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SCIENCE

TEXTBOOK FOR CLASS IX

Part - II



0964



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Chapter 3



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ATOMS AND MOLECULES

Ancient Indian and Greek philosophers have always wondered about the unknown and unseen form of matter. The idea of divisibility of matter was considered long back in India, around 500 BC. An Indian philosopher Maharishi Kanad, postulated that if we go on dividing matter (*padarth*), we shall get smaller and smaller particles. Ultimately, a stage will come when we shall come across the smallest particles beyond which further division will not be possible. He named these particles *Parmanu*. Another Indian philosopher, Pakudha Katyayama, elaborated this doctrine and said that these particles normally exist in a combined form which gives us various forms of matter.

Around the same era, ancient Greek philosophers – Democritus and Leucippus suggested that if we go on dividing matter, a stage will come when particles obtained cannot be divided further. Democritus called these indivisible particles atoms (meaning indivisible). All this was based on philosophical considerations and not much experimental work to validate these ideas could be done till the eighteenth century.

By the end of the eighteenth century, scientists recognised the difference between elements and compounds and naturally became interested in finding out how and why elements combine and what happens when they combine.

Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

3.1 Laws of Chemical Combination

The following two laws of chemical combination were established after

much experimentations by Lavoisier and Joseph L. Proust.

3.1.1 LAW OF CONSERVATION OF MASS

Is there a change in mass when a chemical change (chemical reaction) takes place?

Activity 3.1

- Take one of the following sets, X and Y of chemicals—

X	Y
(i) copper sulphate	sodium carbonate
(ii) barium chloride	sodium sulphate
(iii) lead nitrate	sodium chloride
- Prepare separately a 5% solution of any one pair of substances listed under X and Y each in 10 mL in water.
- Take a little amount of solution of Y in a conical flask and some solution of X in an ignition tube.
- Hang the ignition tube in the flask carefully; see that the solutions do not get mixed. Put a cork on the flask (see Fig. 3.1).

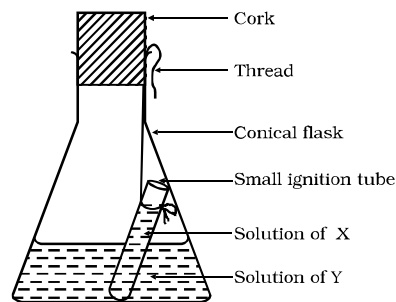


Fig. 3.1: Ignition tube containing solution of X, dipped in a conical flask containing solution of Y

- Weigh the flask with its contents carefully.
- Now tilt and swirl the flask, so that the solutions X and Y get mixed.
- Weigh again.
- What happens in the reaction flask?
- Do you think that a chemical reaction has taken place?
- Why should we put a cork on the mouth of the flask?
- Does the mass of the flask and its contents change?

Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.

3.1.2 LAW OF CONSTANT PROPORTIONS

Lavoisier, along with other scientists, noted that many compounds were composed of two or more elements and each such compound had the same elements in the same proportions, irrespective of where the compound came from or who prepared it.

In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 1:8, whatever the source of water. Thus, if 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained. Similarly in ammonia, nitrogen and hydrogen are always present in the ratio 14:3 by mass, whatever the method or the source from which it is obtained.

This led to the law of constant proportions which is also known as the law of definite proportions. This law was stated by Proust as *“In a chemical substance the elements are always present in definite proportions by mass”*.

The next problem faced by scientists was to give appropriate explanations of these laws. British chemist John Dalton provided the basic theory about the nature of matter. Dalton picked up the idea of divisibility of matter, which was till then just a philosophy. He took the name ‘atoms’ as given by the Greeks and said that the smallest particles of matter are atoms. His theory was based on the laws of chemical combination. Dalton’s atomic theory provided an explanation for the law of

conservation of mass and the law of definite proportions.

John Dalton was born in a poor weaver’s family in 1766 in England. He began his career as a teacher at the age of twelve. Seven years later he became a school principal. In 1793, Dalton left for Manchester to teach mathematics, physics and chemistry in a college. He spent most of his life there teaching and researching. In 1808, he presented his atomic theory which was a turning point in the study of matter.



John Dalton

According to Dalton’s atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms. The postulates of this theory may be stated as follows:

- All matter is made of very tiny particles called atoms, which participate in chemical reactions.
- Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
- Atoms of a given element are identical in mass and chemical properties.
- Atoms of different elements have different masses and chemical properties.
- Atoms combine in the ratio of small whole numbers to form compounds.
- The relative number and kinds of atoms are constant in a given compound.

You will study in the next chapter that all atoms are made up of still smaller particles.



Questions

1. In a reaction, 5.3 g of sodium carbonate reacted with 6 g of acetic acid. The products were 2.2 g of carbon dioxide, 0.9 g water and 8.2 g of sodium acetate. Show that these

observations are in agreement with the law of conservation of mass.

sodium carbonate + acetic acid
 $\rightarrow$ sodium acetate + carbon dioxide + water

2. Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas?
3. Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?
4. Which postulate of Dalton's atomic theory can explain the law of definite proportions?

3.2 What is an Atom?

Have you ever observed a mason building walls, from these walls a room and then a collection of rooms to form a building? What is the building block of the huge building? What about the building block of an ant-hill? It is a small grain of sand. Similarly, the building blocks of all matter are atoms.

How big are atoms?

Atoms are very small, they are smaller than anything that we can imagine or compare with. More than millions of atoms when stacked would make a layer barely as thick as this sheet of paper.

Atomic radius is measured in nanometres.
 $1/10^9 \text{ m} = 1 \text{ nm}$
 $1 \text{ m} = 10^9 \text{ nm}$

Relative Sizes	
Radii (in m)	Example
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

We might think that if atoms are so insignificant in size, why should we care about them? This is because our entire world is made up of atoms. We may not be able to see them, but they are there, and constantly affecting whatever we do. Through modern techniques, we can now produce magnified images of surfaces of elements showing atoms.

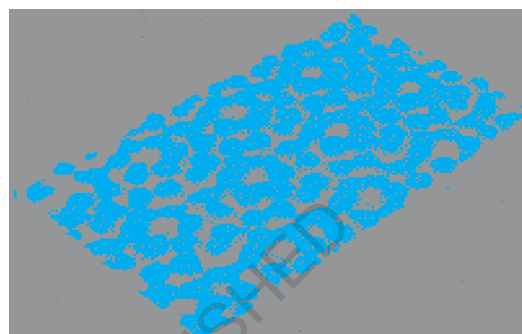


Fig. 3.2: An image of the surface of silicon

3.2.1 WHAT ARE THE MODERN DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element. Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element.

	Hydrogen		Carbon		Oxygen
	Phosphorus		Sulphur		Iron
	Copper		Lead		Silver
	Gold		Platina		Mercury

Fig. 3.3: Symbols for some elements as proposed by Dalton

In the beginning, the names of elements were derived from the name of the place where they were found for the first time. For example, the name copper was taken from Cyprus. Some names were taken from specific colours. For example, gold was taken from the English word meaning yellow. Now-a-days, IUPAC (International Union of Pure and Applied Chemistry) is an international scientific organisation which approves names of elements, symbols and units. Many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

For example

- (i) hydrogen, H
- (ii) aluminium, Al and not AL
- (iii) cobalt, Co and not CO.

Symbols of some elements are formed from the first letter of the name and a letter, appearing later in the name. Examples are: (i) chlorine, Cl, (ii) zinc, Zn etc.

Other symbols have been taken from the names of elements in Latin, German or Greek. For example, the symbol of iron is Fe from its Latin name ferrum, sodium is Na from natrium, potassium is K from kalium. Therefore, each element has a name and a unique chemical symbol.

passage of time and repeated usage you will automatically be able to reproduce the symbols).

3.2.2 ATOMIC MASS

The most remarkable concept that Dalton's atomic theory proposed was that of the atomic mass. According to him, each element had a characteristic atomic mass. The theory could explain the law of constant proportions so well that scientists were prompted to measure the atomic mass of an atom. Since determining the mass of an individual atom was a relatively difficult task, relative atomic masses were determined using the laws of chemical combinations and the compounds formed.

Let us take the example of a compound, carbon monoxide (CO) formed by carbon and oxygen. It was observed experimentally that 3 g of carbon combines with 4 g of oxygen to form CO. In other words, carbon combines with $\frac{4}{3}$ times its mass of oxygen. Suppose we define the atomic mass unit (earlier abbreviated as 'amu', but according to the latest IUPAC recommendations, it is now written as 'u' – unified mass) as equal to the mass of one carbon atom, then we would

Table 3.1: Symbols for some elements

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

(The above table is given for you to refer to whenever you study about elements. Do not bother to memorise all in one go. With the

assign carbon an atomic mass of 1.0 u and oxygen an atomic mass of 1.33 u. However, it is more convenient to have these numbers as

whole numbers or as near to a whole numbers as possible. While searching for various atomic mass units, scientists initially took $1/16$ of the mass of an atom of naturally occurring oxygen as the unit. This was considered relevant due to two reasons:

- oxygen reacted with a large number of elements and formed compounds.
- this atomic mass unit gave masses of most of the elements as whole numbers.

However, in 1961 for a universally accepted atomic mass unit, carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass unit is a mass unit equal to exactly one-twelfth ($1/12^{\text{th}}$) the mass of one atom of carbon-12. The relative atomic masses of all elements have been found with respect to an atom of carbon-12.

Imagine a fruit seller selling fruits without any standard weight with him. He takes a watermelon and says, “this has a mass equal to 12 units” (12 watermelon units or 12 fruit mass units). He makes twelve equal pieces of the watermelon and finds the mass of each fruit he is selling, relative to the mass of one piece of the watermelon. Now he sells his fruits by relative fruit mass unit (fmu), as in Fig. 3.4.

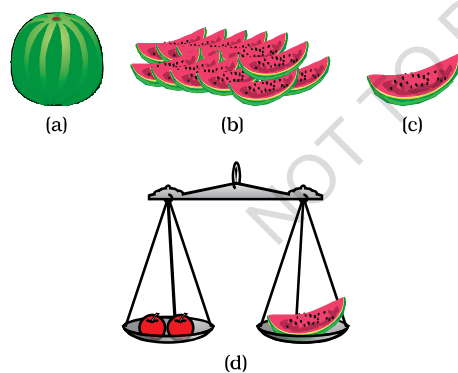


Fig. 3.4 : (a) Watermelon, (b) 12 pieces, (c) $1/12$ of watermelon, (d) how the fruit seller can weigh the fruits using pieces of watermelon

Similarly, the relative atomic mass of the atom of an element is defined as the average

mass of the atom, as compared to $1/12^{\text{th}}$ the mass of one carbon-12 atom.

Table 3.2: Atomic masses of a few elements

Element	Atomic Mass (u)
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

3.2.3 HOW DO ATOMS EXIST?

Atoms of most elements are not able to exist independently. Atoms form molecules and ions. These molecules or ions aggregate in large numbers to form the matter that we can see, feel or touch.

Questions

1. Define the atomic mass unit.
2. Why is it not possible to see an atom with naked eyes?

3.3 What is a Molecule?

A molecule is in general a group of two or more atoms that are chemically bonded together, that is, tightly held together by attractive forces. A molecule can be defined as the smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of that substance. Atoms of the same element or of different elements can join together to form molecules.

3.3.1 MOLECULES OF ELEMENTS

The molecules of an element are constituted by the same type of atoms. Molecules of many elements, such as argon (Ar), helium (He) etc. are made up of only one atom of that element. But this is not the case with most of the non-metals. For example, a molecule of oxygen consists of two atoms of oxygen and hence it is known as a diatomic molecule, O_2 . If 3 atoms of oxygen unite into a molecule, instead of the usual 2, we get ozone, O_3 . The number of atoms constituting a molecule is known as its atomicity.

Metals and some other elements, such as carbon, do not have a simple structure but consist of a very large and indefinite number of atoms bonded together.

Let us look at the atomicity of some non-metals.

Table 3.3 : Atomicity of some elements

Type of Element	Name	Atomicity
Non-Metal	Argon	Monoatomic
	Helium	Monoatomic
	Oxygen	Diatomic
	Hydrogen	Diatomic
	Nitrogen	Diatomic
	Chlorine	Diatomic
	Phosphorus	Tetra-atomic
	Sulphur	Poly-atomic

3.3.2 MOLECULES OF COMPOUNDS

Atoms of different elements join together in definite proportions to form molecules of compounds. Few examples are given in Table 3.4.

Table 3.4 : Molecules of some compounds

Compound	Combining Elements	Ratio by Mass
Water (H_2O)	Hydrogen, Oxygen	1:8
Ammonia (NH_3)	Nitrogen, Hydrogen	14:3
Carbon dioxide (CO_2)	Carbon, Oxygen	3:8

Activity 3.2

- Refer to Table 3.4 for ratio by mass of atoms present in molecules and Table 3.2 for atomic masses of elements. Find the ratio by number of the atoms of elements in the molecules of compounds given in Table 3.4.
- The ratio by number of atoms for a water molecule can be found as follows:

Element	Ratio by mass	Atomic mass (u)	Mass ratio/atomic mass	Simplest ratio
H	1	1	$\frac{1}{1} = 1$	2
O	8	16	$\frac{8}{16} = \frac{1}{2}$	1

- Thus, the ratio by number of atoms for water is $H:O = 2:1$.

3.3.3 WHAT IS AN ION?

Compounds composed of metals and non-metals contain charged species. The charged species are known as *ions*. Ions may consist of a single charged atom or a group of atoms that have a net charge on them. An ion can be negatively or positively charged. A negatively charged ion is called an 'anion' and the positively charged ion, a 'cation'. Take, for example, sodium chloride (NaCl). Its constituent particles are positively charged sodium ions (Na^+) and negatively charged

chloride ions (Cl^-). A group of atoms carrying a charge is known as a polyatomic ion (Table 3.6). We shall learn more about the formation of ions in Chapter 4.

Table 3.5: Some ionic compounds

Ionic Compound	Constituting Elements	Ratio by Mass
Calcium oxide	Calcium and oxygen	5:2
Magnesium sulphide	Magnesium and sulphur	3:4
Sodium chloride	Sodium and chlorine	23:35.5

3.4 Writing Chemical Formulae

The chemical formula of a compound is a symbolic representation of its composition. The chemical formulae of different compounds can be written easily. For this exercise, we need to

learn the symbols and combining capacity of the elements.

The combining power (or capacity) of an element is known as its valency. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound. The valency of the atom of an element can be thought of as hands or arms of that atom.

Human beings have two arms and an octopus has eight. If one octopus has to catch hold of a few people in such a manner that all the eight arms of the octopus and both arms of all the humans are locked, how many humans do you think the octopus can hold? Represent the octopus with O and humans with H. Can you write a formula for this combination? Do you get OH_4 as the formula? The subscript 4 indicates the number of humans held by the octopus.

The valencies of some common ions are given in Table 3.6. We will learn more about valency in the next chapter.

Table 3.6: Names and symbols of some ions

Valency	Name of ion	Symbol	Non-metallic element	Symbol	Polyatomic ions	Symbol
1.	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH_4^+
	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
	Copper (I)*	Cu^+	Bromide	Br^-	Hydrogen carbonate	HCO_3^-
			Iodide	I^-		
2.	Magnesium	Mg^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
	Calcium	Ca^{2+}	Sulphide	S^{2-}	Sulphite	SO_3^{2-}
	Zinc	Zn^{2+}			Sulphate	SO_4^{2-}
	Iron (II)*	Fe^{2+}				
	Copper (II)*	Cu^{2+}				
3.	Aluminium	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
	Iron (III)*	Fe^{3+}				

*Some elements show more than one valency. A Roman numeral shows their valency in a bracket.

The rules that you have to follow while writing a chemical formula are as follows:

- the valencies or charges on the ion must balance.
- when a compound consists of a metal and a non-metal, the name or symbol of the metal is written first. For example: calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO), etc., where oxygen, chlorine, sulphur are non-metals and are written on the right, whereas calcium, sodium, iron and copper are metals, and are written on the left.
- in compounds formed with polyatomic ions, the number of ions present in the compound is indicated by enclosing the formula of ion in a bracket and writing the number of ions outside the bracket. For example, $\text{Mg}(\text{OH})_2$. In case the number of polyatomic ion is one, the bracket is not required. For example, NaOH.

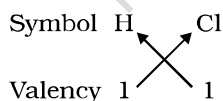
3.4.1 FORMULAE OF SIMPLE COMPOUNDS

The simplest compounds, which are made up of two different elements are called binary compounds. Valencies of some ions are given in Table 3.6. You can use these to write formulae for compounds.

While writing the chemical formulae for compounds, we write the constituent elements and their valencies as shown below. Then we must crossover the valencies of the combining atoms.

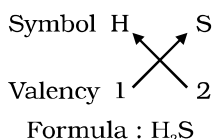
Examples

1. Formula of hydrogen chloride

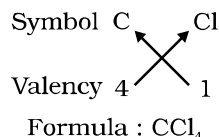


Formula of the compound would be HCl.

2. Formula of hydrogen sulphide

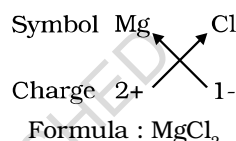


3. Formula of carbon tetrachloride



For magnesium chloride, we write the symbol of cation (Mg^{2+}) first followed by the symbol of anion (Cl^-). Then their charges are criss-crossed to get the formula.

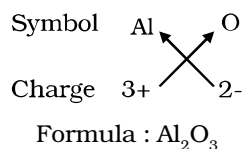
4. Formula of magnesium chloride



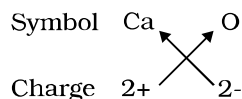
Thus, in magnesium chloride, there are two chloride ions (Cl^-) for each magnesium ion (Mg^{2+}). The positive and negative charges must balance each other and the overall structure must be neutral. Note that in the formula, the charges on the ions are not indicated.

Some more examples

(a) Formula for aluminium oxide:

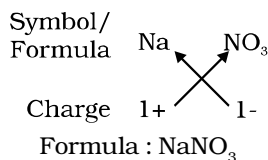


(b) Formula for calcium oxide:

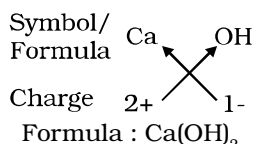


Here, the valencies of the two elements are the same. You may arrive at the formula Ca_2O_2 . But we simplify the formula as CaO.

(c) Formula of sodium nitrate:

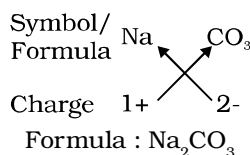


(d) Formula of calcium hydroxide:



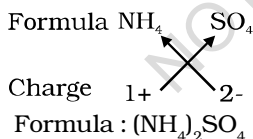
Note that the formula of calcium hydroxide is Ca(OH)₂ and not CaOH₂. We use brackets when we have two or more of the same ions in the formula. Here, the bracket around OH with a subscript 2 indicates that there are two hydroxyl (OH) groups joined to one calcium atom. In other words, there are two atoms each of oxygen and hydrogen in calcium hydroxide.

(e) Formula of sodium carbonate:



In the above example, brackets are not needed if there is only one ion present.

(f) Formula of ammonium sulphate:



Questions

- Write down the formulae of
 - sodium oxide
 - aluminium chloride
 - sodium sulphide
 - magnesium hydroxide
- Write down the names of compounds represented by the

following formulae:

- Al₂(SO₄)₃
- CaCl₂
- K₂SO₄
- KNO₃
- CaCO₃

- What is meant by the term chemical formula?
- How many atoms are present in a
 - H₂S molecule and
 - PO₄³⁻ ion?

3.5 Molecular Mass

3.5.1 MOLECULAR MASS

In section 3.2.2 we discussed the concept of atomic mass. This concept can be extended to calculate molecular masses. The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore the relative mass of a molecule expressed in *atomic mass units (u)*.

Example 3.1 (a) Calculate the relative molecular mass of water (H₂O).
(b) Calculate the molecular mass of HNO₃.

Solution:

- (a) Atomic mass of hydrogen = 1u,
oxygen = 16 u
So the molecular mass of water, which contains two atoms of hydrogen and one atom of oxygen is
= 2 × 1 + 1 × 16
= 18 u
- (b) The molecular mass of HNO₃ = the atomic mass of H + the atomic mass of N + 3 × the atomic mass of O
= 1 + 14 + 48 = 63 u

3.5.2 FORMULA UNIT MASS

The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound. Formula unit mass is calculated in the same manner as we calculate the molecular mass. The only difference is that

we use the word formula unit for those substances whose constituent particles are ions. For example, sodium chloride as discussed above, has a formula unit NaCl. Its formula unit mass can be calculated as–

$$1 \times 23 + 1 \times 35.5 = 58.5 \text{ u}$$

Example 3.2 Calculate the formula unit mass of CaCl_2 .

Solution:

$$\begin{aligned} &\text{Atomic mass of Ca} \\ &+ (2 \times \text{atomic mass of Cl}) \\ &= 40 + 2 \times 35.5 = 40 + 71 = 111 \text{ u} \end{aligned}$$

Questions

1. Calculate the molecular masses of H_2 , O_2 , Cl_2 , CO_2 , CH_4 , C_2H_6 , C_2H_4 , NH_3 , CH_3OH .
2. Calculate the formula unit masses of ZnO , Na_2O , K_2CO_3 , given atomic masses of $\text{Zn} = 65 \text{ u}$, $\text{Na} = 23 \text{ u}$, $\text{K} = 39 \text{ u}$, $\text{C} = 12 \text{ u}$, and $\text{O} = 16 \text{ u}$.



What you have learnt

- During a chemical reaction, the sum of the masses of the reactants and products remains unchanged. This is known as the Law of Conservation of Mass.
- In a pure chemical compound, elements are always present in a definite proportion by mass. This is known as the Law of Definite Proportions.
- An atom is the smallest particle of the element that cannot usually exist independently and retain all its chemical properties.
- A molecule is the smallest particle of an element or a compound capable of independent existence under ordinary conditions. It shows all the properties of the substance.
- A chemical formula of a compound shows its constituent elements and the number of atoms of each combining element.
- Clusters of atoms that act as an ion are called polyatomic ions. They carry a fixed charge on them.
- The chemical formula of a molecular compound is determined by the valency of each element.
- In ionic compounds, the charge on each ion is used to determine the chemical formula of the compound.

Exercises



1. A 0.24 g sample of compound of oxygen and boron was found by analysis to contain 0.096 g of boron and 0.144 g of oxygen. Calculate the percentage composition of the compound by weight.
2. When 3.0 g of carbon is burnt in 8.00 g oxygen, 11.00 g of carbon dioxide is produced. What mass of carbon dioxide will be formed when 3.00 g of carbon is burnt in 50.00 g of oxygen? Which law of chemical combination will govern your answer?
3. What are polyatomic ions? Give examples.
4. Write the chemical formulae of the following.
 - (a) Magnesium chloride
 - (b) Calcium oxide
 - (c) Copper nitrate
 - (d) Aluminium chloride
 - (e) Calcium carbonate.
5. Give the names of the elements present in the following compounds.
 - (a) Quick lime
 - (b) Hydrogen bromide
 - (c) Baking powder
 - (d) Potassium sulphate.

Group Activity



Play a game for writing formulae.

Example 1 : Make placards with symbols and valencies of the elements separately. Each student should hold two placards, one with the symbol in the right hand and the other with the valency in the left hand. Keeping the symbols in place, students should criss-cross their valencies to form the formula of a compound.

Example 2 : A low cost model for writing formulae: Take empty blister packs of medicines. Cut them in groups, according to the valency of the element, as shown in the figure. Now, you can make formulae by fixing one type of ion into other.

For example:



Formula for sodium sulphate:

2 sodium ions can be fixed on one sulphate ion.

Hence, the formula will be: Na_2SO_4

Do it yourself :

Now, write the formula of sodium phosphate.

Chapter 4



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STRUCTURE OF THE ATOM

In Chapter 3, we have learnt that atoms and molecules are the fundamental building blocks of matter. The existence of different kinds of matter is due to different atoms constituting them. Now the questions arise: (i) What makes the atom of one element different from the atom of another element? and (ii) Are atoms really indivisible, as proposed by Dalton, or are there smaller constituents inside the atom? We shall find out the answers to these questions in this chapter. We will learn about sub-atomic particles and the various models that have been proposed to explain how these particles are arranged within the atom.

A major challenge before the scientists at the end of the 19th century was to reveal the structure of the atom as well as to explain its important properties. The elucidation of the structure of atoms is based on a series of experiments.

One of the first indications that atoms are not indivisible, comes from studying static electricity and the condition under which electricity is conducted by different substances.

4.1 Charged Particles in Matter

For understanding the nature of charged particles in matter, let us carry out the following activities:

Activity _____ 4.1

- A. Comb dry hair. Does the comb then attract small pieces of paper?
- B. Rub a glass rod with a silk cloth and bring the rod near an inflated balloon. Observe what happens.

From these activities, can we conclude that on rubbing two objects together, they become electrically charged? Where does this charge come from? This question can be answered by knowing that an atom is divisible and consists of charged particles.

Many scientists contributed in revealing the presence of charged particles in an atom.

It was known by 1900 that the atom was indivisible particle but contained at least one sub-atomic particle – the electron identified by J.J. Thomson. Even before the electron was identified, E. Goldstein in 1886 discovered the presence of new radiations in a gas discharge and called them canal rays. These rays were positively charged radiations which ultimately led to the discovery of another sub-atomic particle. This sub-atomic particle had a charge, equal in magnitude but opposite in sign to that of the electron. Its mass was approximately 2000 times as that of the electron. It was given the name of proton. In general, an electron is represented as 'e⁻' and a proton as 'p⁺'. The mass of a proton is taken as one unit and its charge as plus one. The mass of an electron is considered to be negligible and its charge is minus one.

It seemed that an atom was composed of protons and electrons, mutually balancing their charges. It also appeared that the protons were in the interior of the atom, for whereas electrons could easily be removed off but not protons. Now the big question was: what sort of structure did these particles of the atom form? We will find the answer to this question below.

Questions

1. What are canal rays?
2. If an atom contains one electron and one proton, will it carry any charge or not?

4.2 The Structure of an Atom

We have learnt Dalton's atomic theory in Chapter 3, which suggested that the atom was indivisible and indestructible. But the discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of this aspect of Dalton's atomic theory. It was then considered necessary to know how electrons and protons are arranged within an atom. For explaining this, many scientists proposed various atomic models. J.J. Thomson was the first one to propose a model for the structure of an atom.

4.2.1 THOMSON'S MODEL OF AN ATOM

Thomson proposed the model of an atom to be similar to that of a Christmas pudding. The electrons, in a sphere of positive charge, were like currants (dry fruits) in a spherical Christmas pudding. We can also think of a watermelon, the positive charge in the atom is spread all over like the red edible part of the watermelon, while the electrons are studded in the positively charged sphere, like the seeds in the watermelon (Fig. 4.1).

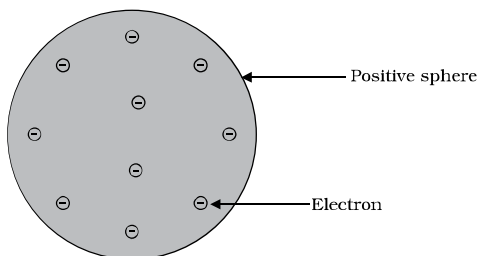
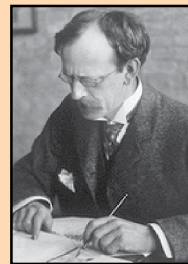


Fig. 4.1: Thomson's model of an atom

J.J. Thomson (1856–1940), a British physicist, was born in Cheetham Hill, a suburb of Manchester, on 18 December 1856. He was awarded the Nobel prize in Physics in 1906 for his work on the discovery of electrons. He directed the Cavendish Laboratory at Cambridge for 35 years and seven of his research assistants subsequently won Nobel prizes.



Thomson proposed that:

- (i) An atom consists of a positively charged sphere and the electrons are embedded in it.
- (ii) The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.

Although Thomson's model explained that atoms are electrically neutral, the results of experiments carried out by other scientists could not be explained by this model, as we will see below.

4.2.2 RUTHERFORD'S MODEL OF AN ATOM

Ernest Rutherford was interested in knowing how the electrons are arranged within an atom. Rutherford designed an experiment for this. In this experiment, fast moving alpha (α)-particles were made to fall on a thin gold foil.

- He selected a gold foil because he wanted as thin a layer as possible. This gold foil was about 1000 atoms thick.
- α -particles are doubly-charged helium ions. Since they have a mass of 4 u, the fast-moving α -particles have a considerable amount of energy.
- It was expected that α -particles would be deflected by the sub-atomic particles in the gold atoms. Since the α -particles were much heavier than the protons, he did not expect to see large deflections.

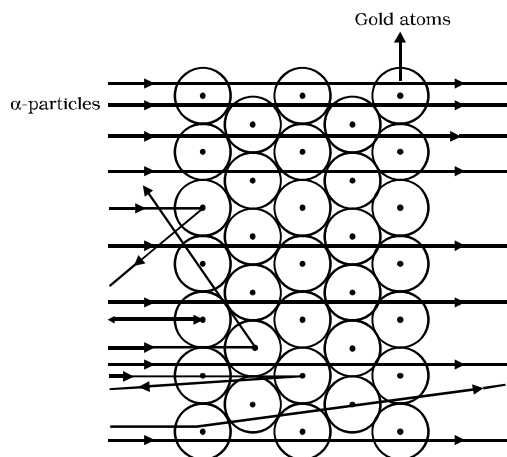
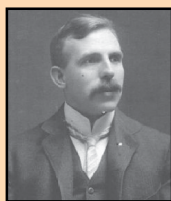


Fig. 4.2: Scattering of α -particles by a gold foil

But, the α -particle scattering experiment gave totally unexpected results (Fig. 4.2). The following observations were made:

- (i) Most of the fast moving α -particles passed straight through the gold foil.
- (ii) Some of the α -particles were deflected by the foil by small angles.
- (iii) Surprisingly one out of every 12000 particles appeared to rebound.

In the words of Rutherford, "*This result was almost as incredible as if you fire a 15-inch shell at a piece of tissue paper and it comes back and hits you*".



E. Rutherford (1871–1937) was born at Spring Grove on 30 August 1871. He was known as the 'Father' of nuclear physics. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment. He got the Nobel prize in chemistry in 1908.

Let us think of an activity in an open field to understand the implications of this experiment. Let a child stand in front of a wall with his eyes closed. Let him throw stones at the wall from a distance.

He will hear a sound when each stone strikes the wall. If he repeats this ten times, he will hear the sound ten times. But if a blind-folded child were to throw stones at a barbed-wire fence, most of the stones would not hit the fencing and no sound would be heard. This is because there are lots of gaps in the fence which allow the stone to pass through them.

Following a similar reasoning, Rutherford concluded from the α -particle scattering experiment that—

- (i) Most of the space inside the atom is empty because most of the α -particles passed through the gold foil without getting deflected.
- (ii) Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.
- (iii) A very small fraction of α -particles were deflected by 180° , indicating that all the positive charge and mass of the gold atom were concentrated in a very small volume within the atom.

From the data he also calculated that the radius of the nucleus is about 10^5 times less than the radius of the atom.

On the basis of his experiment, Rutherford put forward the nuclear model of an atom, which had the following features:

- (i) There is a positively charged centre in an atom called the nucleus. Nearly all the mass of an atom resides in the nucleus.
- (ii) The electrons revolve around the nucleus in circular paths.
- (iii) The size of the nucleus is very small as compared to the size of the atom.

Drawbacks of Rutherford's model of the atom

The revolution of the electron in a circular orbit is not expected to be stable. Any particle in a circular orbit would undergo acceleration. During acceleration, charged particles would radiate energy. Thus, the revolving electron would lose energy and finally fall into the nucleus. If this were so, the atom should be highly unstable and hence matter would not exist in the form that we know. We know that atoms are quite stable.

4.2.3 BOHR'S MODEL OF ATOM

In order to overcome the objections raised against Rutherford's model of the atom, Neils Bohr put forward the following postulates about the model of an atom:

- (i) Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.
- (ii) While revolving in discrete orbits the electrons do not radiate energy.



Neils Bohr (1885–1962) was born in Copenhagen on 7 October 1885. He was appointed professor of physics at Copenhagen University in 1916. He got the Nobel prize for his work on the structure of atom in 1922. Among Professor

Bohr's numerous writings, three appearing as books are:

- (i) The Theory of Spectra and Atomic Constitution, (ii) Atomic Theory and, (iii) The Description of Nature.

These orbits or shells are called energy levels. Energy levels in an atom are shown in Fig. 4.3.

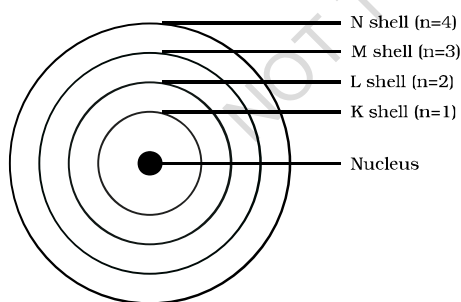


Fig. 4.3: A few energy levels in an atom

These orbits or shells are represented by the letters K, L, M, N, ... or the numbers, $n=1, 2, 3, 4, \dots$

Questions

1. On the basis of Thomson's model of an atom, explain how the atom is neutral as a whole.
2. On the basis of Rutherford's model of an atom, which sub-atomic particle is present in the nucleus of an atom?
3. Draw a sketch of Bohr's model of an atom with three shells.
4. What do you think would be the observation if the α -particle scattering experiment is carried out using a foil of a metal other than gold?

4.2.4 NEUTRONS

In 1932, J. Chadwick discovered another sub-atomic particle which had no charge and a mass nearly equal to that of a proton. It was eventually named as neutron. Neutrons are present in the nucleus of all atoms, except hydrogen. In general, a neutron is represented as 'n'. The mass of an atom is therefore given by the sum of the masses of protons and neutrons present in the nucleus.

Questions

1. Name the three sub-atomic particles of an atom.
2. Helium atom has an atomic mass of 4 u and two protons in its nucleus. How many neutrons does it have?

4.3 How are Electrons Distributed in Different Orbits (Shells)?

The distribution of electrons into different orbits of an atom was suggested by Bohr and Bury.

The following rules are followed for writing the number of electrons in different energy levels or shells:

- (i) The maximum number of electrons present in a shell is given by the

formula $2n^2$, where 'n' is the orbit number or energy level index, 1,2,3,... Hence the maximum number of electrons in different shells are as follows:

first orbit or K-shell will be $= 2 \times 1^2 = 2$,
second orbit or L-shell will be $= 2 \times 2^2 = 8$,
third orbit or M-shell will be $= 2 \times 3^2 = 18$,
fourth orbit or N-shell will be $= 2 \times 4^2 = 32$, and so on.

- (ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.
- (iii) Electrons are not accommodated in a given shell, unless the inner shells are filled. That is, the shells are filled in a step-wise manner.

Atomic structure of the first eighteen elements is shown schematically in Fig. 4.4.

The composition of atoms of the first eighteen elements is given in Table 4.1.

Questions

- Write the distribution of electrons in carbon and sodium atoms.
- If K and L shells of an atom are full, then what would be the total number of electrons in the atom?

4.4 Valency

We have learnt how the electrons in an atom are arranged in different shells/orbits. The electrons present in the outermost shell of an atom are known as the valence electrons.

From the Bohr-Bury scheme, we also know that the outermost shell of an atom can

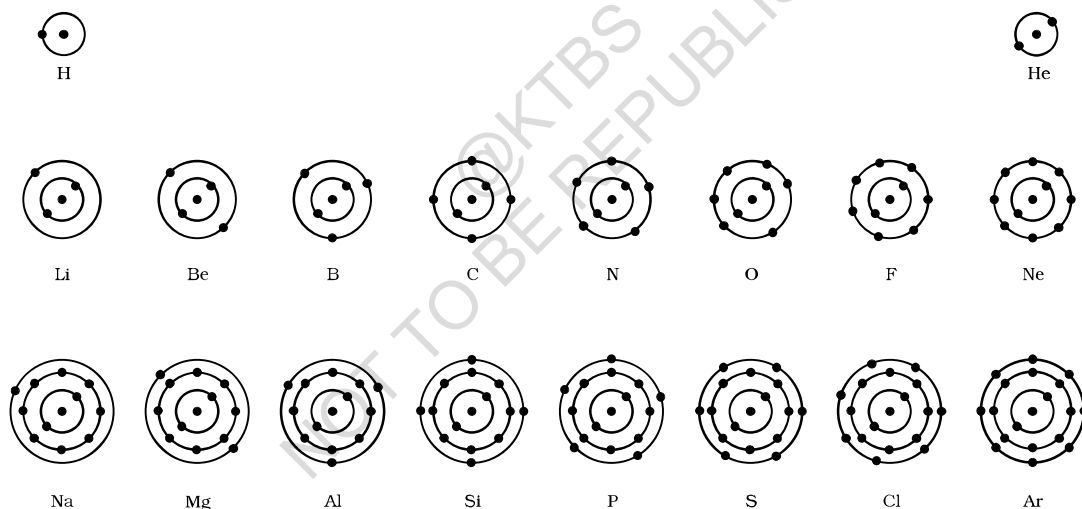


Fig. 4.4: Schematic atomic structure of the first eighteen elements

Activity 4.2

- Make a static atomic model displaying electronic configuration of the first eighteen elements.

accommodate a maximum of 8 electrons. It was observed that the atoms of elements, completely filled with 8 electrons in the outermost shell show little chemical activity. In other words, their combining capacity or valency is zero. Of these inert elements, the

Table 4.1: Composition of Atoms of the First Eighteen Elements with Electron Distribution in Various Shells

Name of Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution of Electrons				Valency
						K	L	M	N	
Hydrogen	H	1	1	-	1	1	-	-	-	1
Helium	He	2	2	2	2	2	-	-	-	0
Lithium	Li	3	3	4	3	2	1	-	-	1
Beryllium	Be	4	4	5	4	2	2	-	-	2
Boron	B	5	5	6	5	2	3	-	-	3
Carbon	C	6	6	6	6	2	4	-	-	4
Nitrogen	N	7	7	7	7	2	5	-	-	3
Oxygen	O	8	8	8	8	2	6	-	-	2
Fluorine	F	9	9	10	9	2	7	-	-	1
Neon	Ne	10	10	10	10	2	8	-	-	0
Sodium	Na	11	11	12	11	2	8	1	-	1
Magnesium	Mg	12	12	12	12	2	8	2	-	2
Aluminium	Al	13	13	14	13	2	8	3	-	3
Silicon	Si	14	14	14	14	2	8	4	-	4
Phosphorus	P	15	15	16	15	2	8	5	-	3,5
Sulphur	S	16	16	16	16	2	8	6	-	2
Chlorine	Cl	17	17	18	17	2	8	7	-	1
Argon	Ar	18	18	22	18	2	8	8	-	0

helium atom has two electrons in its outermost shell and all other elements have atoms with eight electrons in the outermost shell.

The combining capacity of the atoms of elements, that is, their tendency to react and form molecules with atoms of the same or different elements, was thus explained as an attempt to attain a fully-filled outermost shell. An outermost-shell, which had eight electrons was said to possess an octet. Atoms would thus react, so as to achieve an octet in the outermost shell. This was done by sharing, gaining or losing electrons. The number of electrons gained, lost or shared so as to make the octet of electrons in the outermost shell, gives us directly the combining capacity of the

element, that is, the valency discussed in the previous chapter. For example, hydrogen/lithium/sodium atoms contain one electron each in their outermost shell, therefore each one of them can lose one electron. So, they are said to have valency of one. Can you tell, what is valency of magnesium and aluminium? It is two and three, respectively, because magnesium has two electrons in its outermost shell and aluminium has three electrons in its outermost shell.

If the number of electrons in the outermost shell of an atom is close to its full capacity, then valency is determined in a different way. For example, the fluorine atom has 7 electrons in the outermost shell, and its valency could be 7. But it is easier for

fluorine to gain one electron instead of losing seven electrons. Hence, its valency is determined by subtracting seven electrons from the octet and this gives you a valency of one for fluorine. Valency can be calculated in a similar manner for oxygen. What is the valency of oxygen that you get from this calculation?

Therefore, an atom of each element has a definite combining capacity, called its valency. Valency of the first eighteen elements is given in the last column of Table 4.1.

Question

1. How will you find the valency of chlorine, sulphur and magnesium?

4.5 Atomic Number and Mass Number

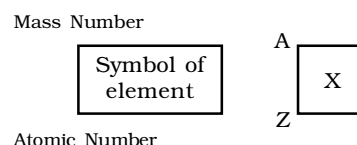
4.5.1 ATOMIC NUMBER

We know that protons are present in the nucleus of an atom. It is the number of protons of an atom, which determines its atomic number. It is denoted by 'Z'. All atoms of an element have the same atomic number, Z. In fact, elements are defined by the number of protons they possess. For hydrogen, $Z = 1$, because in hydrogen atom, only one proton is present in the nucleus. Similarly, for carbon, $Z = 6$. Therefore, the atomic number is defined as the total number of protons present in the nucleus of an atom.

4.5.2 MASS NUMBER

After studying the properties of the sub-atomic particles of an atom, we can conclude that mass of an atom is practically due to protons and neutrons alone. These are present in the nucleus of an atom. Hence protons and neutrons are also called nucleons. Therefore, the mass of an atom resides in its nucleus. For example, mass of carbon is 12 u because it has 6 protons and

6 neutrons, $6\text{ u} + 6\text{ u} = 12\text{ u}$. Similarly, the mass of aluminium is 27 u (13 protons + 14 neutrons). The mass number is defined as the sum of the total number of protons and neutrons present in the nucleus of an atom. It is denoted by 'A'. In the notation for an atom, the atomic number, mass number and symbol of the element are to be written as:



For example, nitrogen is written as ${}^{14}_7\text{N}$.

Questions

1. If number of electrons in an atom is 8 and number of protons is also 8, then (i) what is the atomic number of the atom? and (ii) what is the charge on the atom?
2. With the help of Table 4.1, find out the mass number of oxygen and sulphur atom.

4.6 Isotopes

In nature, a number of atoms of some elements have been identified, which have the same atomic number but different mass numbers. For example, take the case of hydrogen atom, it has three atomic species, namely protium (${}^1_1\text{H}$), deuterium (${}^2_1\text{H}$ or D)

and tritium (${}^3_1\text{H}$ or T). The atomic number of each one is 1, but the mass number is 1, 2 and 3, respectively. Other such examples are (i) carbon, ${}^{12}_6\text{C}$ and ${}^{14}_6\text{C}$, (ii) chlorine, ${}^{35}_{17}\text{Cl}$ and ${}^{37}_{17}\text{Cl}$, etc.

On the basis of these examples, isotopes are defined as the atoms of the same element, having the same atomic number but different mass numbers. Therefore, we can say that there are three isotopes of hydrogen atom, namely protium, deuterium and tritium.

Many elements consist of a mixture of isotopes. Each isotope of an element is a pure substance. The chemical properties of isotopes are similar but their physical properties are different.

Chlorine occurs in nature in two isotopic forms, with masses 35 u and 37 u in the ratio of 3:1. Obviously, the question arises: what should we take as the mass of chlorine atom? Let us find out.

The average atomic mass of chlorine atom, on the basis of above data, will be

$$\left[\left(35 \times \frac{75}{100} + 37 \times \frac{25}{100} \right) \right. \\ \left. = \left(\frac{105}{4} + \frac{37}{4} \right) = \frac{142}{4} = 35.5 \text{ u} \right]$$

The mass of an atom of any natural element is taken as the average mass of all the naturally occurring atoms of that element. If an element has no isotopes, then the mass of its atom would be the same as the sum of protons and neutrons in it. But if an element occurs in isotopic forms, then we have to know the percentage of each isotopic form and then the average mass is calculated.

This does not mean that any one atom of chlorine has a fractional mass of 35.5 u. It means that if you take a certain amount of chlorine, it will contain both isotopes of chlorine and the average mass is 35.5 u.

Applications

Since the chemical properties of all the isotopes of an element are the same, normally we are not concerned about taking a mixture. But some isotopes have special properties which find them useful in various fields. Some of them are :

- (i) An isotope of uranium is used as a fuel in nuclear reactors.
- (ii) An isotope of cobalt is used in the treatment of cancer.
- (iii) An isotope of iodine is used in the treatment of goitre.

4.6.1 ISOBARS

Let us consider two elements — calcium, atomic number 20, and argon, atomic number 18. The number of protons in these atoms is different, but the mass number of both these elements is 40. That is, the total number of nucleons is the same in the atoms of this pair of elements. Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.

Questions

1. For the symbol H, D and T tabulate three sub-atomic particles found in each of them.
2. Write the electronic configuration of any one pair of isotopes and isobars.



What you have learnt

- Credit for the discovery of electron and proton goes to J.J. Thomson and E. Goldstein, respectively.
- J.J. Thomson proposed that electrons are embedded in a positive sphere.

- Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.
- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.
- J. Chadwick discovered presence of neutrons in the nucleus of an atom. So, the three sub-atomic particles of an atom are: (i) electrons, (ii) protons and (iii) neutrons. Electrons are negatively charged, protons are positively charged and neutrons

have no charges. The mass of an electron is about $\frac{1}{2000}$ times the mass of an hydrogen atom. The mass of a proton and a neutron is taken as one unit each.

- Shells of an atom are designated as K,L,M,N,....
- Valency is the combining capacity of an atom.
- The atomic number of an element is the same as the number of protons in the nucleus of its atom.
- The mass number of an atom is equal to the number of nucleons in its nucleus.
- Isotopes are atoms of the same element, which have different mass numbers.
- Isobars are atoms having the same mass number but different atomic numbers.
- Elements are defined by the number of protons they possess.

Exercises



1. Compare the properties of electrons, protons and neutrons.
2. What are the limitations of J.J. Thomson's model of the atom?
3. What are the limitations of Rutherford's model of the atom?
4. Describe Bohr's model of the atom.
5. Compare all the proposed models of an atom given in this chapter.
6. Summarise the rules for writing of distribution of electrons in various shells for the first eighteen elements.
7. Define valency by taking examples of silicon and oxygen.

8. Explain with examples (i) Atomic number, (ii) Mass number, (iii) Isotopes and iv) Isobars. Give any two uses of isotopes.
9. Na^+ has completely filled K and L shells. Explain.
10. If bromine atom is available in the form of, say, two isotopes $^{79}_{35}\text{Br}$ (49.7%) and $^{81}_{35}\text{Br}$ (50.3%), calculate the average atomic mass of bromine atom.
11. The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes $^{16}_8\text{X}$ and $^{18}_8\text{X}$ in the sample?
12. If $Z = 3$, what would be the valency of the element? Also, name the element.
13. Composition of the nuclei of two atomic species X and Y are given as under

	X	Y
Protons =	6	6
Neutrons =	6	8

Give the mass numbers of X and Y. What is the relation between the two species?
14. For the following statements, write T for True and F for False.
 - (a) J.J. Thomson proposed that the nucleus of an atom contains only nucleons.
 - (b) A neutron is formed by an electron and a proton combining together. Therefore, it is neutral.
 - (c) The mass of an electron is about $\frac{1}{2000}$ times that of proton.
 - (d) An isotope of iodine is used for making tincture iodine, which is used as a medicine.

Put tick (✓) against correct choice and cross (×) against wrong choice in questions 15, 16 and 17
15. Rutherford's alpha-particle scattering experiment was responsible for the discovery of
 - (a) Atomic Nucleus
 - (b) Electron
 - (c) Proton
 - (d) Neutron
16. Isotopes of an element have
 - (a) the same physical properties
 - (b) different chemical properties
 - (c) different number of neutrons
 - (d) different atomic numbers.
17. Number of valence electrons in Cl^- ion are:
 - (a) 16
 - (b) 8
 - (c) 17
 - (d) 18

18. Which one of the following is a correct electronic configuration of sodium?

- (a) 2,8 (b) 8,2,1 (c) 2,1,8 (d) 2,8,1

19. Complete the following table.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	-	10	-	-	-
16	32	-	-	-	Sulphur
-	24	-	12	-	
-	2	-	1	-	
-	1	0	1	0	

Chapter 9



0964CH10

GRAVITATION

We have learnt about the motion of objects and force as the cause of motion. We have learnt that a force is needed to change the speed or the direction of motion of an object. We always observe that an object dropped from a height falls towards the earth. We know that all the planets go around the Sun. The moon goes around the earth. In all these cases, there must be some force acting on the objects, the planets and on the moon. Isaac Newton could grasp that the same force is responsible for all these. This force is called the gravitational force.

In this chapter we shall learn about gravitation and the universal law of gravitation. We shall discuss the motion of objects under the influence of gravitational force on the earth. We shall study how the weight of a body varies from place to place. We shall also discuss the conditions for objects to float in liquids.

9.1 Gravitation

We know that the moon goes around the earth. An object when thrown upwards, reaches a certain height and then falls downwards. It is said that when Newton was sitting under a tree, an apple fell on him. The fall of the apple made Newton start thinking. He thought that: if the earth can attract an apple, can it not attract the moon? Is the force the same in both cases? He conjectured that the same type of force is responsible in both the cases. He argued that at each point of its orbit, the moon falls towards the earth, instead of going off in a straight line. So, it must be attracted by the earth. But we do not really see the moon falling towards the earth.

Let us try to understand the motion of the moon by recalling activity 7.11.

Activity 9.1

- Take a piece of thread.
- Tie a small stone at one end. Hold the other end of the thread and whirl it round, as shown in Fig. 9.1.
- Note the motion of the stone.
- Release the thread.
- Again, note the direction of motion of the stone.

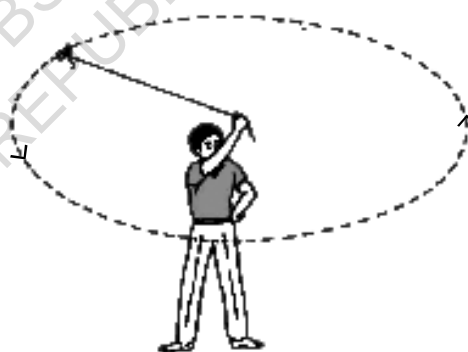


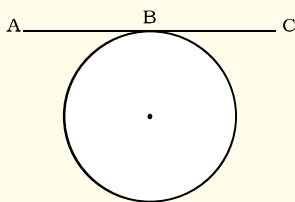
Fig. 9.1: A stone describing a circular path with a velocity of constant magnitude.

Before the thread is released, the stone moves in a circular path with a certain speed and changes direction at every point. The change in direction involves change in velocity or acceleration. The force that causes this acceleration and keeps the body moving along the circular path is acting towards the centre. This force is called the centripetal (meaning 'centre-seeking') force.

In the absence of this force, the stone flies off along a straight line. This straight line will be a tangent to the circular path.

More to know

Tangent to a circle



A straight line that meets the circle at one and only one point is called a tangent to the circle. Straight line ABC is a tangent to the circle at point B.

The motion of the moon around the earth is due to the centripetal force. The centripetal force is provided by the force of attraction of the earth. If there were no such force, the moon would pursue a uniform straight line motion.

It is seen that a falling apple is attracted towards the earth. Does the apple attract the earth? If so, we do not see the earth moving towards an apple. Why?

According to the third law of motion, the apple does attract the earth. But according to the second law of motion, for a given force, acceleration is inversely proportional to the mass of an object [Eq. (8.4)]. The mass of an apple is negligibly small compared to that of the earth. So, we do not see the earth moving towards the apple. Extend the same argument for why the earth does not move towards the moon.

In our solar system, all the planets go around the Sun. By arguing the same way, we can say that there exists a force between the Sun and the planets. From the above facts Newton concluded that not only does the earth attract an apple and the moon, but all objects in the universe attract each other. This force of attraction between objects is called the gravitational force.

9.1.1 UNIVERSAL LAW OF GRAVITATION

Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. The force is along the line joining the centres of two objects.

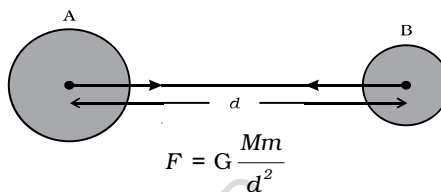


Fig. 9.2: The gravitational force between two uniform objects is directed along the line joining their centres.

Let two objects A and B of masses M and m lie at a distance d from each other as shown in Fig. 9.2. Let the force of attraction between two objects be F . According to the universal law of gravitation, the force between two objects is directly proportional to the product of their masses. That is,

$$F \propto M \times m \quad (9.1)$$

And the force between two objects is inversely proportional to the square of the distance between them, that is,

$$F \propto \frac{1}{d^2} \quad (9.2)$$

Combining Eqs. (10.1) and (10.2), we get

$$F \propto \frac{M \times m}{d^2} \quad (9.3)$$

$$\text{or, } F = G \frac{M \times m}{d^2} \quad (9.4)$$

where G is the constant of proportionality and is called the universal gravitation constant. By multiplying crosswise, Eq. (9.4) gives

$$F \times d^2 = G M \times m$$

$$\text{or } G = \frac{F d^2}{M \times m} \quad (9.5)$$

The SI unit of G can be obtained by substituting the units of force, distance and mass in Eq. (9.5) as $\text{N m}^2 \text{kg}^{-2}$.

The value of G was found out by Henry Cavendish (1731 – 1810) by using a sensitive balance. The accepted value of G is $6.673 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2}$.

We know that there exists a force of attraction between any two objects. Compute the value of this force between you and your friend sitting closely. Conclude how you do not experience this force!

More to know

The law is universal in the sense that it is applicable to all bodies, whether the bodies are big or small, whether they are celestial or terrestrial.

Inverse-square

Saying that F is inversely proportional to the square of d means, for example, that if d gets bigger by a factor of 6, F becomes

$\frac{1}{36}$ times smaller.

Example 9.1 The mass of the earth is $6 \times 10^{24} \text{ kg}$ and that of the moon is $7.4 \times 10^{22} \text{ kg}$. If the distance between the earth and the moon is $3.84 \times 10^5 \text{ km}$, calculate the force exerted by the earth on the moon. (Take $G = 6.7 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2}$)

Solution:

The mass of the earth, $M = 6 \times 10^{24} \text{ kg}$

The mass of the moon,

$$m = 7.4 \times 10^{22} \text{ kg}$$

The distance between the earth and the moon,

$$\begin{aligned} d &= 3.84 \times 10^5 \text{ km} \\ &= 3.84 \times 10^5 \times 1000 \text{ m} \\ &= 3.84 \times 10^8 \text{ m} \end{aligned}$$

$$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2}$$

From Eq. (9.4), the force exerted by the earth on the moon is

$$\begin{aligned} F &= G \frac{M \times m}{d^2} \\ &= \frac{6.7 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2} \times 6 \times 10^{24} \text{ kg} \times 7.4 \times 10^{22} \text{ kg}}{(3.84 \times 10^8 \text{ m})^2} \\ &= 2.02 \times 10^{20} \text{ N.} \end{aligned}$$

Thus, the force exerted by the earth on the moon is $2.02 \times 10^{20} \text{ N}$.

Questions

1. State the universal law of gravitation.
2. Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.

9.1.2 IMPORTANCE OF THE UNIVERSAL LAW OF GRAVITATION

The universal law of gravitation successfully explained several phenomena which were believed to be unconnected:

- (i) the force that binds us to the earth;
- (ii) the motion of the moon around the earth;
- (iii) the motion of planets around the Sun; and
- (iv) the tides due to the moon and the Sun.

9.2 Free Fall

Let us try to understand the meaning of free fall by performing this activity.

Activity 9.2

- Take a stone.
- Throw it upwards.
- It reaches a certain height and then it starts falling down.

We have learnt that the earth attracts objects towards it. This is due to the gravitational force. Whenever objects fall towards the earth under this force alone, we say that the objects are in free fall. Is there any

change in the velocity of falling objects? While falling, there is no change in the direction of motion of the objects. But due to the earth's attraction, there will be a change in the magnitude of the velocity. Any change in velocity involves acceleration. Whenever an object falls towards the earth, an acceleration is involved. This acceleration is due to the earth's gravitational force. Therefore, this acceleration is called the acceleration due to the gravitational force of the earth (or acceleration due to gravity). It is denoted by g . The unit of g is the same as that of acceleration, that is, m s^{-2} .

We know from the second law of motion that force is the product of mass and acceleration. Let the mass of the stone in activity 9.2 be m . We already know that there is acceleration involved in falling objects due to the gravitational force and is denoted by g . Therefore the magnitude of the gravitational force F will be equal to the product of mass and acceleration due to the gravitational force, that is,

$$F = mg \quad (9.6)$$

From Eqs. (9.4) and (9.6) we have

$$mg = G \frac{M \times m}{d^2}$$

$$\text{or } g = G \frac{M}{d^2} \quad (9.7)$$

where M is the mass of the earth, and d is the distance between the object and the earth.

Let an object be on or near the surface of the earth. The distance d in Eq. (9.7) will be equal to R , the radius of the earth. Thus, for objects on or near the surface of the earth,

$$mg = G \frac{M \times m}{R^2} \quad (9.8)$$

$$g = G \frac{M}{R^2} \quad (9.9)$$

The earth is not a perfect sphere. As the radius of the earth increases from the poles to the equator, the value of g becomes greater at the poles than at the equator. For most

calculations, we can take g to be more or less constant on or near the earth. But for objects far from the earth, the acceleration due to gravitational force of earth is given by Eq. (9.7).

9.2.1 TO CALCULATE THE VALUE OF g

To calculate the value of g , we should put the values of G , M and R in Eq. (9.9), namely, universal gravitational constant, $G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$, mass of the earth, $M = 6 \times 10^{24} \text{ kg}$, and radius of the earth, $R = 6.4 \times 10^6 \text{ m}$.

$$g = G \frac{M}{R^2}$$

$$= \frac{6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 6 \times 10^{24} \text{ kg}}{(6.4 \times 10^6 \text{ m})^2}$$

$$= 9.8 \text{ m s}^{-2}$$

Thus, the value of acceleration due to gravity of the earth, $g = 9.8 \text{ m s}^{-2}$.

9.2.2 MOTION OF OBJECTS UNDER THE INFLUENCE OF GRAVITATIONAL FORCE OF THE EARTH

Let us do an activity to understand whether all objects hollow or solid, big or small, will fall from a height at the same rate.

Activity 9.3

- Take a sheet of paper and a stone. Drop them simultaneously from the first floor of a building. Observe whether both of them reach the ground simultaneously.
- We see that paper reaches the ground little later than the stone. This happens because of air resistance. The air offers resistance due to friction to the motion of the falling objects. The resistance offered by air to the paper is more than the resistance offered to the stone. If we do the experiment in a glass jar from which air has been sucked out, the paper and the stone would fall at the same rate.

We know that an object experiences acceleration during free fall. From Eq. (9.9), this acceleration experienced by an object is independent of its mass. This means that all objects hollow or solid, big or small, should fall at the same rate. According to a story, Galileo dropped different objects from the top of the Leaning Tower of Pisa in Italy to prove the same.

As g is constant near the earth, all the equations for the uniformly accelerated motion of objects become valid with acceleration a replaced by g . The equations are:

$$v = u + at \quad (9.10)$$

$$s = ut + \frac{1}{2} at^2 \quad (9.11)$$

$$v^2 = u^2 + 2as \quad (9.12)$$

where u and v are the initial and final velocities and s is the distance covered in time, t .

In applying these equations, we will take acceleration, a to be positive when it is in the direction of the velocity, that is, in the direction of motion. The acceleration, a will be taken as negative when it opposes the motion.

Example 9.2 A car falls off a ledge and drops to the ground in 0.5 s. Let $g = 10 \text{ m s}^{-2}$ (for simplifying the calculations).

- What is its speed on striking the ground?
- What is its average speed during the 0.5 s?
- How high is the ledge from the ground?

Solution:

Time, $t = \frac{1}{2}$ second

Initial velocity, $u = 0 \text{ m s}^{-1}$

Acceleration due to gravity, $g = 10 \text{ m s}^{-2}$

Acceleration of the car, $a = + 10 \text{ m s}^{-2}$
(downward)

$$\begin{aligned} \text{(i) speed} \quad v &= at \\ v &= 10 \text{ m s}^{-2} \times 0.5 \text{ s} \\ &= 5 \text{ m s}^{-1} \end{aligned}$$

$$\begin{aligned} \text{(ii) average speed} &= \frac{u+v}{2} \\ &= (0 \text{ m s}^{-1} + 5 \text{ m s}^{-1})/2 \\ &= 2.5 \text{ m s}^{-1} \end{aligned}$$

$$\begin{aligned} \text{(iii) distance travelled, } s &= \frac{1}{2} at^2 \\ &= \frac{1}{2} \times 10 \text{ m s}^{-2} \times (0.5 \text{ s})^2 \\ &= \frac{1}{2} \times 10 \text{ m s}^{-2} \times 0.25 \text{ s}^2 \\ &= 1.25 \text{ m} \end{aligned}$$

Thus,

- its speed on striking the ground
 $= 5 \text{ m s}^{-1}$
- its average speed during the 0.5 s
 $= 2.5 \text{ m s}^{-1}$
- height of the ledge from the ground
 $= 1.25 \text{ m}.$

Example 9.3 An object is thrown vertically upwards and rises to a height of 10 m. Calculate (i) the velocity with which the object was thrown upwards and (ii) the time taken by the object to reach the highest point.

Solution:

Distance travelled, $s = 10 \text{ m}$

Final velocity, $v = 0 \text{ m s}^{-1}$

Acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$

Acceleration of the object, $a = -9.8 \text{ m s}^{-2}$
(upward motion)

$$\begin{aligned} \text{(i) } v^2 &= u^2 + 2as \\ 0 &= u^2 + 2 \times (-9.8 \text{ m s}^{-2}) \times 10 \text{ m} \\ -u^2 &= -2 \times 9.8 \times 10 \text{ m}^2 \text{ s}^{-2} \\ u &= \sqrt{196} \text{ m s}^{-1} \\ u &= 14 \text{ m s}^{-1} \\ \text{(ii) } v &= u + at \\ 0 &= 14 \text{ m s}^{-1} - 9.8 \text{ m s}^{-2} \times t \\ t &= 1.43 \text{ s}. \end{aligned}$$

Thus,

- Initial velocity, $u = 14 \text{ m s}^{-1}$, and
- Time taken, $t = 1.43 \text{ s}.$

Questions

- What do you mean by free fall?
- What do you mean by acceleration due to gravity?

9.3 Mass

We have learnt in the previous chapter that the mass of an object is the measure of its inertia. We have also learnt that greater the mass, the greater is the inertia. It remains the same whether the object is on the earth, the moon or even in outer space. Thus, the mass of an object is constant and does not change from place to place.

9.4 Weight

We know that the earth attracts every object with a certain force and this force depends on the mass (m) of the object and the acceleration due to the gravity (g). The weight of an object is the force with which it is attracted towards the earth.

We know that

$$F = m \times a, \quad (9.13)$$

that is,

$$F = m \times g. \quad (9.14)$$

The force of attraction of the earth on an object is known as the weight of the object. It is denoted by W . Substituting the same in Eq. (9.14), we have

$$W = m \times g \quad (9.15)$$

As the weight of an object is the force with which it is attracted towards the earth, the SI unit of weight is the same as that of force, that is, newton (N). The weight is a force acting vertically downwards; it has both magnitude and direction.

We have learnt that the value of g is constant at a given place. Therefore at a given place, the weight of an object is directly proportional to the mass, say m , of the object, that is, $W \propto m$. It is due to this reason that at a given place, we can use the weight of an object as a measure of its mass. The mass of an object remains the same everywhere, that is, on the earth and on any planet whereas its weight depends on its location because g depends on location.

9.4.1 WEIGHT OF AN OBJECT ON THE MOON

We have learnt that the weight of an object on the earth is the force with which the earth

attracts the object. In the same way, the weight of an object on the moon is the force with which the moon attracts that object. The mass of the moon is less than that of the earth. Due to this the moon exerts lesser force of attraction on objects.

Let the mass of an object be m . Let its weight on the moon be W_m . Let the mass of the moon be M_m and its radius be R_m .

By applying the universal law of gravitation, the weight of the object on the moon will be

$$W_m = G \frac{M_m \times m}{R_m^2} \quad (9.16)$$

Let the weight of the same object on the earth be W_e . The mass of the earth is M and its radius is R .

Table 9.1

Celestial body	Mass (kg)	Radius (m)
Earth	5.98×10^{24}	6.37×10^6
Moon	7.36×10^{22}	1.74×10^6

From Eqs. (9.9) and (9.15) we have,

$$W_e = G \frac{M \times m}{R^2} \quad (9.17)$$

Substituting the values from Table 10.1 in Eqs. (9.16) and (9.17), we get

$$W_m = G \frac{7.36 \times 10^{22} \text{ kg} \times m}{(1.74 \times 10^6 \text{ m})^2}$$

$$W_m = 2.431 \times 10^{10} G \times m \quad (9.18a)$$

$$\text{and } W_e = 1.474 \times 10^{11} G \times m \quad (9.18b)$$

Dividing Eq. (9.18a) by Eq. (9.18b), we get

$$\frac{W_m}{W_e} = \frac{2.431 \times 10^{10}}{1.474 \times 10^{11}}$$

$$\text{or } \frac{W_m}{W_e} = 0.165 \approx \frac{1}{6} \quad (9.19)$$

$$\frac{\text{Weight of the object on the moon}}{\text{Weight of the object on the earth}} = \frac{1}{6}$$

Weight of the object on the moon
= $(1/6) \times$ its weight on the earth.

Example 9.4 Mass of an object is 10 kg.
What is its weight on the earth?

Solution:

Mass, $m = 10 \text{ kg}$

Acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$

$$W = m \times g$$

$$W = 10 \text{ kg} \times 9.8 \text{ m s}^{-2} = 98 \text{ N}$$

Thus, the weight of the object is 98 N.

Example 9.5 An object weighs 10 N when measured on the surface of the earth.
What would be its weight when measured on the surface of the moon?

Solution:

We know,

Weight of object on the moon

$$= (1/6) \times \text{its weight on the earth.}$$

That is,

$$W_m = \frac{W_e}{6} = \frac{10}{6} \text{ N.}$$

$$= 1.67 \text{ N.}$$

Thus, the weight of object on the surface of the moon would be 1.67 N.

Questions

1. What are the differences between the mass of an object and its weight?
2. Why is the weight of an object on the moon $\frac{1}{6}$ th its weight on the earth?

of the net force in a particular direction (thrust) and the force per unit area (pressure) acting on the object concerned.

Let us try to understand the meanings of thrust and pressure by considering the following situations:

Situation 1: You wish to fix a poster on a bulletin board, as shown in Fig 9.3. To do this task you will have to press drawing pins with your thumb. You apply a force on the surface area of the head of the pin. This force is directed perpendicular to the surface area of the board. This force acts on a smaller area at the tip of the pin.

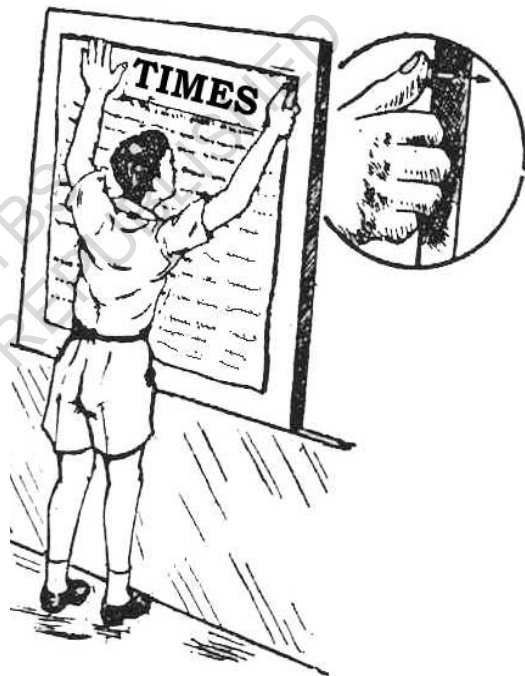


Fig. 9.3: To fix a poster, drawing pins are pressed with the thumb perpendicular to the board.

9.5 Thrust and Pressure

Have you ever wondered why a camel can run in a desert easily? Why an army tank weighing more than a thousand tonne rests upon a continuous chain? Why a truck or a motorbus has much wider tyres? Why cutting tools have sharp edges? In order to address these questions and understand the phenomena involved, it helps to introduce the concepts

Situation 2: You stand on loose sand. Your feet go deep into the sand. Now, lie down on the sand. You will find that your body will not go that deep in the sand. In both cases the force exerted on the sand is the weight of your body.

You have learnt that weight is the force acting vertically downwards. Here the force is acting perpendicular to the surface of the sand. The force acting on an object perpendicular to the surface is called thrust.

When you stand on loose sand, the force, that is, the weight of your body is acting on an area equal to area of your feet. When you lie down, the same force acts on an area equal to the contact area of your whole body, which is larger than the area of your feet. Thus, the effects of forces of the same magnitude on different areas are different. In the above cases, thrust is the same. But effects are different. Therefore the effect of thrust depends on the area on which it acts.

The effect of thrust on sand is larger while standing than while lying. The thrust on unit area is called pressure. Thus,

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} \quad (9.20)$$

Substituting the SI unit of thrust and area in Eq. (9.20), we get the SI unit of pressure as N/m^2 or N m^{-2} .

In honour of scientist Blaise Pascal, the SI unit of pressure is called pascal, denoted as Pa.

Let us consider a numerical example to understand the effects of thrust acting on different areas.

Example 9.6 A block of wood is kept on a tabletop. The mass of wooden block is 5 kg and its dimensions are $40 \text{ cm} \times 20 \text{ cm} \times 10 \text{ cm}$. Find the pressure exerted

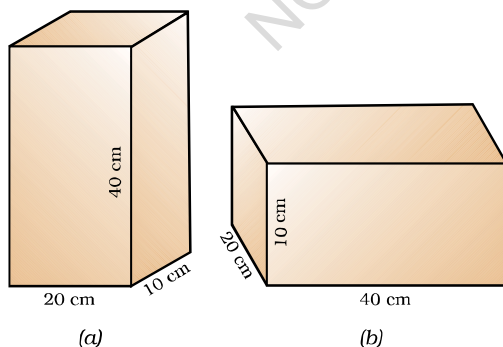


Fig. 9.4

by the wooden block on the table top if it is made to lie on the table top with its sides of dimensions (a) $20 \text{ cm} \times 10 \text{ cm}$ and (b) $40 \text{ cm} \times 20 \text{ cm}$.

Solution:

The mass of the wooden block = 5 kg

The dimensions

$$= 40 \text{ cm} \times 20 \text{ cm} \times 10 \text{ cm}$$

Here, the weight of the wooden block applies a thrust on the table top.

That is,

$$\begin{aligned} \text{Thrust} = F &= m \times g \\ &= 5 \text{ kg} \times 9.8 \text{ m s}^{-2} \\ &= 49 \text{ N} \end{aligned}$$

Area of a side = length $\times$ breadth

$$= 20 \text{ cm} \times 10 \text{ cm}$$

$$= 200 \text{ cm}^2 = 0.02 \text{ m}^2$$

From Eq. (9.20),

$$\begin{aligned} \text{Pressure} &= \frac{49 \text{ N}}{0.02 \text{ m}^2} \\ &= 2450 \text{ N m}^{-2}. \end{aligned}$$

When the block lies on its side of dimensions $40 \text{ cm} \times 20 \text{ cm}$, it exerts the same thrust.

Area = length $\times$ breadth

$$= 40 \text{ cm} \times 20 \text{ cm}$$

$$= 800 \text{ cm}^2 = 0.08 \text{ m}^2$$

From Eq. (9.20),

$$\begin{aligned} \text{Pressure} &= \frac{49 \text{ N}}{0.08 \text{ m}^2} \\ &= 612.5 \text{ N m}^{-2} \end{aligned}$$

The pressure exerted by the side $20 \text{ cm} \times 10 \text{ cm}$ is 2450 N m^{-2} and by the side $40 \text{ cm} \times 20 \text{ cm}$ is 612.5 N m^{-2} .

Thus, the same force acting on a smaller area exerts a larger pressure, and a smaller pressure on a larger area. This is the reason why a nail has a pointed tip, knives have sharp edges and buildings have wide foundations.

9.5.1 PRESSURE IN FLUIDS

All liquids and gases are fluids. A solid exerts pressure on a surface due to its weight. Similarly, fluids have weight, and they also

exert pressure on the base and walls of the container in which they are enclosed. Pressure exerted in any confined mass of fluid is transmitted undiminished in all directions.

9.5.2 BUOYANCY

Have you ever had a swim in a pool and felt lighter? Have you ever drawn water from a well and felt that the bucket of water is heavier when it is out of the water? Have you ever wondered why a ship made of iron and steel does not sink in sea water, but while the same amount of iron and steel in the form of a sheet would sink? These questions can be answered by taking buoyancy in consideration. Let us understand the meaning of buoyancy by doing an activity.

Activity _____ 9.4

- Take an empty plastic bottle. Close the mouth of the bottle with an airtight stopper. Put it in a bucket filled with water. You see that the bottle floats.
- Push the bottle into the water. You feel an upward push. Try to push it further down. You will find it difficult to push deeper and deeper. This indicates that water exerts a force on the bottle in the upward direction. The upward force exerted by the water goes on increasing as the bottle is pushed deeper till it is completely immersed.
- Now, release the bottle. It bounces back to the surface.
- Does the force due to the gravitational attraction of the earth act on this bottle? If so, why doesn't the bottle stay immersed in water after it is released? How can you immerse the bottle in water?

The force due to the gravitational attraction of the earth acts on the bottle in the downward direction. So the bottle is pulled downwards. But the water exerts an upward force on the bottle. Thus, the bottle is pushed upwards. We have learnt that weight of an object is the force due to gravitational attraction of the earth. When the bottle is immersed, the upward force exerted by the

water on the bottle is greater than its weight. Therefore it rises up when released.

To keep the bottle completely immersed, the upward force on the bottle due to water must be balanced. This can be achieved by an externally applied force acting downwards. This force must at least be equal to the difference between the upward force and the weight of the bottle.

The upward force exerted by the water on the bottle is known as upthrust or buoyant force. In fact, all objects experience a force of buoyancy when they are immersed in a fluid. The magnitude of this buoyant force depends on the density of the fluid.

9.5.3 WHY OBJECTS FLOAT OR SINK WHEN PLACED ON THE SURFACE OF WATER?

Let us do the following activities to arrive at an answer for the above question.

Activity _____ 9.5

- Take a beaker filled with water.
- Take an iron nail and place it on the surface of the water.
- Observe what happens.

The nail sinks. The force due to the gravitational attraction of the earth on the iron nail pulls it downwards. There is an upthrust of water on the nail, which pushes it upwards. But the downward force acting on the nail is greater than the upthrust of water on the nail. So it sinks (Fig. 9.5).

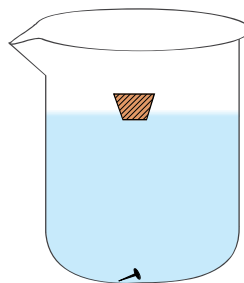


Fig. 9.5: An iron nail sinks and a cork floats when placed on the surface of water.

Activity 9.6

- Take a beaker filled with water.
- Take a piece of cork and an iron nail of equal mass.
- Place them on the surface of water.
- Observe what happens.

The cork floats while the nail sinks. This happens because of the difference in their densities. The density of a substance is defined as the mass per unit volume. The density of cork is less than the density of water. This means that the upthrust of water on the cork is greater than the weight of the cork. So it floats (Fig. 9.5).

The density of an iron nail is more than the density of water. This means that the upthrust of water on the iron nail is less than the weight of the nail. So it sinks.

Therefore objects of density less than that of a liquid float on the liquid. The objects of density greater than that of a liquid sink in the liquid.

Questions

1. Why is it difficult to hold a school bag having a strap made of a thin and strong string?
2. What do you mean by buoyancy?
3. Why does an object float or sink when placed on the surface of water?

9.6 Archimedes' Principle

Activity 9.7

- Take a piece of stone and tie it to one end of a rubber string or a spring balance.
- Suspend the stone by holding the balance or the string as shown in Fig. 9.6 (a).
- Note the elongation of the string or the reading on the spring balance due to the weight of the stone.
- Now, slowly dip the stone in the water in a container as shown in Fig. 9.6 (b).

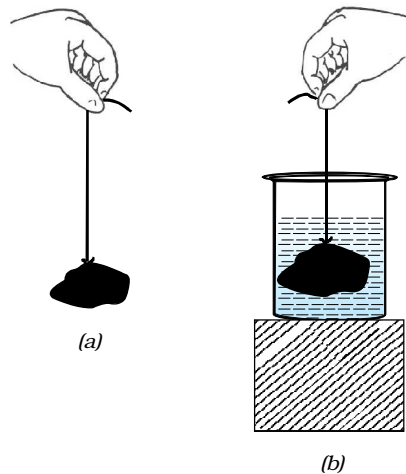


Fig. 9.6: (a) Observe the elongation of the rubber string due to the weight of a piece of stone suspended from it in air. (b) The elongation decreases as the stone is immersed in water.

- Observe what happens to elongation of the string or the reading on the balance.

You will find that the elongation of the string or the reading of the balance decreases as the stone is gradually lowered in the water. However, no further change is observed once the stone gets fully immersed in the water. What do you infer from the decrease in the extension of the string or the reading of the spring balance?

We know that the elongation produced in the string or the spring balance is due to the weight of the stone. Since the extension decreases once the stone is lowered in water, it means that some force acts on the stone in upward direction. As a result, the net force on the string decreases and hence the elongation also decreases. As discussed earlier, this upward force exerted by water is known as the force of buoyancy.

What is the magnitude of the buoyant force experienced by a body? Is it the same in all fluids for a given body? Do all bodies in a given fluid experience the same buoyant force? The answer to these questions is contained in Archimedes' principle, stated as follows:

When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

Now, can you explain why a further decrease in the elongation of the string was not observed in activity 9.7, as the stone was fully immersed in water?

Archimedes was a Greek scientist. He discovered the principle, subsequently named after him, after noticing that the water in a bathtub overflowed when he stepped into it. He ran through the streets shouting "Eureka!", which means "I have got it". This knowledge helped him to determine the purity of the gold in the crown made for the king.



Archimedes

His work in the field of Geometry and Mechanics made him famous. His understanding of levers, pulleys, wheels-and-axle helped the Greek army in its war with Roman army.

Archimedes' principle has many applications. It is used in designing ships and submarines. Lactometers, which are used to determine the purity of a sample of milk and hydrometers used for determining density of liquids, are based on this principle.

Questions

1. You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?
2. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?



What you have learnt

- The law of gravitation states that the force of attraction between any two objects is proportional to the product of their masses and inversely proportional to the square of the distance between them. The law applies to objects anywhere in the universe. Such a law is said to be universal.
- Gravitation is a weak force unless large masses are involved.
- The force of gravity decreases with altitude. It also varies on the surface of the earth, decreasing from poles to the equator.
- The weight of a body is the force with which the earth attracts it.
- The weight is equal to the product of mass and acceleration due to gravity.
- The weight may vary from place to place but the mass stays constant.

- All objects experience a force of buoyancy when they are immersed in a fluid.
- Objects having density less than that of the liquid in which they are immersed, float on the surface of the liquid. If the density of the object is more than the density of the liquid in which it is immersed then it sinks in the liquid.



Exercises

1. How does the force of gravitation between two objects change when the distance between them is reduced to half ?
2. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?
3. What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6×10^{24} kg and radius of the earth is 6.4×10^6 m.)
4. The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why?
5. If the moon attracts the earth, why does the earth not move towards the moon?
6. What happens to the force between two objects, if
 - (i) the mass of one object is doubled?
 - (ii) the distance between the objects is doubled and tripled?
 - (iii) the masses of both objects are doubled?
7. What is the importance of universal law of gravitation?
8. What is the acceleration of free fall?
9. What do we call the gravitational force between the earth and an object?
10. Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why? [Hint: The value of g is greater at the poles than at the equator.]
11. Why will a sheet of paper fall slower than one that is crumpled into a ball?
12. Gravitational force on the surface of the moon is only $\frac{1}{6}$ as strong as gravitational force on the earth. What is the weight in newtons of a 10 kg object on the moon and on the earth?

13. A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate
 - (i) the maximum height to which it rises,
 - (ii) the total time it takes to return to the surface of the earth.
14. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.
15. A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking $g = 10 \text{ m/s}^2$, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?
16. Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = $6 \times 10^{24} \text{ kg}$ and of the Sun = $2 \times 10^{30} \text{ kg}$. The average distance between the two is $1.5 \times 10^{11} \text{ m}$.
17. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.
18. A ball thrown up vertically returns to the thrower after 6 s. Find
 - (a) the velocity with which it was thrown up,
 - (b) the maximum height it reaches, and
 - (c) its position after 4 s.
19. In what direction does the buoyant force on an object immersed in a liquid act?
20. Why does a block of plastic released under water come up to the surface of water?
21. The volume of 50 g of a substance is 20 cm^3 . If the density of water is 1 g cm^{-3} , will the substance float or sink?
22. The volume of a 500 g sealed packet is 350 cm^3 . Will the packet float or sink in water if the density of water is 1 g cm^{-3} ? What will be the mass of the water displaced by this packet?

Chapter 10



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WORK AND ENERGY

In the previous few chapters we have talked about ways of describing the motion of objects, the cause of motion and gravitation. Another concept that helps us understand and interpret many natural phenomena is 'work'. Closely related to work are energy and power. In this chapter we shall study these concepts.

All living beings need food. Living beings have to perform several basic activities to survive. We call such activities 'life processes'. The energy for these processes comes from food. We need energy for other activities like playing, singing, reading, writing, thinking, jumping, cycling and running. Activities that are strenuous require more energy.

Animals too get engaged in activities. For example, they may jump and run. They have to fight, move away from enemies, find food or find a safe place to live. Also, we engage some animals to lift weights, carry loads, pull carts or plough fields. All such activities require energy.

Think of machines. List the machines that you have come across. What do they need for their working? Why do some engines require fuel like petrol and diesel? Why do living beings and machines need energy?

10.1 Work

What is work? There is a difference in the way we use the term 'work' in day-to-day life and the way we use it in science. To make this point clear let us consider a few examples.

10.1.1 NOT MUCH 'WORK' IN SPITE OF WORKING HARD!

Kamali is preparing for examinations. She spends lot of time in studies. She reads books,

draws diagrams, organises her thoughts, collects question papers, attends classes, discusses problems with her friends, and performs experiments. She expends a lot of energy on these activities. In common parlance, she is 'working hard'. All this 'hard work' may involve very little 'work' if we go by the scientific definition of work.

You are working hard to push a huge rock. Let us say the rock does not move despite all the effort. You get completely exhausted. However, you have not done any work on the rock as there is no displacement of the rock.

You stand still for a few minutes with a heavy load on your head. You get tired. You have exerted yourself and have spent quite a bit of your energy. Are you doing work on the load? The way we understand the term 'work' in science, work is not done.

You climb up the steps of a staircase and reach the second floor of a building just to see the landscape from there. You may even climb up a tall tree. If we apply the scientific definition, these activities involve a lot of work.

In day-to-day life, we consider any useful physical or mental labour as work. Activities like playing in a field, talking with friends, humming a tune, watching a movie, attending a function are sometimes not considered to be work. What constitutes 'work' depends on the way we define it. We use and define the term work differently in science. To understand this let us do the following activities:

Activity _____ 10.1

- We have discussed in the above paragraphs a number of activities which we normally consider to be work

in day-to-day life. For each of these activities, ask the following questions and answer them:

- (i) What is the work being done on?
- (ii) What is happening to the object?
- (iii) Who (what) is doing the work?

10.1.2 SCIENTIFIC CONCEPTION OF WORK

To understand the way we view work and define work from the point of view of science, let us consider some situations:

Push a pebble lying on a surface. The pebble moves through a distance. You exerted a force on the pebble and the pebble got displaced. In this situation work is done.

A girl pulls a trolley and the trolley moves through a distance. The girl has exerted a force on the trolley and it is displaced. Therefore, work is done.

Lift a book through a height. To do this you must apply a force. The book rises up. There is a force applied on the book and the book has moved. Hence, work is done.

A closer look at the above situations reveals that two conditions need to be satisfied for work to be done: (i) a force should act on an object, and (ii) the object must be displaced.

If any one of the above conditions does not exist, work is not done. This is the way we view work in science.

A bullock is pulling a cart. The cart moves. There is a force on the cart and the cart has moved. Do you think that work is done in this situation?

Activity 10.2

- Think of some situations from your daily life involving work.
- List them.
- Discuss with your friends whether work is being done in each situation.
- Try to reason out your response.
- If work is done, which is the force acting on the object?
- What is the object on which the work is done?
- What happens to the object on which work is done?

Activity 10.3

- Think of situations when the object is not displaced in spite of a force acting on it.
- Also think of situations when an object gets displaced in the absence of a force acting on it.
- List all the situations that you can think of for each.
- Discuss with your friends whether work is done in these situations.

10.1.3 WORK DONE BY A CONSTANT FORCE

How is work defined in science? To understand this, we shall first consider the case when the force is acting in the direction of displacement.

Let a constant force, F act on an object. Let the object be displaced through a distance, s in the direction of the force (Fig. 10.1). Let W be the work done. We define work to be equal to the product of the force and displacement.

$$\begin{aligned} \text{Work done} &= \text{force} \times \text{displacement} \\ W &= F s \end{aligned} \quad (10.1)$$

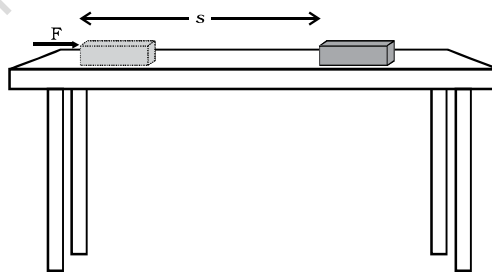


Fig. 10.1

Thus, work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force. Work has only magnitude and no direction.

In Eq. (10.1), if $F = 1 \text{ N}$ and $s = 1 \text{ m}$ then the work done by the force will be 1 N m . Here the unit of work is newton metre (N m) or joule (J). Thus 1 J is the amount of work

done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.

Look at Eq. (10.1) carefully. What is the work done when the force on the object is zero? What would be the work done when the displacement of the object is zero? Refer to the conditions that are to be satisfied to say that work is done.

Example 10.1 A force of 5 N is acting on an object. The object is displaced through 2 m in the direction of the force (Fig. 10.2). If the force acts on the object all through the displacement, then work done is $5 \text{ N} \times 2 \text{ m} = 10 \text{ N m}$ or 10 J.

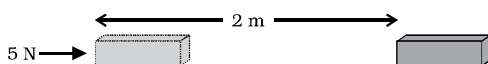


Fig. 10.2



Question

1. A force of 7 N acts on an object. The displacement is, say 8 m, in the direction of the force (Fig. 10.3). Let us take it that the force acts on the object through the displacement. What is the work done in this case?

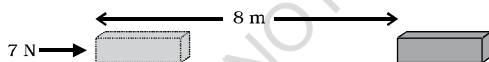


Fig. 10.3

Consider another situation in which the force and the displacement are in the same direction: a baby pulling a toy car parallel to the ground, as shown in Fig. 10.4. The baby has exerted a force in the direction of displacement of the car. In this situation, the work done will be equal to the product of the force and displacement. In such situations, the work done by the force is taken as positive.

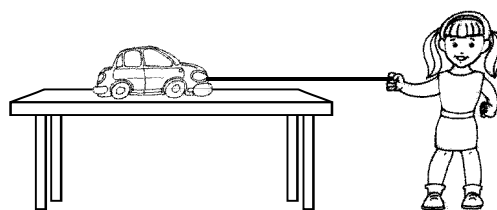


Fig. 10.4

Consider a situation in which an object is moving with a uniform velocity along a particular direction. Now a retarding force, F , is applied in the opposite direction. That is, the angle between the two directions is 180° . Let the object stop after a displacement s . In such a situation, the work done by the force, F is taken as negative and denoted by the minus sign. The work done by the force is $F \times (-s)$ or $(-F \times s)$.

It is clear from the above discussion that the work done by a force can be either positive or negative. To understand this, let us do the following activity:

Activity 10.4

- Lift an object up. Work is done by the force exerted by you on the object. The object moves upwards. The force you exerted is in the direction of displacement. However, there is the force of gravity acting on the object.
- Which one of these forces is doing positive work?
- Which one is doing negative work?
- Give reasons.

Work done is negative when the force acts opposite to the direction of displacement. Work done is positive when the force is in the direction of displacement.

Example 10.2 A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.

Solution:

Mass of luggage, $m = 15 \text{ kg}$ and displacement, $s = 1.5 \text{ m}$.

$$\begin{aligned}
 \text{Work done, } W &= F \times s = mg \times s \\
 &= 15 \text{ kg} \times 10 \text{ m s}^{-2} \times 1.5 \text{ m} \\
 &= 225 \text{ kg m s}^{-2} \text{ m} \\
 &= 225 \text{ N m} = 225 \text{ J}
 \end{aligned}$$

Work done is 225 J.

Questions

1. When do we say that work is done?
2. Write an expression for the work done when a force is acting on an object in the direction of its displacement.
3. Define 1 J of work.
4. A pair of bullocks exerts a force of 140 N on a plough. The field being ploughed is 15 m long. How much work is done in ploughing the length of the field?

10.2 Energy

Life is impossible without energy. The demand for energy is ever increasing. Where do we get energy from? The Sun is the biggest natural source of energy to us. Many of our energy sources are derived from the Sun. We can also get energy from the nuclei of atoms, the interior of the earth, and the tides. Can you think of other sources of energy?

Activity 10.5

- A few sources of energy are listed above. There are many other sources of energy. List them.
- Discuss in small groups how certain sources of energy are due to the Sun.
- Are there sources of energy which are not due to the Sun?

The word energy is very often used in our daily life, but in science we give it a definite and precise meaning. Let us consider the following examples: when a fast moving cricket ball hits a stationary wicket, the wicket is thrown away. Similarly, an object when raised to a certain height gets the capability to do work. You must have seen that when a

raised hammer falls on a nail placed on a piece of wood, it drives the nail into the wood. We have also observed children winding a toy (such as a toy car) and when the toy is placed on the floor, it starts moving. When a balloon is filled with air and we press it we notice a change in its shape. As long as we press it gently, it can come back to its original shape when the force is withdrawn. However, if we press the balloon hard, it can even explode producing a blasting sound. In all these examples, the objects acquire, through different means, the capability of doing work. An object having a capability to do work is said to possess energy. The object which does the work loses energy and the object on which the work is done gains energy.

How does an object with energy do work? An object that possesses energy can exert a force on another object. When this happens, energy is transferred from the former to the latter. The second object may move as it receives energy and therefore do some work. Thus, the first object had a capacity to do work. This implies that any object that possesses energy can do work.

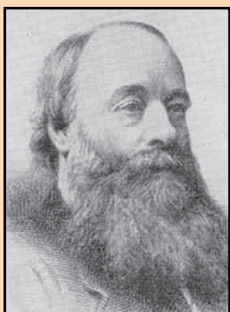
The energy possessed by an object is thus measured in terms of its capacity of doing work. The unit of energy is, therefore, the same as that of work, that is, joule (J). 1 J is the energy required to do 1 joule of work. Sometimes a larger unit of energy called kilo joule (kJ) is used. 1 kJ equals 1000 J.

10.2.1 FORMS OF ENERGY

Luckily the world we live in provides energy in many different forms. The various forms include mechanical energy (potential energy + kinetic energy), heat energy, chemical energy, electrical energy and light energy.

Think it over !

How do you know that some entity is a form of energy? Discuss with your friends and teachers.



James Prescott Joule
(1818 – 1889)

James Prescott Joule was an outstanding British physicist. He is best known for his research in electricity and thermodynamics. Amongst other things, he formulated a law for the heating effect of electric current. He also

verified experimentally the law of conservation of energy and discovered the value of the mechanical equivalent of heat. The unit of energy and work called joule, is named after him.

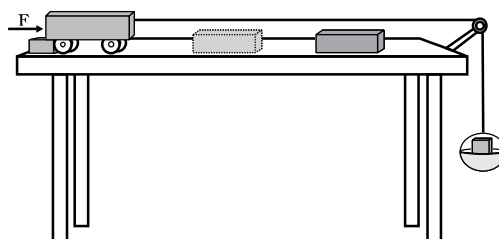


Fig. 10.5

10.2.2 KINETIC ENERGY

Activity 10.6

- Take a heavy ball. Drop it on a thick bed of sand. A wet bed of sand would be better. Drop the ball on the sand bed from height of about 25 cm. The ball creates a depression.
- Repeat this activity from heights of 50 cm, 1 m and 1.5 m.
- Ensure that all the depressions are distinctly visible.
- Mark the depressions to indicate the height from which the ball was dropped.
- Compare their depths.
- Which one of them is deepest?
- Which one is shallowest? Why?
- What has caused the ball to make a deeper dent?
- Discuss and analyse.

Activity 10.7

- Set up the apparatus as shown in Fig. 10.5.
- Place a wooden block of known mass in front of the trolley at a convenient fixed distance.
- Place a known mass on the pan so that the trolley starts moving.

- The trolley moves forward and hits the wooden block.
- Fix a stop on the table in such a manner that the trolley stops after hitting the block. The block gets displaced.
- Note down the displacement of the block. This means work is done on the block by the trolley as the block has gained energy.
- From where does this energy come?
- Repeat this activity by increasing the mass on the pan. In which case is the displacement more?
- In which case is the work done more?
- In this activity, the moving trolley does work and hence it possesses energy.

A moving object can do work. An object moving faster can do more work than an identical object moving relatively slow. A moving bullet, blowing wind, a rotating wheel, a speeding stone can do work. How does a bullet pierce the target? How does the wind move the blades of a windmill? Objects in motion possess energy. We call this energy kinetic energy.

A falling coconut, a speeding car, a rolling stone, a flying aircraft, flowing water, blowing wind, a running athlete etc. possess kinetic energy. In short, kinetic energy is the energy possessed by an object due to its motion. The kinetic energy of an object increases with its speed.

How much energy is possessed by a moving body by virtue of its motion? By definition, we say that the kinetic energy of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity.

Let us now express the kinetic energy of an object in the form of an equation. Consider an object of mass, m moving with a uniform velocity, u . Let it now be displaced through a distance s when a constant force, F acts on it in the direction of its displacement. From Eq. (10.1), the work done, W is $F s$. The work done on the object will cause a change in its velocity. Let its velocity change from u to v . Let a be the acceleration produced.

We studied three equations of motion. The relation connecting the initial velocity (u) and final velocity (v) of an object moving with a uniform acceleration a , and the displacement, s is

$$v^2 - u^2 = 2a s$$

This gives

$$s = \frac{v^2 - u^2}{2a} \quad (10.2)$$

From section 9.4, we know $F = m a$. Thus, using (Eq. 10.2) in Eq. (10.1), we can write the work done by the force, F as

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

or

$$W = \frac{1}{2} m (v^2 - u^2) \quad (10.3)$$

If the object is starting from its stationary position, that is, $u = 0$, then

$$W = \frac{1}{2} m v^2 \quad (10.4)$$

It is clear that the work done is equal to the change in the kinetic energy of an object.

If $u = 0$, the work done will be $\frac{1}{2} m v^2$.

Thus, the kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is

$$E_k = \frac{1}{2} m v^2 \quad (10.5)$$

Example 10.3 An object of mass 15 kg is moving with a uniform velocity of 4 m s⁻¹. What is the kinetic energy possessed by the object?

Solution:

Mass of the object, $m = 15$ kg, velocity of the object, $v = 4$ m s⁻¹.

From Eq. (10.5),

$$\begin{aligned} E_k &= \frac{1}{2} m v^2 \\ &= \frac{1}{2} \times 15 \text{ kg} \times 4 \text{ m s}^{-1} \times 4 \text{ m s}^{-1} \\ &= 120 \text{ J} \end{aligned}$$

The kinetic energy of the object is 120 J.

Example 10.4 What is the work to be done to increase the velocity of a car from 30 km h⁻¹ to 60 km h⁻¹ if the mass of the car is 1500 kg?

Solution:

Mass of the car, $m = 1500$ kg,
initial velocity of car, $u = 30$ km h⁻¹

$$\begin{aligned} &= \frac{30 \times 1000 \text{ m}}{60 \times 60 \text{ s}} \\ &= 25/3 \text{ m s}^{-1}. \end{aligned}$$

Similarly, the final velocity of the car,

$$\begin{aligned} v &= 60 \text{ km h}^{-1} \\ &= 50/3 \text{ m s}^{-1}. \end{aligned}$$

Therefore, the initial kinetic energy of the car,

$$\begin{aligned} E_{ki} &= \frac{1}{2} m u^2 \\ &= \frac{1}{2} \times 1500 \text{ kg} \times (25/3 \text{ m s}^{-1})^2 \\ &= 156250/3 \text{ J}. \end{aligned}$$

The final kinetic energy of the car,

$$\begin{aligned} E_{kf} &= \frac{1}{2} \times 1500 \text{ kg} \times (50/3 \text{ m s}^{-1})^2 \\ &= 625000/3 \text{ J}. \end{aligned}$$

Thus, the work done = Change in kinetic energy

$$\begin{aligned} &= E_{kf} - E_{ki} \\ &= 156250 \text{ J}. \end{aligned}$$

Questions

1. What is the kinetic energy of an object?
2. Write an expression for the kinetic energy of an object.
3. The kinetic energy of an object of mass, m moving with a velocity of 5 m s^{-1} is 25 J . What will be its kinetic energy when its velocity is doubled? What will be its kinetic energy when its velocity is increased three times?

10.2.3 POTENTIAL ENERGY

Activity 10.8

- Take a rubber band.
- Hold it at one end and pull from the other. The band stretches.
- Release the band at one of the ends.
- What happens?
- The band will tend to regain its original length. Obviously the band had acquired energy in its stretched position.
- How did it acquire energy when stretched?

Activity 10.9

- Take a slinky as shown below.
- Ask a friend to hold one of its ends. You hold the other end and move away from your friend. Now you release the slinky.



- What happened?
- How did the slinky acquire energy when stretched?
- Would the slinky acquire energy when it is compressed?

Activity 10.10

- Take a toy car. Wind it using its key.
- Place the car on the ground.
- Did it move?
- From where did it acquire energy?
- Does the energy acquired depend on the number of windings?
- How can you test this?

Activity 10.11

- Lift an object through a certain height. The object can now do work. It begins to fall when released.
- This implies that it has acquired some energy. If raised to a greater height it can do more work and hence possesses more energy.
- From where did it get the energy? Think and discuss.

In the above situations, the energy gets stored due to the work done on the object. The energy transferred to an object is stored as potential energy if it is not used to cause a change in the velocity or speed of the object.

You transfer energy when you stretch a rubber band. The energy transferred to the band is its potential energy. You do work while winding the key of a toy car. The energy transferred to the spring inside is stored as potential energy. The potential energy possessed by the object is the energy present in it by virtue of its position or configuration.

Activity 10.12

- Take a bamboo stick and make a bow as shown in Fig. 10.6.
- Place an arrow made of a light stick on it with one end supported by the stretched string.
- Now stretch the string and release the arrow.
- Notice the arrow flying off the bow. Notice the change in the shape of the bow.
- The potential energy stored in the bow due to the change of shape is thus used in the form of kinetic energy in throwing off the arrow.

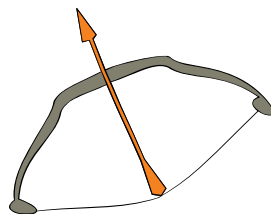


Fig.10.6: An arrow and the stretched string on the bow.

10.2.4 POTENTIAL ENERGY OF AN OBJECT AT A HEIGHT

An object increases its energy when raised through a height. This is because work is done on it against gravity while it is being raised. The energy present in such an object is the gravitational potential energy.

The gravitational potential energy of an object at a point above the ground is defined as the work done in raising it from the ground to that point against gravity.

It is easy to arrive at an expression for the gravitational potential energy of an object at a height.

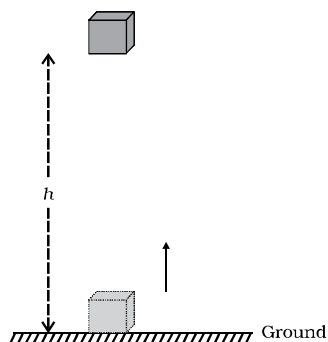


Fig. 10.7

Consider an object of mass, m . Let it be raised through a height, h from the ground. A force is required to do this. The minimum force required to raise the object is equal to the weight of the object, mg . The object gains energy equal to the work done on it. Let the work done on the object against gravity be W . That is,

$$\begin{aligned}\text{work done, } W &= \text{force} \times \text{displacement} \\ &= mg \times h \\ &= mgh\end{aligned}$$

Since work done on the object is equal to mgh , an energy equal to mgh units is gained by the object. This is the potential energy (E_p) of the object.

$$E_p = mgh \quad (10.6)$$

More to know

The potential energy of an object at a height depends on the ground level or the zero level you choose. An object in a given position can have a certain potential energy with respect to one level and a different value of potential energy with respect to another level.

It is useful to note that the work done by gravity depends on the difference in vertical heights of the initial and final positions of the object and not on the path along which the object is moved. Fig. 10.8 shows a case where a block is raised from position A to B by taking two different paths. Let the height $AB = h$. In both the situations the work done on the object is mgh .

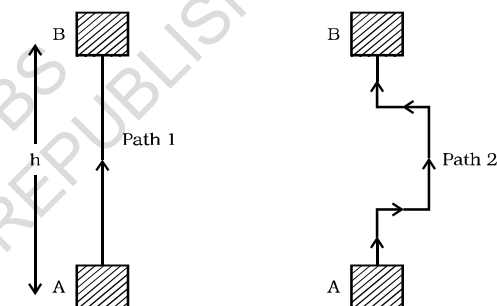


Fig. 10.8

Example 10.5 Find the energy possessed by an object of mass 10 kg when it is at a height of 6 m above the ground. Given, $g = 9.8 \text{ m s}^{-2}$.

Solution:

Mass of the object, $m = 10 \text{ kg}$, displacement (height), $h = 6 \text{ m}$, and acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$. From Eq. (10.6),

$$\begin{aligned}\text{Potential energy} &= mgh \\ &= 10 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 6 \text{ m} \\ &= 588 \text{ J}.\end{aligned}$$

The potential energy is 588 J.

Example 10.6 An object of mass 12 kg is at a certain height above the ground. If the potential energy of the object is 480 J, find the height at which the object is with respect to the ground. Given, $g = 10 \text{ m s}^{-2}$.

Solution:

Mass of the object, $m = 12 \text{ kg}$,
potential energy, $E_p = 480 \text{ J}$.

$$E_p = mgh$$

$$480 \text{ J} = 12 \text{ kg} \times 10 \text{ m s}^{-2} \times h$$

$$h = \frac{480 \text{ J}}{120 \text{ kg ms}^{-2}} = 4 \text{ m}.$$

The object is at the height of 4 m.

10.2.5 ARE VARIOUS ENERGY FORMS INTERCONVERTIBLE?

Can we convert energy from one form to another? We find in nature a number of instances of conversion of energy from one form to another.

Activity 10.13

- Sit in small groups.
- Discuss the various ways of energy conversion in nature.
- Discuss following questions in your group:
 - (a) How do green plants produce food?
 - (b) Where do they get their energy from?
 - (c) Why does the air move from place to place?
 - (d) How are fuels, such as coal and petroleum formed?
 - (e) What kinds of energy conversions sustain the water cycle?

Activity 10.14

- Many of the human activities and the gadgets we use involve conversion of energy from one form to another.
- Make a list of such activities and gadgets.
- Identify in each activity/gadget the kind of energy conversion that takes place.

10.2.6 LAW OF CONSERVATION OF ENERGY

In activities 10.13 and 10.14, we learnt that the form of energy can be changed from one form to another. What happens to the total energy of a system during or after the process? Whenever energy gets transformed, the total energy remains unchanged. This is the law of conservation of energy. According to this law, energy can only be converted from one form to another; it can neither be created or destroyed. The total energy before and after the transformation remains the same. The law of conservation of energy is valid in all situations and for all kinds of transformations.

Consider a simple example. Let an object of mass, m be made to fall freely from a height, h . At the start, the potential energy is mgh and kinetic energy is zero. Why is the kinetic energy zero? It is zero because its velocity is zero. The total energy of the object is thus mgh . As it falls, its potential energy will change into kinetic energy. If v is the velocity of the object at a given instant, the kinetic energy would be $\frac{1}{2}mv^2$. As the fall of the object continues, the potential energy would decrease while the kinetic energy would increase. When the object is about to reach the ground, $h = 0$ and v will be the highest. Therefore, the kinetic energy would be the largest and potential energy the least. However, the sum of the potential energy and kinetic energy of the object would be the same at all points. That is,

potential energy + kinetic energy = constant
or

$$mgh + \frac{1}{2}mv^2 = \text{constant.} \quad (10.7)$$

The sum of kinetic energy and potential energy of an object is its total mechanical energy.

We find that during the free fall of the object, the decrease in potential energy, at any point in its path, appears as an equal amount of increase in kinetic energy. (Here the effect of air resistance on the motion of the object has been ignored.) There is thus a continual transformation of gravitational potential energy into kinetic energy.

Activity 10.15

- An object of mass 20 kg is dropped from a height of 4 m. Fill in the blanks in the following table by computing the potential energy and kinetic energy in each case.

Height at which object is located	Potential energy ($E_p = mgh$)	Kinetic energy ($E_k = mv^2/2$)	$E_p + E_k$
m	J	J	J
4			
3			
2			
1			
Just above the ground			

- For simplifying the calculations, take the value of g as 10 m s^{-2} .

Think it over !

What would have happened if nature had not allowed the transformation of energy? There is a view that life could not have been possible without transformation of energy. Do you agree with this?

10.3 Rate of Doing Work

Do all of us work at the same rate? Do machines consume or transfer energy at the same rate? Agents that transfer energy do work at different rates. Let us understand this from the following activity:

Activity 10.16

- Consider two children, say A and B. Let us say they weigh the same. Both start climbing up a rope separately. Both reach a height of 8 m. Let us say A takes 15 s while B takes 20 s to accomplish the task.
- What is the work done by each?
- The work done is the same. However, A has taken less time than B to do the work.
- Who has done more work in a given time, say in 1 s?

A stronger person may do certain work in relatively less time. A more powerful vehicle would complete a journey in a shorter time than a less powerful one. We talk of the power of machines like motorbikes and motorcars. The speed with which these vehicles change energy or do work is a basis for their classification. Power measures the speed of work done, that is, how fast or slow work is done. Power is defined as the rate of doing work or the rate of transfer of energy. If an agent does a work W in time t , then power is given by:

$$\text{Power} = \text{work/time}$$

$$\text{or } P = \frac{W}{t} \quad (10.8)$$

The unit of power is watt [in honour of James Watt (1736 – 1819)] having the symbol W. 1 watt is the power of an agent, which does work at the rate of 1 joule per second. We can also say that power is 1 W when the rate of consumption of energy is 1 J s^{-1} .

1 watt = 1 joule/second or $1 \text{ W} = 1 \text{ J s}^{-1}$. We express larger rates of energy transfer in kilowatts (kW).

$$1 \text{ kilowatt} = 1000 \text{ watts}$$

$$1 \text{ kW} = 1000 \text{ W}$$

$$1 \text{ kW} = 1000 \text{ J s}^{-1}$$

The power of an agent may vary with time. This means that the agent may be doing work at different rates at different intervals of time. Therefore the concept of average power is useful. We obtain average power by dividing the total energy consumed by the total time taken.

Example 10.7 Two girls, each of weight 400 N climb up a rope through a height of 8 m. We name one of the girls A and the other B. Girl A takes 20 s while B takes 50 s to accomplish this task. What is the power expended by each girl?

Solution:

- (i) Power expended by girl A:
Weight of the girl, $mg = 400 \text{ N}$
Displacement (height), $h = 8 \text{ m}$

Time taken, $t = 20$ s
From Eq. (10.8),

$$\begin{aligned}\text{Power, } P &= \text{Work done/time taken} \\ &= \frac{mgh}{t} \\ &= \frac{400 \text{ N} \times 8 \text{ m}}{20 \text{ s}} \\ &= 160 \text{ W.}\end{aligned}$$

- (ii) Power expended by girl B:
Weight of the girl, $mg = 400$ N
Displacement (height), $h = 8$ m
Time taken, $t = 50$ s

$$\begin{aligned}\text{Power, } P &= \frac{mgh}{t} \\ &= \frac{400 \text{ N} \times 8 \text{ m}}{50 \text{ s}} \\ &= 64 \text{ W.}\end{aligned}$$

Power expended by girl A is 160 W.
Power expended by girl B is 64 W.

Example 10.8 A boy of mass 50 kg runs up a staircase of 45 steps in 9 s. If the height of each step is 15 cm, find his power. Take $g = 10 \text{ m s}^{-2}$.

Solution:

Weight of the boy,
 $mg = 50 \text{ kg} \times 10 \text{ m s}^{-2} = 500 \text{ N}$
Height of the staircase,
 $h = 45 \times 15/100 \text{ m} = 6.75 \text{ m}$
Time taken to climb, $t = 9$ s
From Eq. (10.8),

power, $P = \text{Work done/time taken}$

$$\begin{aligned}&= \frac{mgh}{t} \\ &= \frac{500 \text{ N} \times 6.75 \text{ m}}{9 \text{ s}} \\ &= 375 \text{ W.}\end{aligned}$$

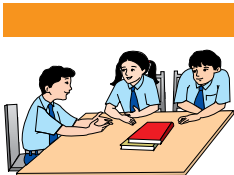
Power is 375 W.

Questions

1. What is power?
2. Define 1 watt of power.
3. A lamp consumes 1000 J of electrical energy in 10 s. What is its power?
4. Define average power.

Activity 10.17

- Take a close look at the electric meter installed in your house. Observe its features closely.
- Take the readings of the meter each day at 6.30 am and 6.30 pm.
- Do this activity for about a week.
- How many 'units' are consumed during day time?
- How many 'units' are used during night?
- Tabulate your observations.
- Draw inferences from the data.
- Compare your observations with the details given in the monthly electricity bill (One can also estimate the electricity to be consumed by specific appliances by tabulating their known wattages and hours of operation).



What you have learnt

- Work done on an object is defined as the magnitude of the force multiplied by the distance moved by the object in the direction of the applied force. The unit of work is joule: $1 \text{ joule} = 1 \text{ newton} \times 1 \text{ metre}$.
- Work done on an object by a force would be zero if the displacement of the object is zero.
- An object having capability to do work is said to possess energy. Energy has the same unit as that of work.
- An object in motion possesses what is known as the kinetic energy of the object. An object of mass, m moving with velocity v has a kinetic energy of $\frac{1}{2}mv^2$.
- The energy possessed by a body due to its change in position or shape is called the potential energy. The gravitational potential energy of an object of mass, m raised through a height, h from the earth's surface is given by mgh .
- According to the law of conservation of energy, energy can only be transformed from one form to another; it can neither be created nor destroyed. The total energy before and after the transformation always remains constant.
- Energy exists in nature in several forms such as kinetic energy, potential energy, heat energy, chemical energy etc. The sum of the kinetic and potential energies of an object is called its mechanical energy.
- Power is defined as the rate of doing work. The SI unit of power is watt. $1 \text{ W} = 1 \text{ J/s}$.



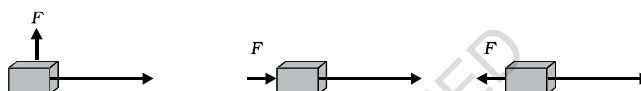
Exercises

1. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.
 - Suma is swimming in a pond.
 - A donkey is carrying a load on its back.
 - A wind-mill is lifting water from a well.
 - A green plant is carrying out photosynthesis.
 - An engine is pulling a train.

- Food grains are getting dried in the sun.
 - A sailboat is moving due to wind energy.
2. An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?
 3. A battery lights a bulb. Describe the energy changes involved in the process.
 4. Certain force acting on a 20 kg mass changes its velocity from 5 m s^{-1} to 2 m s^{-1} . Calculate the work done by the force.
 5. A mass of 10 kg is at a point A on a table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain your answer.
 6. The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?
 7. What are the various energy transformations that occur when you are riding a bicycle?
 8. Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going?
 9. A certain household has consumed 250 units of energy during a month. How much energy is this in joules?
 10. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down.
 11. What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer.
 12. Can there be displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher.
 13. A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not? Justify your answer.
 14. An electric heater is rated 1500 W. How much energy does it use in 10 hours?
 15. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob

eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

16. An object of mass, m is moving with a constant velocity, v . How much work should be done on the object in order to bring the object to rest?
17. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h?
18. In each of the following a force, F is acting on an object of mass, m . The direction of displacement is from west to east shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



19. Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her? Why?
20. Find the energy in joules consumed in 10 hours by four devices of power 500 W each.
21. A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy?

Chapter 11



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SOUND

Everyday we hear sounds from various sources like humans, birds, bells, machines, vehicles, televisions, radios etc. Sound is a form of energy which produces a sensation of hearing in our ears. There are also other forms of energy like mechanical energy, light energy, etc. We have talked about mechanical energy in the previous chapters. You have been taught about conservation of energy, which states that we can neither create nor destroy energy. We can just change it from one form to another. When you clap, a sound is produced. Can you produce sound without utilising your energy? Which form of energy did you use to produce sound? In this chapter we are going to learn how sound is produced and how it is transmitted through a medium and received by our ears.

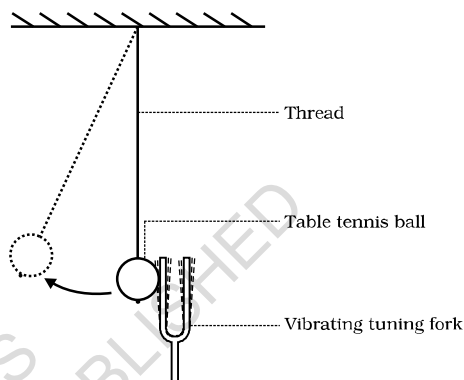


Fig. 11.1: Vibrating tuning fork just touching the suspended table tennis ball.

11.1 Production of Sound

Activity 11.1

- Take a tuning fork and set it vibrating by striking its prong on a rubber pad. Bring it near your ear.
- Do you hear any sound?
- Touch one of the prongs of the vibrating tuning fork with your finger and share your experience with your friends.
- Now, suspend a table tennis ball or a small plastic ball by a thread from a support [Take a big needle and a thread, put a knot at one end of the thread, and then with the help of the needle pass the thread through the ball]. Touch the ball gently with the prong of a vibrating tuning fork (Fig. 11.1).
- Observe what happens and discuss with your friends.

Activity 11.2

- Fill water in a beaker or a glass up to the brim. Gently touch the water surface with one of the prongs of the vibrating tuning fork, as shown in Fig. 11.2.
- Next dip the prongs of the vibrating tuning fork in water, as shown in Fig. 11.3.
- Observe what happens in both the cases.
- Discuss with your friends why this happens.

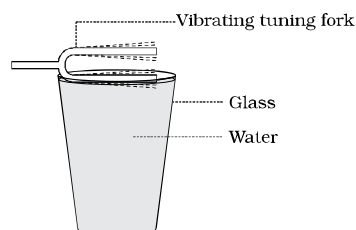


Fig. 11.2: One of the prongs of the vibrating tuning fork touching the water surface.

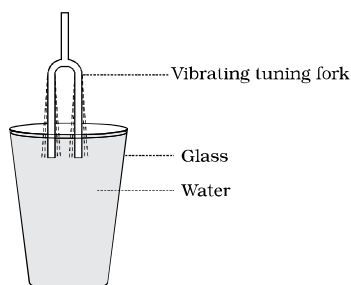


Fig. 11.3: Both the prongs of the vibrating tuning fork dipped in water

From the above activities what do you conclude? Can you produce sound without a vibrating object?

In the above activities we have produced sound by striking the tuning fork. We can also produce sound by plucking, scratching, rubbing, blowing or shaking different objects. As per the above activities what do we do to the objects? We set the objects vibrating and produce sound. Vibration means a kind of rapid to and fro motion of an object. The sound of the human voice is produced due to vibrations in the vocal cords. When a bird flaps its wings, do you hear any sound? Think how the buzzing sound accompanying a bee is produced. A stretched rubber band when plucked vibrates and produces sound. If you have never done this, then do it and observe the vibration of the stretched rubber band.

Activity 11.3

- Make a list of different types of musical instruments and discuss with your friends which part of the instrument vibrates to produce sound.

11.2 Propagation of Sound

Sound is produced by vibrating objects. The matter or substance through which sound is transmitted is called a medium. It can be solid, liquid or gas. Sound moves through a medium from the point of generation to the listener. When an object vibrates, it sets the particles of the medium around it vibrating. The particles do not travel all the way from

the vibrating object to the ear. A particle of the medium in contact with the vibrating object is first displaced from its equilibrium position. It then exerts a force on the adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches your ear. The disturbance created by a source of sound in the medium travels through the medium and not the particles of the medium.

A wave is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion. They in turn produce similar motion in others. The particles of the medium do not move forward themselves, but the disturbance is carried forward. This is what happens during propagation of sound in a medium, hence sound can be visualised as a wave. Sound waves are characterised by the motion of particles in the medium and are called mechanical waves.

Air is the most common medium through which sound travels. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure. This region is called a compression (C), as shown in Fig. 11.4. This compression starts to move away from the vibrating object. When the vibrating object moves backwards, it creates a region of low pressure called rarefaction (R), as shown in Fig. 11.4. As the object moves back and forth rapidly, a series of compressions and rarefactions is created in the air. These make the sound wave that

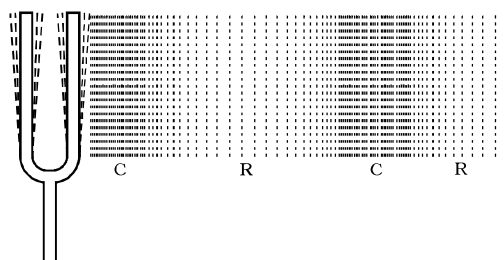


Fig. 11.4: A vibrating object creating a series of compressions (C) and rarefactions (R) in the medium.

propagates through the medium. Compression is the region of high pressure and rarefaction is the region of low pressure. Pressure is related to the number of particles of a medium in a given volume. More density of the particles in the medium gives more pressure and vice versa. Thus, propagation of sound can be visualised as propagation of density variations or pressure variations in the medium.

Question

1. How does the sound produced by a vibrating object in a medium reach your ear?
2. Explain how sound is produced by your school bell.
3. Why are sound waves called mechanical waves?
4. Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

11.2.1 SOUND WAVES ARE LONGITUDINAL WAVES

Activity 11.4

- Take a slinky. Ask your friend to hold one end. You hold the other end. Now stretch the slinky as shown in Fig. 11.5(a). Then give it a sharp push towards your friend.
- What do you notice? If you move your hand pushing and pulling the slinky alternatively, what will you observe?
- If you mark a dot on the slinky, you will observe that the dot on the slinky will move back and forth parallel to the direction of the propagation of the disturbance.

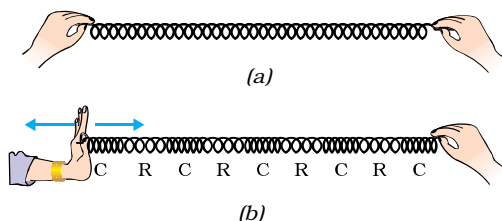


Fig. 11.5: Longitudinal wave in a slinky.

The regions where the coils become closer are called compressions (C) and the regions where the coils are further apart are called rarefactions (R). As we already know, sound propagates in the medium as a series of compressions and rarefactions. Now, we can compare the propagation of disturbance in a slinky with the sound propagation in the medium. These waves are called longitudinal waves. In these waves the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance. The particles do not move from one place to another but they simply oscillate back and forth about their position of rest. This is exactly how a sound wave propagates, hence sound waves are longitudinal waves.

There is also another type of wave, called a transverse wave. In a transverse wave particles do not oscillate along the direction of wave propagation but oscillate up and down about their mean position as the wave travels. Thus, a transverse wave is the one in which the individual particles of the medium move about their mean positions in a direction perpendicular to the direction of wave propagation. When we drop a pebble in a pond, the waves you see on the water surface is an example of transverse wave. Light is a transverse wave but for light, the oscillations are not of the medium particles or their pressure or density— it is not a mechanical wave. You will come to know more about transverse waves in higher classes.

11.2.2 CHARACTERISTICS OF A SOUND WAVE

We can describe a sound wave by its

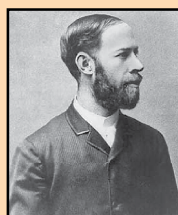
- frequency
- amplitude and
- speed.

A sound wave in graphic form is shown in Fig. 11.6(c), which represents how density and pressure change when the sound wave moves in the medium. The density as well as the pressure of the medium at a given time varies with distance, above and below the average value of density and pressure. Fig. 11.6(a) and

Fig. 11.6(b) represent the density and pressure variations, respectively, as a sound wave propagates in the medium.

Compressions are the regions where particles are crowded together and represented by the upper portion of the curve in Fig. 11.6(c). The peak represents the region of maximum compression. Thus, compressions are regions where density as well as pressure is high. Rarefactions are the regions of low pressure where particles are spread apart and are represented by the lower portion of the curve in Fig. 11.6(c). A peak is called the crest and a valley is called the trough of a wave.

The distance between two consecutive compressions (C) or two consecutive rarefactions (R) is called the wavelength, as shown in Fig. 11.6(c). The wavelength is usually represented by λ (Greek letter lambda). Its SI unit is metre (m).



H. R. Hertz

Heinrich Rudolph Hertz was born on 22 February 1857 in Hamburg, Germany and educated at the University of Berlin. He confirmed J.C. Maxwell's electromagnetic theory by his experiments. He laid the foundation for future development of radio, telephone, telegraph and even television. He also discovered the photoelectric effect which was later explained by Albert Einstein. The SI unit of frequency was named as hertz in his honour.

Frequency tells us how frequently an event occurs. Suppose you are beating a drum. How many times you are beating the drum in unit time is called the frequency of your beating the drum. We know that when sound is propagated through a medium, the

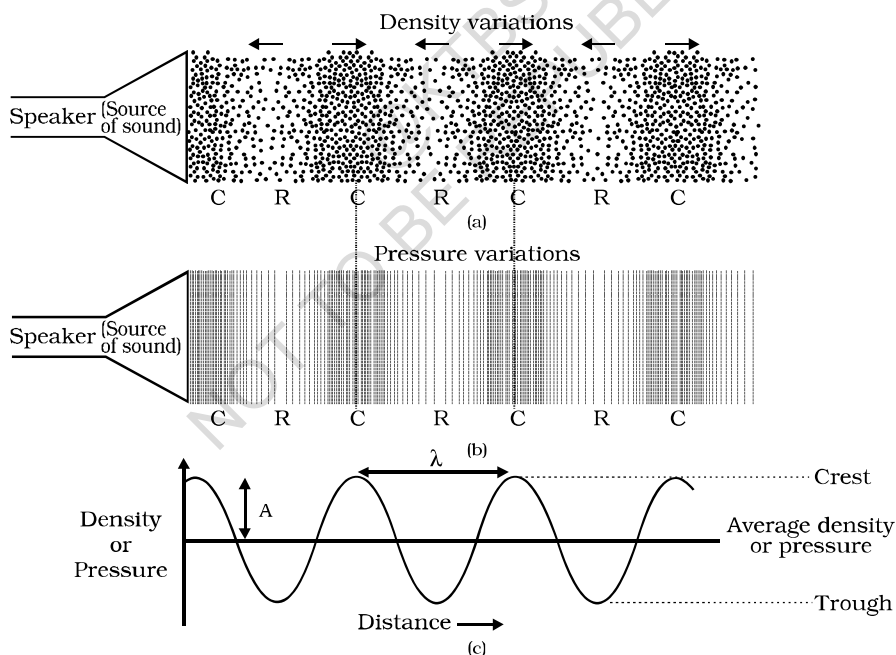


Fig. 11.6: Sound propagates as density or pressure variations as shown in (a) and (b), (c) represents graphically the density and pressure variations.

density of the medium oscillates between a maximum value and a minimum value. The change in density from the maximum value to the minimum value, then again to the maximum value, makes one complete oscillation. The number of such oscillations per unit time is the frequency of the sound wave. If we can count the number of the compressions or rarefactions that cross us per unit time, we will get the frequency of the sound wave. It is usually represented by ν (Greek letter, nu). Its SI unit is hertz (symbol, Hz).

The time taken by two consecutive compressions or rarefactions to cross a fixed point is called the time period of the wave. In other words, we can say that the time taken for one complete oscillation is called the time period of the sound wave. It is represented by the symbol T . Its SI unit is second (s). Frequency and time period are related as follows:

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

A violin and a flute may both be played at the same time in an orchestra. Both sounds travel through the same medium, that is, air and arrive at our ear at the same time. Both sounds travel at the same speed irrespective of the source. But the sounds we receive are different. This is due to the different characteristics associated with the sound.

Pitch is one of the characteristics.

How the brain interprets the frequency of an emitted sound is called its pitch. The faster the vibration of the source, the higher is the frequency and the higher is the pitch, as shown in Fig. 11.7. Thus, a high pitch sound corresponds to more number of compressions and rarefactions passing a fixed point per unit time.

Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.

The magnitude of the maximum disturbance in the medium on either side of the mean value is called the amplitude of the wave. It is usually represented by the letter A ,

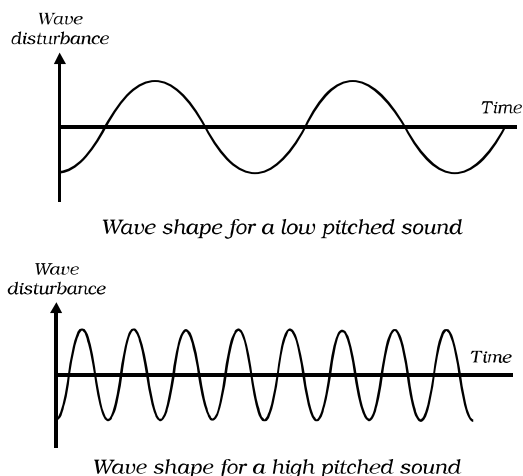


Fig. 11.7: Low pitch sound has low frequency and high pitch of sound has high frequency.

as shown in Fig. 11.6(c). For sound its unit will be that of density or pressure.

The loudness or softness of a sound is determined basically by its amplitude. The amplitude of the sound wave depends upon the force with which an object is made to vibrate. If we strike a table lightly, we hear a soft sound because we produce a sound wave

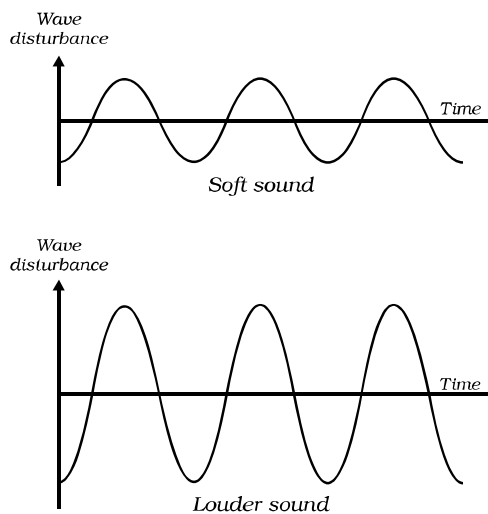


Fig. 11.8: Soft sound has small amplitude and louder sound has large amplitude.

of less energy (amplitude). If we hit the table hard we hear a louder sound. Can you tell why? A sound wave spreads out from its source. As it moves away from the source its amplitude as well as its loudness decreases. Louder sound can travel a larger distance as it is associated with higher energy. Fig. 11.8 shows the wave shapes of a loud and a soft sound of the same frequency.

The quality or timber of sound is that characteristic which enables us to distinguish one sound from another having the same pitch and loudness. The sound which is more pleasant is said to be of a rich quality. A sound of single frequency is called a tone. The sound which is produced due to a mixture of several frequencies is called a note and is pleasant to listen to. Noise is unpleasant to the ear! Music is pleasant to hear and is of rich quality.

Questions

1. Which wave property determines (a) loudness, (b) pitch?
2. Guess which sound has a higher pitch: guitar or car horn?

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit time.

We know,

$$\text{speed, } v = \text{distance} / \text{time}$$

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

Here λ is the wavelength of the sound wave. It is the distance travelled by the sound wave in one time period (T) of the wave. Thus,

$$v = \lambda v \left(\because \frac{1}{T} = v \right)$$

$$\text{or } v = \lambda v$$

That is, speed = wavelength $\times$ frequency.

The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Example 11.1 A sound wave has a frequency of 2 kHz and wave length 35 cm. How long will it take to travel 1.5 km?

Solution:

Given,

Frequency, $v = 2 \text{ kHz} = 2000 \text{ Hz}$

Wavelength, $\lambda = 35 \text{ cm} = 0.35 \text{ m}$

We know that speed, v of the wave

$$= \text{wavelength} \times \text{frequency}$$

$$v = \lambda v$$

$$= 0.35 \text{ m} \times 2000 \text{ Hz} = 700 \text{ m/s}$$

The time taken by the wave to travel a distance, d of 1.5 km is

$$t = \frac{d}{v} = \frac{1.5 \times 1000 \text{ m}}{700 \text{ m s}^{-1}} = \frac{15}{7} \text{ s} = 2.1 \text{ s.}$$

Thus sound will take 2.1 s to travel a distance of 1.5 km.

Questions

1. What are wavelength, frequency, time period and amplitude of a sound wave?
2. How are the wavelength and frequency of a sound wave related to its speed?
3. Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium.
4. A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source?

The amount of sound energy passing each second through unit area is called the intensity of sound. We sometimes use the terms “loudness” and “intensity” interchangeably, but they are not the same. Loudness is a measure of the response of the ear to the sound. Even when two sounds are of equal intensity, we may hear one as louder than the other simply because our ear detects it better.

Question

1. Distinguish between loudness and intensity of sound.

11.2.3 SPEED OF SOUND IN DIFFERENT MEDIA

Sound propagates through a medium at a finite speed. The sound of a thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels. You will learn about this dependence in higher classes. The speed of sound in a medium depends on temperature of the medium. The speed of sound decreases when we go from solid to gaseous state. In any medium as we increase the temperature, the speed of sound increases. For example, the speed of sound in air is 331 m s^{-1} at 0°C and 344 m s^{-1} at 22°C . The speeds of sound at a particular temperature in various media are listed in Table 11.1. You need not memorise the values.

Table 11.1: Speed of sound in different media at 25°C

State	Substance	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

SOUND

Question

1. In which of the three media, air, water or iron, does sound travel the fastest at a particular temperature?

11.3 Reflection of Sound

Sound bounces off a solid or a liquid like a rubber ball bounces off a wall. Like light, sound gets reflected at the surface of a solid or liquid and follows the same laws of reflection as you have studied in earlier classes. The directions in which the sound is incident and is reflected make equal angles with the normal to the reflecting surface at the point of incidence, and the three are in the same plane. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves.

Activity 11.5

- Take two identical pipes, as shown in Fig. 11.9. You can make the pipes using chart paper. The length of the pipes should be sufficiently long as shown.
 - Arrange them on a table near a wall.
 - Keep a clock near the open end of one of the pipes and try to hear the sound of the clock through the other pipe.
 - Adjust the position of the pipes so that you can best hear the sound of the clock.
 - Now, measure the angles of incidence and reflection and see the relationship between the angles.
 - Lift the pipe on the right vertically to a small height and observe what happens.
- (In place of a clock, a mobile phone on vibrating mode may also be used.)

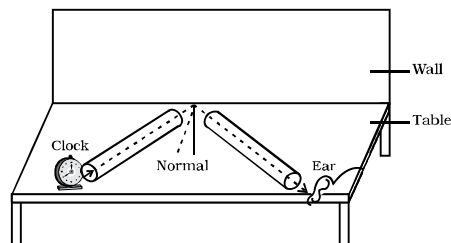


Fig. 11.9: Reflection of sound

11.3.1 ECHO

If we shout or clap near a suitable reflecting object such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1 s. To hear a distinct echo the time interval between the original sound and the reflected one must be at least 0.1 s. If we take the speed of sound to be 344 m/s at a given temperature, say at 22 °C in air, the sound must go to the obstacle and reach back the ear of the listener on reflection after 0.1 s. Hence, the total distance covered by the sound from the point of generation to the reflecting surface and back should be at least $(344 \text{ m/s}) \times 0.1 \text{ s} = 34.4 \text{ m}$. Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance, that is, 17.2 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections. The rolling of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land.

11.3.2 REVERBERATION

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound-absorbent materials like compressed fibreboard, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Example 11.2 A person clapped his hands near a cliff and heard the echo after 2 s.

What is the distance of the cliff from the person if the speed of the sound, v is taken as 346 m s^{-1} ?

Solution:

Given,

Speed of sound, $v = 346 \text{ m s}^{-1}$

Time taken for hearing the echo,

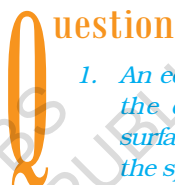
$t = 2 \text{ s}$

Distance travelled by the sound

$$= v \times t = 346 \text{ m s}^{-1} \times 2 \text{ s} = 692 \text{ m}$$

In 2 s sound has to travel twice the distance between the cliff and the person. Hence, the distance between the cliff and the person

$$= 692 \text{ m} / 2 = 346 \text{ m}.$$



Question

1. An echo is heard in 3 s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m s^{-1} ?

11.3.3 USES OF MULTIPLE REFLECTION OF SOUND

1. Megaphones or loudhailers, horns, musical instruments such as trumpets and *shehanais*, are all designed to send sound in a particular direction without spreading it in all directions, as shown in Fig 11.10.

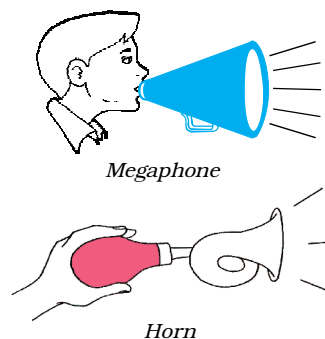


Fig 11.10: A megaphone and a horn.

In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

2. Stethoscope is a medical instrument used for listening to sounds produced within the body, mainly in the heart or lungs. In stethoscopes the sound of the patient's heartbeat reaches the doctor's ears by multiple reflection of sound, as shown in Fig. 11.11.

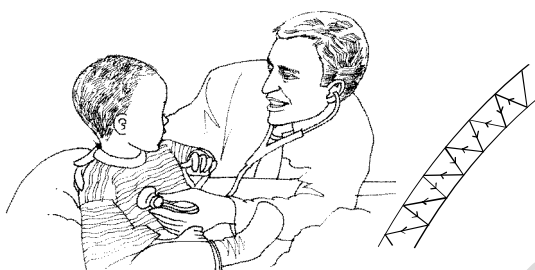


Fig. 11.11: Stethoscope

3. Generally the ceilings of concert halls, conference halls and cinema halls are curved so that sound after reflection reaches all corners of the hall, as shown in Fig 11.12. Sometimes a curved soundboard may be placed behind the stage so that the sound, after reflecting from the sound board, spreads evenly across the width of the hall (Fig 11.13).

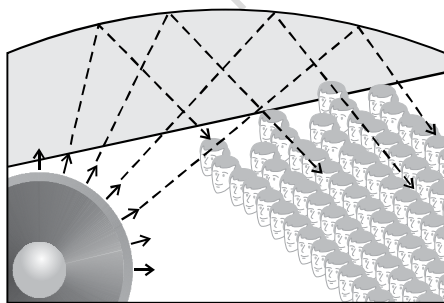


Fig. 11.12: Curved ceiling of a conference hall.

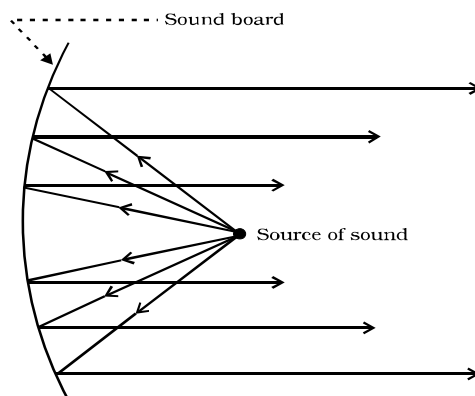


Fig. 11.13: Sound board used in a big hall.

Question

1. Why are the ceilings of concert halls curved?

11.4 Range of Hearing

The audible range of sound for human beings extends from about 20 Hz to 20000 Hz (one Hz = one cycle/s). Children under the age of five and some animals, such as dogs can hear up to 25 kHz (1 kHz = 1000 Hz). As people grow older their ears become less sensitive to higher frequencies. Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound. If we could hear infrasound we would hear the vibrations of a pendulum just as we hear the vibrations of the wings of a bee. Rhinoceroses communicate using infrasound of frequency as low as 5 Hz. Whales and elephants produce sound in the infrasound range. It is observed that some animals get disturbed before earthquakes. Earthquakes produce low-frequency infrasound before the main shock waves begin which possibly alert the animals. Frequencies higher than 20 kHz are called ultrasonic sound or ultrasound. Ultrasound is produced by animals such as dolphins, bats and porpoises. Moths of certain families have very sensitive hearing equipment. These moths can hear the high frequency

squeaks of the bat and know when a bat is flying nearby, and are able to escape capture. Rats also play games by producing ultrasound.

Hearing Aid: People with hearing loss may need a hearing aid. A hearing aid is an electronic, battery operated device. The hearing aid receives sound through a microphone. The microphone converts the sound waves to electrical signals. These electrical signals are amplified by an amplifier. The amplified electrical signals are given to a speaker of the hearing aid. The speaker converts the amplified electrical signal to sound and sends to the ear for clear hearing.

Questions

1. What is the audible range of the average human ear?
2. What is the range of frequencies associated with
 - (a) Infrasound?
 - (b) Ultrasound?

11.5 Applications of Ultrasound

Ultrasonounds are high frequency waves. Ultrasonounds are able to travel along well-defined paths even in the presence of obstacles. Ultrasonounds are used extensively in industries and for medical purposes.

- Ultrasound is generally used to clean parts located in hard-to-reach places, for example, spiral tube, odd shaped parts, electronic components, etc. Objects to be cleaned are placed in a cleaning solution and ultrasonic waves are sent into the solution. Due to the high frequency, the particles of dust, grease and dirt get detached and drop out. The objects thus get thoroughly cleaned.
- Ultrasonounds can be used to detect cracks and flaws in metal blocks.

in construction of big structures like buildings, bridges, machines and also scientific equipment. The cracks or holes inside the metal blocks, which are invisible from outside reduces the strength of the structure. Ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. If there is even a small defect, the ultrasound gets reflected back indicating the presence of the flaw or defect, as shown in Fig. 11.14.

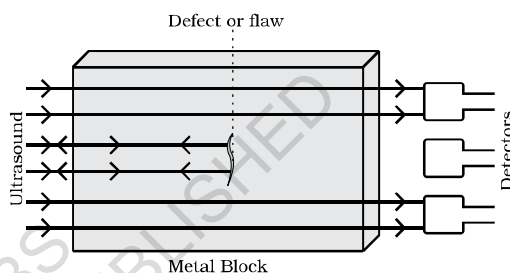


Fig 11.14: Ultrasound is reflected back from the defective locations inside a metal block.

Ordinary sound of longer wavelengths cannot be used for such purpose as it will bend around the corners of the defective location and enter the detector.

- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echocardiography'.
- Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs of the human body. A doctor may image the patient's organs, such as the liver, gall bladder, uterus, kidney, etc. It helps the doctor to detect abnormalities, such as stones in the gall bladder and kidney or tumours in different organs. In this technique the ultrasonic waves travel through the tissues of the body and get reflected from a region where there is a change of tissue density.

These waves are then converted into electrical signals that are used to generate images of the organ. These images are then displayed on a monitor or printed on a film. This technique is called 'ultrasonography'. Ultrasonography is also used for

examination of the foetus during pregnancy to detect congenial defects and growth abnormalities.

- Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains. These grains later get flushed out with urine.



What you have learnt

- Sound is produced due to vibration of different objects.
- Sound travels as a longitudinal wave through a material medium.
- Sound travels as successive compressions and rarefactions in the medium.
- In sound propagation, it is the energy of the sound that travels and not the particles of the medium.
- The change in density from one maximum value to the minimum value and again to the maximum value makes one complete oscillation.
- The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength, λ .
- The time taken by the wave for one complete oscillation of the density or pressure of the medium is called the time period, T .
- The number of complete oscillations per unit time is called the frequency (ν), $\nu = \frac{1}{T}$.
- The speed v , frequency ν , and wavelength λ , of sound are related by the equation, $v = \lambda \nu$.
- The speed of sound depends primarily on the nature and the temperature of the transmitting medium.
- The law of reflection of sound states that the directions in which the sound is incident and reflected make equal angles with the normal to the reflecting surface at the point of incidence and the three lie in the same plane.
- For hearing a distinct sound, the time interval between the original sound and the reflected one must be at least 0.1 s.
- The persistence of sound in an auditorium is the result of repeated reflections of sound and is called reverberation.

- Sound properties such as pitch, loudness and quality are determined by the corresponding wave properties.
- Loudness is a physiological response of the ear to the intensity of sound.
- The amount of sound energy passing each second through unit area is called the intensity of sound.
- The audible range of hearing for average human beings is in the frequency range of 20 Hz – 20 kHz.
- Sound waves with frequencies below the audible range are termed “infrasonic” and those above the audible range are termed “ultrasonic”.
- Ultrasound has many medical and industrial applications.



Exercises

1. What is sound and how is it produced?
2. Describe with the help of a diagram, how compressions and rarefactions are produced in air near a source of sound.
3. Why is sound wave called a longitudinal wave?
4. Which characteristic of the sound helps you to identify your friend by his voice while sitting with others in a dark room?
5. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?
6. A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s^{-1} .
7. Two children are at opposite ends of an aluminium rod. One strikes the end of the rod with a stone. Find the ratio of times taken by the sound wave in air and in aluminium to reach the second child.
8. The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?
9. Does sound follow the same laws of reflection as light does? Explain.
10. When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remains the same. Do you hear echo sound on a hotter day?
11. Give two practical applications of reflection of sound waves.
12. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, $g = 10 \text{ m s}^{-2}$ and speed of sound = 340 m s^{-1} .

13. A sound wave travels at a speed of 339 m s^{-1} . If its wavelength is 1.5 cm , what is the frequency of the wave? Will it be audible?
14. What is reverberation? How can it be reduced?
15. What is loudness of sound? What factors does it depend on?
16. How is ultrasound used for cleaning?
17. Explain how defects in a metal block can be detected using ultrasound.

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Chapter 12



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IMPROVEMENT IN FOOD RESOURCES

We know that all living organisms need food. Food supplies proteins, carbohydrates, fats, vitamins and minerals, all of which we require for body development, growth and health. Both plants and animals are major sources of food for us. We obtain most of this food from agriculture and animal husbandry.

We read in newspapers that efforts are always being made to improve production from agriculture and animal husbandry. Why is this necessary? Why we cannot make do with the current levels of production?

India is a very populous country. Our population is more than one billion people, and it is still growing. As food for this growing population, we will soon need more than a quarter of a billion tonnes of grain every year. This can be done by farming on more land. But India is already intensively cultivated. As a result, we do not have any major scope for increasing the area of land under cultivation. Therefore, it is necessary to increase our production efficiency for both crops and livestock.

Efforts to meet the food demand by increasing food production have led to some successes so far. We have had the green revolution, which contributed to increased food-grain production. We have also had the white revolution, which has led to better and more efficient use as well as availability of milk.

However, these revolutions mean that our natural resources are getting used more intensively. As a result, there are more chances of causing damage to our natural resources to the point of destroying their balance completely. Therefore, it is important that we should increase food production without degrading our environment and

disturbing the balances maintaining it. Hence, there is a need for sustainable practices in agriculture and animal husbandry.

Also, simply increasing grain production for storage in warehouses cannot solve the problem of malnutrition and hunger. People should have money to purchase food. Food security depends on both availability of food and access to it. The majority of our population depends on agriculture for their livelihood. Increasing the incomes of people working in agriculture is therefore necessary to combat the problem of hunger. Scientific management practices should be undertaken to obtain high yields from farms. For sustained livelihood, one should undertake mixed farming, intercropping, and integrated farming practices, for example, combine agriculture with livestock/poultry/fisheries/bee-keeping.

The question thus becomes – how do we increase the yields of crops and livestock?

12.1 Improvement in Crop Yields

Cereals such as wheat, rice, maize, millets and sorghum provide us carbohydrate for energy requirement. Pulses like gram (*chana*), pea (*matar*), black gram (*urad*), green gram (*moong*), pigeon pea (*arhar*), lentil (*masoor*), provide us with protein. And oil seeds including soyabean, ground nut, sesame, castor, mustard, linseed and sunflower provide us with necessary fats (Fig. 12.1). Vegetables, spices and fruits provide a range of vitamins and minerals in addition to small amounts of proteins, carbohydrates and fats. In addition to these food crops, fodder crops like *berseem*, *oats* or *sudan grass* are raised as food for the livestock.



Fig. 12.1: Different types of crops

Question

1. What do we get from cereals, pulses, fruits and vegetables?

Different crops require different climatic conditions, temperature and photoperiods for their growth and completion of their life cycle. Photoperiods are related to the duration of sunlight. Growth of plants and flowering are dependent on sunlight. As we all know, plants manufacture their food in sunlight by the process of photosynthesis. There are some crops, which are grown in rainy season, called

the *kharif* season from the month of June to October, and some of the crops are grown in the winter season, called the *rabi* season from November to April. Paddy, soyabean, pigeon pea, maize, cotton, green gram and black gram are *kharif* crops, whereas wheat, gram, peas, mustard, linseed are *rabi* crops.

In India there has been a four times increase in the production of food grains from 1952 to 2010 with only 25% increase in the cultivable land area. How has this increase in production been achieved? If we think of the practices involved in farming, we can see that we can divide it into three stages. The first is the choice of seeds for planting. The second is the nurturing of the crop plants. The third is the protection of the growing and harvested crops from loss. Thus, the major groups of activities for improving crop yields can be classified as:

- Crop variety improvement
- Crop production improvement
- Crop protection management.

12.1.1 CROP VARIETY IMPROVEMENT

This approach depends on finding a crop variety that can give a good yield. Varieties or strains of crops can be selected by breeding for various useful characteristics such as disease resistance, response to fertilisers, product quality and high yields. One way of incorporating desirable characters into crop varieties is by hybridisation. Hybridisation refers to crossing between genetically dissimilar plants. This crossing may be intervarietal (between different varieties), interspecific (between two different species of the same genus) or intergeneric (between different genera). Another way of improving the crop is by introducing a gene that would provide the desired characteristic. This results in genetically modified crops.

For new varieties of crops to be accepted, it is necessary that the variety produces high yields under different conditions that are found in different areas. Farmers would need to be provided with good quality seeds of a particular variety, that is, the seeds should all

be of the same variety and germinate under the same conditions.

Cultivation practices and crop yield are related to weather, soil quality and availability of water. Since weather conditions such as drought and flood situations are unpredictable, varieties that can be grown in diverse climatic conditions are useful. Similarly, varieties tolerant to high soil salinity have been developed. Some of the factors for which variety improvement is done are:

- Higher yield: To increase the productivity of the crop per acre.
- Improved quality: Quality considerations of crop products vary from crop to crop. Baking quality is important in wheat, protein quality in pulses, oil quality in oilseeds and preserving quality in fruits and vegetables.
- Biotic and abiotic resistance: Crops production can go down due to biotic (diseases, insects and nematodes) and abiotic (drought, salinity, water logging, heat, cold and frost) stresses under different situations. Varieties resistant to these stresses can improve crop production.
- Change in maturity duration: The shorter the duration of the crop from sowing to harvesting, the more economical is the variety. Such short durations allow farmers to grow multiple rounds of crops in a year. Short duration also reduces the cost of crop production. Uniform maturity makes the harvesting process easy and reduces losses during harvesting.
- Wider adaptability: Developing varieties for wider adaptability will help in stabilising the crop production under different environmental conditions. One variety can then be grown under different climatic conditions in different areas.
- Desirable agronomic characteristics: Tallness and profuse branching are desirable characters for fodder crops. Dwarfness is desired in cereals, so that

less nutrients are consumed by these crops. Thus developing varieties of desired agronomic characters help give higher productivity.

Questions

1. How do biotic and abiotic factors affect crop production?
2. What are the desirable agronomic characteristics for crop improvements?

12.1.2 CROP PRODUCTION MANAGEMENT

In India, as in many other agriculture-based countries, farming ranges from small to very large farms. Different farmers thus have more or less land, money and access to information and technologies. In short, it is the money or financial conditions that allow farmers to take up different farming practices and agricultural technologies. There is a correlation between higher inputs and yields. Thus, the farmer's purchasing capacity for inputs decides cropping system and production practices. Therefore, production practices can be at different levels. They include 'no cost' production, 'low cost' production and 'high cost' production practices.

12.1.2 (i) NUTRIENT MANAGEMENT

Just as we need food for development, growth and well-being, plants also require nutrients for growth. Nutrients are supplied to plants by air, water and soil. There are several nutrients which are essential for plants. Air supplies carbon and oxygen, hydrogen comes from water, and soil supplies the other thirteen nutrients to plants. Amongst these, some are required in large quantities and are therefore called macro-nutrients. The other nutrients are used by plants in small quantities and are therefore called micro-nutrients (Table 12.1).

Table 12.1: Nutrients supplied by air, water and soil

Source	Nutrients
Air	carbon, oxygen
Water	hydrogen, oxygen
Soil	(i) <i>Macronutrients:</i> nitrogen, phosphorus, potassium, calcium, magnesium, sulphur (ii) <i>Micronutrients:</i> iron, manganese, boron, zinc, copper, molybdenum, chlorine

Deficiency of these nutrients affects physiological processes in plants including reproduction, growth and susceptibility to diseases. To increase the yield, the soil can be enriched by supplying these nutrients in the form of manure and fertilizers.

Questions

1. What are macro-nutrients and why are they called macro-nutrients?
2. How do plants get nutrients?

MANURE

Manure contains large quantities of organic matter and also supplies small quantities of nutrients to the soil. Manure is prepared by the decomposition of animal excreta and plant waste. Manure helps in enriching soil with nutrients and organic matter and increasing soil fertility. The bulk of organic matter in manure helps in improving the soil structure. This involves increasing the water holding capacity in sandy soils. In clayey soils, the large quantities of organic matter help in drainage and in avoiding water logging.

In using manure we use biological waste material, which is advantageous in protecting

our environment from excessive use of fertilizers. Using biological waste material is also a way of recycling farm waste. Based on the kind of biological material used, manure can be classified as:

- (i) Compost and vermi-compost: The process in which farm waste material like livestock excreta (cow dung, etc.), vegetable waste, animal refuse, domestic waste, sewage waste, straw, eradicated weeds etc. is decomposed in pits is known as composting. The compost is rich in organic matter and nutrients. Compost is also prepared by using earthworms to hasten the process of decomposition of plant and animal refuse. This is called vermi-compost.
- (ii) Green manure: Prior to the sowing of the crop seeds, some plants like sun hemp or guar are grown and then mulched by ploughing them into the soil. These green plants thus turn into green manure which helps in enriching the soil in nitrogen and phosphorus.

FERTILIZERS

Fertilizers are commercially produced plant nutrients. Fertilizers supply nitrogen, phosphorus and potassium. They are used to ensure good vegetative growth (leaves, branches and flowers), giving rise to healthy plants. Fertilizers are a factor in the higher yields of high-cost farming.

Fertilizers should be applied carefully in terms of proper dose, time, and observing pre- and post-application precautions for their complete utilisation. For example, sometimes fertilizers get washed away due to excessive irrigation and are not fully absorbed by the plants. This excess fertilizer then leads to water pollution.

Also, as we have seen in the previous chapter, continuous use of fertilizers in an area can destroy soil fertility because the organic matter in the soil is not replenished and micro-organisms in the soil are harmed by the fertilizers used. Short-term benefits of using fertilizers and long-term benefits of using

manure for maintaining soil fertility have to be considered while aiming for optimum yields in crop production.

Question

1. Compare the use of manure and fertilizers in maintaining soil fertility.

Organic farming is a farming system with minimal or no use of chemicals as fertilizers, herbicides, pesticides, etc., and with a maximum input of organic manures, recycled farm-wastes (straw and livestock excreta), use of bio-agents such as culture of blue green algae in preparation of biofertilizers, *neem* leaves or turmeric specifically in grain storage as bio-pesticides, with healthy cropping systems [mixed cropping, inter-cropping and crop rotation as discussed below in 12.1.2.(iii)]. These cropping systems are beneficial in insect, pest and wheat control besides providing nutrients.

12.1.2 (ii) IRRIGATION

Most agriculture in India is rain-fed, that is, the success of crops in most areas is dependent on timely monsoons and sufficient rainfall spread through most of the growing season. Hence, poor monsoons cause crop failure. Ensuring that the crops get water at the right stages during their growing season can increase the expected yields of any crop. Therefore, many measures are used to bring more and more agricultural land under irrigation.

More to know

Droughts occur because of scarcity or irregular distribution of rains. Drought poses a threat to rain-fed farming areas, where farmers do not use irrigation for crop production and depend only on rain. Light soils have less water retention capacity. In areas with light soils, crops get adversely affected by drought conditions. Scientists have developed some crop varieties which can tolerate drought conditions.

India has a wide variety of water resources and a highly varied climate. Under such conditions, several different kinds of irrigation systems are adopted to supply water to agricultural lands depending on the kinds of water resources available. These include wells, canals, rivers and tanks.

- **Wells:** There are two types of wells, namely dug wells and tube wells. In a dug well, water is collected from water bearing strata. Tube wells can tap water from the deeper strata. From these wells, water is lifted by pumps for irrigation.
- **Canals:** This is usually an elaborate and extensive irrigation system. In this system canals receive water from one or more reservoirs or from rivers. The main canal is divided into branch canals having further distributaries to irrigate fields.
- **River Lift Systems:** In areas where canal flow is insufficient or irregular due to inadequate reservoir release, the lift system is more rational. Water is directly drawn from the rivers for supplementing irrigation in areas close to rivers.
- **Tanks:** These are small storage reservoirs, which intercept and store the run-off of smaller catchment areas.

Fresh initiatives for increasing the water available for agriculture include rainwater harvesting and watershed management. This involves building small check-dams which lead to an increase in ground water levels. The check-dams stop the rainwater from flowing away and also reduce soil erosion.

12.1.2 (iii) CROPPING PATTERNS

Different ways of growing crops can be used to give maximum benefit.

Mixed cropping is growing two or more crops simultaneously on the same piece of land, for example, wheat + gram, or wheat + mustard, or groundnut + sunflower. This reduces risk and gives some insurance against failure of one of the crops.

Inter-cropping is growing two or more crops simultaneously on the same field in a definite pattern (Fig. 12.2). A few rows of one crop alternate with a few rows of a second crop, for example, soyabean + maize, or finger millet (*bajra*) + cowpea (*lobia*). The crops are selected such that their nutrient requirements are different. This ensures maximum utilisation of the nutrients supplied, and also prevents pests and diseases from spreading to all the plants belonging to one crop in a field. This way, both crops can give better returns.

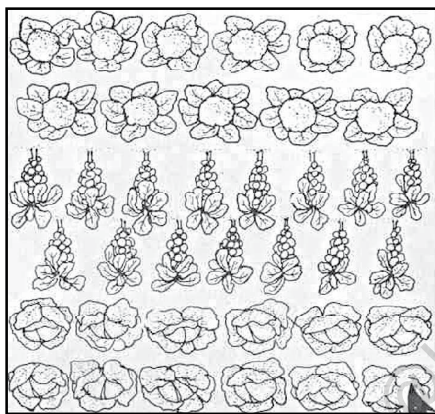


Fig. 12.2 : Intercropping

The growing of different crops on a piece of land in a pre-planned succession is known as crop rotation. Depending upon the duration, crop rotation is done for different crop combinations. The availability of moisture and irrigation facilities decide the choice of the crop to be cultivated after one harvest. If crop rotation is done properly then two or three crops can be grown in a year with good harvests.

12.1.3 CROP PROTECTION MANAGEMENT

Field crops are infested by a large number of weeds, insect pests and diseases. If weeds and pests are not controlled at the appropriate time then they can damage the crops so much that most of the crop is lost.

Weeds are unwanted plants in the cultivated field, for example, *Xanthium*

(*gokhroo*), *Parthenium* (*gajar ghas*), *Cyperinus rotundus* (*motha*). They compete for food, space and light. Weeds take up nutrients and reduce the growth of the crop. Therefore, removal of weeds from cultivated fields during the early stages of crop growth is essential for a good harvest.

Generally insect pests attack the plants in three ways: (i) they cut the root, stem and leaf, (ii) they suck the cell sap from various parts of the plant, and (iii) they bore into stem and fruits. They thus affect the health of the crop and reduce yields.

Diseases in plants are caused by pathogens such as bacteria, fungi and viruses. These pathogens can be present in and transmitted through the soil, water and air.

Weeds, insects and diseases can be controlled by various methods. One of the most commonly used methods is the use of pesticides, which include herbicides, insecticides and fungicides. These chemicals are sprayed on crop plants or used for treating seeds and soil. However, excessive use of these chemicals creates problems, since they can be poisonous to many plant and animal species and cause environmental pollution.

Weed control methods also include mechanical removal. Preventive methods such as proper seed bed preparation, timely sowing of crops, intercropping and crop rotation also help in weed control. Some other preventive measures against pests are the use of resistant varieties, and summer ploughing, in which fields are ploughed deep in summers to destroy weeds and pests.

Question

1. Which of the following conditions will give the most benefits? Why?
 - (a) Farmers use high-quality seeds, do not adopt irrigation or use fertilizers.
 - (b) Farmers use ordinary seeds, adopt irrigation and use fertilizer.
 - (c) Farmers use quality seeds, adopt irrigation, use fertilizer and use crop protection measures.

Table 12.2: Nutritional values of animal products

Animal Products	Per cent (%) Nutrients					
	Fat	Protein	Sugar	Minerals	Water	Vitamins
Milk (Cow)	3.60	4.00	4.50	0.70	87.20	B1, B2, B12, D, E
Egg	12.00	13.00	*	1.00	74.00	B2, D
Meat	3.60	21.10	*	1.10	74.20	B2, B12
Fish	2.50	19.00	*	1.30	77.20	Niacin, D, A

*Present in very small amounts

Activity 12.1

- Visit a nearby garden/agricultural field and make a list of the weeds and the flowers/crops found in the area. Also, make a list of insect pests, if any, infesting the flowers/crops.

Activity 12.2

- Collect grains/seeds of cereals, pulses and oil seeds and gather information about the seasons in which they are sown and harvested.

STORAGE OF GRAINS

Storage losses in agricultural produce can be very high. Factors responsible for such losses are biotic—insects, rodents, fungi, mites and bacteria, and abiotic—inappropriate moisture and temperatures in the place of storage. These factors cause degradation in quality, loss in weight, poor germinability, discolouration of produce, all leading to poor marketability. These factors can be controlled by proper treatment and by systematic management of warehouses.

Preventive and control measures are used before grains are stored for future use. They include strict cleaning of the produce before storage, proper drying of the produce first in sunlight and then in shade, and fumigation using chemicals that can kill pests.

Questions

- Why should preventive measures and biological control methods be preferred for protecting crops?
- What factors may be responsible for losses of grains during storage?

12.2 Animal Husbandry

Animal husbandry is the scientific management of animal livestock. It includes various aspects such as feeding, breeding and disease control. Animal-based farming includes cattle, goat, sheep, poultry and fish farming. As the population increases and as living standards increase, the demand for milk, eggs and meat is also going up. Also, the growing awareness of the need for humane treatment of livestock has brought in new limitations in livestock farming. Thus, livestock production also needs to be improved.

12.2.1 CATTLE FARMING

Cattle husbandry is done for two purposes—milk and draught labour for agricultural work such as tilling, irrigation and carting. Indian cattle belong to two different species, *Bos indicus*, cows, and *Bos bubalis*, buffaloes. Milk-producing females are called milch animals (dairy animals), while the ones used for farm labour are called draught animals.

Milk production depends, to some extent, on the duration of the lactation period, meaning the period of milk production after



Fig. 12.3: Indigenous milch breed of cattle

the birth of a calf. So, milk production can be increased by increasing the lactation period. Exotic or foreign breeds (for example, Jersey, Brown Swiss) are selected for long lactation periods, while local breeds (for example, Red Sindhi, Sahiwal) show excellent resistance to diseases. The two can be cross-bred to get animals with both the desired qualities.

Question

1. Which method is commonly used for improving cattle breeds and why?

Activity 12.3

- Visit a livestock farm. Note the following:
 - (1) Number of cattle and number of different breeds.
 - (2) The amount of daily milk production from the different breeds.

Proper cleaning and shelter facilities for cows and buffaloes are required for humane farming, for the health of the animals and for production of clean milk as well. Animals require regular brushing to remove dirt and

loose hair. They should be sheltered under well-ventilated roofed sheds that protect them from rain, heat and cold. The floor of the cattle shed needs to be sloping so as to stay dry and to facilitate cleaning.

The food requirements of dairy animals are of two types: (a) maintenance requirement, which is the food required to support the animal to live a healthy life, and (b) milk producing requirement, which is the type of food required during the lactation period. Animal feed includes: (a) roughage, which is largely fibre, and (b) concentrates, which are low in fibre and contain relatively high levels of proteins and other nutrients. Cattle need balanced rations containing all nutrients in proportionate amounts. Besides such nutritious food material, certain feed additives containing micronutrients promote the health and milk output of dairy animals.

Cattle suffer from a number of diseases. The diseases, besides causing death, reduce milk production. A healthy animal feeds regularly and has a normal posture. The parasites of cattle may be both external parasites and internal parasites. The external parasites live on the skin and mainly cause skin diseases. The internal parasites like worms, affect stomach and intestine while flukes damage the liver. Infectious diseases are also caused by bacteria and viruses. Vaccinations are given to farm animals against many major viral and bacterial diseases.

12.2.2 POULTRY FARMING

Poultry farming is undertaken to raise domestic fowl for egg production and chicken meat. Therefore, improved poultry breeds are developed and farmed to produce layers for eggs and broilers for meat.

The cross-breeding programmes between Indian (indigenous, for example, *Aseel*) and foreign (exotic, for example, Leghorn) breeds for variety improvement are focused on to develop new varieties for the following desirable traits—

- (i) number and quality of chicks;

- (ii) dwarf broiler parent for commercial chick production;
- (iii) summer adaptation capacity/ tolerance to high temperature;
- (iv) low maintenance requirements;
- (v) reduction in the size of the egg-laying bird with ability to utilise more fibrous cheaper diets formulated using agricultural by-products.



Aseel



Leghorn

Fig. 12.4

Question

1. Discuss the implications of the following statement:
"It is interesting to note that poultry is India's most efficient converter of low fibre food stuff (which is unfit for human consumption) into highly nutritious animal protein food."

EGG AND BROILER PRODUCTION

Broiler chickens are fed with vitamin-rich supplementary feed for good growth rate and better feed efficiency. Care is taken to avoid mortality and to maintain feathering and carcass quality. They are produced as broilers and sent to market for meat purposes.

For good production of poultry birds, good management practices are important. These include maintenance of temperature and hygienic conditions in housing and poultry feed, as well as prevention and control of diseases and pests.

The housing, nutritional and environmental requirements of broilers are somewhat different from those of egg layers.

The ration (daily food requirement) for broilers is protein rich with adequate fat. The level of vitamins A and K is kept high in the poultry feeds.

Poultry fowl suffer from a number of diseases caused by virus, bacteria, fungi, parasites, as well as from nutritional deficiencies. These necessitate proper cleaning, sanitation, and spraying of disinfectants at regular intervals. Appropriate vaccination can prevent the occurrence of infectious diseases and reduce loss of poultry during an outbreak of disease.

Questions

1. What management practices are common in dairy and poultry farming?
2. What are the differences between broilers and layers and in their management?

Activity 12.4

- Visit a local poultry farm. Observe types of breeds and note the type of ration, housing and lighting facilities given to them. Identify the growers, layers and broilers.

12.2.3 FISH PRODUCTION

Fish is a cheap source of animal protein for our food. Fish production includes the finned true fish as well as shellfish such as prawns and molluscs. There are two ways of obtaining fish. One is from natural resources, which is called capture fishing. The other way is by fish farming, which is called culture fishery.

The water source of the fish can be either seawater or fresh water, such as in rivers and ponds. Fishing can thus be done both by capture and culture of fish in marine and freshwater ecosystems.

12.2.3 (i) MARINE FISHERIES

India's marine fishery resources include 7500 km of coastline and the deep seas

beyond it. Popular marine fish varieties include pomphret, mackerel, tuna, sardines, and Bombay duck. Marine fish are caught using many kinds of fishing nets from fishing boats. Yields are increased by locating large schools of fish in the open sea using satellites and echo-sounders.

Some marine fish of high economic value are also farmed in seawater. This includes finned fishes like mullets, *bhetki*, and pearl spots, shellfish such as prawns (Fig. 12.5), mussels and oysters as well as seaweed. Oysters are also cultivated for the pearls they make.

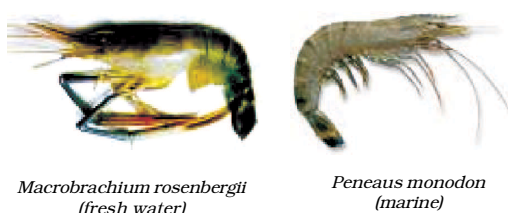


Fig. 12.5 : Fresh water and marine prawns

As marine fish stocks get further depleted, the demand for more fish can only be met by such culture fisheries, a practice called mariculture.

12.2.3 (ii) INLAND FISHERIES

Fresh water resources include canals, ponds, reservoirs and rivers. Brackish water resources, where seawater and fresh water mix together, such as estuaries and lagoons are also important fish reservoirs. While capture fishing is also done in such inland water bodies, the yield is not high. Most fish production from these resources is through aquaculture.

Fish culture is sometimes done in combination with a rice crop, so that fish are grown in the water in the paddy field. More intensive fish farming can be done in composite fish culture systems. Both local and imported fish species are used in such systems.

In such a system, a combination of five or six fish species is used in a single fishpond. These species are selected so that they do not compete for food among them having different types of food habits. As a result, the food available in all the parts of the pond is used. As Catlas are surface feeders, Rohus feed in the middle-zone of the pond, Mrigals and Common Carps are bottom feeders, and Grass Carps feed on the weeds, together these species (Fig. 12.6) can use all the food in the pond without competing with each other. This increases the fish yield from the pond.

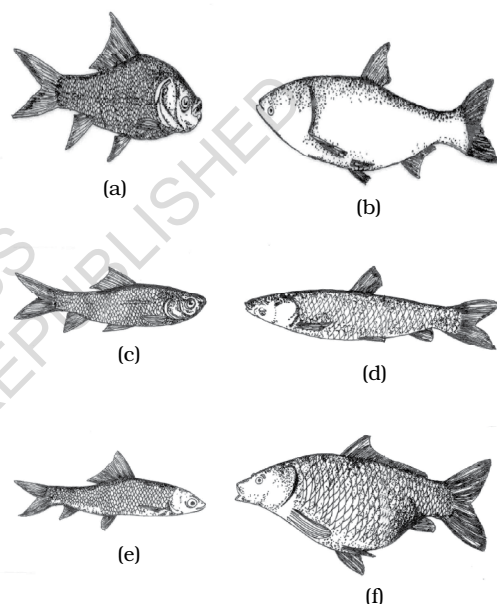


Fig. 12.6: (a) Catla (b) Silver carp (c) Rohu (d) Grass Carp (e) Mrigal (f) Common Carp

One problem with such composite fish culture is that many of these fish breed only during monsoon. Even if fish seed is collected from the wild, it can be mixed with that of other species as well. So, a major problem in fish farming is the lack of availability of good-quality seed. To overcome this problem, ways have now been worked out to breed these fish in ponds using hormonal stimulation. This has ensured the supply of pure fish seed in desired quantities.

Questions

1. How are fish obtained?
2. What are the advantages of composite fish culture?

Activity 12.5

- Visit a fish farm in fish breeding season and note the following:
 - (1) Varieties of fish in fish farm
 - (2) Types of ponds
 - (3) Feed ingredients used
 - (4) Production capacity of the farm
 If there are no fish farms close to your locality, gather the above information from Internet, by referring books or talking to people who are engaged in fishery.

12.2.4 BEE-KEEPING

Honey is widely used and therefore bee-keeping for making honey has become an agricultural enterprise. Since bee-keeping needs low investments, farmers use it as an additional income generating activity. In addition to honey, the beehives are a source of wax which is used in various medicinal preparations.

The local varieties of bees used for commercial honey production are *Apis cerana indica*, commonly known as the Indian bee, *A. dorsata*, the rock bee and *A. florae*, the little bee. An Italian bee variety, *A. mellifera*, has also been brought in to increase yield of honey.



What you have learnt

- There are several nutrients essential for crops. Of these, some are required in large quantities and are known as macro-nutrients whereas rest of the nutrients are required in small quantities and are known as micro-nutrients.
- Manure and fertilizers are the main sources of nutrient supply to crops.
- Organic farming is a farming system with minimal or no use of chemicals as fertilizers, herbicides, pesticides etc. and



(a)



(b)

Fig. 12.7: (a) Arrangement of beehive in an apiary (b) honey extractor

This is the variety commonly used for commercial honey production.

The Italian bees have high honey collection capacity. They sting somewhat less. They stay in a given beehive for long periods, and breed very well. For commercial honey production, bee farms or apiaries are established.

The value or quality of honey depends upon the pasturage, or the flowers available to the bees for nectar and pollen collection. In addition to adequate quantity of pasturage, the kind of flowers available will determine the taste of the honey.

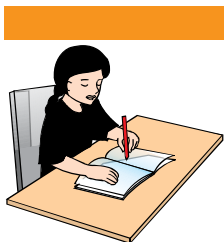
Questions

1. What are the desirable characters of bee varieties suitable for honey production?
2. What is pasturage and how is it related to honey production?

with a maximum input of organic manures, recycled farm wastes, and bio-agents, with healthy cropping systems.

- Mixed farming is a system of farming on a particular farm which includes crop production, raising of livestock etc.
- Mixed cropping is growing of two or more crops simultaneously on the same piece of land.
- Growing two or more crops in definite row patterns is known as inter-cropping.
- The growing of different crops on a piece of land in pre-planned succession is called crop rotation.
- Varietal improvement is required for higher yield, good quality, biotic and abiotic resistance, shortening the maturity duration, wider adaptability and desirable agronomic characteristics.
- Farm animals require proper care and management such as shelter, feeding, breeding and disease control. This is called animal husbandry.
- Poultry farming is done to raise domestic fowls. Poultry production includes egg production and broiler production for poultry meat.
- To enhance poultry production, cross breeding is done between Indian and exotic breeds for variety improvement.
- Fish may be obtained from marine resources as well as inland resources.
- To increase production of fish, they can be cultured in marine and inland ecosystems.
- Marine fish capture is done by fishing nets guided by echo-sounders and satellites.
- Composite fish culture system is commonly used for fish farming.
- Bee-keeping is done to get honey and wax.

Exercises



1. Explain any one method of crop production which ensures high yield.
2. Why are manure and fertilizers used in fields?
3. What are the advantages of inter-cropping and crop rotation?
4. What is genetic manipulation? How is it useful in agricultural practices?
5. How do storage grain losses occur?
6. How do good animal husbandry practices benefit farmers?
7. What are the benefits of cattle farming?
8. For increasing production, what is common in poultry, fisheries and bee-keeping?
9. How do you differentiate between capture fishing, mariculture and aquaculture?

Answers

Chapter 3

4. (a) MgCl_2
(b) CaO
(c) $\text{Cu}(\text{NO}_3)_2$
(d) AlCl_3
(e) CaCO_3
5. (a) Calcium, oxygen
(b) Hydrogen, bromine
(c) Sodium, hydrogen, carbon and oxygen
(d) Potassium, sulphur and oxygen
6. (a) 26 g
(b) 256 g
(c) 124 g
(d) 36.5 g
(e) 63 g

Chapter 4

10. 80.006
11. $\frac{16}{8} \times 100\% = 90\%$, $\frac{18}{8} \times 100\% = 10\%$
12. Valency = 1, Name of the element is lithium.
13. Mass number of X = 12, Y = 14, Relationship is Isotope.
14. (a) F (b) F (c) T (d) F
15. (a) ✓ (b) × (c) × (d) ×
16. (a) × (b) × (c) ✓ (d) ×
17. (a) × (b) ✓ (c) × (d) ×
18. (a) × (b) × (c) × (d) ✓
- 19.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	19	10	9	9	Fluorine
16	32	16	16	16	Sulphur
12	24	12	12	12	Magnesium
01	2	01	1	01	Deuterium
01	1	0	1	0	Protium

Chapter 9

3. 9.8 N
12. Weight on earth is 98 N and on moon is 16.3 N.
13. Maximum height is 122.5 m and total time is $5\text{ s} + 5\text{ s} = 10\text{ s}$.
14. 19.6 m/s
15. Maximum height = 80 m, Net displacement = 0, Total distance covered = 160 m.
16. Gravitational force = $3.56 \times 10^{22}\text{ N}$.
17. 4 s, 80 m from the top.
18. Initial velocity = 29.4 m s^{-1} , height = 44.1 m. After 4 s the ball will be at a distance of 4.9 m from the top or 39.2 m from the bottom.
21. The substance will sink.
22. The packet will sink. The mass of water displaced is 350 g.

Chapter 10

2. Zero
4. -210 J
5. Zero
9. $9 \times 10^8\text{ J}$
10. 2000 J, 1000 J
11. Zero
14. $5.4 \times 10^7\text{ J}$
17. 208333.3 J
18. (i) Zero
(ii) Positive
(iii) Negative
20. $7.2 \times 10^7\text{ J}$

Chapter 11

7. 17.2 m, 0.0172 m
8. 18.55
9. 6000
13. 11.47 s
14. 22,600 Hz

Constitution of India

Part IV A (Article 51 A)

Fundamental Duties

It shall be the duty of every citizen of India —

- (a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;
- (b) to cherish and follow the noble ideals which inspired our national struggle for freedom;
- (c) to uphold and protect the sovereignty, unity and integrity of India;
- (d) to defend the country and render national service when called upon to do so;
- (e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;
- (f) to value and preserve the rich heritage of our composite culture;
- (g) to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures;
- (h) to develop the scientific temper, humanism and the spirit of inquiry and reform;
- (i) to safeguard public property and to abjure violence;
- (j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;
- * (k) who is a parent or guardian, to provide opportunities for education to his child or, as the case may be, ward between the age of six and fourteen years.

Note: The Article 51A containing Fundamental Duties was inserted by the Constitution (42nd Amendment) Act, 1976 (with effect from 3 January 1977).

* (k) was inserted by the Constitution (86th Amendment) Act, 2002 (with effect from 1 April 2010).