guiding the people for the emergency evacuation shelters.
5. Steps should be followed by everyone to reduce the global warming.

Activity: By using old newspapers, asking elders and using internet, prepare a report on damage caused by avalanche in Mt. Everest and Rasuwa district during the earthquake in Nepal in 2072

Fact file:
On Saturday, 5th May 2012. the flash flooding in the Kaski district of north-western Nepal resulted in the death of at least 31 people, left dozens more missing and caused a great loss of property including homes, business, crops and livestock. The flood occurred in a tributary of the Seti River originating from the east of Mt. Machhapuchhre. It is believed that the flood took place due to the outburst of a dammed lake.

B. Glacial lake outburst (GLOF)

The lakes formed at mountain regions are called glacier lakes. Glacier lakes are naturally formed. In mountain regions, small or big valleys are converted into lakes after the collection of water. Some glacier lakes may be stagnant whereas some lakes may form rivers.

Fig.23.12: Glacier outburst

Nowadays, due to climatic change, day by day the areas of glacier lakes are becoming broad. It is the result of worldwide global warming. Global warming leads to the outburst of glacier lakes causing flood and destruction of life and property

A glacial lake outburst flood (GLOF) is a type of outburst flood that occurs when the dam containing a glacial lake fails.

In the world, most of the areas of glacier lakes are widening day by day. The major problem is faced by the countries with mountainous region. Due to the melting of more snow, the water level of the glacier lake is rising. There is a threat that glacier lake may outburst in near future. When a glacier lake outbursts, fast flowing flood takes place causing maximum destruction on the banks of rivers. It even destroys fertile land, crops, life and property.

Fact file:
In 1968 AD. there was a destructive flood in Budhi Gandaki due to a glacier lake outburst. Similarly, in 1985 AD, due to the outburst of Dig Cho Glacier lake, a hydropower project situated at Thane village of Namche Bazaar was completely destroyed.

a. Cause of glacial lake outburst

The major causes of glacier lake outburst.

1. When an avalanche of rock or heavy snow hits a glacial lake then it outbursts
2. An earthquake also splashes out water from lake.
3. Volcanic eruption under ice also leads to an outburst.
4. If a large portion of a glacier breaks off and massively displaces the water in a glacial lake at its base then the lake outbursts.
5. Excessive rain may lead to outbursting as it increases water level in lakes.
6. Global warming is also one of the main causes of glacial lake outburst.

Fig.23.13: Glacial splashing

b. Effect of glacial lake outburst

The following are some major effects of glacial lake outburst.

1. Water level rises in rivers leading to flood.
2. Debris and other materials carried during outburst will be deposited at lower levels on human settlements and farms.
3. Human settlement will be destroyed resulting in loss of life and property.
4. Development work such as roads, and other infrastructures, bridges, hydropower projects are swept away by the outburst.

Fig.23.14: Glacial outburst

c. Protective measures of glacial lake outburst

Some main protective measures of glacial lake outburst are given below.

1. After finishing the construction of natural dam, a little 60 m high section dam can be constructed for the care of the entire basin.
2. The local communities' technical capacity should be increased by various programmes so that they can easily understand and address the immediate glacial lake outbursting flood risks.
3. Risk and vulnerability assessment should be prepared along with hazard mapping to reduce the effect in future.

Fig.23.15: Communication

4. Community-based hazard watch groups and disaster management committees should be formed to monitor and report emerging threats from glacial lake outburst.
5. Programmes should be conducted to reduce global warming and climate change.

Activity: Imagine yourself as a responsible citizen of the mountain region. Write the steps that you will follow to reduce the effect of outbursting flood. Compare your answers with that of your bench partner and give feedback to each other.

C. Cyclone

It originates in between 5° to 25° N and S lattitudes as this region recieves the direct sun rays to heat water throughout the year.

According to meteorology, a cyclone is an area of closed, circular fluid motion rotating in the same direction as the earth. This is usually characterized by inward spiraling winds that rotate counter clockwise in the northern hemisphere and clockwise in the southern hemisphere of the earth.

Cyclone refers to any spinning storm that rotates around a low pressure centre. The low- pressure centre is also referred to as the 'eye' of the storm. It is well known for being clearly calm compared to the areas under the spinning 'arms' of the storm.

Meteorologists give human names to cyclones. So each cyclone has its separate name. For example, Bhola cyclone in Bangladesh in 1970 AD, Katrina cyclone in USA in 2005 AD, Nargis cyclone in Myanmar in 2008 AD, Hayan cyclone in 2013 AD, etc.

Cyclones may also be formed in tropical (Tropical cyclone) regions, polar region (polar cyclone)and in the middle region of two storms (mesocyclone).

Cyclonic storm

Hurricane, tropical cyclone and typhoon are different names for the cyclonic storm. It is a system that forms over the oceans. It is caused by evaporated water that comes off the ocean and becomes a storm. The coriolis effect causes the storms to spin and a hurricane is declared when this spinning mass of storms attains a wind speed. The wind speed may be greater than 19 km/hr.

Hurricane is used for this phenomenon in the Atlantic and Eastern Pacific oceans. Tropical cyclone in the Indian, and typhoon in the Western Pacific. The speed of wind decreases when it comes to coastal areas. But until the speed decreases, it destroys everything on its way. It destroys trees, houses, roots, humans, vehicles, etc.

a. Cause of cyclone

When the ocean water is heated at 26.50 °C at up to the depth of 50 metres, the situation of cyclone creates. In this condition air pressure reduces above the sea surface. Due to it the surrounding air begins to move towards it. It pushes the water vapour and hot air upwards. The central region of the hot air region has low pressure. Thus the surrounding air migrates towards it. As it approaches the core region the velocity of wind increases. When the wind gains the speed of 120km/hr, it takes the form of cyclone. Due to the formation of a convectional current in this region, a regular flow of wind occurs in the form of cyclone here. Especially it occurs in between the months of August and October.

b. Effects of cyclone

Some main effects of cyclone are given below.

1. The main effects of tropical cyclones include heavy rain and landslides.
2. Strong wind may damage human settlement causing loss of life and property.
3. Coastal businesses like shipyards and oil wells are destroyed.
4. The ecosystem of the surrounding region is disturbed.

Fig.23.16: Heavy rain

5. Civic facilities are disturbed.
6. Agricultural land is severely affected especially in terms of water supply and soil erosion.
7. It causes harm to human, plant and animal life.
8. Communication systems are badly affected.

c. Protective measures of cyclone

We can minimize the adverse effects of cyclone in the following ways.

1. Coastal areas should be well-prepared to cope with the eventualities that arise from cyclones.
2. Houses which can withstand the heavy rainfall and forceful winds should be constructed.
3. Shelter beds should be created to check soil erosion and speed of winds.
4. To forecast cyclones appropriately, remote sensing techniques should be used.
5. Rescue and relief operation should be immediately started when cyclones occur.
6. If required, the place should be evacuated before cyclones hit.

Lesson Summary

1. Hazards or disasters are a sudden great misfortune that occurs without notice.
2. Natural hazards can be grouped into geological, meteorological and biological hazards. There are anthropogenic hazards too.
3. Natural hazards can be managed by prediction, emergency preparedness, awareness, immediate rescue and relief services, rehabililation and reconstruction, etc.
4. For the management of anthropogenic hazards, measures for reducing road accidents are followed, alertness in chemical industries and nuclear power plant is maintained, use of organic fertilizers and insecticides is increased, awareness programmes etc. are conducted.
5. Disaster management cycle completes in four steps such as preparation, response, recovery and mitigation one after another.
6. Avalanche is a natural hazard in which a large snow mass slides down on the slope of high Himalayan region. That's why it is also called snowslide.
7. Snowslide is caused by thickness of snow on the slope of a mountain, earthquake, movement on the slope, global warming, construction of development structures on the region, etc.
8. Snowslide destroys life and property.
9. Lakes formed on mountains are called glacial lakes.
10. When the natural dams of glacial lakes break, the water flows in the form of flood called GLOF i.e. Glacial Lake Outburst Flood.
11. Hit of avalanche, earthquake, weak rock structure of the dam, excessive rain, global warming, etc. are some main causes of glacial lake outburst.
12. Glacial lake outburst causes flood in nearby rivers which sweep life and properties. It also may cause destruction of development structures.
13. Regular monitoring of glacial lakes is the main protective measure of glacial lake outburst.
14. Tropical storms are called cyclones or hurricanes. They originate over the ocean and may migrate over land.
15. The formation of low pressure region on the ocean near equator due to hot water is the cause of cyclone.
16. Cyclone causes destruction in a large scale and it also causes flood.
17. Evacution in the coastal region is also the main protective measure of cyclone.

Project work

Write causes and effects of the natural hazards that occurred in Nepal in the past. Mention the disaster management practised by the government to reduce the effects of the hazards.

Conceptual questions with their answers

Q.1. "A cyclone or hurricane originated close to the equatorial zone only." Why?

It is because these phenomena are caused by hot water of the ocean up to a particular depth and it is possible near the equator due to the direct rays of the sun.

Exercise

1. Answer the following questions.

a. What is a hurricane? How does it occur?
b. What is the eye of a hurricane? Write its characteristics.
c. What are the effects of hurricanes?
d. What are the preventive measures that can be applied to minimize the loss of life and property due to cyclone?
e. Which two natural disasters are most likely to occur in Nepal? Explain with reason.
f. Mention the types of natural disasters.
g. What are meterological hazards ? Give examples.
h. What are geological hazards? Give examples.
i. Describe disaster management cycle.
j. List out any five points for the management of
   i. Natural hazard
   ii. Anthropogenic hazards.
k. What are snowslides (avalanches)? Mention their any three causes, effects and preventive measures.
l. What is GLOF? How does it occur ? What are its effects? Mention its any two preventive measures.

2. Write the differences between

a. Avalanche and GLOF
b. Cyclone and storm.
c. Eye and margin (arm) of a cyclone.

3. Give reasons.

a. Cyclone is frequent in between August and October.
b. In our country there are many glacial lakes which are quite risky in view of outburst.
c. Northern belt of Nepal is very risky in view of snowslide.

Multiple Choice Questions

1. Circle the correct answers.

a. Which of the following natural hazards occurs in tropical regions?

i. Avalanche	ii. Cyclone
iii. GLOF	iv. Landslide.

b. Eye is the central part of a

i. Cyclone	ii. Snowslide
iii. Glacial flood	iv. Glaciated lakes.

c. GLOF (Glacial Lake Outburst Flood) is caused by

i. Deforestation	ii. Construction of dams
iii. Landslide	iv. Global warming

d. Avalanche is also known as

i. Volcanic eruption	ii. Landslide
iii. Snowslide	iv. Glacial flood

e. Which of the following may not cause flood?

i. Cyclone	ii. Snowslide
iii. GLOF	iv. Hurricane

Unit 24

Green House

Total estimated teaching hours = 4

Learning Outcomes

After the completion of this unit, students will learn:

- *introduction to green house effects.*
- *difference between natural and artificial green houses.*
- *climate change.*
- *causes, effects and control measures of climate change.*

John Sawyer (1916AD-2000AD)

KEY WORDS

1. **Convection** : the transmission of heat in fluid by the motion of particle
2. **Macrowaves** : wave having more wave-length and low energy
3. **Pollutant** : the factor which causes pollution
4. **Degrades** : decrement of quality
5. **Starvation** : a condition of severe suffering due to lack of nutrition
6. **Topography** : graphic representation of surface feature
7. **Extinct** : disappeared
8. **Worsening** : worse situation
9. **Incriminating:** charging or suggestive of guilt or blame

Green House Effect

Before understanding green house effects, let's be clear about The Green House. Green House is a building traditionally made of glass, but now of plastic, i.e. polythene in which plants are grown more rapidly than outside. Such buildings trap the heat inside and create warmer environment. The effect is relatively higher temperature in the glass house than that outside for photosynthesis. This is called artificial green house. Our earth works as a natural green house.

Fig.24.1: Green house

Air is polluted because of over-population, unmanaged urbanization and industrialization.

Climate changes and global temperature increases. There is a release of carbondioxide, carbon monoxide, methane etc. in the atmosphere so the deposition of these gases in the atmosphere is increasing. Waste gases create their own sinks and turbulence and may not be able to mix with the atmospheric gases. So a gas layer is formed at the lower level of the atmosphere. The heat radiation gets trapped in this layer which prevents heat from escaping by convection. The heat of the sun is trapped within the atmosphere. The process is called green house effect and the gases responsible for it are called green house gases. The heat of the sun which is reflected by the surface of the earth is again reflected back to the earth by the layer of gases at the lower level of the atmosphere.

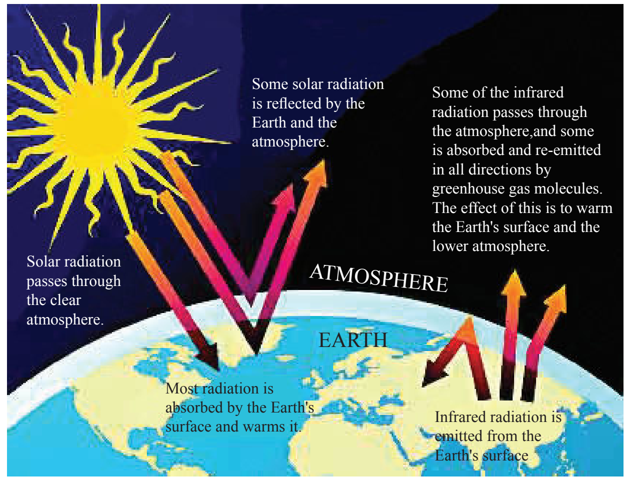


Fig.24.2: Green house effect

Balanced green house effect is useful for living organisms. Due to green house effect, the temperature of the earth remains warmer at night even if the sun dissapears. The temperature of the earth becomes suitable for the survival of organisms. Life processes are possible due to it. But when the green house gases are imbalanced then the problem arises.

Greenhouse effect of atmosphere

The production of carbon dioxide is unavoidable until fossil fuels are burned. Carbon dioxide is not termed as pollutant as the gas in itself is not dangerous to health. But it helps to trap the solar radiation by preventing much of it from escaping from the earth's atmosphere when radiation from the earth occurs. This results in the warming of the planet. This is called greenhouse effect. The greenhouse effect causes rise in the temperature of the atmosphere. The earth receives energy from the sun in the form of radiation. Out of the total energy it receives, 30% of it is reflected. The remaining 70% is absorbed which warms the land, ocean and atmosphere. The solar radiation mostly heats the surface but not the atmosphere. Most of the infrared radiation is emitted from the upper atmosphere to the space. But the infrared radiation emitted by the surface is mostly absorbed in the atmosphere and does not escape directly to the space. The gases like carbon dioxide, carbon monoxide, nitrous oxide, ozone, methane, chlorofluorocarbon and water vapour absorb the infrared radiation reradiated from the surface of the earth. These gases are called greenhouse gases. Because of the greenhouse gas in the atmosphere heat energy obtained from the sun is stored and the temperature of the earth increases. The process in which the emission of infrared radiation by atmosphere warms the surface of a planet is called greenhouse effect.

Global warming of the earth is the result of increased concentration of greenhouse gases which are produced by various activities such as burning of fossil fuel, refrigerator, chemical fertilizer etc. A layer of these gases thus acts like a glass in the artificial greenhouse. Presence of greenhouse gases in the atmosphere is advantageous too. If there were no greenhouse gases as there are now, the earth's temperature would be less by 39°C. You might imagine what the earth would be like in such a low temperature. If there is an accumulation of larger quantity of green house gases, it will cause the rise in the temperature of the earth. Increase in the temperature even in a small degree affects weather and disturbs climate of the earth.

Activity: Prepare a report on the causes of green house effects. Paste pictures to show causes and write captions. Do peer evaluation

Impact of green house effects

We knew that greenhouse effect is essential in the atmosphere. Without green house effect we cannot even imagine life on the earth. But, if the amount of greenhouse gasses increases in the atmosphere, it causes the rise in the temperature which produces various unnatural changes.

Fig.24.3: *Impact of green house effect*

1. The increase in the greenhouse gases in the atmosphere results in the rise of the temperature. This causes the change in the climate.
2. The increased temperature due to the excessive greenhouse effect causes the melting of polar ice caps, and glaciers. This results in the rise of the sea level which is responsible for the coastal flooding.
3. The increase in the greenhouse effect changes the biological activities. There may be alternation in the harvesting periods of crops.
4. The increase in the temperature of the earth causes disturbance to the natural water cycle.
5. Rise in the temperature makes life uncomfortable.
6. It may cause glacial lake outbursting. which leads to flood, landslide, soil erosion and crop destruction.
7. It degrades bio-diversity and affects tourism industry too.
8. It imbalances eco-system, so animals and plants get affected negatively
9. It decreases agricultural production which leads to starvation, diseases, malnutrition, etc.
10. Due to lack of adaptation to the changing climate, various animals and plants may be extinct from the world.

11. Drought, excess rain, drying of water resources, disturbance in water cycle, etc. affect all the organisms on the earth.

Artificial green house

A structure with a glass or plastic roof and wall that warms plants, soil and other things inside the structure with the heat from the solar radiation is called a greenhouse. In a greenhouse the air warmed by the heat of the interior surface is retained in the house by the roof and walls. Thus, a greenhouse traps heat radiation and prevents it from escaping by convection.

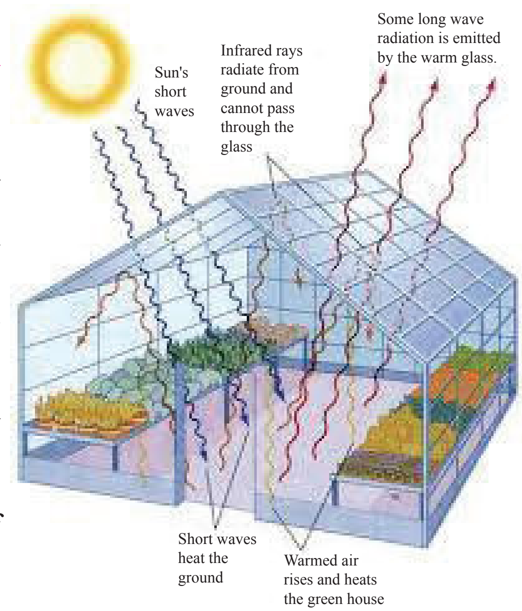


Fig.24.4: *Artificial green house*

When the solar radiation heats the ground inside the greenhouse, the warm surface reradiates macro waves. But these waves cannot escape through the glass/plastic roof and wall, neither can they leave the house by convection. As a result, the inner surface gets heated and warmth is stored inside of it.

We knew that the temperature of the greenhouse is higher than that of the surrounding. Thus a greenhouse can be used to grow flowers, vegetables, fruits that require higher temperature,. Similarly, it is also useful for growing summer plants during winter season. Small model green houses are called cold frames.

Importance and utility of artificial green house

1. Certain types of crops can be cultivated whole year.
2. It is useful at polar regions where cultivation is less done due to low temperature.
3. Non-seasonal vegetables can be cultivated. This will increase the income of farmers.
4. We can protect rare plants of cold regions.
5. Even in cold regions, the plants that can be grown in hot regions can be cultivated. This practice will help production increase.

Activity: Prepare a small green house model by using plastic and bamboo sticks. Plant seeds in that green house and in an open area. Observe the difference of germination of the seeds in both the places and prepare a report on it.

Climate change

The topography of Nepal differs with altitude. The altitude of our country is 60 m to

8848 m from the sea level. Our country is divided into mountain, hill and terai regions. The climatic condition differs i.e. hot in terai regions and cold in mountain regions. Climate change is a long term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature. Our country is very sensitive to climate change. Climate changes naturally. The change takes very long time (period) so that organisms can adapt and survive. But nowadays, due to various human activities, climate is changing rapidly. Many plants and animals cannot adapt within less time (period) so they die and become extinct. The worsening of green house effect plays a crucial role in climate change. Each one of us has to be aware that now we have to reduce green house gas emissions.


Fig.24.5: *Causes of climate change*

Causes of climate change

1. The current climate change is linked mostly to green house gas emissions resulting from human activities.
2. The consumption of fossil fuels for various purposes is the most incriminating factor.
3. Deforestation is the main cause of increasing CO_2 in the environment.
4. Excessive use of chemical fertilizers leads to climate change.
5. Industrialization, urbanization, transportation, etc. release green house gases into the atmosphere which increase global temperature and bring about climate change.
6. Due to natural cause i.e. volcanic eruption, smoke and ashes spread in the atmosphere. They interrupt the heat of the sun and the temperature falls down.
7. Methane gas released by degradable waste, use of other chemicals for various purposes, excessive use of water in industries also increase green house gases leading to climate change.

Fact file:

1. *When we compare the temperature of the world of 1980 AD with the temperature of the world between 2001-2010, we find the temperature increased.*
2. *When excessive chemical fertilizer is used, the left-over fertilizer releases green house gases. When it mixes with water bodies then aquatic creatures die and aquatic plants grow rapidly hampering breeding grounds for animals.*

Climate change and its adverse effect

Climate plays a vital role in physical environment and living things. Climate is the long-term manifestations of weather and other atmospheric conditions in a given area or country. Generally 30 years of statistical summary of weather condition is required to ensure the climatic condition of any area. Climate is the arithmetic average of heat, moisture and wind. Climate varies in most of the areas of the earth.

Fig.24.6: *Sweating earth*

The change in climate due to physical structure, time, season is called climate change. It is a significant time variation in weather patterns occuring over periods ranging from decades to millions of year. It may refer to a change in average weather conditions or in the time variation of weather around long-term average conditions (i.e. more or fewer extreme weather events.

Fig.24.7: *Melting glacier*

Climate change is caused by various factors such as biotic processes, variations in solar radiation received by earth, tectonic plates and volcanic erouptions. Certain human activities have also been identified as significant causes of recent climate change, often reffered to as 'global warming'. In the present situation, due to climate change, there is a rise in the temperature of the earth. It not only affects the physical environment of the earth but also all the organisms poorly. The effects of climate change are as follows.

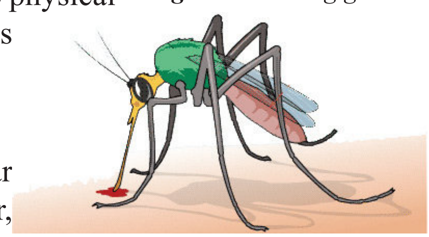


Fig.24.8: *Mosquito*

a. Impact on human health

Along with the rise in the temperature, every year new diseases such as, cholera plague, malaria, kalajar, typhoid, Japanese encephalitis, ebola, bird flu, swine flu etc. spread. The health of human depends on natural and man-made environment.

Due to rise in temperature air becomes hot and Loo spreads in terai region of Nepal, i.e. in tropical and sub-tropical climate every year many people lose their life.

Fact file:
Do you know, in 1995 AD, due to the absence of mist for five years, in New Orleans, Louisiana, a city of USA, there was a rapid growth in the number of termides, mosquitoes and cockroaches and diseases increased as the number of these insects grew?

b. Impact on agricultural system and crop production

Nepal is an agricultural country. Many people depend on agricultural products for their subsistence. Climatic change badly affects the production of agriculture. Various insects and diseases attack our crops. There might be change in crop production areas too.

As climate changes, rise in temperature, irregular rainfall, drought, etc. decrease the crop production. High productive seeds today may be useless tomorrow. Along with 30 main crops, more than 7 thousand species of plants are consumed by humans as food and medicines. Tundra vegetation of Himalayan region is affected by the climate change which, in turn, affects livestock and agricultural farming. Owing to the change in water cycle and seasons, traditional crop species are on the verge of extinction and new diseases are seen in crops. These diseases reduce the crop production.

Fig.24.9: *Dry crops*

c. Impact on water resources

In Nepal, water resource is adversely affected by climatic change. There is imbalance in the flow of water for lack of snowfall, rainfall, excessive melting of snow, etc.

Rise in temperature makes water level increase in rivers at the beginning in summer but it is not sustainable as there is threat from drying rivers following excessive melting of ice and less snowfall. It also has negative effects on aquatic ecosystem, irrigation and hydropower project. There are high chances of avalanches, bursting of glaciers, drought, flood, etc.

Fig.24.10: *Dead fishes*

d. Impact on infrastructures

Because of climatic change, physical infrastructures are threatened of being damaged. Due to Acid rain is the cause of depletion of metal parts of monuments. Roads and bridges are damaged in places where it rains heavily. Flood and landslides may damage infrastructures in hills and on the banks of rivers. The present infrastructure of development may not be sustainable.

e. Impact on average temperature (global warming)

Rise in temperature is one of the impacts of climatic change. If we see the data compiled in 1880 AD, the temperature of the earth has increased by 0.85°C. The temperature of earth has increased by 0.7°C over the last millennium. It is believed that the temperature of earth has increased by 1.4°F within a century. If it continues no organisms will remain untouched by its bad effects in some centuries to come.

In Nepal, a research has shown that global warming has affected a lot. In Nepal, yearly 0.04°C temperature

Fig.24.11: *Earth*

has increased. If the same continues, the temperature will rise by 1.4 °C by 2030 AD and 1.7 °C in 2050 AD. It is estimated that, in western region of Nepal, there will be extreme rise in temperature compared to other regions. If it happens, then life will be difficult in those areas.

f. Impact on biodiversity and eco-system

When climate changes, many animals and plant species cannot adapt to the change in the environment. As a result, various species are on the verge of extinction. Many species have already become entinct before humans identified them. Even after identification, some species are found to be disappearing.

Fig.24.12: *Dead animal*

Fact file:

Plants too are very sensitive to temperature. If there is rise or fall in the temperature in the area they have adapted to, then they may not flower. Change may come at the time of flowering which disturbs their life cycle.

Animals adapted to hot environment will survive in hot environment but others will die. This inciolence affects the food web as well as food chain and the entire ecosystem.

Some plants have the high rate of respiration in comparison to photosynthesis as temperature rises. As a result, CO_2 increases in the environment. Due to rise in temperature, vegetation found in hot regions of Nepal is now found in cold regions too. For example, mango grows in hilly region too and rice is now cultivated in Himalayan region. In Nepal, biodiversity and ecosystem will be badly affected when species get adapted to more height. They may change their place of growth etc. As a result, the situation of diversity may vary in future. Shelter and food may change in many species. Consequently ecosystem will be imbalanced.

g. Impact on natural disasters

The frequency of disasters is high with the rise in climatic change. In south Asian countries such as Sri lanka, the Maldives, Bangladesh, etc. people face the problem of flood and rise in sea level every year. It destroys life as well as property. Various disasters such as excessive rainfall, droughts, storms, cyclones, landslides, etc. make life difficult. In Nepal, irregular rainfall, excessive rainfall, flood, landslide, etc. are seen frequently in the last 10 years.

Fig.24.13: *Natural disasters*

Activity 2: Prepare a report on how climatic change has made life of all organisms difficult.

h. Impact on human settlement

The life of people living in mountain, hills, river banks, etc. is becoming difficult day by day. Climatic change is the cause of various disasters. All the organisms are badly affected. Many settlements are flooded. Many people are displaced. Even in our country many human settlements are affected by flood in Koshi, Seti, Sunkoshi etc. Rivers are blocked by landslide and lake is formed. It outbursts along with debris and water with great force and sweeps away everything on its way.

i. Impact in physical facilities

On the climatic change destroys infrastructures such as roads, bridges, man-made settlements, water resources, etc. are badly affected. It destroys natural beauty and makes our efforts and budget used for the construction useless. There is a huge loss of life, property and infrastructures.

Measures of management of climate change

The measures of managing climate change are as follows.

1. conducting afforestation programmes effectively.
2. awareness programmes for people
3. conserving and managing water resources
4. reducing the production of green house gases.
5. improving cultivation system
6. developing the disease resistant developed varieties of crops
7. low consumption of fossil fuels and bio-fuels.
8. developing alternative energy sources
9. constructing nature friendly development structures.
10. controlling pollution caused by different industries and means of transportation.
11. managing means of transportation in a proper way.
12. managing the waste in a proper way
13. reducing the uncontrolled development structures
14. conserving nature.

Fig.24.14: *Measures*

Lesson Summary

1. A house made of glass or plastic roof and walls that warms plants, soil and other things inside of it with the solar radiation is called greenhouse. It is usually used to grow off-season crops.
2. The earth's atmosphere also acts as a greenhouse due to the presence of CO_2, CO nitrous oxide, methane, ozone, chlorofluorocarbon, water vapour at the lower layer of the atmosphere.
3. Increased greenhouse effect results in the harmful effect such as increased global warming, disturbance in water cycle, climate change, etc.
4. Artificial green house is advantageous to us in many ways
5. A long term change in earth's climate especially the change due to the increase in average temperature is called climate change
6. Climate change is a challenge for our survival and the survival of other organisms.
7. The main causes of climate change are deforestation, emission of green house gases, industrialization, overusing chemical fertilizers, volcanic eruption, etc.
8. The major effects of climate change are global warming, imbalancing biodiversity and ecosystem, degradation of human health and cultivation system, irregular rain, energy crisis, etc.
9. There are many ways of climate change management.

Project work

Write a research report on the possibility of vegetable and fruit cultivation in green houses in the Himali region and present in the class.

Conceptual questions with their answers

Q.1. "The roofs of artificial greenhouse are made slanted." Why?

It is done so to receive more light energy and store more heat.

Q.2. Why is plastic or glass preferred to make a greenhouse?

As they do not allow long wave (heat/infra-red) light to escape once the light enters the greenhouse.

Q.3. "Our earth is also a greenhouse." How?

Yes, our earth is a natural greenhouse as atmosphere is present around the earth which works as a roof for the greenhouse.

Exercise

1. Answer the following questions.

a. What is green house effect? Make a list of green house gases.
b. Is green house advantageous or disadvantageous? Describe in short
c. What is an artificial green house?
d. How can we make a cold frame? Explain in short
e. What is the use of artificial green house?
f. How does a green house work? Describe in short
g. Enumerate the impacts of green house effects.
h. What is climate change?
i. Mention the causes of climate change.
j. List any five impacts of climate change and describe any two of them in short.
k. How are the green house effect and climate change interrelated?
l. How does climate change affect human settlement?
m. How can we manage climate change? Write any five points.

2. Give reasons.

a. The adverse effects of climate change can be minimized by afforestation.
b. Green house effect is advantageous as well as disadvantageous.
c. Green house is very advantageous for Himali region.

Multiple Choice Questions

1. Circle the correct answers.

a. What is green house gas?
   i. The gas necessary for the survival of green plants
   ii. The gas which absorbs solar radiation.
   iii. The gas which produces heat
   iv. The gas which is emitted by industries
b. Which of the following is not the cause of the emission of green house gases?
   i. Aforestation
   ii. Industrialization
   iii. Means of transportation
   iv. Use of fossil fuel
c. What is cold frame?
   i. Green house made for cold regions
   ii. Green house made for very cold regions
   iii. Very big green house
   iv. Small green house
d. What is a green house made of?
   i. Glass or plastic
   ii. Only plastic
   iii. Green glass
   iv. Only glass
e. Which of the following is not the impact of climate change?
   i. Global warming
   ii. Volcanic eruption
   iii. Imbalanced ecology
   iv. Irregular rain

Unit 25 The Earth in the Universe

Total estimated teaching hours = 5

Learning Outcomes

After the completion of this unit, students will learn:

- *the universe, units used to measure astronomical distance.*
- *diurnal and annual motion of earth with their effects.*
- *phases of the moon.*
- *the occurrence of different types of solar and lunar eclipses with diagrams.*

Stephen Hawking (1942AD-2018AD)

KEY WORDS

1. **Galaxy** : a huge group of billions of stars
2. **Asteroids** : minor planets or baby planets
3. **Meteoroids** : combined form of meteors and meteorites
4. **Thermonuclear fusion:** the nuclear fusion reaction that emits heat
5. **Elliptical plane** : the plane of the earth's orbit around the sun
6. **Waning** : gradual decrement
7. **Waxing** : gradual increment
8. **Umbra** : dark shadow
9. **Penumbra** : light shadow

Universe

Astronomy is the scientific study of the heavenly bodies, their motion, relative position and nature. It is the oldest science. People have been amazed by the mysterious phenomena and appearance of the sky. But the study of the universe has always remained challenging due to its vast space and for lack of sophisticated equipments.

Universe is a vast space in which all the heavenly bodies lie. It is believed that the universe is expanding outward continuously. It is hard to determine the size and limitation of the universe. The universe consists of countless galaxies in it. A galaxy has numerous stars. The sun is one of medium-sized stars which is the source of life on earth. This is the star nearest to the earth. It is 150,000,000 km or 1.5×10^8 km away from the earth. The sun lies at the centre of the solar system. All the planets including earth revolve around the sun on their elliptical paths called orbits.

Light year

The distance in space between stars and galaxies is enormous. Therefore it is inconvenient to remember or to express it in units like metre or kilometre. One of the popular units used to express astronomical distance is light year. We know that light travels in space at a speed of 300,000 km each second. A light year is the distance light travels in one year. Light travels 300, 000×60×60×24×365 km in a year. This comes to be about 9,460,000,000,000 km (9.46×10^{12} km). Thus one light year is equivalent to 9.46×10^{12} km which is roughly expressed as 9.5×10^{12} km.

Light from the sun reaches the earth in 8 minutes. 20 seconds. So we can say that this distance is 8.3 light minutes. The nearest star Promixa Centauri is 4.3 light year away from the solar system. It means light takes 4.3 years to reach the solar system from this star. The length of our home galaxy is 100,000 light years and its thickness is estimated to be 80,000 light years. The nearest galaxy (Andromeda) is 2.5 million light years away from the earth. Astronomical unit is another unit that is used to measure the distance between the heavenly bodies. The distance between the sun and the earth is 1 Astronomical unit (1 AU).

we know that

speed of light is 3×10^8 m/s

It means

In 1 sec light travels 3×10^8 m

In 1 min (60 sec) light travels $60\times3\times10^8$ m

In 1 hr (60 min) light travels $60\times60\times3\times10^8$ m

In 1 day (24 hr) light travels $24\times60\times60\times3\times10^8$ m

In 1 year (365 days) light travels $365\times24\times60\times60\times3\times10^8$ m = 9.46×10^{12} km

Light travels 9.46×10^{12} km in one year. Therefore, 1 light year is equivalent to 9.46×10^{12} km

Parsec is another unit used to measure distance between heavenly bodies. The distance from the earth at which the mean radius of the earth's orbit around the sun forms an angle of 1 arc second is called 1 parsec 1 parsec = 3.26 light year

Solar system

A solar system is a group of heavenly bodies that consists of the sun, planets and other objects those orbit around the sun. The solar system includes many smaller objects that revolve around the sun. Eight planet and their satellites, asteroids, comets, meteoroids, etc. revolve around the sun. The largest and most important member of the solar system is the sun. It contains 99.8 percent of the total mass of solar system. The origin and existence of life on the earth is made possible due to the heat and light energy of the sun. It mainly contains hydrogen and helium. The energy is produced by the thermonuclear fusion of hydrogen. The sun is 150,000,000 km away from the earth.

	Average distance from the sun km	Minimum distance from the earth $\times 10^6$ km	Revolution period (approx.)	Average orbital speed km/sec	Diameter (approx.) km	Rotation period (approx.)	Surface temperature (approx.)°C	Gravitational force Earth = 1	Atmospheric gases (potential)	Mass Earth = 1	Density Gm/cm^3	Density Earth = 1	Number of satellites
Mercury	5.76×10^7	891.7	87.97 days	47.89	4,851.2	58.65 days	400°C to -170°C	0.386	not present	0.055	5.42	1.0	0
Venus	10.72×10^7	41.4	224.7 days	35.63	12,035.2	243.02 days	480°C	0.871	CO_2, O_2, H_2O	0.815	5.25	0.97	0
Earth	14.88×10^7		365.25 days	29.79	12,672	23 hours 56 minutes	22°C	1	N_2, O_2, CO_2, H_2O	1	5.52	1.0	1
Mars	22.56×10^7	55.7	686.98 days	24.13	6,742.4	24 hrs. 37 min 22 sec	20°C to -140°C	0.38	CO_2, O_2, $H_2O(s)$	0.107	3.99	0.73	2
Jupiter	76.8×10^7	628.76	12 years	13.06	11,39,040	9 hrs. 55 min 30 sec	-150°C	2.53	H_2, He, CH_4, NH_3, H_2O	317.892	1.33	0.25	67
Saturn	144×10^7	1277.4	29.5 years	9.64	1,15,811.2	10 hrs. 30 min	-180°C	1.07	H_2, He, CH_4, NH_3	95.16	0.69	0.13	62
Uranus	288×10^7	2587	84 years	6.81	50,441.6	17 hrs. 14 min 24 sec	-215°C	0.91	H_2, He, CH_4, NH_3, H_2O	14.54	1.27	0.23	27
Neptune	448×10^7	4130	164 years	5.43	48,972.8	16 hrs. 6 min 36 sec	-220°C	1.14	CH_4, Hydrocarbon	17.15	1.64	0.30	14

Interrelation among the sun, moon and the earth

The sun is the centre of the solar system. It is a medium sezed star and the closes star to the earth. The major component of the star is hydrogen (74%) that works as fuel for nuclear fusion occurring inside it continuousely. Nuclear fusion is the process of energy producing system of the star. When hydrogen nuclei fuse to for helium nuclei soar energy is produced in the form of heat and light. The star is also not at rest but rounds up around the galactic centre of milky way. It takes about 2500 million years to complete one revolution.

The earth is third closest planet to the sun. It is only the planet known which has suitable conditions for the survival of living beings on it. It rotates on its axis as well as revolves around the sun. it takes about one year to complete one round (revolution) around the sun. it is a non-luminous body that means it does not have its own light. It has a moon in its gravitational field

The moon is a natural satellite of the earth. Its revolution and rotation periods are same i. e 27.33 days. As the earth revolves around the sun, it also revolves around the sun with the earth. The comparative study of the sun, moon and the earth are as given below-

A comparative study of the earth, the moon and the sun

Basis	Sun	Earth	Moon
Mass	2×10^{30} kg	6×10^{24} kg	7.35×10^{22} kg
A. Radius equatorial	6955800 km	6371 km	1737 km
Circumference	4370005 km	4370005 km	10921 km
Surface area	11990 times more than that of the earth	510072000 km^3	37930000 km^2
Surface temperature	5700°C	15°C	-125°C to 130°C
Surface acceleration due to gravity	274.2 m/s^2	9.8 m/s^2	1.6 m/s^2
Escape velocity	617 km/s^2	11.2 km/s	2.38 km/s
Rovolution period	2.5×10^8 years	365.25 days	27.33 days
Revolution velocity	221 km/s	29.8 km/s	1.022 km/s
Density	1410 kg/m^3	5514 kg/m^3	3344 kg/m^3
Atmosphere	H_2 He	N_2, O_2, CO_2 Ar	Ar, He, Na, K, H_2, Rn

Motion of the earth

The earth is not stationary. It is dyanamic and spins on its axis as well as in the orbit around the sun. Its motion can be classified into following two types-

A. Diurnal motion B. Annual motion

A. Diurnal motion

The earth spins on its axis which is called as diurnal motion of the earth. A complete rotation of the earth on its axis is one rotation of the earth. The time takes for one rotation is about 24 hr (23 hr, 56 m and 4s). It is also known as a solar day. The earth spins in anticlock wise direction (west to east).

Effects of diurnal motion of the earth

When the earth rotates in its axis, only one portion of the earth's surface faces the sun and experiences daylight. The other portion which is away from the sun's rays will be in darkness. Thus it causes day and night on the earth's surface.

When the earth rotates from west to east every part will be brought under the sun at some time or other. Thus in the rotation the eastern part will receive the light earlier than the western part. This causes the earlier sunrise in the eastern part than in the western part of the earth.

B. Annual motion of the earth

The earth also moves around the sun in a fixed path called orbit, which is called as annual motion of the earth. It takes about 365 days (365 days, 6 hr, 9 min and 10 sec to complete one round called as revolution.

We known that the earth goes round the sun and completes its revolution in 365.25 days which is a year. It is not possible to show a quarter of the day (0.25). therefore the duration of normal year in 365 days only. Six hours of every year are accumulated for four years make one extra day available for every fourth year. Thus in an interval of every four years the duration of year becomes 366 days. It Is called leap year. When the earth spins in its axis it makes an angle of 66.5 with the elliptical plane. This causes the varying length of day and night and change in seasons. If the axis was not tilted there wouldn't be varying lengths of day and night.

The following diagram illustrates how variable lengths of the day and night and seasons occur on the earth.

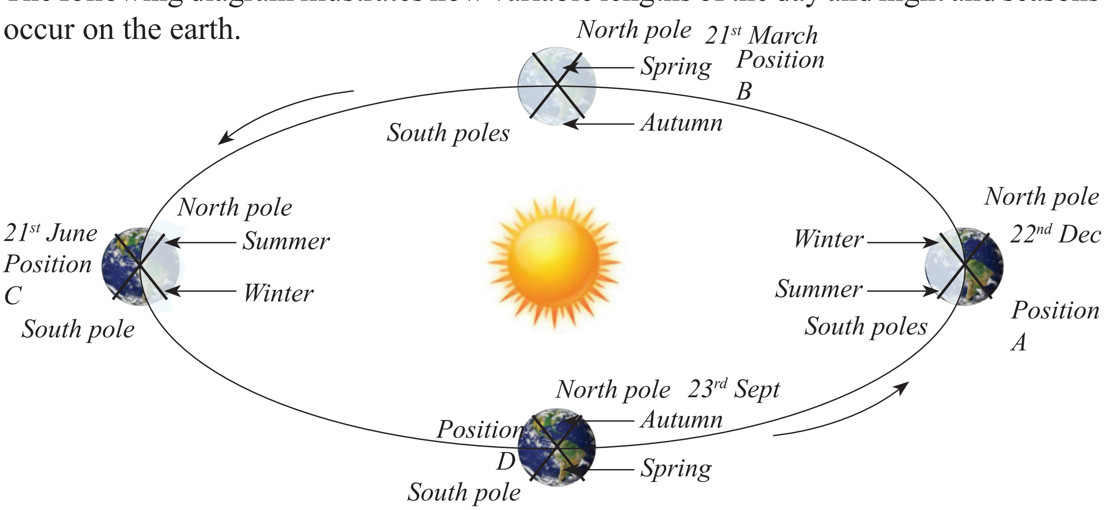


Fig.25.1: *Earth's annual motion*

Effect of annual motion of the earth

In position i.e on 22 December the north pole of the earth is tilted away from the sun. in this position the north hemisphere receives slanted rays of the sun for short period thus the hemisphere experiences winter and the night is the longest. Unlike it southern hemisphere experiences summer and the day is the longest.

In position C i.e 27 june the north pole of the earth is tilting towards the sun and maximum part of northern hemsphere recieves the sun rays of the sun for longer time. In the position the hemisphere experiences summer and the day will be the longest. But in southern hemisphere the situation is opposite.

In positions 'B' and 'D' (21st march and 23rd september respectively) Equal parts of the both hemispheres receive the mild sun rays for equal times. It causes equal duration of day and night all over the world on these days. They are called as spring equinox and autumn equinox in northern hemisphere. Unlike it in southern hemisphere the condition is opposite.

Sun, Earth and moon

Moon is the nearest heavenly body of the earth. It is only the satellite of the earth. We know that earth goes around the sun in its orbits once in a year. similarly the moon also revolves around the earth in its orbit. As well as on its axis. The revolution period of the moon around the earth is named differently as sidereal month and synodic month.

a. Sidereal month

The moon makes a complete revolution around the earth once in a 27.33 days (27 days, 7 hours, 43 minutes and 11 seconds) and it is called sidereal month (Nakshyatra mass). In the illustration the time taken to move the moon form M_1 position to M_2 position is one sidereal month.

Once the sun, earth and moon are in the same straight line as M_1 condition of the moon. In the given diagram, it takes certain time for the earth and moon to come to the same position. In a period

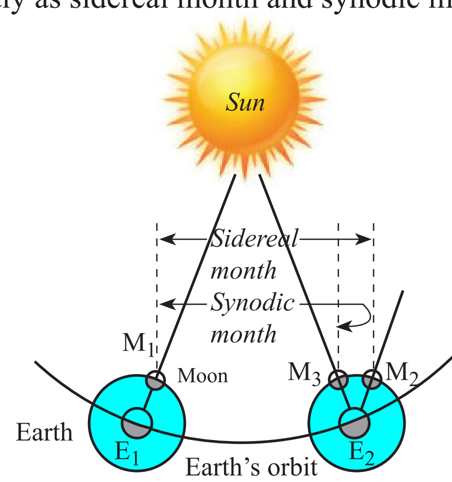


Fig.25.2: *Monthly motion*

Of 27.33 days the earth and moon come to the previous position but they do not lie in the same straight line with the sun as before. So the moon has to travel further for 2 days 5hours to be in the same straight line with the sun. The duration for the moon to move from M_1 position to M_3 position (M_1M_3) is called synodic month. The moon in M_1 position is a new moon day and it takes 29.5 (29 day, 12 hr, 44 m, 3s) days to be in the next new moon position. The duration between two successive phases of the moon is called synodic month (Chandra mass).

Phases of the moon

The moon does not have its own light but its surface seems illuminated due to the light reflected from the sun. the size and shape of the illuminated portion of the moon is not always constant. The illuminated part of the moon first appears as a thin crescent and increases to a bright sphere and again becomes invisible after crescent form. The process repeats as it again appears as crescent and gradually grows into full bright sphere as before. This type of periodic change of the shape of the moon is called phases of the moon.

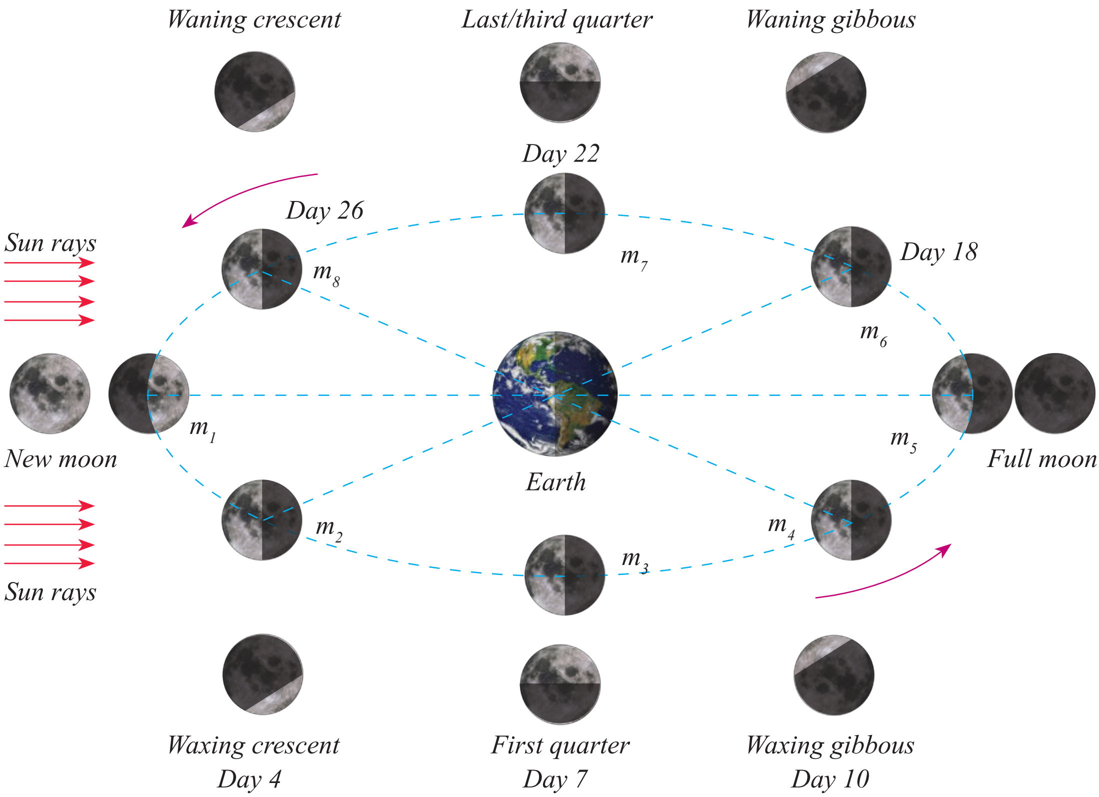


Fig.25.3: *Phases of moon*

When the moon lies in between the sun, and earth in a straight its illuminated portion is facing away from the earth and moon is not seen at all from the earth. It is called new moon (m_1). The appearance of illuminated surface increases everyday. On day 7, the moon's surface is illuminated in the form of hemisphere first quarter (m_3). The size of the bright part increases further and only a small part remains dark and it is called waxing gibbous. When the moon reaches the other side of the earth and falls in the same straight line, the moon appears as a bright round disc. It is called full moon (m_5)

After a full moon condition the illuminated portion starts decrease. When only a small part of the moon is covered by darkness it is called waning gibbous (m_6). It further passes to last quarter (m_7), waning crescent (m_8) and in one complete revolution the new moon (m_1) occurs again.

A period of 15 days from new moon day to full moon day in which the waxing of the moon occurs or the appearance of the illuminated portion increases and becomes maximum is called bright half (Shukla pakshya). The period of 15 days from full moon day to new moon day in which the waning of the moon occurs i.e. the appearance of the illuminated portion of the moon goes on decreasing and the moon finally disappears is called dark half (Krishna pakshya). The moon rises along with the sun on the day of new moon. It rises along with the sun set on the full moon. The moon rises on the mid day at first quarter and it rises at mid night on third quarter.

Umbra and penumbra

Arrange the ball, an opaque object in front of a sheet of paper or near a wall so that the shadow of the opaque object casts on the paper.

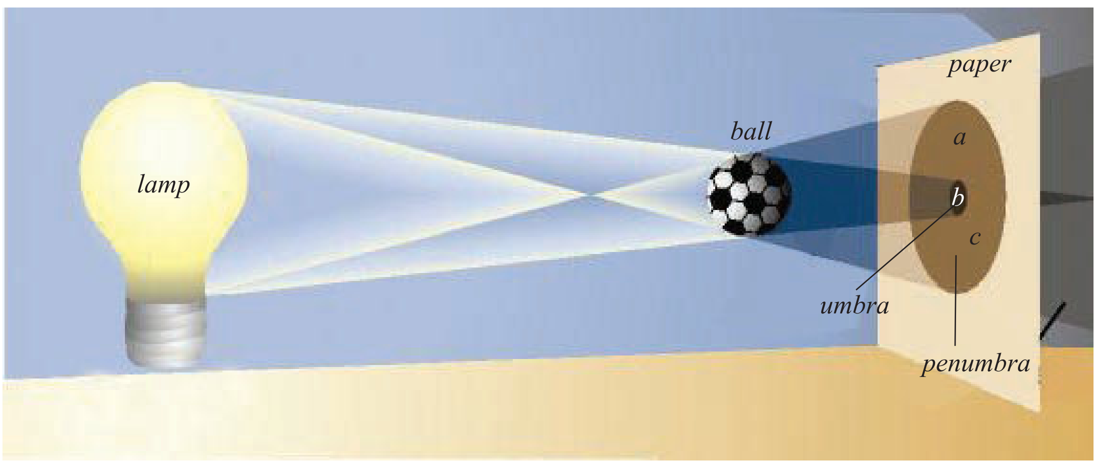


Fig.25.4: *Umbra and penumbra shadow*

The region of complete darkness where all the light from the source is blocked called umbra. In the above figure, 'b' is umbra. The region of partial darkness, where the light rays are partially blocked is called penumbra. In the figure, a and c show penumbra. Umbra and penumbra determine the type of eclipses.

Eclipse

The revolution of the earth around the sun and the moon around the earth may cause them to line up in space. If they fall on the same line and plane then the earth or moon's surface may be obstructed partially or completely. It is called eclipse.

An eclipse is the passage of a non-luminous body into the shadow of another body.

a) A lunar eclipse occurs when the sun, the earth and the moon are in line so that the shadow of the earth falls upon the moon.

b) An eclipse of the sun or (solar eclipse) occurs when the shadow of the moon falls on the earth.

Lunar eclipse

When the earth passes between the sun and the moon the shadow of the earth may fall on the moon and causes the partial or complete darkness of the moon's surface. It is called lunar eclipse. If the moon is completely darkened it is called total lunar eclipse and if it is darkened partly it is called partial lunar eclipse.

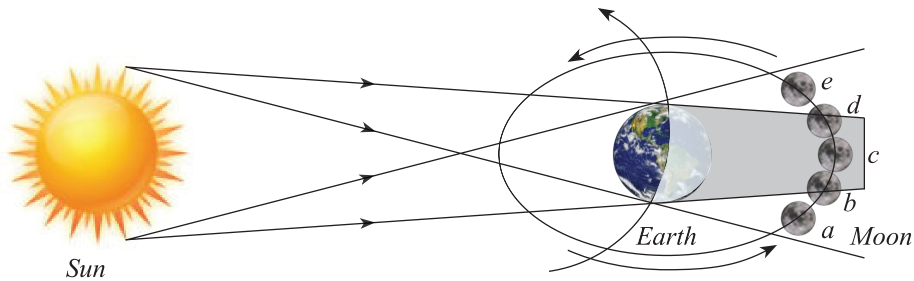


Fig.25.5: *Lunar eclipse*

In the above diagram the lunar eclipse occurs when the moon lies in the position 'b' to 'd'. when the moon is in position 'b' it seems to be partially blocked forming a partial eclipse. If the moon reaches position 'c' it is completely blocked forming a total lunar eclipse. When it passes to position 'd' there is a partial eclipse again as in the position 'b'. when the moon reaches position 'e', or lies at position 'a', seems to be dimmed as it is under the penumbral shadow of the earth. They are also termed as penumbral eclipse if the moon passes beyond 'e', no eclipse is seen.

Lunar eclipse occurs on a full moon only. The possibility of the occurrence of the lunar eclipse is more because the shadow cast by the earth is much bigger than the size of the moon. The duration of the total lunar eclipse remains as much as 1 hour 40 minutes. The occurrence of lunar eclipse begins from the eastern part of the moon because the revolution of the moon occurs in eastward direction.

Solar eclipse

When the moon passes between the sun and the earth and the sun is blocked, a shadow is cast on the earth, the sun is partly or wholly darkened. From this shadowed zone of the earth, the sun is not seen partially or completely , it is called solar eclipse. In this, solar eclipse may be partial or total. But the occurrence of total solar eclipse is rare. The total solar eclipse occurs in the duration of 360 years at a particular place on the earth. The total solar eclipse lasts for maximum 8 minutes only and unlike lunar

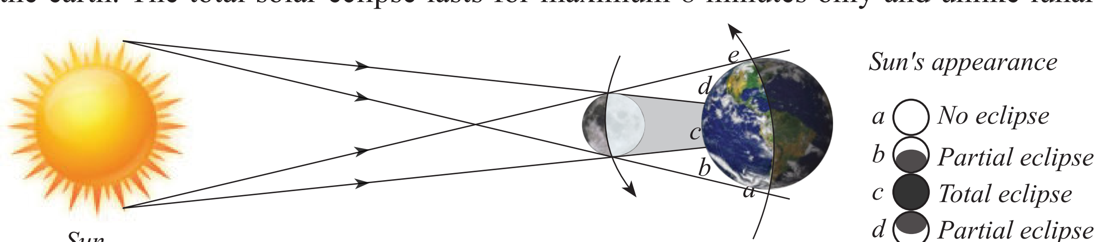


Fig.25.6: *Solar eclipse*

eclipse the solar eclipse begins from western part of the sun.

In the above diagram, the sun seems to be totally darkened when viewed from position 'c' and partially darkened while viewing form position 'b' and 'd'.

Annular solar eclipse

If two umbral opposite cones are formed by the moon's shadow in between the moon and the earth. The bright part of the sun is seen as a ring called annular eclipse. The occurrence of annular eclipse is very rare.

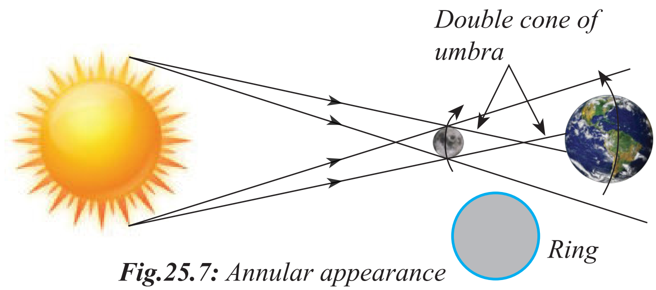


Fig.25.7: *Annular appearance*

Eclipses do not occur on every full moon or new moon

For the occurrence of an eclipse the moon, earth and sun must lie on the straight line and either the moon or the earth must obscure the sun. as the orbital plane of the moon and the earth makes an angle of 5.15° to 5.5° on every new moon the sun, moon and earth lie on the same line bit not on the same plane. Therefore neither of the heavenly objects casts the shadow on another. The points where the intersection of the orbits of the moon and the earth occur are called nodes (Rahu and Ketu). The line that joins the two nodes is called line of nodes. An eclipse occurs only when line of nodes coincide or nearly coincide with the line joining the sun and the earth i.e. sun and earth are at the nodes or close to the nodes.

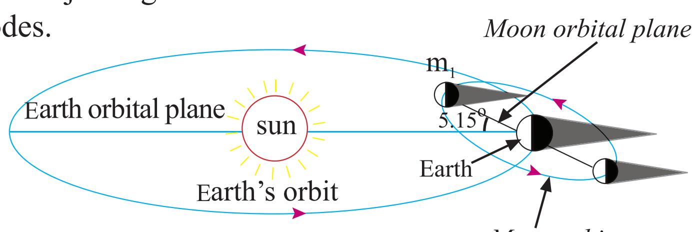


Fig.25.8: *Orbit planes of earth and moon*

Lesson Summary

1. The distance in space is measured by a unit called light year. It is the distance travelled by light in one year which is equal to 9.46×10^{12} km
2. Astronomical unit and parsec are also used for the same purpose.
3. The sun's family that consists of 8 planets, satellites, comets, asteroids, and meteors is called solar system. The earth is the only planet where life is found.
4. The earth has two types of motion- diurnal motion and annual motion. The spinning of the earth on its axis once in 24 hours is called a rotation. The earth goes round the sun in its orbit in 365.25 days. It is called revolution.

5. The rotation causes day and night and the revolution causes seasons and elongation days and nights
6. The earth goes round the sun. At the same time, the moon revolves round the earth. The moon completes one revolution around the earth once in a 27.33 days called sidereal month. The time taken by the moon to repeat new moon condition is synodic month. The duration of synodic month is about 29.5 days.
7. The periodic change in the apparent shape of the moon is called phases of the moon.
8. An eclipse occurs when a shadow is cast on the moon or the earth.
9. A lunar eclipse occurs when the earth's shadow falls on the moon and a solar eclipse occurs when the sun is obscured by the moon thereby letting its shadow on the earth's surface.

Project work

1. Write on a chart paper various informations on planets mentioned in the text and display it in your classroom.
2. Draw on a chart paper a lunar eclipse and a solar eclipse and display it in your classroom.

Conceptual questions with their answers

Q.1. "Partial eclipse remains longer then the total eclipse." Why?

It is due to the fact that a partial eclipse is usually caused by penumbra while a total eclipse is caused by umbra. And the area of penumbra is more than the area of umbra. That's why partial eclipse remains longer than the total eclipse.

Q.2. "Lunar eclipse remains longer than Solar eclipse." Explain.

The following explanation justifies the statement.

a. The area of earth's shadow is more than that of the moon's shadow

b. During the lunar eclipse both the earth and the moon move in the same direction but during the solar eclipse they are in the opposite direction.

From the above we can conclude that the moon has to remain for a longer time in the shadow of the earth, than the earth has to be in the shadow of the moon.

Exercise

1. Answer the following questions.

a. What is universe? Which unit is used to measure the distance in space?
b. What is light year? How many kilometres make one light year?
c. Name the nearest star next to the sun (from the earth). How far is it?
d. What is the effect of diurnal motion?
e. What is the effect of the inclination of the earth's orbit with the ellipse by 66.5°?
f. When are the durations of day and night equal in the earth?
g. How does lunar eclipse occur? Explain with diagram.
h. How does the solar eclipse occur? Explain with diagram.
i. What is annular eclipse? When does it occur?
j. Why do the solar and lunar eclipses not seen from all parts of the earth?
k. During the solar eclipse on the earth, what eclipse can be observed from the moon?

2. Write the difference between

a. Rotation and revolution of the earth
b. Solar eclipse and lunar eclipse
c. Sideral month and synodic month
d. Bright half and dark half
e. New moon and full moon.
f. Umbra and penumbra
g. Partial eclipse and total eclipse

3. Answer the following questions after the study of the given diagram 25.9.

a. What is the period between M_1 and M_2 called? What is its duration?
b. How long does the moon take from M_2 to M_3?
c. What is the motion between M_1 to M_3 called? What is its duration?
d. What phase of the moon will there be in M_1 and M_3 conditions?

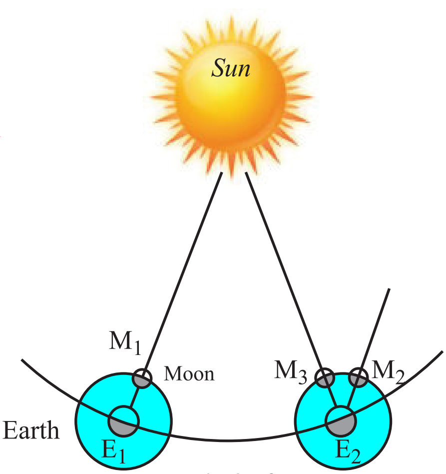


Fig.25.9:

4. Give reasons.

a. Eclipses occur on new moon and full moon only.
b. Eclipses do not occur on every new moon and full moon.
c. Lunar eclipse stays longer than solar eclipse

d. During total lunar eclipse the moon appears reddish.
e. On 21 March the whole world has equal durations of day and night.
f. Moon rising occurs 48 minutes later daily.

5. Answer the questions on the basis of the given diagram 25.10.

a. If E_1 has summer in the northern hemisphere, what season will there be in E_3 ?
b. When are day and night equal?
c. When is night the longest in the northern hemisphere?
d. Write the month and day when the earth comes to position E_3 and E_4?

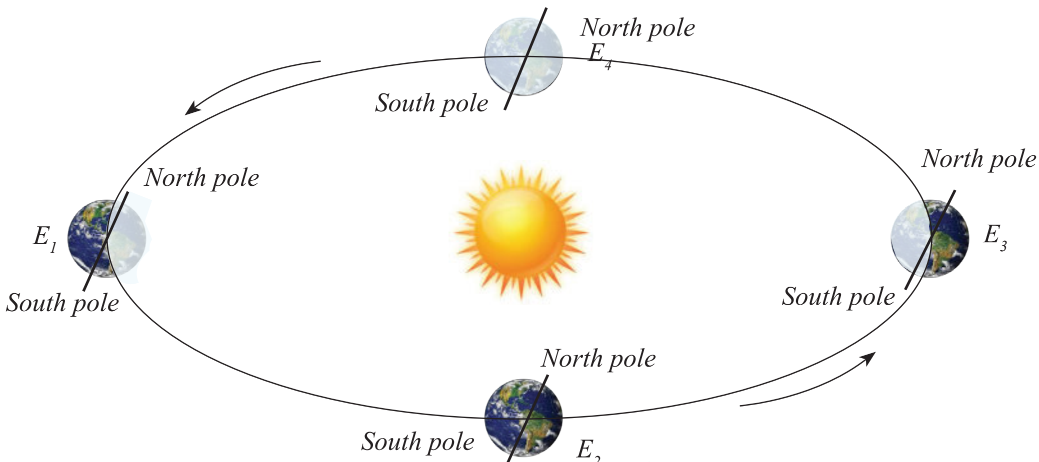


Fig.25.10:

Multiple Choice Questions

1. Tick the correct alternative.

a. Which one is sidereal month?
   i. Rotation of the moon on its axis
   ii. Rotation of the earth on its axis
   iii. A complete revolution of the moon around the earth
   iv. A complete revolution of the earth around the sun.
b. What is the duration of synodic month?
   i. 27.33 days ii. 29 ½ days iii. 24 hours iv. 365 days
c. Which one of the following events occurs in the Northern hemisphere?
   i. The longest day ii. The longest night.
   iii. The shortest day iv. The coldest day.
d. What do you call when durations of day and night are equal?
   i. Equinox ii. Crescent iii. First quarter iv. Solistice
e. In which condition can we see geo eclipse from the moon?
   i. During total solar eclipse ii. During lunar eclipse
   iii. At crescent iv. At new moon.

Specification Grid for Science and Environment (Theory) class IX

Area	S.N.	Topics	K	U	A	HA	Remark
A. Physics	1	Measurement	5 × 1	3 × 2	2 × 3	2 × 3	23 marks
	2	Force					
	3	Machine					
	4	Work, energy and power					
	5	Light					
	6	Sound					
	7	Electricity and magnetism					
B. Chemistry	1	Matter	5 × 1	3 × 2	2 × 3	2 × 3	23 marks
	2	Chemical reaction					
	3	Solubility					
	4	Some gases					
	5	Metal					
	6	Carbon and its compounds					
	7	Water					
	8	Materials in daily use					
C. Biology	1	Plants and animals	5 × 1	3 × 2	2 × 3	2 × 3	23 marks
	2	Adaptation					
	3	Sense organs					
	4	Skeletal system					
	5	Digestive system					
	6	Evolution					
	7	Nature and environment					
D. Astro + Geo	1	Natural disaster	1 × 1	1 × 2	1 × 3		6 marks
	2	Green house					
	3	The earth in the universe					

K = knowledge
U = understanding
A = application
HA = Higher ability

Total question	16	10	7	6	39
Total marks	16	20	21	18	75

Note: 1- While setting questions don't repeat the lessons for objective questions.
2- Don't repeat the lesson for any type of subjective question.

Practise Yourself

Class: 9 FM: 75

Time: 2 hrs. 15 min. PM: 30

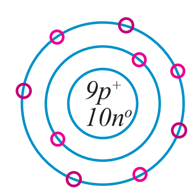
A. Very short answer-type questions: (Knowledge type) **16×1=16**

Answer the following questions in one sentence

1. On which system of units are SI units based?
2. Which type of machine is a pair of scissors?
3. Write the formula to be used to calculate kinetic energy.
4. What is the speed of sound in water?
5. Write the formula that gives the value of resistance.
6. Name the element that has atomic number 15 and atomic weight 31.
7. Which chemical is used to prepare oxygen gas by heating process?
8. Mention any two properties of metals.
9. Name the compounds that cause temporary hardness of water.
10. Write names of any two chemical fertilizers.
11. Name the group of plants with their excess food in the form of glycogen.
12. Name any two arborial animals.
13. Name the smallest bone found in human body.
14. Name the layer of the eye that has photoreceptor cells.
15. Which evolution theory is also called the theory of natural selection?
16. What type of eclipse occurs when the earth falls in between the sun and the moon?

B. Short answer-type questions (Understanding type) **10×2=20**

1. Write any two differences between fundamental and derived units.
2. How does a wheel and axle work as a continuous lever? Describe in short.
3. What effect is seen on the resistor of a conducting wire when-
   a. its cross sectional area is increased?
   b. its length is increased?
4. Answer the following questions with the help of the diagram given.
   a. Is it electropositive or electronegative? Why?
   b. What is its valency? How?



5. Why is copper a suitable metal to make utensils as well as electric wire?
6. Why does hard water not form lather with soap easily?
7. How are camels and cactus adapted to desert?

8. How do ears work? Describe in short.
9. How is food digested in duodenum. Explain briefly.
10. How can you show that 1 light year is equal to 9.46×10^{12}km ?

C. Long answer-type question: (Application and higher ability type) 13×3=39

1. If v is final veclocity, 'u' is initial velocity, 'a' is acceleration due to gravity and 's' is distance covered by a body, derive the inter-relation among them.
2. Usually signals are red. Why? How can you demonstrate that white light consists of seven colours?
3. A car is running in the velocity of 90 km/h. If it is stopped at a distance of 20 metres by applying brakes, calculate its retardation and time taken to stop it.
4. What relation is in between resistivity and conductivity. If resistivity of manganin is $4.43\times10^{-5}\ \Omega$ m, calculate its conductivity.
5. Translate the following word-equations into the form of balanced formulae equations.
   a. Calcium oxide+Nitric acid→calcium nitrate+water
   b. Zinc+Nitrogen →Zine nitride
   c. Iron+ Oxygen→Ferric oxide
6. Describe in short with a diagram the method of making crystals of $CuSO_4$ from its given solution.
7. Dependence on chemical fertilizers should be shifted to organic fertilizers. Why? Clarify by giving three suitable points in support to your answer.
8. Sketch a neat and labelled diagram of apparatus set for the preparation of that gas which neither burns itself nor helps in burning. Also mention a balanced chemical equation involved in the preparation of the gas.
9. Classify the following organisms with one special feature of each
   a. Sea anemone b. Mosquito c. Salamander
10. Apply the knowledge of the theory of natural selection to explain the mechanism of elongation of the neck of giraffes.
11. Sketch a neat and labeled diagram of different bones of human forelimb.
12. Sketch a graphic diagram of pond ecosystem and explain in short what role can be played by decomposers in balancing the nature.
13. How can you prepare a low-cost greenhouse for your nursery? Describe briefly the role of transparent materials used in controlling the temperature inside it.

Specification grid for practical (Science)

S.N.	Activities	Marks
1.	Sketching/labelling/characters	5
2.	Report writing/Experiment	5
3.	Material construction	5
4.	Micro project	6
5.	Viva/Record	4
6.	Total	25

Syllabus

Physics

		Theory	Practical
1.	Measurement	3	1
	- Fundamental and derived units		
2.	Force	5	1
	- Motion, force and inertia		
	- Newton's laws of motion laws		
	- Balanced and imbalanced forces		
3.	Machines	5	2
	- Principles of moment		
	- Mechanical advantages		
	- Velocity ratio		
	- Performance of machines		
4.	Work, Energy and Power	8	2
	- Types of energy		
	- Inter-relationship among work, energy and power		
	- Human power		
5.	Light	3	1
	- Reflection/refraction		
	- Use of X-ray and ultra-violet rays		
6.	Sound	10	2
	- Sound waves		
	- Infra, audible and ultra sound		
	- Echo		
	- Loudness, pitch and velocity		
7.	Current, Electricity and Magnetism	10	2
	- Rules of Ohm		
	- Obstruction		
	- Conduction capacity		
	- Magnetic area		
	- Magnetic force line		
	- Elements of geo-magnetism		
	Total	42	10

Chemistry

		Theory	Practical
1.	Classification of elements	9	2
	- Elements and compounds		
	- Nuclear structure		
	- Electronic configuration		
	- Valence, electron and valency		
	- Chemical bondes		
	- Formula		
	- Radical		
	- Ion		
2.	Chemical reaction	2	-
	- Chemical equation		
3.	Solubility	5	3
	- Saturated and unsaturated solution		
	- Super-saturated solution		
	- Solubility		
	- Relation between solubility and temperature		
	- Crystallization		
4.	Some gases	5	3
	- Construction, use and qualities of Hydrogen, Oxygen and Nitrogen gases		
5.	Metals	5	-
	- Qualities of metals		
	- Difference between metals and non-metals		
	- Roles of metals in organisms		
6.	Carbon and its compounds	6	-
	- Carbons in ordinary things		
	- Chemical and physical qualities of carbon		
	- Organic and inorganic compounds		
7.	Water, source, quality, etc.	4	2
	- Source, quality, types, hardness		
8.	Chemical fertilizers	6	-
	- Used in agriculture, types and uses of nitrogen, phosphorus, potassium compounds		
	Total	42	10

Biology

		Theory	Practical
1.	Classification of plants and animals	8	3
	- Flowering and non-flowering plants		
	- (Up to sub-division), vertebrate and invertebrate animals (class)		
	- Mosquito, its life cycle and negative effects		
2.	Adaptation of living beings	5	1
	- Concept of adaptation of plants and animals		
	- Micro-organisms		
	- Introduction to bacteria, fungi, virus, protozoa and diseases caused by them		
	- Life processes of organisms/living beings		
3.	Systems	5	1
	- Inter-relationship of systems with cells, tissues and organs		
	- Types of vegetations and the places where they are found		
4.	Human skeletal system	4	1
	- Function		
	- Classification of bones		
5.	Sense organs	2	-
	- Sense organs in human body and their functions		
6.	Human nutritions	5	2
	- Digestive system, teeth, respiratory system, transpiration and its importance		
7.	Evolution	4	-
	- Introduction to evolution		
	- Principles of evolution		
8.	Nature and Environment	9	2
	- The factors that affect plants and animals		
	- Impacts of climate change		
	- Introduction to eco-system		
	- Autotrophs and heterotrophs		
	- Human dependence on other organisms (Food, clothes, shelter, etc.)		
	Total	42	10

Astronomy and Geology

		Theory	Practical
1.	Natural calamities/hazards	4	1
	- Introduction to natural and man-made hazards		
	- Avalanches, glacial lakes and hurricane		
	- Causes, effects and measures to control		
2.	Green house	4	-
	- Introduction to the impact of green house		
	- Artificial green house and its use		
	- Introduction to climate change		
	- Causes and effects		
	- Measures to control		
3.	Universe	4	1
	- The earth in the universe		
	- Diurnal motion and annual motion		
	- The phases of the moon		
	- Situation of the sun, earth and moon		
	- Shadows: Umbra and Penumbra		
	- Lunar and solar eclipses		
	Total	12	2