PHYSICS

1

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استنادًا إلى القانون يوزع مجانًا ويمنع بيعه وتداوله في الاسواق

PREFACE

Some students think that physics is too difficult a discipline to learn. This is due to a lack of discussion and demonstrations of the present day uses and practical applications of physics concepts, theories and equations. This leaves the pupil with lack of enthusiasm,and the impression that physics has more to do with the world of the mind rather than what it really is a science. Science is a discipline, which is based in the real physical world and its foundation is practical applications and data from the physical world.

We have tried to explain the concepts in this book in the most understandable way and have taken advantage of the natural ability of young people to instantly and intuitively grasp concepts through graphics. Full coloured figures and photographs support the explanations.

This book explains the phenomena related to 1st intermediate 8rde subjects.

This book aims to improve the level of understanding of modern physics by inclusion of the following; main texts, figures and illustrations, extensive questions and articles.

The Authors

CONTENTS

CHAPTER 1
HISTORY OF PHYSICS

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Know the History of physics.

2. Know The Arab and Muslim Scientists.

HISTORY of PHYSICS

Physics is a branch of science that developed out of philosophy, and thus was referred to as natural philosophy until the late 19th century - a term describing a field of study concerned with "the workings of nature". Currently, physics is traditionally defined as the study of matter, energy, and the relation between them. Physics is, in some senses, the oldest and most basic pure science; its discoveries find applications throughout the natural sciences, since matter and energy are the basic constituents of the natural world. The other sciences are generally more limited in their scope and may be considered branches that have split off from physics to become sciences in their own right. Physics today may be divided loosely into classical physics and modern physics.

Elements of what became physics were drawn primarily from the fields of astronomy, optics, and mechanics, which were methodologically united through the study of geometry. These mathematical disciplines began in Antiquity with the Babylonians and with Hellenistic writers such as Archimedes and Ptolemy. Meanwhile, philosophy, including what was called "physics", focused on explanatory (rather than descriptive) schemes, largely developed around the Aristotelian idea of the four types of "causes".

ARAB and MUSLIM SCIENTISTS

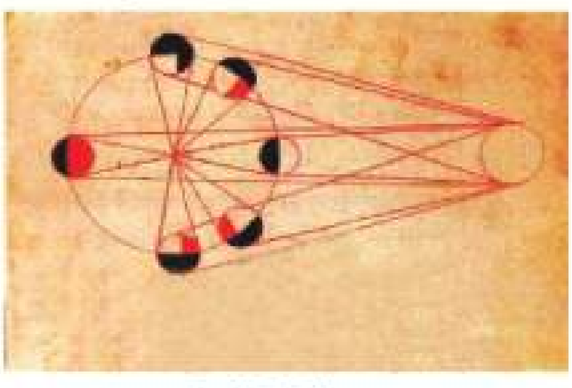
During the period of time known as the Dark Ages (5th to 15th centuries), much scientific progress occurred in the Muslim world. The scientific research of the Islamic scientists is often overlooked due to the conflict of the Crusades and "it's possible, too, that many scholars in the Renaissance later downplayed or even disguised their connection to the Middle East for both political and religious reasons." The Islamic Abbasid caliphs gathered many classic works of antiquity and had them translated into Arabic within the House of Wisdom in Baghdad, Iraq. Islamic philosophers such as Al-Kindi (Alkindus), Al-Farabi (Alpharabius), and Averroes (Ibn Rushd) reinterpreted Greek thought in the context of their religion. Ibn Sina (980 – 1037), known by the Latin name Avicenna, was a medical researcher from Bukhara, Uzbekistan responsible for important contributions to the disciplines of physics, optics, philosophy and medicine. He is most famous for writing The Canon of Medicine, a text used to teach student doctors in Europe until the 1600s.

Important contributions were made by Ibn al-Haytham (965 – 1040), a mathematician from Basra, Iraq considered one of the founders of modern optics. Ptolemy and Aristotle theorised that light either shone from the eye to illuminate objects or that light emanated from objects themselves, whereas al-Haytham (known by the Latin name Alhazen) suggested that light travels to the eye in rays from different points on an object.

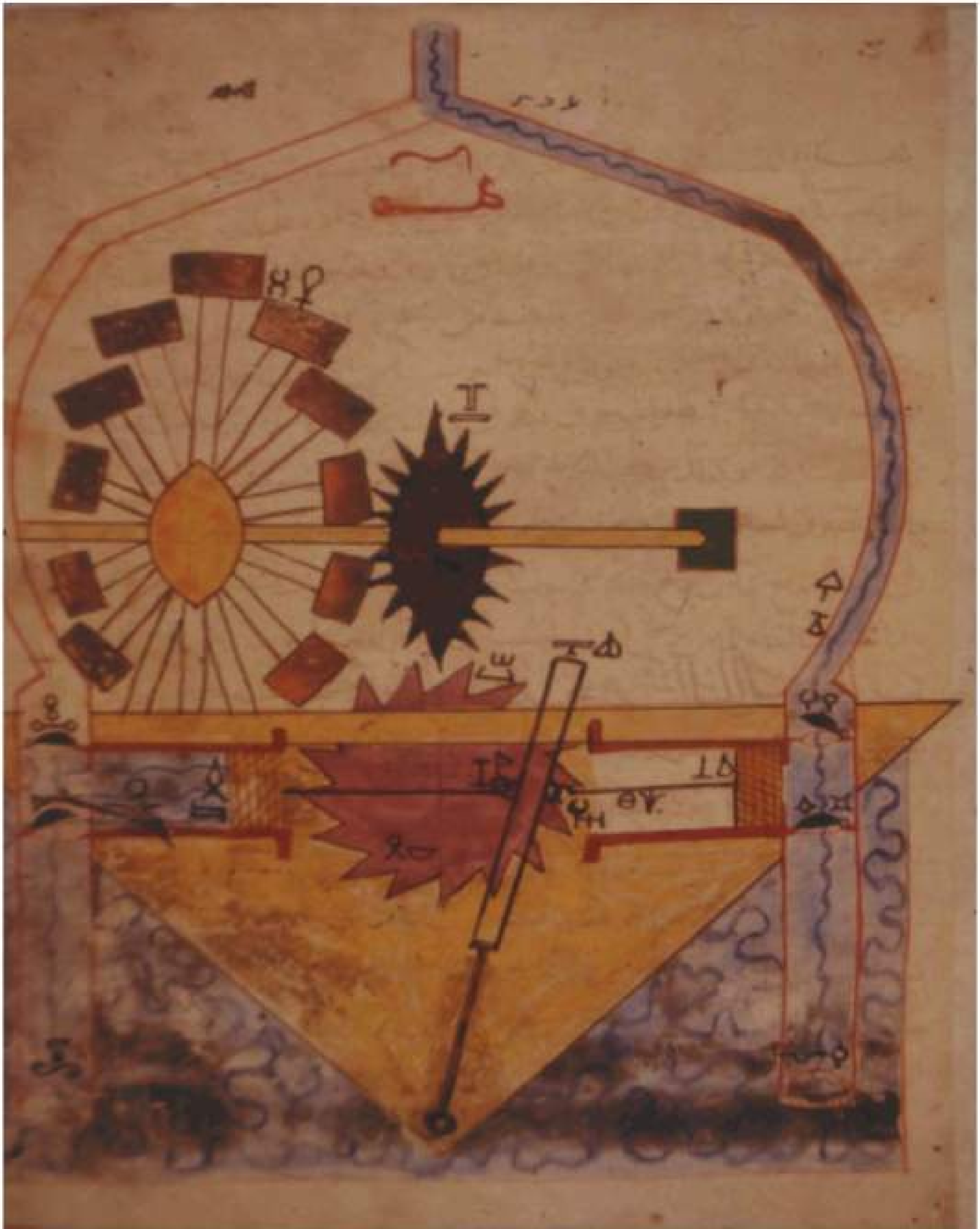
The works of Ibn Al-Haytham and Abu Rayhan Biruni eventually passed on to Western Europe where they were studied by scholars such as Roger Bacon and Witelo.Omar Khayyam (1048–1131), a Persian scientist, calculated the length of a solar year to 10 decimal places and was only out by a fraction of a second when compared to our modern day calculations. He used this to compose a calendar considered more accurate than the Gregorian calendar that came along 500 years later. He is classified as one of the world's first great science communicators –(he is said to have convinced)a Sufi theologist that the world turns on an axis. Muhammad Ibn Jabir al-Harrani al-Battani (858 – 929), from Harran, Turkey, further developed trigonometry (first conceptualised in Ancient Greece) as an independent branch of mathematics, developing relationships such as $\tan\theta = \sin\theta / \cos\theta$. His driving force was to obtain the ability to locate Mecca from any given geographical point – aiding in Muslim rituals such as burial and prayer, which require participants to face the holy city, as well as making the pilgrimage to Mecca (known as the hajj).

Ibn Al Haytham

Furthermore, Nasir Al-Din Al-Tusi (1201–1274), an astronomer and mathematician from Baghdad, authored the Treasury of Astronomy, a remarkably accurate table of planetary movements that reformed the existing planetary model of Roman astronomer Ptolemy by describing a uniform circular motion of all planets in their orbits. This work led to the later discovery, by one of his students, that planets actually have an elliptical orbit. Copernicus later drew heavily on the work of al-Din al-Tusi and his students, but without acknowledgment. The gradual chipping away of the Ptolemaic system paved the way for the revolutionary idea that the Earth actually orbited the Sun (heliocentrism). Jabir Ibn Hayyan (721 – 815) was a chemist and alchemist from Iran who, in his quest to make gold from other metals, discovered strong acids such as sulphuric, hydrochloric and nitric acids. He was the also first person to identify the only substance that can dissolve gold – aqua regis (royal water) – a volatile mix of hydrochloric and nitric acid. It is disputed whether Jabir was the first to use or describe distillation, but he was definitely the first to perform it in the lab using an alembic (from 'al-inbiq'). The most famous Arabic mathematician is considered to be Muhammad Ibn Musa AL-Khwarizmi (780 – 850), who produced a comprehensive guide to the numbering system developed from the Brahmi system in India, using only 10 digits (0-9, the so-called "Arabic numerals"). AL-Khwarizmi also used the word algebra ('al-jabr') to describe the mathematical operations he introduced, such as balancing equations, which helped in several problems.



A study of El Birun



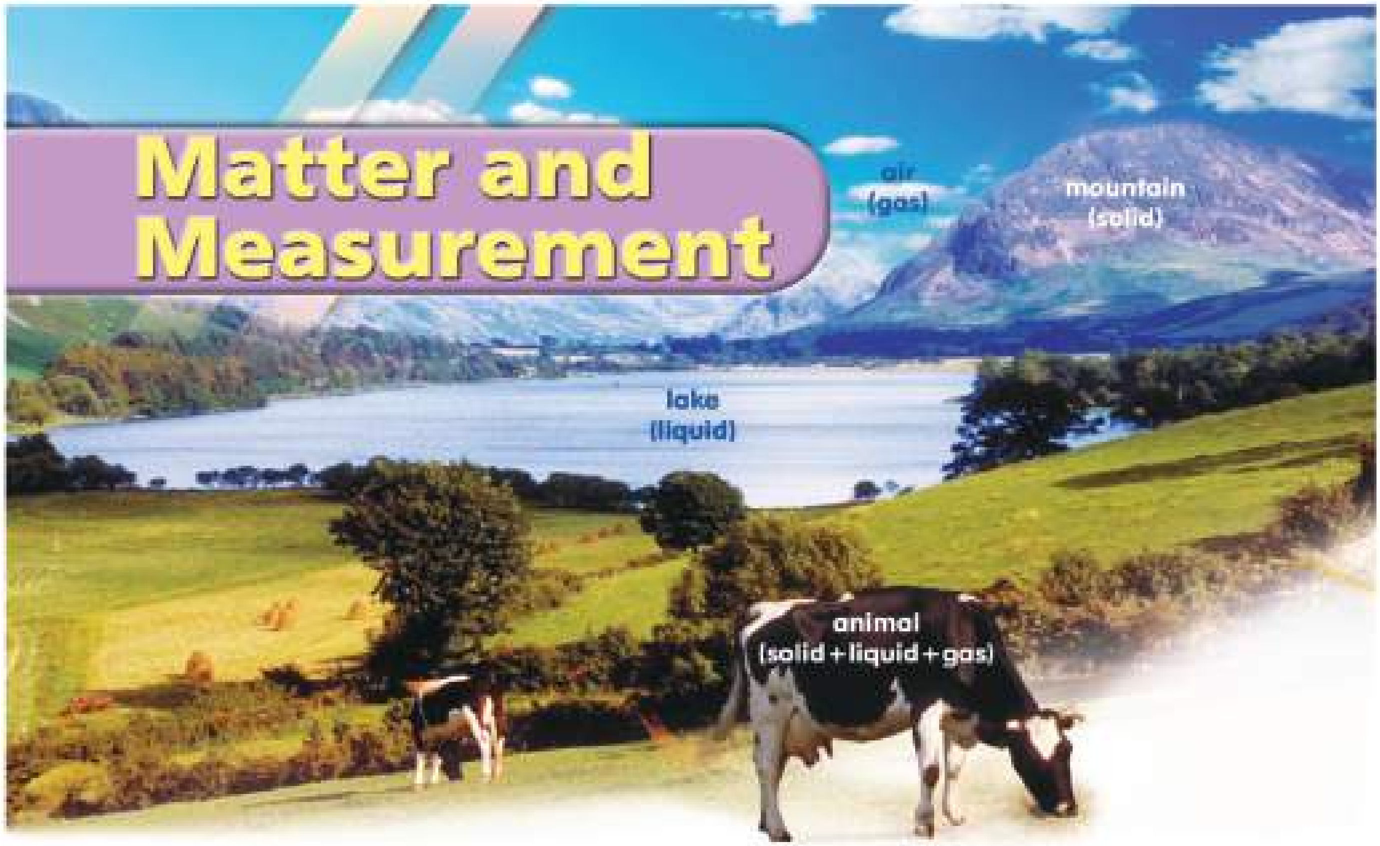
CHAPTER 2
MATTER AND MEASUREMENT

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Give a definition of matter.
2. Explain what is made up of matter.
3. Classify state of matter .
4. Understand the properties of matter.
5. Express how to measure: Length, Area and Volume.
6. Define the System International units.

Matter and Measurement



How do we define matter? What is matter made up of?
Which one is heavier, iron or wool?
Why do we measure things? What are the units for measuring very small things?
In this chapter you will find the answers to such questions.

Are light, sound and heat matter? Why?

2.1 MATTER

Everything around us such as air, water, plants, animals and the earth is all matter. The living and non-living things on earth are different forms of matter. Matter can be defined as anything which has mass and volume. Light, sound and heat are not examples of matter because they have no mass and volume. To understand that matter has mass, let us carry out the following activities.

activity

Matter and mass

Take two balloons and a ruler. Inflate the balloons. Then, set up a simple lever balance, as in figure a. When the lever is in equilibrium burst one of the balloons and see what happens.

a b

activity

Matter and mass

This activity concerns the melting of ice. Take a simple lever balance, a glass and some ice. Place the glass with ice on one side of the lever, and balance it with masses on the other side, as shown in(figure a).Wait until all the ice melts in the glass and see if there is any change in balance (Figure b).

a b

In the first activity, when the balloon bursts, the equilibrium position of the ruler is lost. The inflated balloon falls while the bursted one rises. This shows that the gas inside the balloon has a mass.

In the second activity, the balance is not disturbed after the ice melts because there is no decrease in the amount of matter. This also shows that solids and liquids have mass. So far, we have demonstrated that matter has mass. Now let us see that matter also has volume.

activity

Matter and volume

Take a glass half filled with water and put a stone in it (see figure a) What do you observe?

Then take the stone out and pour in some alcohol as shown in figure b. What do you observe? Is there any change in the level of water?

a b

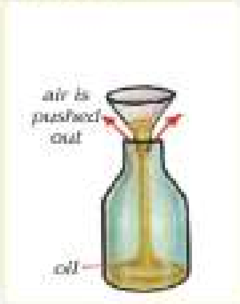
In the this activity, both the stone and alcohol have volumes, so when they are placed in the glass, they increase the level of water.

Now do the following activity to demonstrate this physical fact.

Activity — Matter and volume

Have an empty bottle, some oil and a funnel. Put the funnel into the mouth of the bottle. Now pour oil into the funnel to fill the bottle as in the figure below. What do you observe? Why the oil does not enter the bottle?

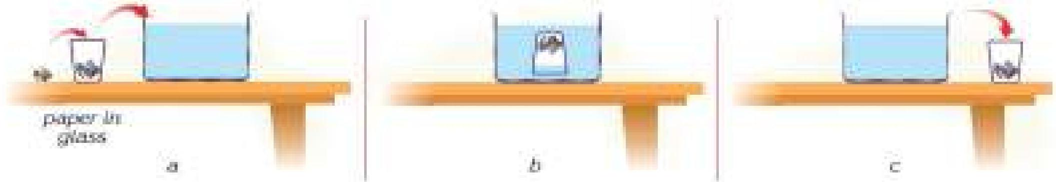
Because the air in the bottle has a volume, it does not allow the oil to fill in. Therefore the funnel must be raised a little, so that there is a gap for air to go out. Then the oil entering the bottle forces air out through this gap and fills up the bottle.



Activity — Matter and volume

Get a bowl and fill it with water. Let's observe an invisible type of matter. Take an empty glass and place a crunched-up piece of paper in it (see Figure a). Turn the glass upside down and immerse it in the water (Figure b). Then take out the glass, keeping it inverted and observe if the paper is wet or not (Figure c).

Did water enter the glass?



Since the glass contains air, water cannot enter it, therefore the paper should remain dry.
In conclusion, we can say that all matter has mass and volume. Mass is the amount of matter in an object and volume is the space occupied by that matter.

Figure 2.1 Which forms of matter are seen in the picture?

2.1.1 States of Matter

Matter exists in three states. These are solid, liquid and gas. A solid has a definite shape and volume. For example glass, spoon, wood, paper , pencil and ice are all solids.

Look at the pictures below. What can you say about the properties of liquids?

A liquid has a definite volume but no definite shape, it takes the shape of its container (Figure 2.2). Water, oil and alcohol are examples of liquids. The milk in a bottle has the shape of the bottle, but when it is poured into a bowl, it takes the shape of the bowl. Its volume, however, remains the same. Look at the pictures below. What can you say about the properties of liquids?

Figure 2.2

A gas has neither a definite shape nor volume, it fills up the contain . For example, a small amount of perfume can be smelt everywhere in a room. Air, oxygen, hydrogen, water vapour and exhaust fumes are examples of gases (Figure 2.3).

Figure 2.3

In the picture on the first page of this chapter, we can observe the three states of matter. The rocks and plants are solid, water is a liquid and air is a gas. See Figure 2.4, state the name of the parts of the motorbike. Which is made up from gas, solid and liquid?

Figure 2.4

2.1.2 PROPERTIES OF MATTER

Matter has certain properties. Some of them, such as mass and volume, are common for all substances. Other properties like boiling point, density, solubility, etc... are characteristic to each type of substance. Now, let's see how we can classify them:

Every substance has two kinds of properties.

1. Chemical Properties
2. Physical Properties

2.1.3 CHEMICAL PROPERTIES

Chemical properties are properties that change the nature of matter. Flammability, aciditiy, basicity, and reactivity with water are some examples of chemical properties. When the chemical properties of a substance are altered, it means a chemical change (new substance formed) occurred

Flammability is a chemical property

Fireworks are comprised of tiny metals.

The rusting of iron is a chemical change.

2.1.4 PHYSICAL PROPERTIES

Physical properties are the properties of a substance that can be observed and measured with out altering the substance. Physical properties can be organized as intensive and extensive.

Mass is an extensive property

Extensive Properties

Extensive properties of matter depend on the amount of matter involved. Extensive properties are also called common properties, such as mass,weight, volume, length and charge.

Mercury and some of its intensive properties

Intensive Properties

Intensive properties matter do not depend on the amount of matter given. Intensive properties are sometimes called distinctive, or characteristic, properties. Color, odor, solubility, hardness, heat/electrical conductivity, melting/freezing point, boiling point, density, luster, ductility, malleability, etc. are all intensive properties.

2.1.5 MOLECULAR PROPERTIES

Matter is made up of tiny particles called atoms. Atoms are building blocks of matter. A group of atoms held together is called a molecule. In the figures below, the atom is represented as a small sphere.

In a solid, the particles are packed very closely together, each particle is tightly fixed in a position (Figure 2.5a)

In a liquid, the particles are almost as close as in a solid, but they can move over each other. Therefore, a liquid can flow and takes the shape of the container it is put in. The liquid has no definite shape although it has a definite volume (Figure 2.5b).

In a gas, the particles are far away from each other. They can move freely in all directions. Therefore, gases have no definite shape and volume, they expand to fill up their container (Figure 2.5c)

a) Particles in a solid | b) Particles in a liquid | c) particles in a gas

Figure 2.5 The arrangement of particles in solid, liquid and gas state.

EXTRA

Plasma is the fourth state of matter


Lightning


Aurora

Plasma and Our Lives

Plasma has no definite volume or shape and contains electrically charged particles. Plasmas are collections of freely moving particles. Plasma temperatures may change, but they are generally very hot (a few thousands to millions of degrees °C). Fluorescent light and high - intensity arc lamps are some examples of where plasma can be seen. In addition to these, many products today are manufactured using plasma technologies. Computer chips, aircraft parts, systems for safe drinking water, high efficiency lighting products are all examples of these technologies. The word *Plasma* entered our dictionaries in 1929.


Stars in galaxies


Flame

2.2 MEASUREMENT

Every day, we make many estimations. For example, the distance from home to school, the time to do homework, the air temperature. However, these estmations are not very exact and sometimes they mislead us. Therefore, scientists make measurements rather than estimate them, since they have to be very accurate in their studies.

Measurements one of the three methods used in science. The others are experimentation and observation. A scientific study can only be useful if we use accurate measurements. Before making any measurement we have to choose a standard, of a quantity. The following activity will show the importance of using units.

activity — Matter and volume

Using a pencil, measure the length of ten different objects and make a table as shown.

	Object	Measurement
1.	Length of the book	(e.g.)1.5 pencil length
2.	Width of the book	..... pencil length
3.	Height of the table	..... pencil length
4.	...	...
5.	...	...
6.	...	...

Now, find the length and width of ten different places such as the garden, canteen, classroom etc. by pacing, and write your results in the table as shown.

	Object	Measurement
1.	Length of the classroom	(e.g.)10 steps
2.	Width of the garden	..... steps
3.	Length of the canteen	..... steps
4.	...	...
5.	...	...
6.	...	...

After finishing these activities compare your results with those of your friends. Do you have the same results? The results should not be exactly the same, even though you measured the same things, because you have different kinds of units. To get the same results you should choose a standard length. An amount or quantity used as a standard of measurement is called a unit.

Today, all over the world, scientists use a standard system of units to measure the various properties of matter. This system of units is called international system of units (SI - System International).

1.4 metre
number unit

A quantity and its unit

The international system of units is a decimal family in which units are divided or multiplied by 10 to give smaller or larger units.

Length, mass and time are fundamental quantities we have to measure. The base units to measure these quantities are the metre, the kilogram and the second. From these three units, we can drive units to measure volume, force, energy and so on

a) Length

The unit of length is the metre, represented by m. A metre is divided into smaller units called centimetres (cm) and millimetres (mm) to measure small distances. To measure length, metric rulers are used. In the metric system of measurement, the metre is the international standard unit of length. (Table 2.1)

Table 2.1

Abbreviation	Length in metres
1 km	1000 metres
1 hm	100 metres
1 dam	10 metres
1 m	1 metre
1 dm	0.1 metres
1 cm	0.01 metres
1 mm	0.001 metres

Table of conversion of length

New Age's Technology

Nanotechnology

Nanotechnology is the area of science trying to understand and control of matter at dimensions of nanoscale which is about 1 to 100 nanometers. The aim of nanotechnology is to control individual atoms and molecules to build computer chips, motors, robot arms, machines and other devices that are much more smaller than a human cell! Nanotechnology has a very wide range of study field from microbiology to space researches. The thickness of a strand of human hair is between 50 000 and 100 000 nanometres.

Figure Area of a rectangle

A = L × w

b) Area

Area is the size of the surface enclosed by its boundary lines. The area of a rectangle is simply found by multiplying length by width (Figure).
As a formula, we can state it as follows;

Area =Length×Width in symbols,

A = L × w

If a surface has dimensions of 1 m length and 1 m width, its area is 1 metre squared or 1 square metre and abbreviated as 1 m^2. The units of area change in multiples of one hundred, see Table 2.2.

Table 2.2

Abbreviation	Area in square metres
1 km^2	1 000 000 m^2
1 hm^2	10 000 m^2
1 dam^2	1 00 m^2
1 m^2	1 m^2
1 dm^2	0.01 m^2
1 cm^2	0.000 1 m^2
1 mm^2	0.000 001 m^2

Table of conversion of area

The area of irregular objects

The area of irregular objects can be found with millimetric paper. The object is placed on the paper. The area is calculated by counting the enclosed square centimetres and square millimetres drawn around it on the paper.

c) Volume

The amount of space occupied by an object is called its volume. The volume of regular objects is found by multiplying the base area of the object by its height Figure(2.6). As a formula, it is stated as follows,

Volume = Base area × Height in symbols

$V = A \times h$

where. $A = L \times w$ **so that** $V = L \times w \times h$

A regular object with edges each of 1 metre has a volume of 1 cubic metre or 1 metre cubed and is abbreviated as $1\ m^3$. As can be simply derived, the units of volume change by multiples of one thousand, see Table 2.3.

Figure 2.6 Volume of a rectangular prism $V = L \times w \times h$

Table 2.3

Abbreviation	Volume in cubic metres
$1\ km^3$	$1\ 000\ 000\ 000\ m^3$
$1\ hm^3$	$1\ 000\ 000\ m^3$
$1\ dam^3$	$1\ 000\ m^3$
$1\ m^3$	$1\ m^3$
$1\ dm^3$	$0.001\ m^3$
$1\ cm^3$	$0.000\ 001\ m^3$
$1\ mm^3$	$0.000\ 000\ 001\ m^3$

Table of conversion of volume

How can you calculate the inside volume of the box?

Exmaple 2.1

A classroom has dimensions of 5 m, 6 m and 3 m. What is the volume of air in the room? Convert the result into cm^3 and m^3.

Solution

What is asked in the question?

The volume of air in cm^3 and hm^3, V=?

What is the information given?

The dimensions of the room, L = 5 m, w = 6 m, h = 3 m.

What are the equations of volume and the conversions of its units?

$$V = L \times w \times h,$$

$$1\ m^3 = 1\ 000\ 000\ cm^3$$

Calculation

The volume of the air is;

$V = 5\ m \times 6\ m \times 3\ m = 90\ m^3$.

Now, let us convert the unit,

$90\ m^3 = ?\ cm^3$ $1\ m^3 = 1\ 000\ 000\ cm^3$, then

$90\ m^3 = 90 \times 1\ 000\ 000\ cm^3 = 90\ 000\ 000\ cm^3$

Exercise 2.1

A pool has dimensions of 3 m width, 8 m length and 1 m depth and is full of water. How many dm^3 of water is there in this pool?

Ans :24 000 dm^3

Example 2.2

An aquarium having dimensions of 5 dm height, 70 cm length and 0.4 m width is half filled with water. Find the volume of water in m^3, dm^3 and cm^3.

Solution

What is asked in the question?

Volume of water in m^3, dm^3 and cm^3, V=?

What is the information given?

Dimensions of the aquarium,

h= 5 dm, L= 70 cm, w= 0.4 m.

What are the equations of volume and the conversions of its units?

$$V = L \times w \times h$$

1 m = 10 dm, 1 m = 100 cm,

$1\ m^3 = 1000\ dm^3$, $1\ m^3 = 1\ 000\ 000\ cm^3$.

Calculation

First we have to convert the lengths and then find the volume of the water in the aquarium.

$V_{aquarium} = L \times w \times h$

$V_{aquarium} = 0.4\ m \times 0.7\ m \times 0.5\ m$

$V_{aquarium} = 0.14\ m^3$, because the aquarium is half filled, then

$$V_{water} = \frac{0.14\ m^3}{2} = 0.07\ m^3$$

$V_{water} = ?\ dm^3$ $1\ m^3 = 1\ 000\ dm^3$, then

$V_{water} = 0.07\ m^3 = 0.07 \times 1000\ dm^3 = 70\ dm^3$

$V_{water} = ?\ cm^3$ $1\ m^3 = 1\ 000\ 000\ cm^3$, then

$V_{water} = 0.07\ m^3 = 0.07 \times 1\ 000\ 000\ cm^3 = 70\ 000\ cm^3$

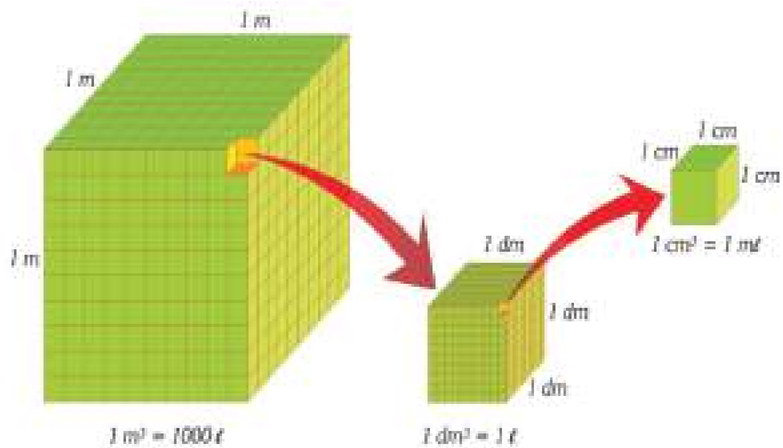
2.2.2 Volume of Liquids

The volume of liquids is measured in cubic decimetres (dm^3) or, more generally, in litres, abbreviated as ℓ. 1 litre is equal to 1 cubic decimetre and its units change by multiples of ten (see table 2.4).

Table 2.4

Unit	Abb.	Volume in litres
kilolitre	kℓ	1000 ℓ
hectolitre	hℓ	100 ℓ
decalitre	daℓ	10 ℓ
litre	ℓ	1 ℓ
decilitre	dℓ	0.1 ℓ
centilitre	cℓ	0.01 ℓ
millilitre	mℓ	0.001 ℓ

Table of conversion of liquid volume

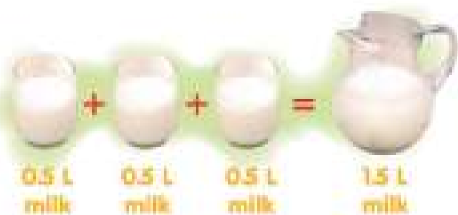


Example 2.3

A large glass can hold 0.5 litres of milk and a jug can hold three glasses of milk. Find the volume of milk in the jug in dm^3, dl and ml.

Solution

$V_{milk} = 0.5\,\ell + 0.5\,\ell + 0.5\,\ell = 1.5\,\ell$ *volume of milk in the jug*



$V_{milk} = 1.5\,\ell = ?\ dm^3$

$1\,\ell = 1\ dm^3$, so $V_{milk} = 1.5 \times 1\ dm^3 = 1.5\ dm^3$,

$1\,\ell = 10\ d\ell$, so $V_{milk} = 1.5 \times 10\ d\ell = 15\ d\ell$,

$1\,\ell = 1000\ m\ell$, so $V_{milk} = 1.5 \times 1000\ m\ell = 1500\ m\ell$.

Exercise 2.2

A water tank can hold 5 m^3 of water, convert this value into dm^3, dl and ml.

Ans :5000 dm^3, 50 000 dl , 5 000 000 ml

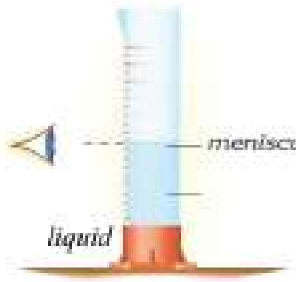


Figure 2.6

Measuring the Volume of Liquids

The volume of a small amount of liquid is found by pouring it into a measuring (graduated) cylinder (Figure 2.6). A measuring cylinder is a large and long glass tube with a scale on it.

The cylinder should stand on a horizontal surface when you pour water into it. To get a correct reading, your eye should be at a level with the bottom of the meniscus, which is a downward curve at the top of the liquid.

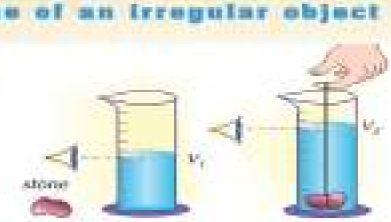
How do we measure the volume of irregular objects?

To measure the volume of irregular objects, such as eggs or stones, we use a measuring (graduated) cylinder. To make it clear carry out the activity below.

activity — **Finding the Volume of an Irregular object**

Take a graduated cylinder, fill it half with some water and read the level. As you lower the stone in the cylinder, the water level rises as seen in the figure. Finally take the second reading, and note the difference between the two readings. The difference gives the volume of the stone.

$V_{stone} = V_2 - V_1$



Example 2.4 A graduated cylinder is filled by colored water and level shows 80 cm^3 . If a stone is immersed to water, level rises to 110 cm^3. Find volume of stone.

solution

$V_{stone}=V_2-V_1$ $\quad V_{stone}=110-80=30\ cm^3$

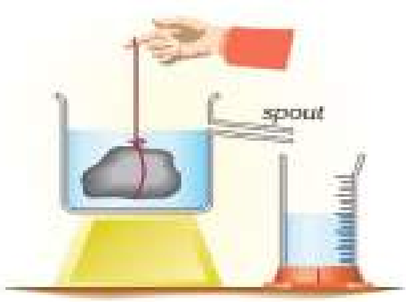


Figure 2.7 using overflow can

To measure the volume of larger objects, we can use an overflow can, The can is filled with water up to the spout, then a measuring cylinder is placed under the spout as shown in the figure(2.7). As the object is gently lowered into the can, the water overflows into the measuring cylinder. The volume of water displaced equals the volume of the object.

2.3 GAS LAWS

The relation between the temperature, volume and pressure of a gas. When we study gaseous matter, we must deal with its temperature,volume and pressure. If one of these quantities is changed, the other two or at least one of them also changes.

There are three important gas laws analyzing the relation between temperature, volume and pressure: Boyle's law, Charles' law and the Gay-Lussac law

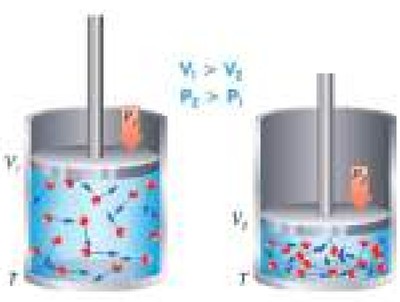


Figure 2.8

a. Boyle's law

At constant temperature, the pressure of a gas in a closed container is inversely proportional to its volume. As the volume of the container decreases, the pressure of the gas increases. This is because the number of collisions of the particles increases (Figure 2.8).

This fact, known as Boyle's Law, states that "By keeping temperature constant, the product of volume and pressure of a fixed amount of gas is constant."

b. Charles' law

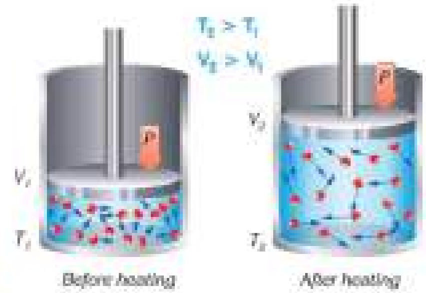


Figure 2.9

By increasing the temperature of gases, the speed of the particles increases and they strike the walls of the container more frequently, and forcing the container to expand. Therefore at a constant pressure, the volume of a gas is directly proportional to its temperature (Figure 2.9). The experiment below demonstrates the relationship between temperature and volume of a gas.

This is known as Charles' law. The law states that, "At constant pressure, the volume of a certain amount of gas is directly proportional to the absolute temperature".

c. Gay-Lussac's Law

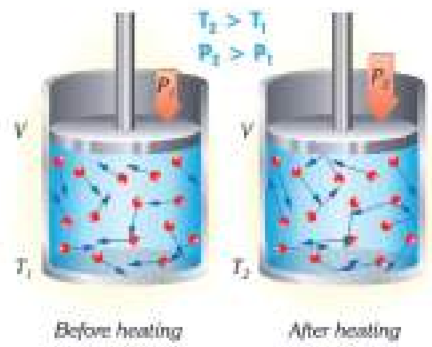


Figure 2.10

For a gas sample at constant volume, an increase in temperature causes an increase in the gas pressure. As the temperature rises molecules gain more energy and strike the walls of the container resulting in an increase in the pressure (Figure 2.10). Under constant volume, temperature and pressure are directly proportional to each other. The scientist Gay-Lussac discovered this fact. This law states that, "At constant volume, the pressure of a certain amount of gas is proportional to the absolute temperature".

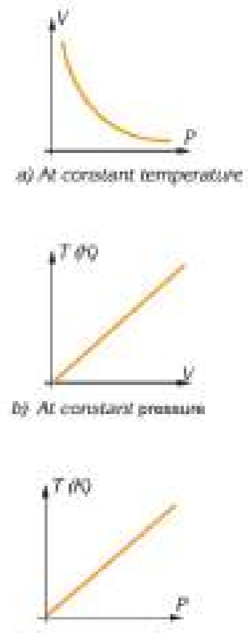


Figure 2.11 Graphs showing relationships between pressure, temperature and volume of a gas sample in a closed container.

Combined relationship of pressure, volume and temperature

The pressure of a gas under constant temperature is inversely proportional to its volume (Boyle's Law). See Figure 2.11a.

At constant pressure, the volume of the gas is directly proportional to the temperature. See figure 2.11b.

If the volume of the container is constant, then the pressure of the gas is directly proportional to its temperature. See figure 2.11c.

A combination of these formulas gives us a relationship between pressure, temperature and volume of a gas in a closed container.

CHAPTER QUESTIONS

Q.1. Choose the correct answer from the followings

1. Which one of the following is property of liquids?

a) they have definite shape but do not have definite volume
b) they have definite volume but do not have definite shape
c) they do not have definite shape and definite volume

d) they have definite shape and definite volume

2. Number of positive charges in matter that is in plasma state

a) more than negative charges
b) less than negative charges
c) equals negative charges
d) all of above

3. The exhausted fire of missile is in _________ state of matter

a) solid b) liquid

c) gaseous d) plasma

4. In rusts moist and hot place. Because of its _____________

a) physical property
b) chemical property
c) iron does not rust
d) both physical and chemical property

5. Which one of the following is not chemical property
a) flammability
b) acidity
c) reactivity
d) solubility

6. What can be said for molecules in solids

a) closer to each other and move freely
b) far away from each other and move freely
c) closer to each other and fixed
d) far away from each other and fixed

7. Liter is unit of _____________

a) length b) area

c) volume d) all of them

8. Aluminum molecules are _______________

a) closer to each other and move freely
b) far away from each other and move freely
c) closer to each other and fixed
d) far away from each other and fixed

9. 1 liter = _________ dm^3

a)0,1 b) 1 c) 10 d) 100

10. This fact, known as Boyle's Law, states that; the product of volume and pressure of a fixed amount of gas is constant by __________.

a) increasing temperature
b) decreasing temperature
c) keeping temperature constant
d) all of above

Q.2. Fill in the blanks
a) When two substances are mixed without changing their natures, this change is called _____________.
b) When two substances are mixed, new substance formed. This change is called_____________.
c) ______________ is space occupied by object.
d) States of matter depends on ____________ and __________.

Q.3. The sentences below are True or false

a) The oil has definite shape and volume
b) Iron has a definite shape and volume.
c) Air is a liquid.

Q.4. A cube container has length of 1m is filled by water. Calculate the volume of water in the container in liter.

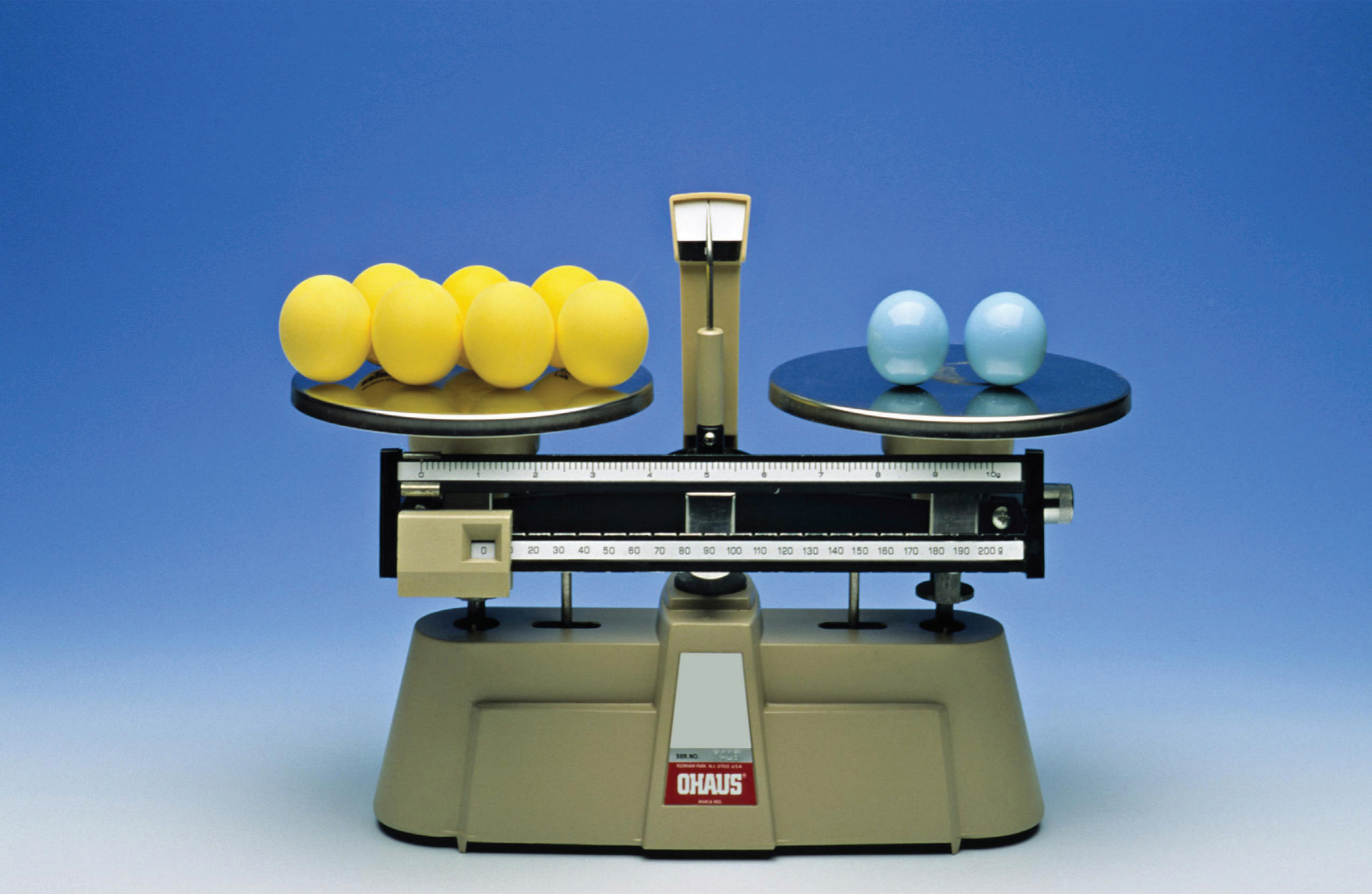
Q.5. A graduated cylinder is filled by colored water and level shows 60 cm^3 . If a piece of iron is immersed to water, level rises to 100 cm^3. Find volume of iron.

Q.6 A room has dimensions of 5m, 4m, 3m. Calculate volume of the room.

Q.7. Draw the table below on your notebook. Then compare piece of lead, lemonade and air according to given conditions.

*Force between molecules
*Distance between molecules
*Motion of molecule

Matter	Distance between molecules	Motion of molecules	Fore between molecules
Lead			
Lemonade			
Air			



CHAPTER 3

MASS AND DENSITY

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Define the Mass.
2. Know how to Measure the mass.
3. Compare between the types of the balance.
4. Knows the physical meaning of density.
5. Write the mathematical relation of density.
6. Determine the relative density.

MASS AND DENSITY

3.1 MASS

Table 3.1

Abbreviation	Mass in Grams
1 kg	1000 grams
1 hg	100 grams
1 dag	10 grams
1 g	1 grams
1 dg	0.1 grams
1 cg	0.01 grams
1 mg	0.001 grams

Table of conversion of mass

Mass is the amount of matter in an object. The SI unit of mass is the kilogram (kg). **The basic unit of mass in the International System of Units (SI), equal to the mass of the international prototype of the kilogram, a platinum-iridium cylinder kept in Sevres, France** (Figure3.1). Mass is measured with a balance. There are several types of balance, but the most commonly used is the equal-arm lever balance. Units of mass change by multiples of ten, see table 3.1.

One type of equal-arm lever balance — The standard platinum-iridium alloy kilogram mass — A set of masses

Figure 3.1

Example 3.1

A 10 cm^3 copper block has a mass of 89 grams. If you take 100 cm^3 of copper, find it's mass in mg, dg and kg.

Solution

First we should find the mass of copper in 100 cm^3.

As 10 cm^3 of copper makes up 89 g, then 100 cm^3 copper makes up 89 x 10 = 890 g.

890 g = ? mg , 1 g = 1000 mg , then m = 890 g = 890 × 1000 mg, m = 890 000 mg,

890 g = ? dg , 1 g = 10 dg , then m = 890 g = 890 × 10 dg , m = 8900 dg,

890 g = ? kg , 1 g = 0.001 kg , then m = 890 g = 890 × 0.001 kg, m = 0.89 kg.

Exercise 3.1

How many milligrams are there in,

a. 1 kg b. 30 g c. 45 hg d. 5 dg

Ans :a. 1 000 000 b. 30 000 c. 4 500 000 d. 500

3.2 Density

In daily usage, 1kg iron is said to be "heavier" than 1kg wool. This does not mean that an iron nail has more mass than 1 m^3 wool. What it means is that a piece of iron has more mass than a piece of wool if both have the same volume. In science, when comparing substances, we consider their densities. Density is defined as the mass in a unit of volume. We calculate the density of matter using the following equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{in symbols,} \quad \rho = \frac{m}{V}$$

In the SI unit system, mass is measured in kg and volume is measured in m^3, thus, the unit of density is kg/m^3 (kilogram per cubic metre). But this is inconvenient for most substances, therefore, g/cm^3 (gram per cubic centimetre) is a more common unit of density.

Density is a characteristic property of matter. We can differentiate substances by using their densities. Table 3.2 shows the density of different substances. The density of copper is 8.9 g/cm^3 , which means 1 cubic centimetre of copper has a mass of 8.9 g. In other words, 8.9 g copper occupies a 1 cm^3 volume (Figure 3.2)

Figure 3.2

Sometimes entering the formula in a triangle, as shown in the figure, is a simple way to remember it.

For example if you want to find the density, you cover d with your finger and then divide the rest; mass (m) by volume (V). This is the equation you need;

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

If you want to calculate mass (m), you cover m with you finger and then multiply ρ by V. This is the formula you want;

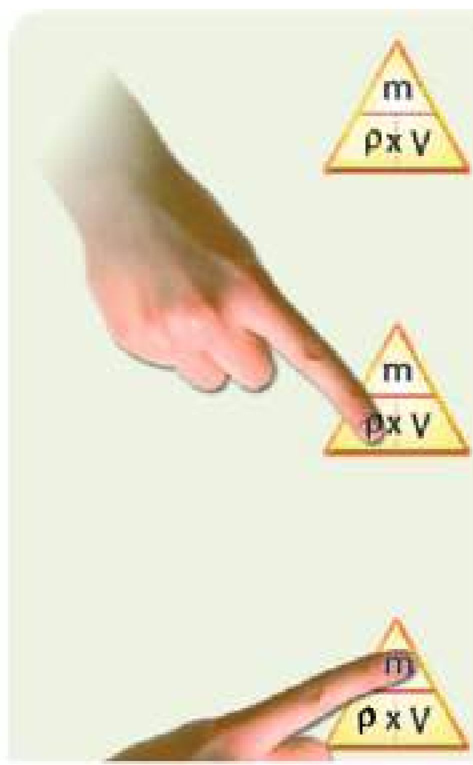
$$m = \rho \times V$$

Table 3.2

Substance	Density (g/cm^3)
Helium	0.00018
Hydrogen	0.00009
Oxygen	0.0013
Air	0.0013
Alcohol	0.8
Oil	0.9
Ice	0.9
Water	1.0 (at +4 °C)
Sugar	1.6
Table salt	2.2
Aluminum	2.7
Iron	7.9
Copper	8.9
Silver	10.5
Lead	11.3
Mercury	13.6
Gold	19.3

Table 3.2 Densities are measured at sea level and 0 °C.

1 g/cm^3 = 1 000 kg/m^3



How can we calculate the density of an object?

In order to calculate the density of an object, first we measure its mass with an equal-arm balance, then we find its volume by measuring it with a ruler, if it has a regular shape. Otherwise we use the graduated cylinder method for irregular objects, and liquids. Then, by dividing mass by volume, we find the density of the object.

3.2.1 RELATIVE DENSITY

In order to determine the density of a substance or an object, we find out the mass and volume of the substance and use the relative;

$$\rho = m/V$$

This is possible only if the object has a regular shape. It is difficult to measure the dimensions of an object with irregular shape. In such cases we express the density of the object in comparison with that of water.

The relative density of a substance is the ratio of the density of the substance to the density of water at 4 Celsius. we take the relative density of water as one.

What is meant by statement relative density of gold is 19.3?

It means that gold is 19.3 times denser than water. Those objects whose relative density is less than one will float in water and those greater than one will sink.

relative density of substance = density of the substance / density of water

$$\rho_r = \rho / \rho'$$

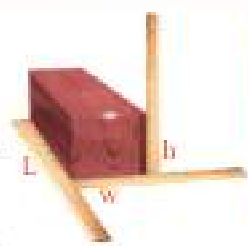
activity — **Finding the density of a regular object**

You need a rectangular object, a ruler and an equal–arm lever balance. Measure the sides of the object using the ruler.

Length, L = ...; width, w = ...; height , h = ...,

Calculate volume by multiplying the side lengths..

Volume, $V = L \times w \times h$ = ...



Then, measure its mass with an equal-arm lever balance as shown in the figure.

m = ...

After taking the measurements divide the mass, m, by the volume,V, to find the density, ρ, of the object.

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

Example 3.2

A piece of iron has a mass of 395 g. Find the volume of the piece of iron using the information in table 3.2.

Solution

Mass of iron, m = 395 g ; density of iron, ρ= 7.9 g/cm^3 ; using the data in the formula,

$$V_{iron} = \frac{m_{iron}}{\rho_{iron}}$$

$$V_{iron} = \frac{395\ g}{7.9\ g/cm^3}$$

$$V_{iron} = 50\ cm^3$$

Result: The volume of the piece of iron is 50 cm^3.

Exercise 3.2

What is the volume of 24 tons of cement? (ρ_{cement}= 3000 kg/m^3)

Ans :8 m^3

Example 3.3

A 0.5 m^3 tank is filled with a liquid of mass 460 kg. What is the density of the liquid?

Solution

What is asked in the question?

Density of the liquid, ρ_{liquid} = ?

What information is given in the question?

Mass of the liquid, m=460 kg; volume of the tank, V = 0.5 m^3

Which equation is needed to find the answer?

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

Calculation

m_{oil} = 460 kg and V =0.5 m^3 ,then

$$\rho_{liquid} = \frac{m_{liquid}}{V_{liquid}} = \frac{460\ kg}{0.5\ m^3} = 920\ \frac{kg}{m^3}$$

Result : The density of the liquid is 920 kg/m^3.

Exercise 3.3

Calculate the mass of copper having the same volume as 31.5 g of silver. Use Table 3.2.

Ans :26.7 g

activity — Finding the density of an irregular object

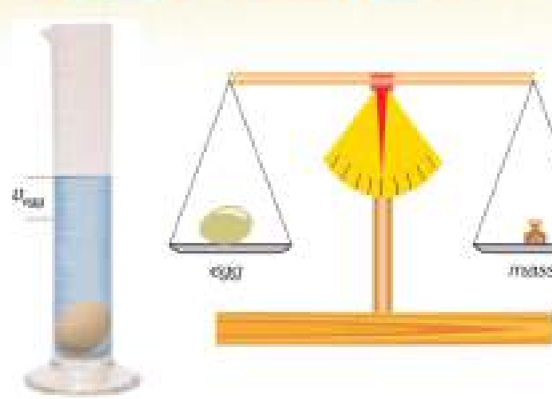
Let's find the density of an egg.

You need a boiled egg, a measuring cylinder, an equal–arm lever balance and some masses.

First, using the cylinder, measure the volume of the egg. Then, using the lever balance, find its mass.

Finally divide mass by volume to find the density of the egg.

$$\rho_{egg} = \frac{m_{egg}}{V_{egg}}$$



Example 3.4

An oil can contains 20 l of oil. If the density of oil is 0.9 g/cm^3, calculate how many kg of oil there is in the can

Solution

What is asked in the question.

The mass of oil, m = ?

What information is given?

The volume and density of oil, $V_{oil} = 20\ \ell$, $\rho_{oil} = 0.9$ g/cm^3.

Which equation is needed to calculate the mass of oil?

$1\ \ell = 1000$ cm^3, 1 g = 0.001 kg , 1 cm^3 = 0.001 ℓ.

Calculation

First convert the units, then calculate the mass. $1\ \ell = 1000$ cm^3, then $V_{oil} = 20\ \ell = 20 \times 1000$ cm^3 = 20 000 cm^3, use this value in the formula; $m_{oil} = 0.9$ g/cm^3 × 20 000 cm^3

$m_{oil} = 18\,000$ g , 1 g = 0.001 kg , then $m_{oil} = 18\,000 \times 0.001$ kg $m_{oil} = 18$ kg

Exercise 3.4

A bottle has a mass of 70 g when it is empty, 90 g when it is full of water and 96 g when it is full of a liquid. What is the density of the liquid in g/cm^3 and kg/m^3 ? (ρ_{water}=1 g/cm^3)

Ans :1.3 g/cm^3 and 1 300 kg/m^3

SUMMARY

Matter is anything which has a mass and occupies a volume in space. It is made up of tiny particles called atoms. Matter is found in three states.

i) Solid state: A solid has a definite shape and volume.

ii) Liquid state: A liquid has no definite shape but a definite volume.

iii) Gas state: A gas has no definite shape or volume.

Measurement is one of the three methods used in science, whereas the other two are experimentation and observation.

mass: The amount of matter in an object. The unit of mass is the kilogram (kg).

Area: The amount of surface enclosed by its boundaries. As a formula, it is stated as :

Area = length x width in symbols $A = L \times w$

The unit of area is m^2.

Volume: The amount of space occupied by an object. As a formula, it is stated as :

Volume = length x width x height

$$V = L \times w \times h$$

The unit of volume is m^3.

Density: The mass of an object per unit volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{in symbols} \quad \rho = \frac{m}{V}$$

The unit of density is kg/m^3 or g/cm^3.

PUZZLE

Fill in the boxes correctly.

1. The amount of surface enclosed by its boundary lines.
2. A state of matter which has neither a definite shape nor a volume.
3. The mass of an object divided by its volume.
4. A unit of measurement for distance from the SI system.
5. A substance which has a density of 1 g/cm^3.
6. A group of atoms.
7. Tiny particles.
8. A state of matter which has a definite shape and volume.
9. A unit of time.
10. An amount or quantity used as a standard of measurement.
11. The amount of matter in an object.
12. A unit of mass equal to 1000 kg.
13. A state of matter which has a definite volume but no definite shape.
14. The amount of space occupied by an object.

CHAPTER QUESTIONS

Q.1. Choose **the correct answer from the followings.**

1. Which one of the followings is not unit of mass?

a) g b) kg

c) m^3 d)mg

2. An ice cube has mass of 3640 kg and its density is 910kg/m^3. Find volume of the ice cube.

a) 6m^3 b) 5m^3

c) 4m^3 c) 3m^3

3. A thermo stone has dimensions of *0.5 mx 0.2 mx 0.4m* and its density is 800kg/m^3. Calculate mass of the stone.

a) 30kg b) 32kg c) 34kg d) 35kg

4. Relative density of fuel is 0.68. Find mass of 1 liter fuel.

a)380g b) 480g c)580g d) 680g

5. What is density of water?

a)1000kg/m^3 b)10000kg/m^3

c)400kg/m^3 d)4000kg/m^3

6. Relative density a rock is 4. Calculate density of the rock.

a) 4kg/m^3 b) 40kg/m^3

c) 400kg/m^3 d) 4000kg/m^3

7. When a piece of sponge is pressed, which one of the following quantity does not change.

a) volume b) mass c) density d) shape

Q.2. Fill in the blanks.

a) Digital scale is used to measure ____________.

b) g/cm^3 is unit of density, g is unit of ____ and cm^3 is unit of ________.

c) Substances which are float in water has relative densities are ________ than density of water.

d) Relative density of solid objects is ratio of their densities and density of _________.

Q.3. Fill in the blanks

Object	Density (kg/m³)	Mass (kg)	Volume (m³)
A	----	4000	2
B	8000	-----	4
C	2000	1000	----
D	----	2000	4

According to table:
Which substance has the greatest mass?
Which substance has the smallest mass?
Which substance float in water?
Which substances are made by same material?

Q.4. The sentences below are True or False. If False correct the sentence.
a) Density is defined as amount mass in unit time.
b) In SI unit system unit of mass is gram.
c) In SI unit system unit of relative density is kg/m^3
d) Mass of an object determines its weight and does not depend on its amount.

Q.5. If you have a bottle of milk and you want to find its density. How can you find density of the milk by using graduated cylinder and digital scale?

Q.6. If two substances have equal volume, it can be said that they have equal mass. Why?

Q.7. A steel palte has mass of 156 kg and density of 7800 kg/m^3. If the width of plate is 0.8mm and the height is 50mm, find its length.

Q.8. Density of mammals approximately equals density of water. According to given information find volume of followings. ($1m^3 = 1\ell$)

a) 150kg cow b) 1400kg whale

Q.9. A water tank has 1m height, 2m with hand 3m length is filled by water. Calculate mass of water in the tank.

Q.10. A room has dimensions of5mx4mx3m is filled by air which density is $3kg/m^3$. Find mass of the air.

Q.11. An object has 180kg mass and 0.3 m^3 volume. Calculate;

a) density of object
b) relative density of object.

Q.12. 400g wooden cube has length of 20 cm. What is the density of cube.

Q.13. Match the following object with given estimated masses.

Petroleum container	500mg
Butterfly	3,5 ton
Wolf	40 ton
Human	250g
Elephant	80kg
Bird	38kg
Car	1000kg

Q.14. density of mercury is 13.6 g/cm^3. Calculate mass of mercury, if its volume is;

a) $1cm^3$
b) $10cm^3$

CHAPTER 4
FORCE

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Knows the physical meaning of the force.
2. Write the units of force.
3. Distinguish between Action and Reaction.
4. Listed the type of forces.
5. Represent the force graphically.
6. Compare between vector and scalar quantities.

Chapter - 4

FORCE

Figure 4.1Some examples of forces being used

4.1 Force

Lifting a hammer, stretching a spring, opening a door, lifting weights, pushing a diskette into a driver and kicking a football are all examples of forces being used (Figure 4.1). A force is either a push or a pull that acts on an object. Whenever you bend, twist, stretch or compress something you are using a pushing or pulling force.

A force cannot be seen and described like an object, but the effects of it on different objects can be seen. We cannot see the wind but we can see a windmill turning, a yacht sailing, a tree bending or a kite flying. Thus, we can define it as follows:

Force is an effect which can,

a) Start motion,
b)Stop motion,
c) Change the speed or direction of motion,
d)Change the shape or size of a body.

Figure 4.2The engines push up a plane forwards.

The ability of a force to change the speed of an object is very useful; an engine increases the speed of a car, a parachute slows down a falling object and a jet engine pushes a plane forwards (Figure 4.2). Look at the pictures below. State which effect of a force is shown in each one.

4.2 MEASUREMENT OF FORCE

a) Unit of Force

Force is represented by the symbol 'F' and is measured in units called Newtons (N). The pull on a 100 g mass is about 1 N on earth.

b) Measuring Force

A spring stretches when you pull it. The harder you pull, the more the spring stretches, as long as you do not keep pulling it until it breaks. A simple way to measure a force is by using it to stretch a spring. A spring with a scale attached to it is called a spring balance or dynamometer(or Newtonmeter) See the (figure 4-3)

Figure 4.3
Spring balance

Action and Reaction

Forces always occur in pairs acting in opposite directions. For every action force, there is always an equal but opposite reaction force. If an object applies a force on a second object, then the second object will exert an equal but opposite force on the first object. This was first noticed by Sir Isaac Newton, he called these forces action and reaction forces. If a man pulls a rope tied to a wall, the rope also pulls the man with an equal but opposite force, this is because the rope reacts to the man's action. The book lying on a table exerts a downward force, the table compensates for it by exerting an equal but opposite upward force (Figure 4.4). When a boy sits on a chair, his weight presses down, the chair balances the boy's downward force by an equal upward force.

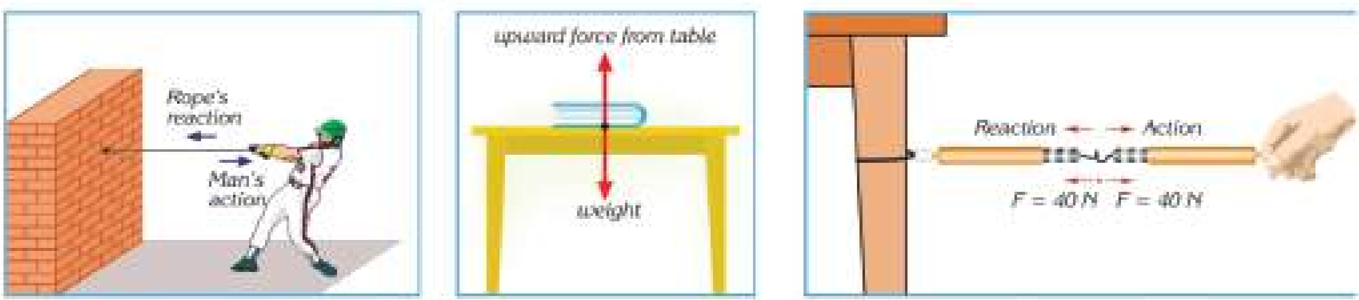
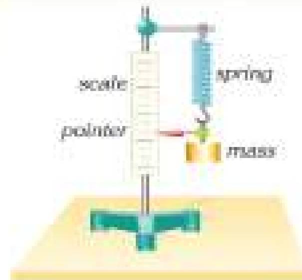


Figure 4.4 Action and reaction forces occur with equal magnitudes but in opposite directions.

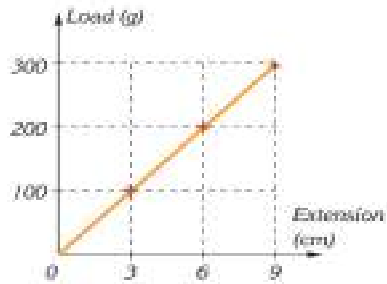
Activity — Making a dynamometer

You need a steel spring, a stand, a scale, a pointer, a weight hanger and masses of different values. Set up the steel spring and scale as shown in the figure. Attach the pointer and weight hanger at the end of the spring. Read the scale at the pointer and note its value. Add a 100 g load and take it's reading. Repeat the same procedure with increasing values of masses. Enter the readings into a table as shown below.



Plot the results obtained to a graph. Every pair of readings will be one point on the graph. Mark the points with small crosses and draw a smooth line through them. The graph will appear similar to that shown in the figure below.

This graph demonstrates that the total amount stretched by the spring is proportional to the force applied.



Load	Reading	Extension (=Reading-Original Reading)
0	(e.g) 10 cm	0 cm (= 10 cm – 10 cm)
100 g	(e.g) 13 cm	3 cm (= 13 cm – 10 cm)
...		...
...		...

4.3 TYPES of FORCES

In fact all known forces (or interactions) in the universe can be grouped into four basic types. Below lists of these forces in the order of decreasing strength.

The Strong Force

This force is responsible for binding of nucleus. It is the dominant one in reactions and decays of most of the fundamental particles. This force is so strong that it binds and stabilize the protons of similar charges within nucleus. However, it is very strong range. No such force will be felt beyond the order of 1Fm(Femtometer)

The Electromagnetic Force

This is the force that exist between all particles which have an electric charge. For example; electrons bind with nuclei of atom, due to the presence of protons. This force is long range, in principle extending over infinite distance. However, the strength can quickly diminishes due to shielding effect. Many everyday experiences such as friction and air resistance due to this force. This is also the resistant force that we feel, for example, when pressing our palm against wall. This is originated from the fact that no two atoms can occupy the same space. However, its strength is about 100 times weaker within the range of 1Fm, where the strong force dominates. But because there is no shielding with in nucleus, the force can be commulative and can compete with strong force. this competition determines the stability structure of nuclei.

The Weak Force

This force is responsible for nuclear beta decay and other similar decay processes involving fundamental particles. The range of this force is smaller than 1Fm and it is very smaller than strong force. Nevertheless, it is important in understanding the behavior of fundamental particles.

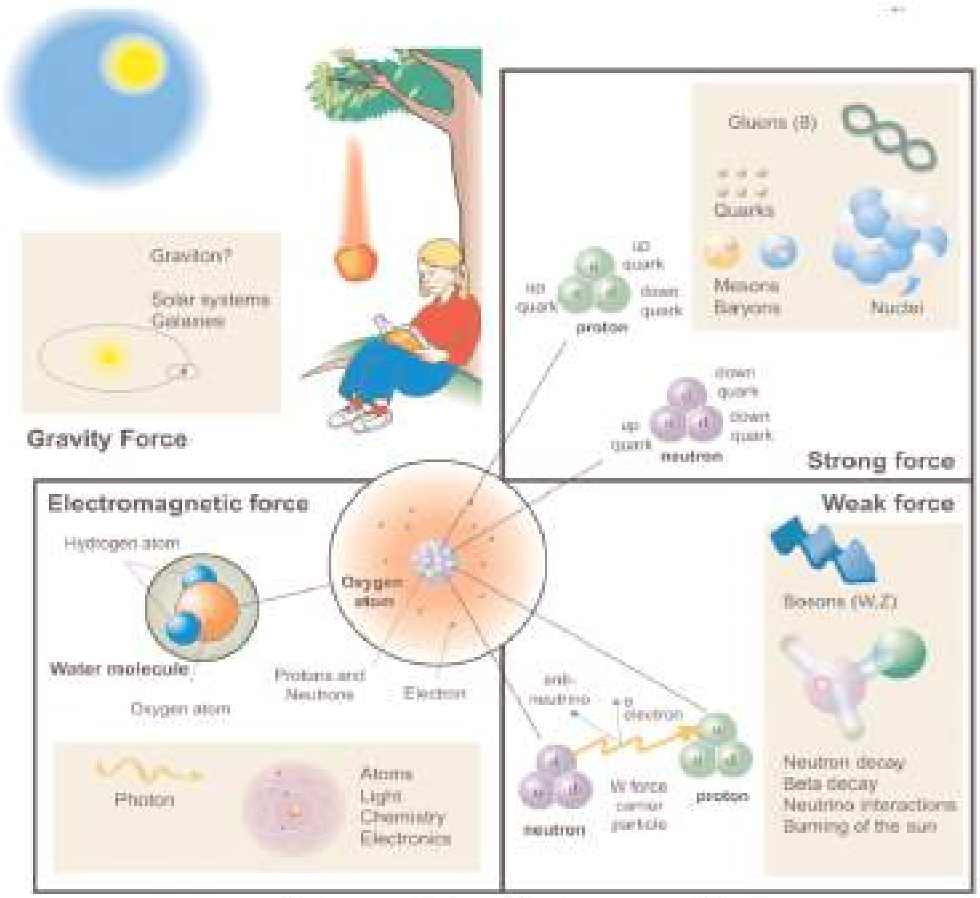
The Gravitational Force

An object released from a height falls to the ground. This indicates that there is a force acting on the object directed towards the centre of the earth. This downward force is called the gravitational force. It is not a force that exists only between the earth and objects. It exists between all objects. In other words, gravitational force is the force of attraction between any two objects (Figure 4.5).

Gravitational force depends on;

a) The masses of the objects,
b)The distance between them.

You will notice that of all the 4 basic forces two of them can be experienced in our daily life. They are also called familiar forces which are the electromagnetic and gravitational forces. Similarly, the strong force and the weak force are called the unfamiliar forces.



(Figure 4.5) Four basic types of forces

Frictional Force

Figure. 4.6

Frictional forces surround us most of the time in the same way we live under the influence of gravity. Frictional force is an important force which only acts when two objects are touching. It is a force that slows down moving objects and brings them to rest. It always acts in the opposite direction to the direction of motion of the object. For example, there is friction between your hands when you rub them together, and walking is only possible with friction, because when your foot pushes against the ground, a frictional force opposes it to make your body move forward. If the frictional force is greatly reduced e.g. by a patch of oil, a banana skin or ice, your foot can slide straight back with painful results (Figure4.6).

There are countless examples of friction being useful; the wheels of bicycles or other vehicles, the braking system of vehicles, and even the ability to pick up and hold objects with our fingers. The treads on tyres increase the friction of the wheels on the road, thus the motion of a vehicle becomes possible. Climbing is also possible due to friction (Figure4.7).

Figure. 4.7 Some examples of friction being experienced

Figure. 4.8

However, friction is usually a problem for the moving parts of almost every machine, because it prevents machinery from moving freely, and causes moving parts to heat up. Therefore, manufacturers try to reduce the force of friction between surfaces that rub together by applying a thin slippery layer such as oil, or mounting wheels on ball or roller bearings (Figure 4.8).

Can you think of other ways to reduce friction?

What does the frictional force depend on?

As explained, when an object is pulled on a table, a frictional force opposes it in a direction opposite to its motion. The frictional force between the object and the table depends on two factors;

a. The weight of the object.
b.The roughness of the surfaces rubbing together.

Friction is directly proportional to the weight of the object; as the weight increases friction also increases, as the weight decreases friction also decreases (Figure 4.9). In Figure 4.9 we see that the pulling force is greater than before because the weight has been increased by the addition of mass.

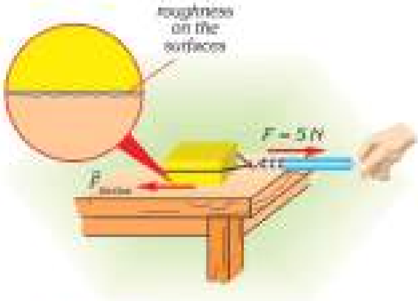


Figure 4.9 Friction occurs because of the roughness between rubbing surfaces

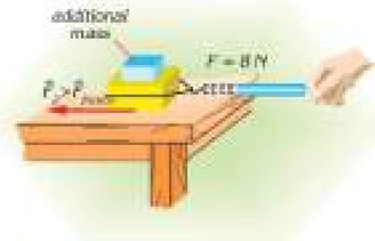


Figure 4.9 The larger the weight, the greater the frictional force.

It is also important to note that friction does not depend on the area of the rubbing surfaces. For example, if surfaces of an object have the same roughness, it is not important onto which of its sides the object is placed, the frictional force will always be the same (Figure 4.10).

Figure 4.10 Frictional force doesn't depend on the area of the rubbing surfaces for objects made of the same material.

What is air and water drag?

Air applies frictional force on the objects moving through it. This force is called ***air resistance*** or ***air drag***. Water also applies friction to the objects moving through it. This force is called ***water resistance*** or ***water drag***.

Birds have an exellent aerodynamic design to decrease air drag. Their bodies are streamlined to enable them to fly as effectively and quickly as possible through air.

Fish also have well designed body structure for swimming in water. Their bodies are elongated which decreases water drag and allows them to move stably and efficiently through water.

Scientists carry out research on bird and fish body shapes to find ways of making vehicles more efficient.

4.4 REPRESENTING FORCE

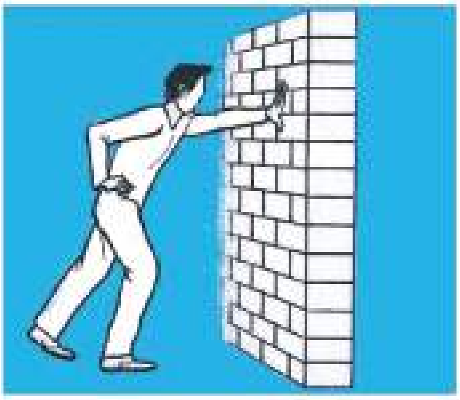


Figure 4.11

a) Representing Force

In the(figure 4 . 11) , a man is applying a force to the wall and the wall is reacting to him. To illustrate the force of the man and the reaction of the wall we can use double-headed arrows as in the figure below:

But this representation does not give enough information about the force. Why?

Look at the (figure 4.12) . What do you think about the forces acting on the bricks? Are they the same? How can you represent the forces acting on the bricks? If all the forces act at the same time on the brick, in which direction does it move? Write down your ideas.

Figure 4.12

In the figure above, each dynamometer may indicate the same magnitude,but they differ in one way: Their direction. If we carefully notice the direction of the forces, we see that one is to the right, one is upwards to the left and one is upwards. From this example we see that for forces, we must take into consideration both their magnitude and direction of application.

In science, quantities are divided into types: Vector quantity and scalar quantity. A vector quantity is a quantity which has both magnitude and direction. A scalar quantity is a quantity which has only magnitude. Force is a vector quantity, therefore it is represented with a vector.

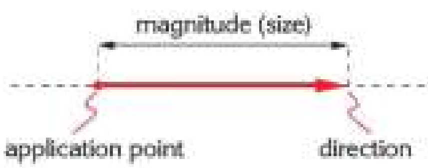


Figure 4.13 Representing a vector

What is a vector?

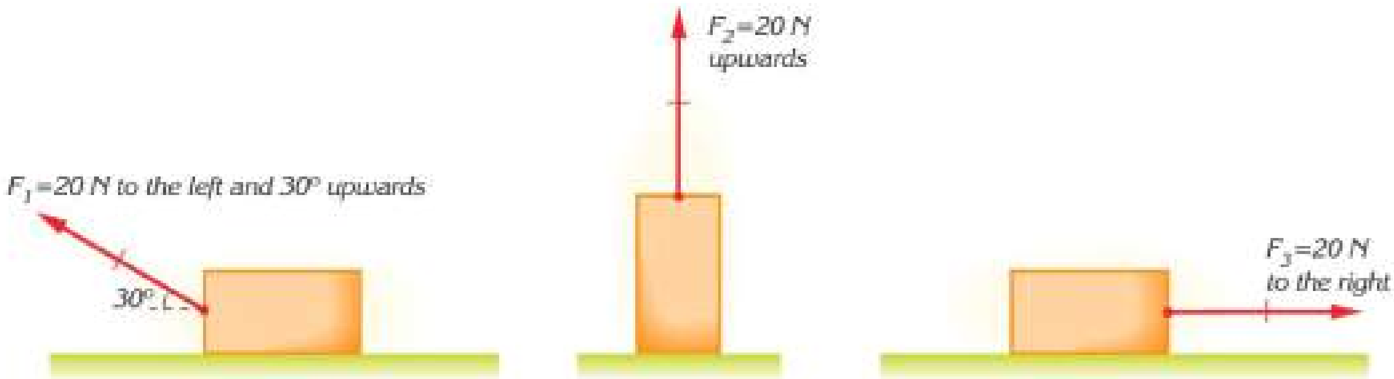
An arrow drawn to scale is called a vector as shown on the Left. A vector has the following properties:

a)An application point (where it is applied)

b)A magnitude (or size)(how long it is)

c)A direction

Now let's indicate the forces acting on the bricks using vectors. Notice that each has the same magnitude but different directions. (10 N is represented by a length of 1 cm.)



b) Examples about vectorial and scalar quantities

Walking 3 m to the west, pulling a box with 10 N to the north, a wind blowing at 70 km/h to the south are examples of vector quantities, because they give information on the direction and magnitude of the quantities. 3 kg of apples, 5 metres in length, 8 days, 6 months, 10 seconds, an air temperature of 25 °C are all examples of scalar quantities, because they give information on only magnitude or size of the quantities.

Example 4.1

Show the following forces using vectors.

a) A block is pulled to the east with a force of 4 N.

b)A chest is pulled to the southwest with a force of 3 N.

c) Three forces act on a block to move it, one with 2 N due north, one with 3 N due east and one with 3 N due west.

Solution

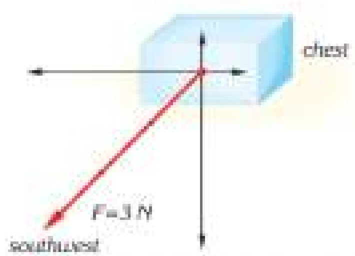
First of all we have to decide on a scale to represent the force. To make drawing simpler, let 1 cm represent 1 Newton.

Then, we take an application point and draw the vector.

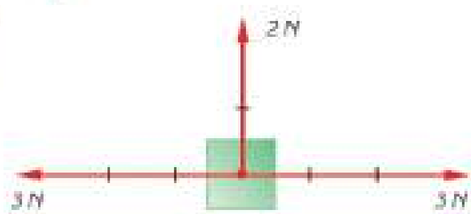
a) Since 1 N is represented by 1 cm, 4 cm represents 4 N.

a)

b)



c)



Exercise 4.1

Represent each of the following forces using a vector diagram:

a)A force of 5 N applied upon a box in a direction towards the west.

b)The earth's gravitational pull on a 50 kg cement bag.

c)A man applying an 80 N force on a block in a direction towards the south.

4.5 COMBINING FORCES

A single force which has the same effect as two or more forces acting together is called a resultant force (R). The forces which form a resultant force are called component forces. Resultant force is found using the following equation;

$$\vec{R} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots$$

The arrowhead (→) over each letter shows that it is a vector quantity, which means the quantity also has a direction.

a) Forces Acting in the Same Direction

Let F_1 and F_2 be forces in the same direction, to find the resultant we add the magnitude of the components. The magnitude of the resultant force R is found using;

$$R = F_1 + F_2$$

Consider two boys, each with the same force trying to lift a box. Then consider a man lifting the same box by himself. The man applies a force twice that of the boys' to lift the box. Therefore we can say that the force applied by the man is the resultant force of that applied by the boys' (Figure 4.14).

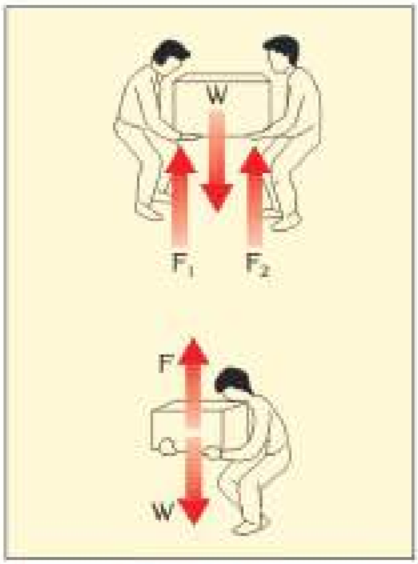


Figure 4.14

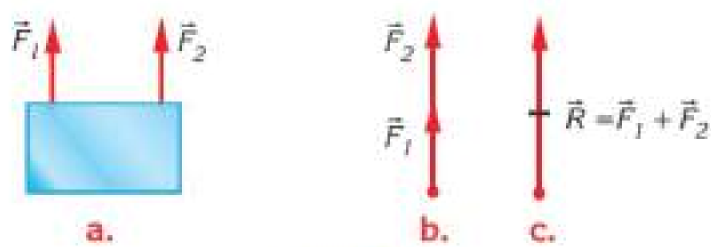


Figure 4.15

Then we draw a vector joining the tail of F_1 to the head of F_2 (Figure 4.15.c). This gives us the resultant force (R).

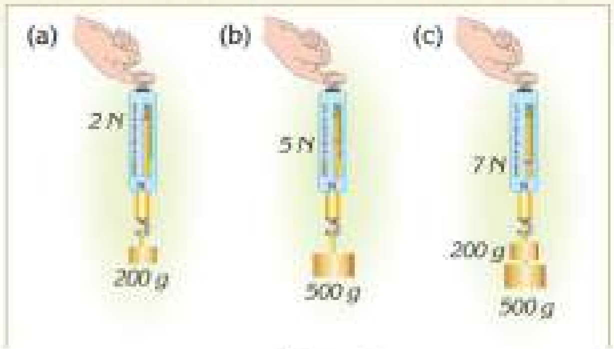
The magnitude of the resultant is

R = 100 N + 100 N = 200 N. It is in an upward direction.

activity — Combining forces in the same direction

Take a spring balance (Figure 4.15), 500 g and 200 g masses. Hang 200 g on the hook, and read the scale of weight (Figure a). Then hang the other mass and take a second reading of weight (Figure b). After that attach the masses to the balance again and take a final reading (Figure c)

What do you observe? Can we use a single weight of 700 g instead of the two separate weights?



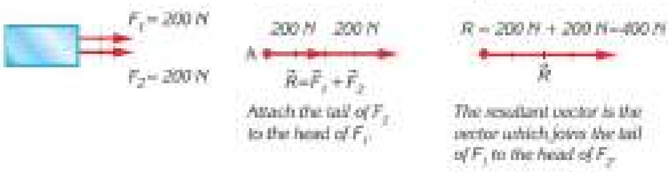
(Figure 4.15)

Example 4.2

Assume that two boys pull a chest to the right, each with a force of 200 N. Find the resultant force acting on the chest.

Solution

Let F_1 and F_2 be the boys' forces and let 1 cm represent 100 N.



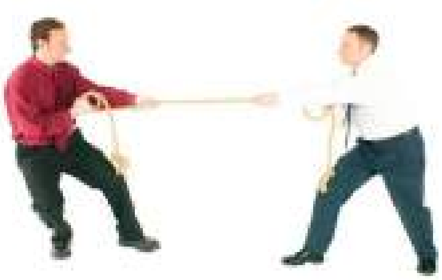
Exercise 4.2

The forces acting on a box in the same direction are $F_1 = 200$ N and $F_2 = 150$ N, what is the resultant force? Represent it by a vector.

Ans :350 N

b) Forces Acting in Opposite Directions

Let F_1 and F_2 be forces in opposite directions and let F_1 be greater than F_2. Then the magnitude of the resultant is $R = F_1 - F_2$. The minus sign shows that the second force is in the opposite direction to the first one. The direction of the resultant force is in the direction of the greater force.



What will be the net force on the box in the (figure 4.16), if it is pulled by the two different forces in opposite directions?

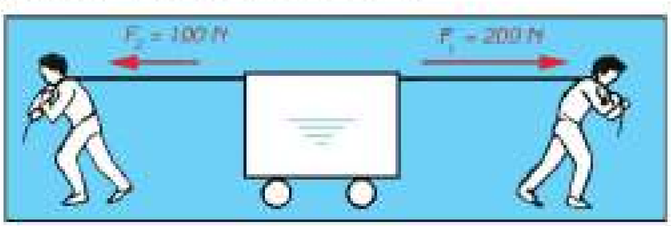


Figure 4.16

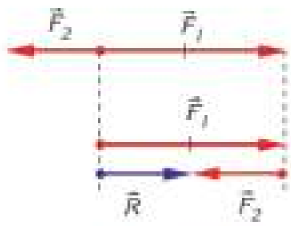


Figure 4.17

The direction of the resultant force is in the direction of the greater force.

Two boys apply forces F_1 and F_2 in opposite directions. F_1 is greater than F_2 so the box will move to the right. In this case we can find the resultant force by using vector addition. We add the tail of the smaller force to the head of the greater force. Then we draw a vector joining the tail of the greater force to the head of the smaller force(Figure 4.17). This is the resultant force. It is in the direction of the greater force. The magnitude of the resultant force on the box is found by subtracting the smaller force from the greater force.

$R = F_1 - F_2$ $\qquad$ $R = 200 - 100 = 100$ N

activity

Combining forces in the opposite direction

You need a toy car, some string, masses ranging from 10 g to 50 g, pulleys and two mass holders. Arrange the materials on a table, as shown in the figure.

Hang 10 g to the left side and 40 g to the right side of the car and observe the direction of motion. Then, add 50 g to the left-hand side. Did the direction of motion change? Then, by adding 20 g to the right side, make the weights on both sides equal. Did the car move?

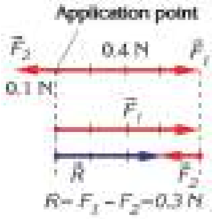
Now to explain the motion of the car, let's examine the resultant force acting on the car for each case. Remember that the pulling force acting on 100 g is about 1 N.

In the first case, the resultant force on the car is,

$R = F_1 - F_2$, so

$R = 0.4$ N $- 0.1$ N $= 0.3$ N to the right.

To represent this with vectors, let 1 cm represent 0.1 N.

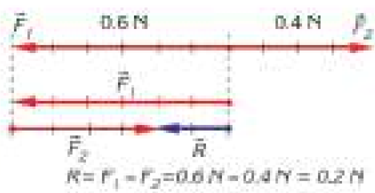


In the second case; the resultant force is

$R = 0.6$ N $- 0.4$ N $= 0.2$ N

to the left, since the force on the left is greater.

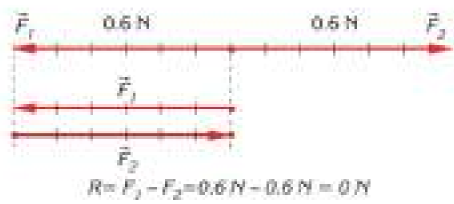
Let 0.5 cm represent 1 N.



In the third condition the resultant force is,

$R = 0.6$ N $- 0.6$ N $= 0$.

Since the forces acting on both sides have the same size the resultant force on the car is zero.



CHAPTER QUESTIONS

Q.1. Fill in the blanks

a) A scalar quantity is a quantity which has only ___________.

b) A falling apple from a tree is applied by _________ force, in direction of _________.

c) A horse that pulls wagon applies _____________ force on wagon.

d) Friction force always acts in the_________direction to the direction of motion of the object. .

Q.2. The sentences below are True or fulse.

a) Earth applies gravitational force on moon.

b) We can decrease magnitude of friction force between our shoes and surface.

Q.3. When a book is thrown on the table, it stops after a period of time. Explain, why?

Q.4. Represent each of the following forces using a vector diagram:

a)A force of 10 applied upon a box in a direction towards the East.

b) A chest is pulled to the south-east with a force of 6 N.

Q.5. Calculate

a) net force on object which pulled by 8N and 2N forces which are in same direction.

b) net force on object which pulled by 8N and 2N forces which are in opposite direction.

Q.6. Two forces are applied to an object which are 5N and 10N. calculate net force on the object represent all forces, if;

a) forces are in same direction

b) forces are in opposite directions

Q.7. An object is pulled to north by 200 N and pulled to south by 200N;

a) represent the forces on the objects

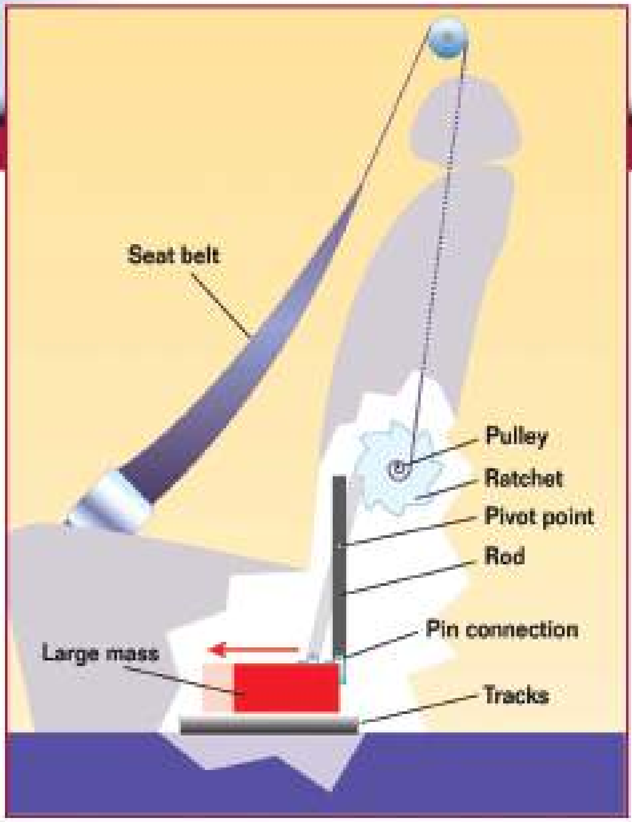
b) calculate net force on the object

c) The object is in equilibrium or not? Why?

The Inside Story on Seat Belts

The purpose of a seat belt is to prevent serious injury by holding a passenger firmly in place in the event of a collision. A seat belt may also lock when a car rapidly slows down or turns a corner. While inertia causes passengers in a car to continue moving forward as the car slows down, inertia also causes seat belts to lock into place.

The illustration shows how one type of shoulder harness operates. Under normal conditions, the ratchet turns freely to allow the harness to wind or unwind along the pulley. In a collision, the car undergoes a large acceleration and rapidly comes to rest. Because of its inertia, the large mass under the seat continues to slide forward along the tracks, in the direction indicated by the arrow. The pin connection between the mass and the rod causes the rod to pivot and lock the ratchet wheel in place. At this point, the harness no longer unwinds, and the seat belt holds the passenger firmly in place.



When the car suddenly slows down, inertia causes the large mass under the seat to continue moving, which activates the lock on the safety belt.

CHAPTER 5
PRESSURE

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. **Define the pressure.**
2. **Write mathematical equation of pressure and its units.**
3. **Distinguish between Action and Reaction.**
4. **Give some examples of the use of pressure by living things.**

Chapter - 5

5.1 PRESSURE

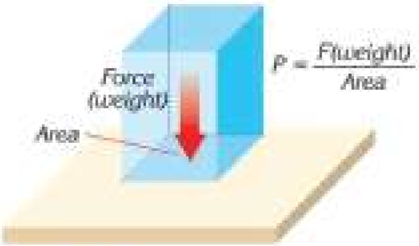
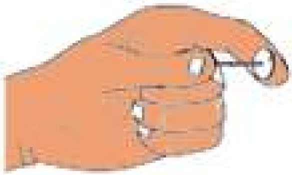


Figure 5.1 A block standing on a surface applies a pressure upon the surface due to its weight.

The word "pressure" is a widely used word among people. On every day T.V. weather forecasts, we hear the word "pressure" many times. Drivers check tyre pressure before going on long journeys. In the kitchen a pressure cooker is sometimes used for cooking vegetables. We apply pressure on keys when we press them, on dough while we prepare pastry, on paper when we stamp it, on the pump when we squeeze it.



Hold a nail between your fingers as shown in the figure on the left. Slightly press your fingers. In which finger do you get pain? Now apply a little bit greater force. Did the pain increase? Why? (Be careful not to injury yourself.)

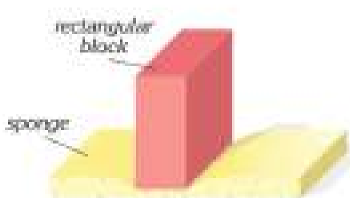
What two things that effect your degree of pain?
As it can be understand from the examples above, in which a force acts on a body, we have to consider not only the force but also the area over which it acts (Figure 5.1). The perpendicular force acting on a unit area is called as pressure.

In an equation we can state pressure as;

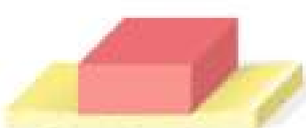
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{in symbols,} \quad P = \frac{F}{A}$$

From the definition, pressure has the units of force(N) and area(m^2). Therefore pressure is measured in Newton/metre^2(N/m^2). The unit N/m^2 has a special name: Pascal(Pa).

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



a. Small area large pressure



b. Large area small pressure

Figure 5.2

Multiples of Pascal are used to express higher pressures. 1000 Pa is called 1 kilopascal(kPa).

$$1 \text{ kPa} = 1000 \text{ Pa}$$

Pressure increases if the area in contact with a force decreases. We can observe this when a rectangular block is placed on a piece of sponge in it's upright position as shown in Figure 5.2.a. Since the weight of the rectangle acts over a small area, the pressure is greater and it sinks into the sponge. If you lay it down horizontally as shown in Figure 5.2.b, it sinks less, because the same weight acts over a larger area, so it applies less pressure. Figure 5.3Why do horses sink into snow?

Figure 5.3 Why do horses sink into snow?

A duck has webbed feet therefore it does not sink into soft snow, but a rooster of the same weight will sink because the area of its feet is smaller than that of the duck's (Figure 5.4).
Study the pictures below. In which position does the man sink into the snow deeply, in which position does he sink less? Explain why?

Figure 5.4

Treads under sport shoes prevent skidding on the grass.

5.1.1 Pressure in use

Sometimes we want to produce a great pressure using a given force. We can apply a greater pressure when the area over which the force acts is small. For example we use the sharp edge of a knife to cut, because the force acts over a much smaller area than the blunt end (Figure 5.5). In the same way nails, pins, drills and needles have sharp points, so they can go into materials easily.

Sometimes we need low pressure therefore we enlarge the contact area. Skies and snowshoes have large areas, they help us to move on snow without sinking in. Tractors and large lorries use large tyres, heavy machines such as bulldozers and excavators use large pallets to move easily on soft ground without sinking in.

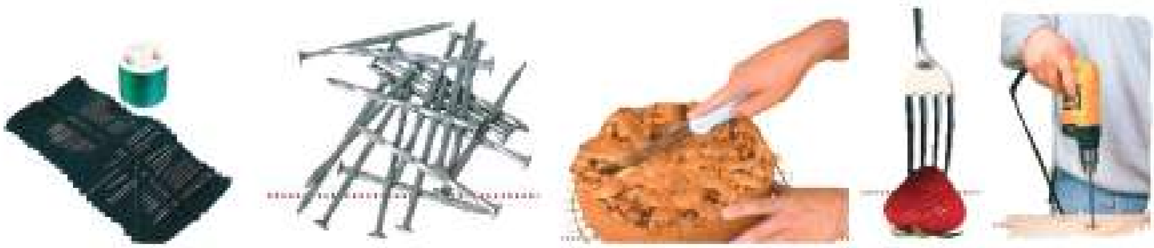
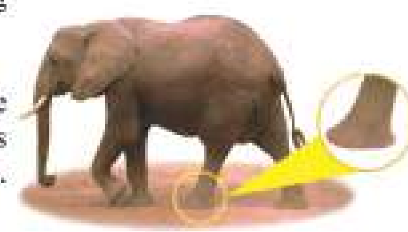


Figure 5.5

Tractor rollers have a large mass, but act over a small area so that it applies a very large pressure on asphalt to squeeze it into shape.

Increasing the number of tyres, lowers the pressure applied on each tyre. Thus the deformation of roads is prevented.

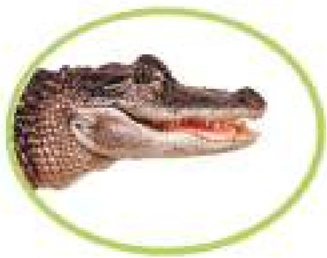
To prevent skidding, we use a chain which lowers the contact area and enlarges the pressure.



Some examples of the use of pressure by living things

If we take a careful look at the environment, we see that animals are created with different features and can use the principles of pressure to survive. Study the pictures on the page.

Big animals, such as elephants, bears and camels have large feet, thus, they apply less pressure on the ground.



Animals have sharp teeth to break food into pieces.

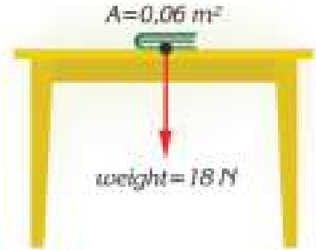
Woodpeckers have sharp beaks to make holes in the trees.

Dogs, cats and birds have sharp claws to help them to easily grasp things.

The pointed beaks of birds help them to cut through the air when they fly.

Example 5.1

A book weighing 18 N has a 0.06 m^2 cover surface and lies on a table. Calculate the pressure of the book on the table? If we place an encyclopedia of 42 N on the book, what will the final pressure be?



Solution

What are you asked to find?
The pressure of the book, P = ?
What is the information given?
Weight of the books, $W_1 = 18$ N, $W_2 = 42$ N
Area of the book, A = 0.06 m^2
What is the equation needed?

Calculation

$$P = \frac{F}{A} \quad P_1 = \frac{18\,N}{0.06\,m^2} = 300\,Pa$$

When the encyclopedia is placed on the book, the weight increases but the area remains the same. The total weight is;

$W_{total} = W_1 + W_2 = 18\ N + 42\ N = 60\ N$

$$P_2 = \frac{W_{total}}{A} = \frac{60\,N}{0.06\,m^2} = 1000\,Pa$$

Result : As the force increases keeping the contact area constant, the pressure also increases.

Exercise 5.1

A 400 N girl whose total shoe area is 0.05 m^2 stands on the floor. What is the pressure exerted by the girl on the floor?

Ans :8000 Pa

Example 5.2

Find the pressure exerted on the table by a 48 N box for the two different positions shown in the figures.

Solution

What are you asked to find?

The pressures of the object in two different positions. $P_1, P_2 = ?$

What is the information given?

Weight of the object $W = F = 48$ N
Dimensions of the object; 0.2 m, 0.4 m, 0.3 m

What are the equations needed to find the pressure?

$$Pressure = \frac{Force}{Area} \quad \text{and} \quad Area = Length \times Width$$

Calculation

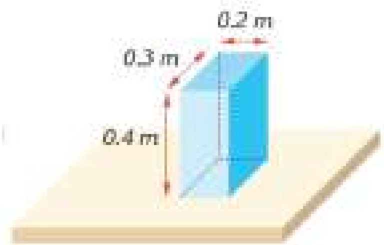
a) In the first case the area is
$A_1 = 0.4\ m \times 0.3\ m = 0.12\ m^2$ and the pressure P_1,

$$P_1 = \frac{F}{A_1} = \frac{48\,N}{0.12\,m^2} = 400\frac{N}{m^2} = 400\,Pa$$

b) The area in the second case is,
$A_2 = 0.3\ m \times 0.2\ m = 0.06\ m^2$ and the pressure P_2,

$$P_2 = \frac{F}{A_2} = \frac{48\,N}{0.06\,m^2} = 800\frac{N}{m^2} = 800\,Pa$$

Result : The box applies greater force in the second position than the first one.



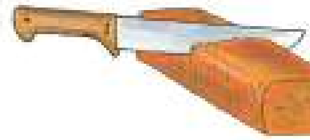
Exercise 5.3

Find the pressure of the block in Example 5.2 when it lies on its third side.

Ans :600 Pa

Example 5.4

A loaf of bread of width 10 cm is to be cut with a knife. Compare the pressures exerted on the bread when,



a)It is cut with the blunt edge of the knife.
b)It is cut with the sharp edge of the knife.

The force applied is 10 N and the blunt edge has a thickness of 2 mm and the sharp edge 0.1 mm.

Solution

What are you asked to find?

The pressures exerted on the bread, P = ?

What is the information given?

Force, F = 10 N ; the thickness of the blunt edge, a_1 = 2 mm = 0.002 m; the thickness of the sharp edge, a_2 = 0.1 mm = 0.0001 m;
the width of the bread, b = 10 cm = 0.1 m

What is the equation relating pressure and force?

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{and} \quad \text{Area} = L \times w$$

Calculation

a) $A_1 = 0.1\ m \times 0.002\ m = 0.0002\ m^2$ and P_1 is;

$$P_1 = \frac{F}{A_1} = \frac{10\ N}{0.0002\ m^2} = 50\,000\ Pa$$

b) $A_2 = 0.1\ m \times 0.0001\ m = 0.00001\ m^2$ and P_2 is;

$$P_2 = \frac{F}{A_2} = \frac{10\ N}{0.00001\ m^2} = 1\,000\,000\ Pa$$

Result : The blunt edge exerts a very low pressure on the bread so that we cannot cut it. Blunt edges are not used for cutting, since they spread out the cutting force and lower the pressure.

Exercise 5.4

Repeat Example 5.4 with a force of 8 N.

Ans :40 000 Pa and 800 000 Pa

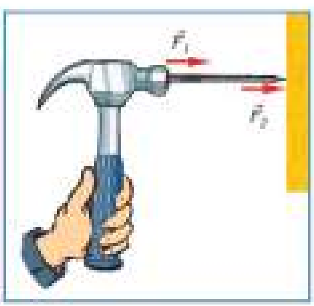


Figure 5.6

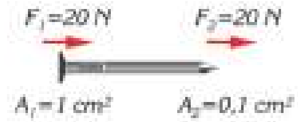
F_1 and F_2 are the same, but the pressure at the tip of the nail is greater.

Pressure and Transmission of Force by Solids

Solids transmit forces only in one direction: In the direction of application without changing its magnitude. For example, while hammering a nail, only the force is transmitted, however the ends of the nail have different surface areas, so the pressures at the two ends are different (Figure 5.6). As you remember, the smaller the area the larger the pressure, for the same force.

Example 5.5

The force applied on a nail by a hammer is 20 N. The ends of the nail are 1 cm^2 and 0.1 cm^2. What are the force and pressure at the tip of the nail?



Solution

What are you asked to find?

The force and pressure at the tip of the nail.

What is the information given?

The areas of the nail's ends and the force applied on it, $A_1 = 1\ cm^2$, $A_2 = 0.1\ cm^2$ and $F = 20$ N.

What is the equation needed to find pressure?

$$\text{Presure} = \frac{\text{Force}}{\text{Area}}$$

The force at the tip of the nail is 20 N too, since solids transmit the force in the direction of application. The pressure at the head is;

$$P_1 = \frac{20\ N}{1\ cm^2} = \frac{20\ N}{0.0001\ m^2} = 200\,000\ \frac{N}{m^2}$$

and the pressure at the tip is;

$$P_2 = \frac{20\ N}{0.1\ cm^2} = \frac{20\ N}{0.00001\ m^2} = 2000\,000\ \frac{N}{m^2}$$

Result: The pressure at the tip is 10 times greater than the pressure at the head, because the smaller the area the larger the pressure for the same force.

Exercise 5.5

You are pushing a needle into paper with a force of 0.02 N. If the areas of the ends of the needle are 1 mm^2 and 0.1mm^2 find the pressures at both ends.

Ans :20 kPa and 200 kPa

5.2 LIQUID PRESSURE

As we discussed in the first chapter liquids have mass and volume but not a definite shape; they take the shape of the container. Since a liquid has a weight, it too exerts a downward pressure but it also exerts pressure in every direction. Liquid pressure increases as we go down from the surface to the bottom of the liquid. To prove this, carry out the following activity.

Fish and divers at the bottom of the sea feel greater pressure, which is due to the weight of water above them. The water presses in all directions on the bodies, see the (figure 5.7). Therefore divers wear very special suits to protect themselves from the effects of pressure.

Figure 5.7 The diver in the sea feels water pressure in every direction.

Figure 5.8 Pressure at the same depth acts equally in all directions.

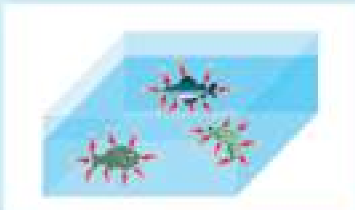


Figure 5.11 The water in an aquarium exerts pressure on the fish in every direction.

In summary we can state the properties of liquid pressure as follows:

* A liquid exerts pressure in all directions.
* The pressure of a liquid is directly proportional to the depth of the liquid.
* The liquid pressure depends on the density of the liquid.

Dams are thicker at the bottom, because water pressure increases as its depth from the surface of the liquid increases.

Because the liquid pressure increases with depth, the patient feeder is hung on a stand.

Figure 5.10

Standpipe (water tower)

Water Supply System

A town's water-supply comes from a reservoir on higher ground or a water storage tank, called a stand pipe or water tower, at the top of a tower. Water coming from a higher level causes larger pressures at the lower levels of the places supplied.

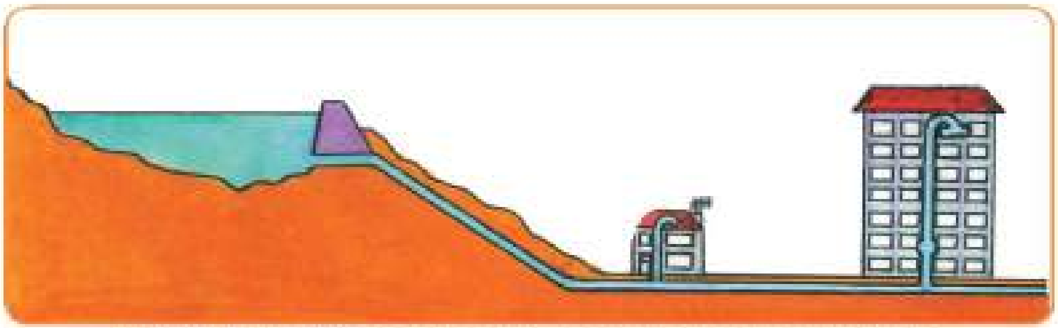


Figure 5.11 Reservoir on high ground and a standpipe

Calculation of Liquid Pressure

As we saw before, pressure is the perpendicular force acting on unit area Now, we will derive a new equation for liquid pressure.

Figure 5.12

Consider a liquid column having a base area A and height, h as shown in Figure 5.12. To find the pressure at the bottom we have to know the weight of the liquid column. First we will find the mass of the liquid, then its weight. Mass is found by multiplying density by volume;

$$m = V \times \rho$$

Volume is found by multiplying base area (A) with height (h),

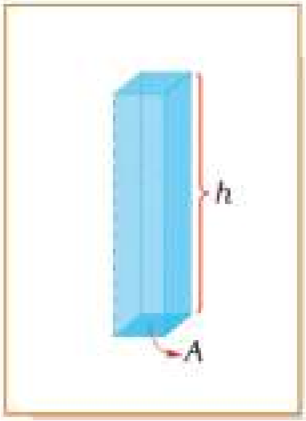
$$V = A \times h$$

Thus we obtain,

$$m = \rho \times A \times h$$

Remember that weight is the pulling force acting on an object, and calculated by multiplying mass with g,

$$\text{weight} = m \times g = \rho \times A \times h \times g$$



Now, after replacing force with weight, we can rewrite the pressure formula as,

$$P = \frac{\text{weight}}{\text{Area}} \quad \text{so that}, \quad P = \frac{\rho \times A \times h \times g}{A} = d \times h \times g$$

Then we obtain;

$$P = h \times \rho \times g$$

From this formula we can see that the liquid pressure depends on both height and density of the liquid, and is independent of the area and shape of the container; This can be understood by observing the(figure 5.13)

(figure 5.13)

The liquid pressure at the bottom of these containers is the same although they have different shapes.

5.3 GAS PRESSURE

Do you know that we are always supporting a weight of about 200 000 N acting on our bodies? Why do some people's noses bleed when they climb to high attitudes? How can we drink through a straw? The answers to these questions depend on air pressure.

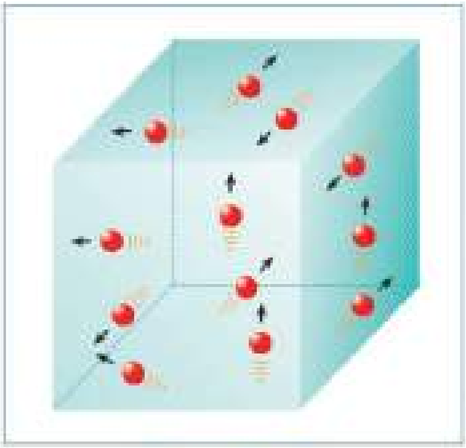


Figure 5.14

a) Gas Pressure

Like liquids, gases also exert pressure on the walls of a container. Tiny particles in the gas strike the walls with a force and cause a pressure (Figure 5.14). A gas can be compressed easily into a small volume, causing an increase in its pressure. Inflation of a ball or a car tyre is a good example of the compressibility property of gases.

b) Air (Atmospheric) Pressure

The gas layer surrounding the earth is called the atmosphere. The atmosphere is composed of nitrogen, oxygen and very small amounts of other gases such as hydrogen and carbon dioxide (Figure 5.15). It is about 900 km deep and we live at the bottom of this huge ocean of air (Figure 5.16)

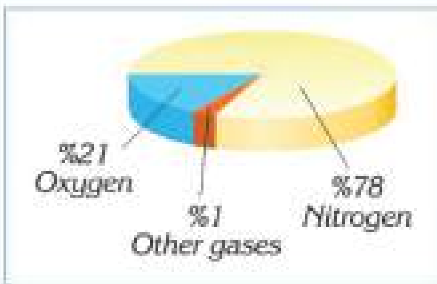


Figure 5.15 Composition of air

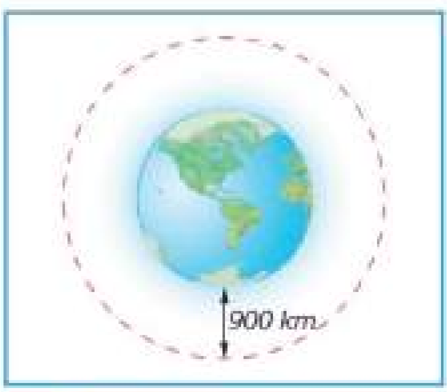
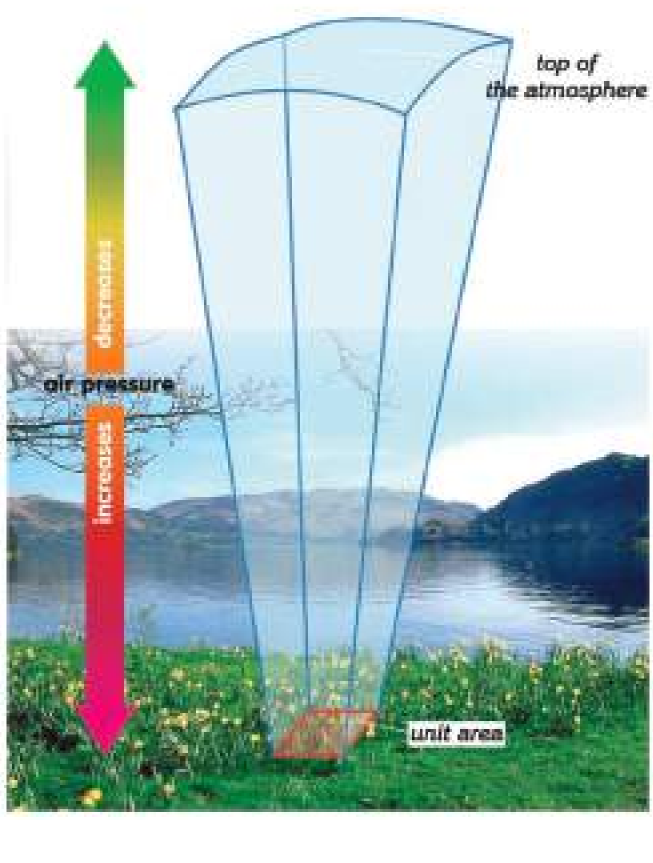


Figure 5.16 The atmosphere is about 900 km thick.

The molecules in the air have weight. Therefore they exert force on the earth surface. The force exerted per unit area on a surface by the weight of air is called air pressure. Look at the diagram in the picture below. As the weight of the air in the column decreases the pressure also decreases. The air pressure is at its greatest at sea level, since there are so many molecules present, and it decreases as height increases



Atmospheric pressure at sea level is about the same as a weight of 1 kg mass per cm^2 area. An ordinary man has a surface area of about 2 m^2; this means that the total force on a man at sea level is about 200 000 N, which is about the weight of a 20 ton-mass acting on our bodies. However, we do not feel this huge pressure exerted on us since the blood pressure of our body balances it. At high altitudes the air pressure decreases, and the blood-air pressure balance of our body is disturbed. This is why a mountain climber's nose bleeds.

The air pressure exerted on an ordinary man is about the same as the weight of a 20- ton mass.

c) Evidence of Air Pressure

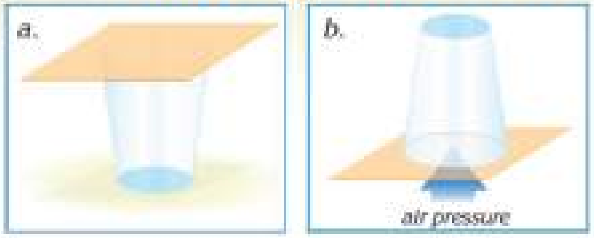
Air pressure cannot be felt, but if we take air out or remove it from a given space, the effect of air pressure can be seen. Vacuum is the special name given to volumes where almost all the air has been taken away. The following activities will help us to understand air pressure.

Activity

Evidence of Air Pressure

Take a glass, fill it with water and cover its mouth with a smooth piece of paper (figure a). Then holding the paper on it, turn the glass upside down. Now, let go of the paper. What do you see? Does water spill out? (figure b).

The pressure exerted by the water on the paper does not exceed the pressure applied by the air, thus the paper does not fall and the water remains in the glass.



What keeps the paper from coming off

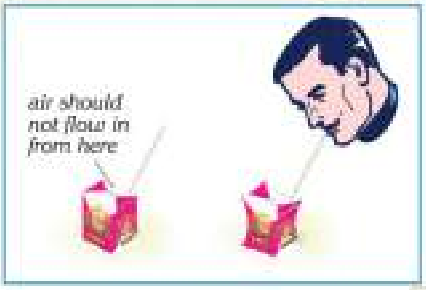
Drinking Through a Straw

When you suck, you lower the pressure at the top end of the straw The air pressure on the drink pushes down the drink and causes high pressure at the bottom of the straw. Due to this pressure difference between the ends of the straw, the liquid moves from the bottom of the glass to yourmouth.

Activity

Evidence of Air Pressure

Get a box of fruit juice and place a straw in it. Be sure that air cannot flow into the box around the straw. Now, suck through the straw. While you suck, observe what happens. The carton is compressed. This is because sucking the liquid decreases the pressure in the box, and the atmospheric pressure exerted on the carton crushes the box and pushes the liquid up the straw.



5.3.1 APPLICATIONS of AIR PRESSURE

Removing gas from a tank

Siphoning

Siphoning is a way to remove a liquid from a tank. To remove the liquid, the tube must be filled and the open end of the tube must be below the level of the tube in the tank. At point B, the pressure in the tube exceeds the atmospheric pressure because of the liquid in the tube, and the liquid moves through the tube from the container to the outside.

In daily life people use siphoning to remove water from an aquarium wit hout disturbing fish or plants, or to empty the gas tank of a car.

Vacuum Cleaner

Vacuum Cleaner applies the principle of atmospheric pressure to remove dust particles. When it is switched on, the fan sucks out the air from space inside the vacuum.

The atmospheric pressure outside, which is greater than forces air and dust particles into the filter bag.

Syringe

When the piston is pulled up, the atmospheric pressure inside the cylinder will decrease. The atmospheric pressure outside pushes the liquid up into the syringe

5.4 BUOYANCY

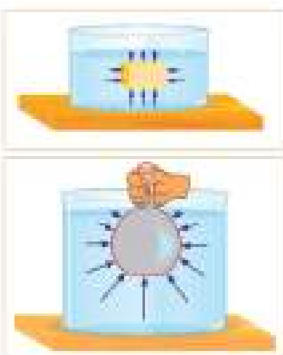


Figure 5.17 A body submerged in water experiences pressure in all directions.

When you swim or lie in the bath you can feel the upthrust from the water. Also, a stone held in water feels lighter than when held in air. A block submerged into water experiences the pressure of water in every direction. This pressure at the lower surface of the block is greater than at the upper surface because liquid pressure increases with depth (Figure 5.17). Thus the force acting on the lower surface of the block is greater than the force acting on the upper surface. This difference in forces causes an upward push on the block which is called up thrust or buoyancy.

If you look at the pressure arrows on the objects in the upper figure, you can see the cause of upthrust on the block. Here, we neglect the forces acting on the block from its sides because they cancel each other out.

a) Archimedes' Principle

Look at the stone in Figure 5.18. It weighs 12 N in air and 8 N in water. This difference in weight comes from buoyant force of water. The amount of up thrust on the block is 4 N.

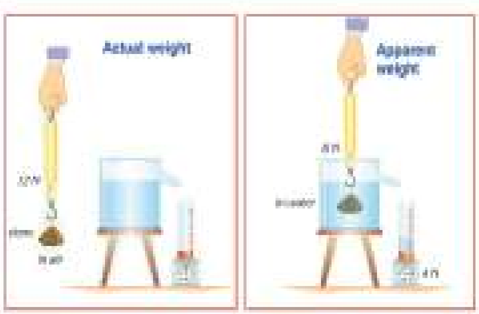


Figure 5.18 Actual and apparent weight of an object.

b) How do objects float in water?

An object in a liquid does not experience only the liquid's upward push, it also experiences the downward force of gravity. If these forces balance each other, the object floats in water (Figure 5.19a). But if the force of gravity is greater than the upthrust, the object sinks (Figure 5.19b).

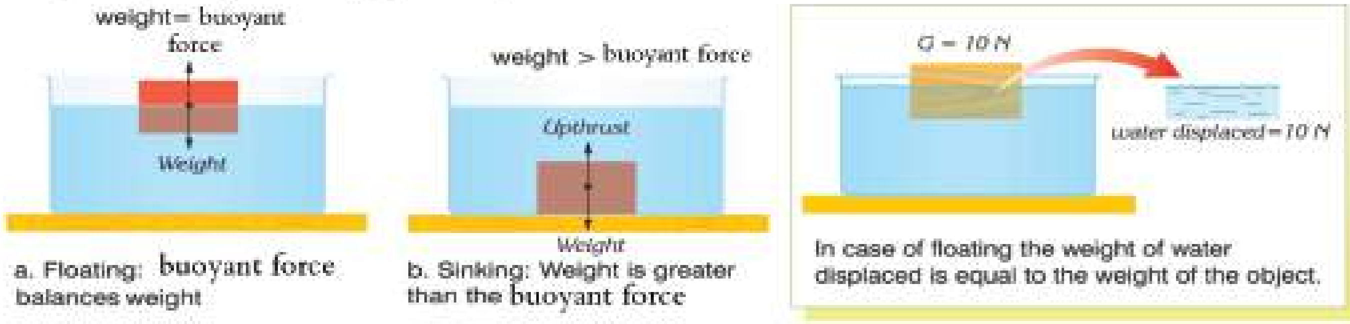


Figure 5.19

Floating is a special case: The buoyancy of the liquid is equal to the weight of the object. Ships, boats and all things moving on water experience buoyancy equal to their weights. And also they displace water equal to their weights.

CHAPTER QUESTIONS

Q.1. Choose the correct answer

1. Pressure of liquid in a container does not depend on;

a) gravitational acceleration
b) density of water
c) height of water
d) liquid surface area

2. Pressure of container which is filled by liquid depe nds on;

a) base are of the container
b) surface area of the liquid
c) height of the liquid
d) mass of the liquid regarded its shape

3. Agricultural machineries and military tanks have a broad chain. Why?

a) to increase pressure on surface
b)to increase speed
c)to decrease pressure on surface
d) to prevent rotation of wheels

4. Tire of car can explode on the move, why?

a) number of air molecules in the tire increases
b) atmospheric pressure increases compare to pressure inside the tire
c) air pressure inside tire increases because of increase in temperature
d)tire expands

5. Volume of displaced water by immersed object equals;
a) volume of immersed object
b)greater than volume of immersed object
c) smaller than volume of immersed object
d) position of immersed object in water

6. If the density of object that floats in liquid equals the density of liquid, volume of displaced liquid is;

a) greater than volume of float object
b) smaller than volume of float object
c) equal to volume of float object
d) zero

7. Some amount of snow is added into graduated cylinder which half of it is filled by water. When the snow melts, height of the water inside cylinder

a) increases
b) decreases
c) does not change
d) increases by volume of snow that is added into cylinder

8. Afish rests on the bottom of a bucket of water while the bucket is being weighed. When the fish begins to swim around in the bucket, how does the reading on the scale change?
a. The motion of the fish cause the scale reading to increase.
b. the motion of the fish cause the scale reading to decrease.
c. the buoyant force on the fish is exerted downward on the bucket causing the scale reading to increase.
d. The mass of the system and so the scale reading will remain unchanged.

9. There are three metal pieces (gold, silver, copper) which have equal masses. Density of gold is 19300 kg/m^3, silver is 10500 kg/m^3 and copper is 8940 kg/m^3. If these three metal pieces are immersed to same container respectively;

a) displaced water by gold is greater than silver and copper
b) displaced water by silver is less than gold
c) displaced water by silver is greater than gold and copper
d) none of them

10. A piece of metal is placed on the object that floats in the swimming pool. Displaced water by float object;

a) equals volume of float object

b) equals volume of float object and piece of metalic)

c) equals volume of immersed part of object

d) depends on distance between center of floating object and base of the pool

Q.2. The sentences below are True or False.

a) A balloon which is filled by helium rise in air steadily

b) Pressure of liquid on base of container depends on only mass of the liquid

c) Weight of sunk object in liquid is greater than upthrust force of the liquid

d) An object floats in water and petroleum. Immersed part of object in water is greater than petroleum, because density of petroleum is greater than density of water.

e) Displaced water by an object that floats in water with whole amount equals volume of the object.

f) Under same pressure height of petroleum is greater than hieght of water, because density of petroleum is greater than water.

Q.3. Think

a) Methods of calculating atmospheric pressure and liquid pressure are different

b) If we want to drain a container, we must drill two holes

c) Explain phenomenon of drinking juice by pipette

d) Fish can change their position at any depth of sea

e) Amateur swimmers use pneumatic tire, why?

f) Even if density of iron greater than density of water, ships float in water but iron ball sinks, why?

g) Elephants can drink water by their proboscis

h) People can swim in clam sea better than in river, why?

Q.4. How does siphon can draw water in toilet?

Q.5. Which effect determines level of balloon in air?

Q.6. What happens, if an inflated balloon is affected by followings at room temperature;

a) under sunlight
b) in the fridge

Q.7. What is the working principle of syringe?

The Steam Engine

This external combustion engine, which transforms the energy in water vapor into mechanical work, was essential to the Industrial Revolution that took place in England in the 17th and 18th centuries. The history of its invention goes back to rudimentary devices without practical application and continues up to the invention of the steam engine by James Watt. The steam engine was of fundamental importance for industry and transportation, replacing beasts of burden, the mill, and even human laborers.

How It Worked

COMPARISON OF SOURCES OF ENERGY ABOUT 1800

Watt's Innovation

Added a separate container where the steam condenses

NAME	JAMES WATT
NATIONALITY	SCOTTISH
OCCUPATION	ENGINEER

The changes he introduced made it possible to apply the steam engine to industrial processes.

CHAPTER 6
HEAT AND TEMPERATURE

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Distinguish between Heat and Temperature.
2. Write Temperature units.
3. Describe the thermometer.
4. Understand Heat exchange.
5. Distinguish between Expansion in solid, liquid and gas.

HEAT

6.1 HEAT And TEMPERATURE

Heat plays an important role in our lives. Our body uses food to produce heat. We listen to weather reports on TV because we want to keep our body temperature constant. We wear either thin or thick clothes depending on the temperature outside. We use heat to cook, to warm up our homes, to shape plastic or metal materials and so on.

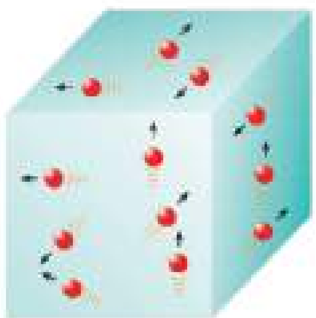


Figure 6.1 All matter is made up of tiny particles which are in a constant state of motion. Molecules in a gas sample move in every direction.

What are heat and temperature?

The kinetic theory tries to explain the behavior of molecules in gases; it states that matter is made up of tiny particles that have kinetic energy and are in a constant state of motion (Figure 6.1).

Particles have kinetic energy because they are in motion, and they have potential energy because there are attraction force between them.

When a gas inside a closed container is heated, its particles gain kinetic energy and move faster. Thus, the temperature and the internal energy of the gas increase. The thermal energy (internal energy) of a substance is the sum of the kinetic and potential energies of all particles in that substance.

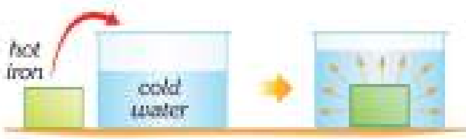


Figure 6.2 When a hot iron piece of iron is in contact with cold water thermal energy is transferred from the iron to the water.

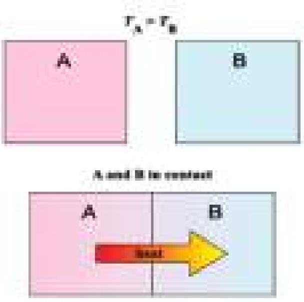
When a hot piece of iron is placed in cold water, the iron becomes cooler and the water becomes warmer. This process continues until both substances reach the same temperature. While the piece of iron loses thermal energy the water gains thermal energy (Figure 6.2).

We can define heat as a form of energy flowing between two bodies in contact when they are at different temperatures. Heat is the energy transferred to a substance, while temperature is the degree of hotness of a substance. A cup of boiling water and a kettle of boiling water have the same average kinetic energies, that is, the temperature of water in the containers is the same. However, there are more water molecules in the kettle than in the cup, so the water in the kettle contains more thermal energy than the water in the cup (Figure 6.3).

Figure 6.3 A kettle full of boiling water has more molecular kinetic energy than a cup full of boiling water.

Temperature is a measure of average kinetic energy of each particle of an object. If the particles of object A have greater kinetic energy than the particles of object B, object A is at a higher temperature than object B.

6.2. Heat exchange



Heat energy starts to flow from the hotter object to the cooler one

If two substances at different temperatures are brought into contact, heat energy starts to flow from the hotter object to the cooler one as illustrated in the figure to the left. When they reach the same final temperature, heat flow stops. The heat lost by the hot object is equal to the heat gained by the cold object. This is called the principle of conservation of heat energy. We can state this in a formula as:

$$\textbf{Heat lost}_{\text{by hot object}} = \textbf{Heat gained}_{\text{by cold object}}$$

$$Q_{lost} = Q_{gained}$$

6.3 What is thermal expansion?

Why are there gaps between railway bars and at the ends of bridges? How do balloons float in air? Why does a glass crack when hot water is poured into it?

These are questions related with thermal expansion.

When an object gets larger without gaining any matter, we say that the object expands. When the object gets smaller without losing any matter, we say that the object contracts.

The amount of expansion or contraction depends upon three factors;

1.The size of the object
2. The type of substance it is made of
3. The temperature change of the substance

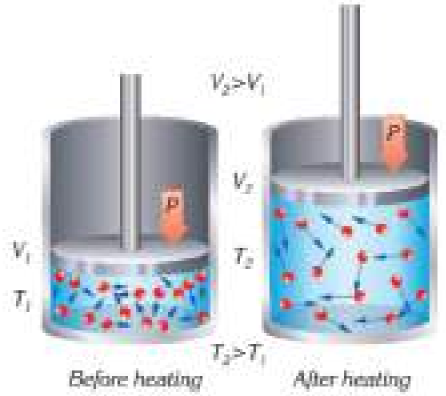


Figure 6.4 As temperature increases molecules move faster and volume increases.

Expansion of gases

The kinetic theory explains thermal expansion too. When a gas is heated in a container, molecules move faster, collide with each other, and move farther apart. As a result the volume increases and the gas expands, as shown in figure 6.4.

Figure 6.5 Heat expands the gas inside the container.

When the heat source under an air balloon heats the gas inside, the heated gas expands, the volume of the balloon increases, and therefore air lifts up the balloon (Figure 6.5). (Remember the upthrust of air from the chapter pressure.)

If you hold a flask as shown in the figure 6.6, you heat the air inside and the expanded air escapes as bubbles into the water.

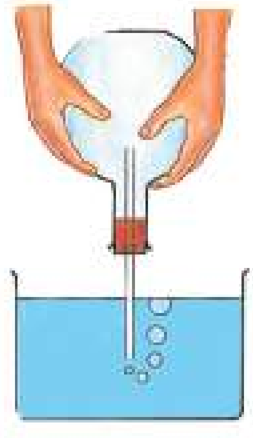
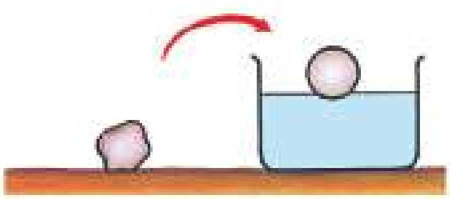


Figure 6.6 Expansion of air

Another example is illustrated in Figure 6.7. On winter days toy balloons or ping-pong balls contract because of the cold. When we place the ball near a stove, it expands and when we place the ping-pong ball into a cup of hot water, it inflates.

Gases expand much more than solids or liquids for a given temperature rise, this is because the gas particles move more freely. The expansion of a gas is not a characteristic property of matter since equal volumes of different gases expand or contract at the same rate.



Contracted ping-pong ball in cold air. Expanded ping-pong ball in hot water.

Figure 6.7

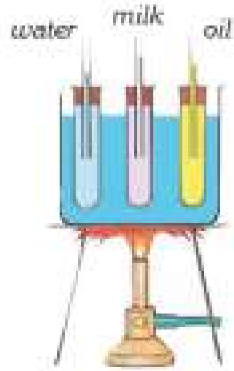


Figure 6.8 Expansion of three different types of liquids.

Expansion of Liquids

When a liquid is heated, the motion of the molecules increases and they spread farther apart so that the liquid occupies a greater volume. In Figure 6.8 the three test tubes in water contain three different types of liquids at the same level and the same temperature. Heating with the bunsen burner makes the water hotter, the liquids rise in the tubes. However, the liquids expand at various rates because they are different substances.

Expansion of Solids

Solids expand for the same reasons as gases and liquids; heated particles in a solid vibrate faster and move farther apart, and thus occupy a larger volume. Many examples of the expansion of solids can be observed in our daily lives, such as telephone cables drooping in summer due to thermal expansion and their contraction in winter. (Figure 6.9)

Telephone cables expand in summer.

Telephone cables contract in winter.

Figure 6.9

We can open a bottle's screw-on metal cap by holding it under hot water so that it expands more than the glass bottle neck, as shown in Figure 6.10 Metal rings are heated prior to being fixed to a wooden barrel. The rings contract when they cool and thus hold the barrel tightly (Figure 6.11).

Figure 6.10

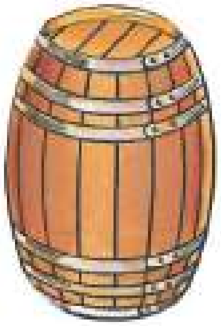


Figure 6.11

Steel bridges get longer when they become hotter. Usually, when steel bridges are constructed, gaps are placed at both of their ends to prevent damage when they expand in summer and contract in winter. (Figure 6.12).

Figure 6.12

Concrete also expands, thus gaps are placed between concrete slabs, to prevent unwanted cracks from occurring. We can see these gaps in roads made of concrete.
Steel rods are placed inside concrete to strengthen it. Since concrete and steel have about the same linear expansivities, they expand equally for the same temperature rise. If their linear expansivities were different, the steel would cause the concrete to crack (Figure6.13)

Figure 6.13

Experiment — Expansion of metals

Aim: To observe the expansion of metals

Materials: Metal ball and ring device, heater.

Procedure: Pass the ball through the ring. When they are at the same temperature, the ball just passes through the ring. Now, heat the ball and try to pass it through the ring again.

Discussion: Does the ball pass through the ring after heating? When the ball cools down will it pass through the ring?

Sometimes thick glass cups or bottles crack if boiling water is poured inside them. This is because the inside of the glass expands before the outside. This is shown in the illustration in figure 6.14.

Steam pipes, hot water pipes and fuel pipes often have large bends in them as shown in the figures below. The bends allow the pipes to expand without getting cracked.

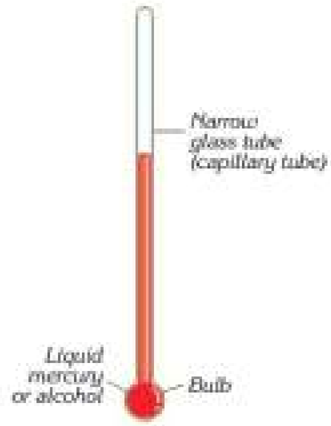
Gaps are always placed between railway bars, otherwise on very hot days the extension of the bars would cause the tracks to buckle and split open. This would present a danger to trains travelling over them (Figure 6.15).

Figure 6.14

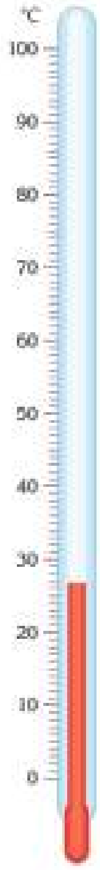
Large bends in pipes

Gaps are placed between railway bars

Figure 6.15



A thermometer is anarrow glass tube with a liquid placedinside it.



Constructing a thermometer

A uniform narrow glass tube (capillary) with a bulb at one end is partially filled with mercury or alcohol. The tube is so narrow that a small expansion or contraction of the liquid causes a noticeable change in the height of the liquid.

When the bulb is heated, the liquid expands and fills the tube, pushing all the air out, this is called the capillary effect. The top of the tube is sealed by melting the glass.

In practice, the freezing and boiling points of water are used as reference points for thermometers, because pure water is readily obtainable and easy to freeze and boil.

When the bulb of a thermometer is inserted into boiling water, the liquid rises in the tube and remains at a constant level during boiling. This point is called the upper fixed point and the level of the liquid is assigned 100 on the thermometer (Figure 6.16a). When the water is cooled down, the liquid level drops until ice forms in the water. This point is called the lower fixed point, it is assigned 0 on the thermometer (Figure 6.16b).

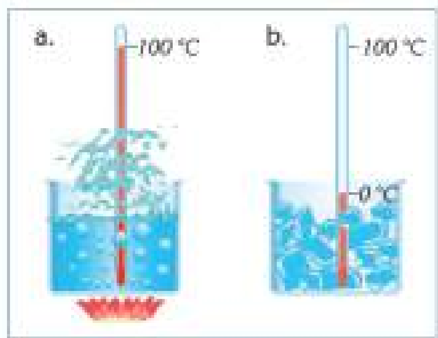


Figure6.16 Finding the reference points of a thermometer

By dividing the distance between upper and lower fixed points into 100 equal parts, we obtain a thermometer scale which indicates small changes in temperature. This kind of division of a thermometer is called the Celsius scale, because of the Swedish scientist who invented this scale in the early 1700's. Another more commonly known name for the Celsius scale is the Centigrade scale. Table 6.1 indicates typical temperatures measured in degrees Celsius (°C). Each step on the scale is called one degree Celsius and is written as 1°C

TABLE 6.1

Center of sun	15 000 000 °C
Surface of sun	6 000 °C
Light bulb filament	2800°C
Bunsen flame	900 °C
Human body	36.5 °C
Freezing point of water	0 °C
Freezing point of mercury	-37 °C
Absolute zero	-273 °C

Typical temperatures measured in degrees Celsius

We cannot measure temperatures below – 273°C, since the particles in a substance have their lowest possible kinetic energy at this point. Since nothing can be colder than – 273°C, this point is called absolute zero. In scientific work, using a temperature scale with negative numbers is not useful. The Kelvin scale which is named after the English Scientist Lord Kelvin, has absolute zero as its zero point. Absolute zero corresponds to the lowest possible kinetic energy of a substance and is related to the Celsius scale as:

Absolute zero = 0 K = –273 °C;

Each Kelvin unit has the same size as each unit on the Celsius scale (Figure 6.17) each unit is called a degree. We can find the corresponding reading on the Kelvin scale from a given Celsius reading using the following equation:

$$K = 273 + °C$$

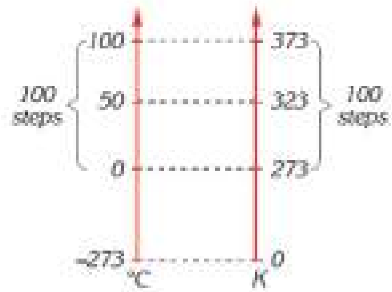


Figure 6.17 Comparing Celsius and Kelvin scales

There is one more common temperature scale: The Fahrenheit scale. On the Fahrenheit scale, the boiling point of water is marked 212 °F and the freezing point of water is marked 32 °F (Figure 6.18). There are 180 equal units between these two points. One unit on the Celsius scale is equal to 1.8 units on the Fahrenheit scale.

$$°F = 1.8 \times °C + 32$$

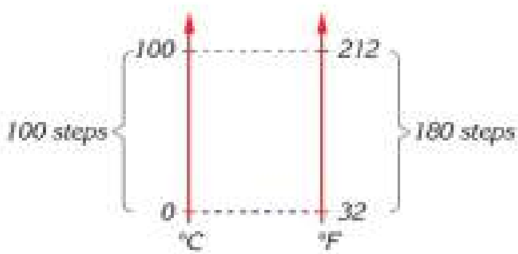


Figure 6.18 Comparing Celsius and Fahrenheit scales

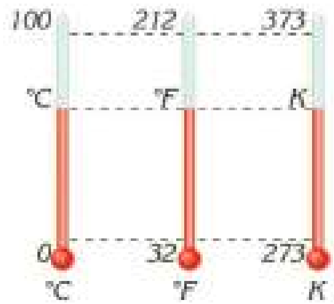


Figure 6.19 Comparing Celsius, Fahrenheit and Kelvin scales

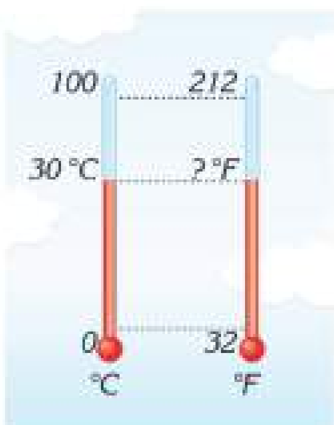
Example 6.1

If the temperature on a summer's day is 30°C, what is the temperature in terms of degrees Fahrenheit?

Solution

What does the question ask ?
The temperature in Fahrenheit, °F=?
What information is given ?
The temperature in Celcius, T=30 °C
What is the relationship between °C and°F scales ?

Calculations:
Use the given data in the formula:
$°F = 1.8 \times °C + 32$
$°F = 1.8 \times 30 + 32$
$°F = 54 + 32$
Result: The temperature is 86 F



Exercise 5.1

Liquid nitrogen boils at 77 °C, what is this temperature in terms of degrees Kelvin ?

Ans : 350 K

CHAPTER QUESTIONS

Q.1. Fill in the blanks

a) When a substance is heated, its molecules move ______________

b) Heat flows form ____ object to _____ to object.

c) ____________ is measure of average kinetic energy of each particle in the object.

d) If objects are in thermal equilibrium, thier ___________ are same.

e) Freezing point of water at sea level is __________ °C

f) boiling poin of water at sea level is _____________K

g) 0K equals ______ °C

h) Scales of thermometer at our homes starts from ___ to ___.

Q.2. Choose the correct answer.

1. A device that measure temperature is;

a) thermometer b) spring-balance

c) barometer d) calorimeter

2.The boiling point of liquid hydrogen is -252.87 °C, what is the value of this temperature on the Fahrenheit scale ?

a. 20.28 °F
b. -220.87 °F
c. -423.2 °F
d. 0 °F

3. Which one of the following effect changes scale of thermometer which is placed in substance?

a) changing size of substance
b) changing temperature of substance
c) changing chemical property of substance
d) changing color of substance

4. What is freezing point of water at sea level in Kelvin?

a) 237 b) 273 c) 0 d) -273

5. If we want to get two objects in thermal equilibrium;
a) objects are made by insulated material
b) objects are painted with different colors
c) one of then is immersed to hot water and the other is immersed to cold water.
d) objects are get into contact

Q.3. What is freezing point of water at sea level?

a) in Celcius b) in Kelvin

Q.4. What does substance gain if it is heated?

Q.5. Why part of medical thermometers that contains mercury is designed as narrow?

Q.6. What is the type of thermometer which is used in industry?

Q.7. Which substances radiate electromagnetic energy, hot substances or cool substances?

Q.8. Convert the following temperrature scales to each other;

a) 86 °C = ___ K

b) 20 °C = ___ °F

c) 373 K = ___ °F

d) 40 °C = ___ K

CHAPTER 7
HEAT TRANSFER

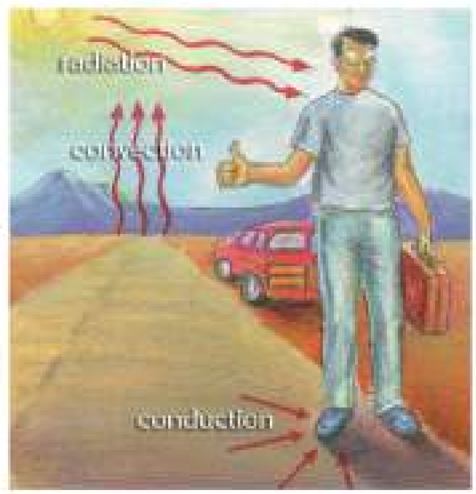
PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Express Heat transfer (conduction, convection and radiation).
2. Compare between Good and Bad absorbers.
3. Compare between Good and Bad emitters.
4. Describe Home heating system.
5. Understand solar heating system.

7.1 Heat transfer

There are three ways for heat to travel; conduction, convection and radiation. These are illustrated in the figure to the left.



Heat can travel in three ways.

7.1.1 Conduction

Particles in hotter places vibrate more quickly than particles in cooler places. Conduction is the flow of heat through matter by the collision of particles from the places of higher temperature to the places of lower temperature as illustrated in figure7.1. Most metals are good conductors of heat; e.g.: iron, copper, aluminum and silver. Some materials such as wood, glass, cork, paper and plastic are poor conductors of heat, and so are called insulators. Insulators are used to prevent heat transfer between hot and cold places, such as water pipes, ovens, refrigerators and the grooves and walls of buildings. For instance the handles of saucepans and kettles are made from insulators to prevent our hands from burning (Figure 7.2).

Figure 7.2 Plastic handles prevent heat conduction

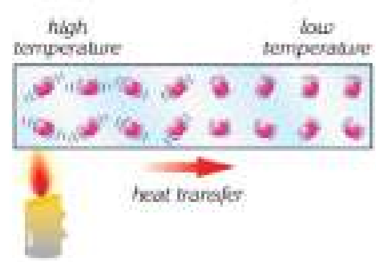


Figure 7.1 Heat transfer through a metal by conduction

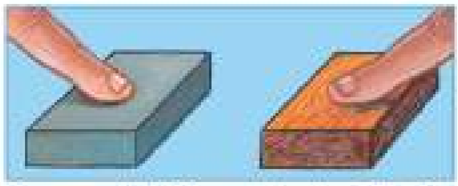


Figure 7.3

Metal objects below body temperature, feel colder than those of the same temperature made of poor conductors. This is because metal objects carry heat away faster from the hand, although all the objects are at the same temperature (Figure 7.3)

We often use wooden spoons for cooking. Why?(Figure 7.4)

Liquids and gases also conduct heat but very slowly, so they are also poor conductors of heat. Water is also a poor conductor, when you heat the tube shown in Figure 7.5, the water at the top of the tube boils before the ice at the bottom melts.

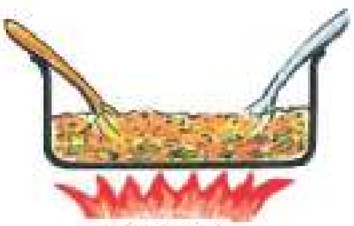


Figure 7.4

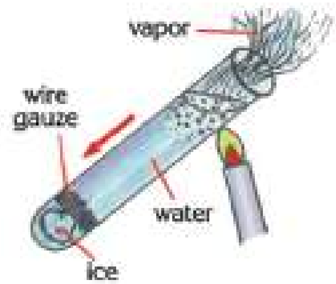


Figure 7.5

7.1.2 Convection

Convection is the flow of heat through a fluid from places of higher temperature to the places of lower temperature by the movement of the fluid itself. Get a matchstick and strike it. Hold your hand both above and then below the flame of the match (Figure7.6). When does your hand warm up? When it is above or below the flame? (Be careful not to burn your hand!)

Figure 7.6

Because hot air rises, dust in the air sticks the walls as shown in figure 7.7. We can also observe convection currents in air with the apparatus shown in Figure 7.8. It is a wooden box with a glass window and a glass tube used as a chimney. The direction of the convection current produced by the candle is made visible by the smoke from a smoldering piece of paper. This also shows how chimneys help to ventilate rooms.

Figure 7.7 Black marks seen on the wall above a lamp or a radiator.

Figure 7.8 Demonstration of convection currents in air.

7.1.3 Radiation

For the flow of heat from hot objects to cool ones by conduction and convection, matter must be present. However, the heat from the sun reaches us through space although there is no matter. Radiation is the third method of heat energy transfer: It is the flow of heat from one place to another by means of electromagnetic waves (Figure 7.9).

Figure 7.9 An electric fire heats the room by radiation.

When radiation falls on an object, it is partly reflected, partly transmitted and partly absorbed. Absorbed heat causes the molecules of the object to vibrate more, and so the object becomes hot (Figure 7.11)

Good absorbers and bad absorbers

Dull black surfaces are better absorbers of radiation than white shiny surfaces. Because of this, the insides of solar collector panels are painted black colour. (Figure 7.10)

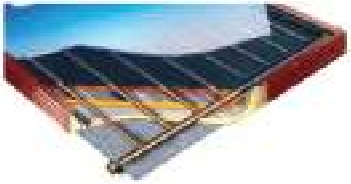
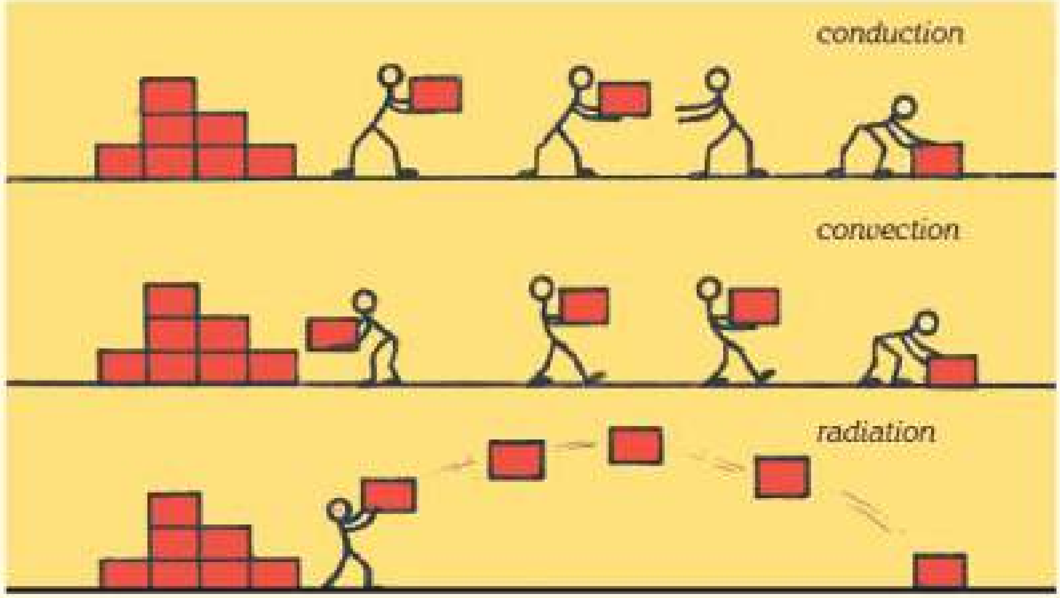


Figure 7.10 Black surface inside a solar collector

Figure 7.11 Shiny surfaces are bad absorbers and reflect the sun's rays.

The following cartoon is a diagram showing the difference between the three methods of heat transfer.



Good emitters and bad emitters

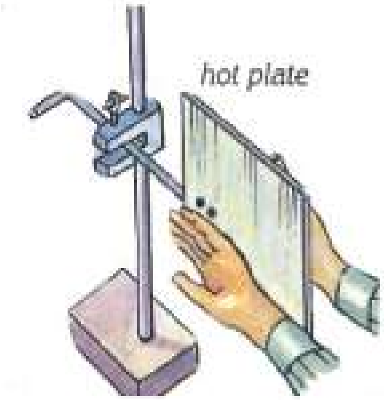


Figure 7.12

Some surfaces emit radiation better than others. If you heat a copper sheet which has one side shiny and the other side blackened, as shown in the figure 7.12 , then hold the backs of your hands to either side of it, you will find that the dull black surface will heat your hand better than the shiny one.

Bright shiny surfaces are bad emitters of heat. They don't lose much heat by radiation when they are hot. For this reason kettles, tea pots and saucepans are brightly polished to keep their insides warm (Figure 7.13).

Figure 7.13 Shiny surfaces are bad emitters.

In an electric fire, a shiny metal mirror is used for the opposite reason; to reflect rays out to the room.
In general, surfaces that are good absorbers of radiation are good emitters when they are hot. Dull black surfaces radiate away much of their energy. Therefore inside of toasters, saucepans, cooling finds of a refrigerator, and car radiators are usually painted dull black (Figure 7.14).

Figure 7.14 The insides of toasters and saucepans are good emitters of heat.

Car and motorcycle radiators are painted black to radiate away heat as quickly as possible.

Vacuum flasks

Avacuum or thermos flask keeps hot liquids hot or cold liquids cold. It is very difficult for heat to travel into or out of a vacuum flask because it is designed to minimize conduction, convection and radiation.

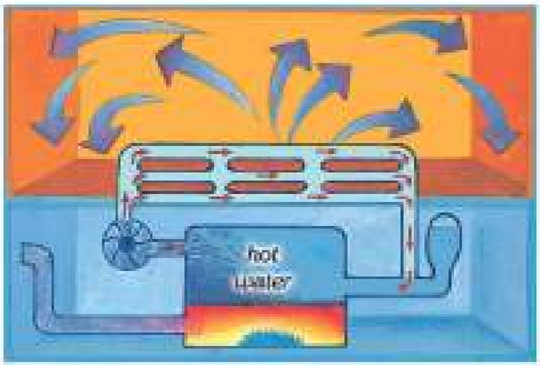
Figure 7.15 A thermos flask and its parts

A vacuum flask is a double walled glass bottle with a vacuum between the walls (Figure7.15). Radiation is reduced by silvering both walls on the vacuum side. The vacuum prevents energy transfer by stopping conduction and convection.

Home heating systems

There are different ways to heat homes and buildings. All heating systems are the technological applications of conduction, convection and radiation.

Heating systems include steam, warm-air, hot-water and solar heating systems which depend upon convection currents to distribute heat. The following figures show how these systems work.



Hot-water heating system

Warm-air heating system

In radiant electric system resistance wires carrying current radiate heat throughout the room, and convection currents distribute it. In radiant hot-water systems hot water pumped through the pipe radiates energy from the floor throughout the room (Figure 7.16).

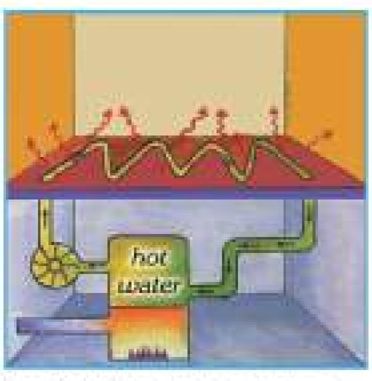


Figure 7.16 Radiant electric system and radiant hot water system

Solar heating system

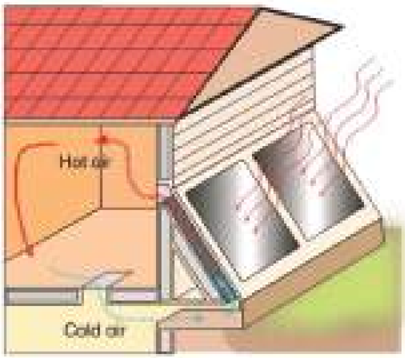
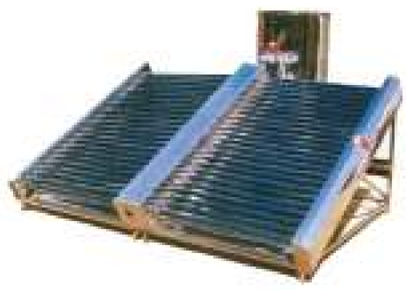


Figure 7.17 Passive solar heating system

There are some other methods to heat rooms, such as active and passive solar heating systems. Solar heat is environment friendly. Passive solar heating does not require too much special equipment, such as pipes or pumps. A solar system is built on the south side of a building. It has a glazing material (glass) outside and a massive material inside to absorb and store sun's heat. The sunlight entering through the glass warms the solar system during the day. Then the air ventilation allows the heat to circulate into the room. Look at the figure 7.17.

The active heating system uses solar collectors on the roof of the building. Pipes run throughout the home, and water is pumped over the hot solar collector, distributing heat to the rooms of the house, or to a hot water storage system (Figure 7.18).



A type of solar collector

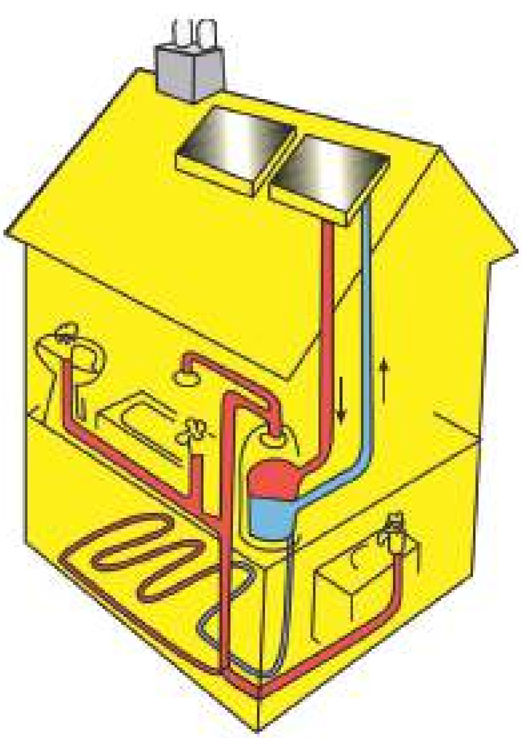


Figure 7.18 Active solar heating system

CHAPTER QUESTIONS

Q.1. Fill in the blanks

1. __________ keeps animals warm.

2. Heat is transferred from Sun to Earth by __________

3. Windows with double glasses keep room___________

4. In __________ days thick clothes, in ________ days thin clothes are worn.

5. When ____________ land breeze occurs, when _____________ sea breeze occurs.

6. ____________ prevents cooling of hot drinks and overheating of cold drinks.

7. Heat is transferred by _______ in solid and transferred by ___________ in liquid.

8. When a container that is filled by liquid is heated, molecules expand on base and molecules which have _________

9. density moves up. Cold molecules which have _______ density takes place of them.

Q.2. Choose the correct answer.

1. Which one of the followings is the best thermal conductor?

a) glass b) aluminum

c) copper d) iron

2. Which one of the following is heat insulator?

a) wool b) iron

c) silver d) aluminum

3. Air inside the balloon is heated, because;

a) air constructs, its density increases and balloon rises

b) air expands, its density decreases and balloon rises

c) in order the keep molecules a medium is generatedd)

ability of heat transfer of air increases

Q.3. Explain

a) heat is placed at the base of kattle

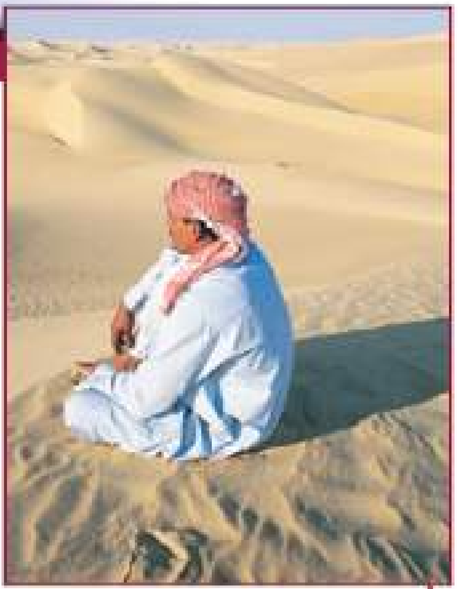
b) Freezing compartment places to upper part.

Q.4. Compare conduction, convection and radiation

Q.5. Explain water is bad but copper is good thermal conductor by activities.

Q.6. Show convection currents in the room that a heater is placed in it.

The Inside Story on Climate and Clothing



The Bedouin headcloth, called a *kefiyah*, employs evaporation to remove energy from the air close to the head, which cools the wearer.

To remain healthy, the human body must maintain a temperature of about 37.0°C (98.6°F), which becomes increasingly difficult as the surrounding air becomes hotter or colder than body temperature.

Unless the body is properly insulated, its temperature will drop in its attempt to reach thermal equilibrium with very cold surroundings. If this situation is not corrected in time, the body will enter a state of hypothermia, which lowers pulse, blood pressure, and respiration. Once body temperature reaches 32.2°C (90.0°F), a person can lose consciousness. When body temperature reaches 25.6°C (78.0°F), hypothermia is almost always fatal.

To prevent hypothermia, the transfer of energy from the human body to the surrounding air must be hindered, which is done by surrounding the body with heat-insulating material. An extremely effective and common thermal insulator is air. Like most gases, air is a very poor thermal conductor, so even a thin layer of air near the skin provides a barrier to energy transfer.

The Inupiat parka, called an *atigi*, consists today of a canvas shell over sheepskin. The wool provides layers of insulating air between the wearer and the cold.

The Inupiat people of northern Alaska have designed clothing to protect them from the severe Arctic climate, where average air temperatures range from 10°C (50°F) to −37°C (−35°F). The Inupiat clothing is made from animal skins that make use of air's insulating properties. Until recently, the traditional parka (*atigi*) was made from caribou skins. Two separate parkas are worn in layers, with the fur lining the inside of the inner parka and the outside of the outer parka. Insulation is provided by air that is trapped between the short inner hairs and within the long, hollow hairs of the fur. Today, inner parkas are made from sheepskin, as shown on the left.

At the other extreme, the Bedouins of the Arabian Desert have developed clothing that permits them to survive another of the harshest environments on Earth. Bedouin garments cover most of the body, which protects the wearer from direct sunlight and prevents excessive loss of body water from evaporation. These clothes are also designed to cool the wearer. The Bedouins must keep their body temperatures from becoming too high in desert temperatures, which often are in excess of 38°C (100°F). Heat exhaustion or heatstroke will result if the body's temperature becomes too high.

Although members of different tribes, as well as men and women within the same tribes, wear different types of clothing, a few basic garments are common to all Bedouins. One such garment is the *kefiyah*, a headcloth worn by Bedouin men, as shown in the photograph above. A similar garment made of two separate cloths, which are called a *mandil* and a *hatta*, is worn by Bedouin women. Firmly wrapped around the head of the wearer, the cloth absorbs perspiration and cools the wearer during evaporation. This same garment is also useful during cold periods in the desert. The garment, wound snugly around the head, has folds that trap air and provide an insulating layer to keep the head warm.

CHAPTER 8
STATES OF MATTER

PERFORMANCE INDEX

After completion of the study this chapter the student should be able to:

1. Define Melting.
2. Describe Specific latent heat of fusion.
3. Explain Freezing.
4. Compare between Evaporation and Boiling

8.1 States of matter

Matter is found in three states; solid, liquid and gas. In the solid state, particles are closely packed and they can only vibrate back and forth about fixed positions. In the liquid state, the particles are close to each other but not in a fixed position. They can slide over each other. In the gaseous state, particles are far apart from each other. They have very high kinetic energy and they can fill the empty space around them completely (Figure 8.1).

Figure 8.1

Solid particles are strongly bonded. They make vibrational motion. A solid has a definite shape and volume

Liquid particles move slowly, they slide over each other. and are held together closely. A liquid has a definite volume but not a definite shape. It takes the shape of the container it is poured into.

Gas particles have very high kinetic energy, they are far apart from each other. A gas neither has a definite volume nor a definite shape. It fills any space it is found in.

Table 8.1

Substance	m.p.(°C)	L_f(cal/g)	L_f(J/kg)
Iron	1535.0	69.1	289 000
Aluminum	658.0	2.5	10 500
Benzene	5.5	30.2	126 000
Copper	1083.0	48.9	207 000
Ethyl alcohol	-114.4	25.8	108 000
Gold	1063.0	15.0	62 800
Ice	0	80.0	335 000
Lead	327.0	6.0	25 000
Mercury	-38.9	2.7	11 400
Silver	960.0	21.1	88 300
Table salt	808.0	116.8	488 000

Melting points and latent heats of fusion of some substances.

Matter can change its state from one form to another. For example if we heat a solid, it can turn into a liquid, and if we cool a liquid it can turn into a solid.

What is Melting?

As we heat a solid, the particles start to vibrate faster. At a certain temperature, the particles have a high enough kinetic energy to break their bonds with neighbouring particles. Then the regular arrangement of the whole solid is destroyed, and the particles slide over each other. This is the change of state from solid to liquid, and is called melting. Solids usually expand when they become liquids (Figure8.2).

The melting point of a solid is a characteristic property of matter, every solid has a different melting point. The melting points of some substances are shown in Table 8.1

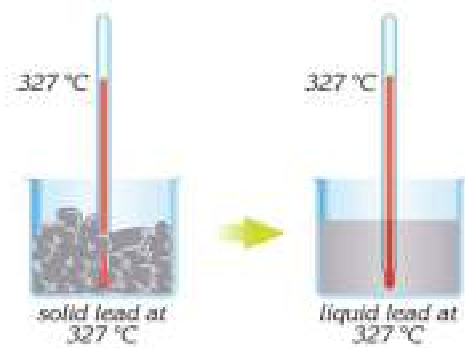


Figure 8.2 Melting of a solid

Specific latent heat of fusion

The specific latent heat of fusion (L_f) is the quantity of heat energy needed to change 1 kg mass of a solid into a liquid without any change in temperature. Different solids have different values of specific latent heat of fusion. It is also a characteristic property of matter.

The specific latent heat of fusion of ice is 335 000 J/kg, or 80 cal/g. That is, in order to change 1 kg ice at 0 °C into water at the same temperature we must provide heat energy of 335 000 J.

What is Freezing?

Freezing is the change in state of matter from the liquid state into the solid state, without any change in temperature. It is the reverse process of melting. We can obtain a solid from a liquid by removing energy from it. During freezing, the particles of liquid lose kinetic energy and slows down. The particles then attract each other and form a regular structure (Figure 8.3). Since the particles are now closer to each other, the volume of matter decreases. Therefore substances usually contract when they freeze and expand when they melt.

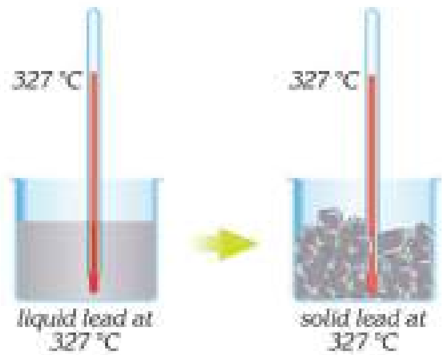


Figure 8.3 Freezing of a liquid

However there are some exceptions. Water is one exception which expands as it freezes to form ice (**Figure 8.4**). If water is heated from 0°C up to +4°C, its volume contracts even though its being heated. Above +4°C, it behaves as other liquids and expands as it is heated. The graph below shows the change in volume of water with temperature. As seen, water has its smallest volume at +4 °C, that is; water is densest at +4°C.

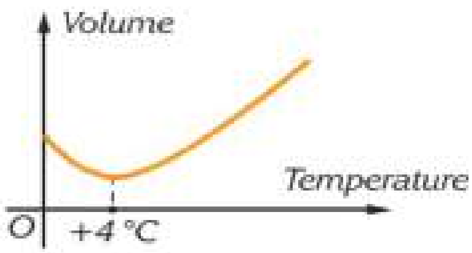


Figure 8.4 Change in volume of water with temperature

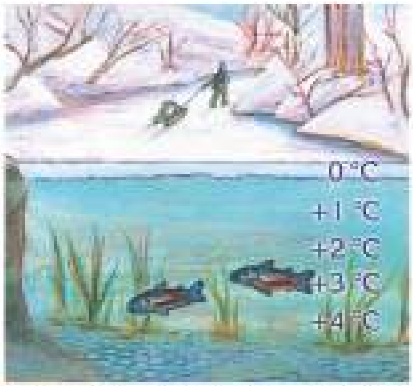


Figure 8.5 Water is densest at +4°C

The freezing point is the same as the melting point for matter. This is because the process of freezing is the opposite process to melting, for any substance the specific latent heat of freezing is equal to the specific latent heat of fusion:

$$L_{fusion} = L_{freezing}$$

What is evaporation? What is boiling?

In a liquid, particles move in all direction at different speeds. Particles with high kinetic energy near to the surface of the liquid can overcome the attraction of the other particles and enter the gas state. The change of state from liquid into gas is called evaporation.

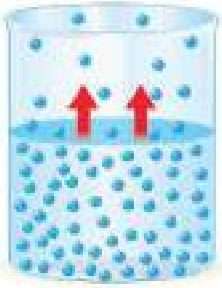


Figure 8.6 Evaporation of a liquid.

At all temperatures, some evaporation occurs at the surface of the liquid. This explains why the level of water in glass left on a table slowly goes down by time. And also it explains why clothes dry even on a cloudy day. Heat increases evaporation. If we heat a liquid continuously many of its particles gain higher kinetic energies and can change into the gas state over the whole of the liquid (Figure 8.6). The moment at which evaporation is at a maximum rate is hot boiling. During the boiling the temperature is constant. The temperature at which boiling occurs is called the boiling point.

Specific latent heat of vaporisation

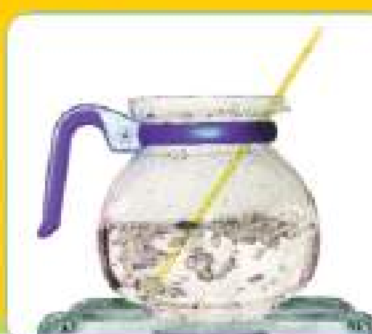
The reading on a thermometer in boiling water remains constant even though heat, called latent heat of vaporisation is still being absorbed from the heater by the water. Specific latent heat of vaporisation (L_v) is the quantity of heat required to change 1 kg of a liquid into its gaseous state without a change in temperature. In the SI unit system it is measured in J/kg, and in thermal units it is measured in cal/g.

Table 8.2

Substance	b.p.(°C)	L_v(cal/g)	L_v(J/kg)
Alcohol (ethyl)	78	204	853000
Bromine	60	43	180000
Lead	1170	175	732000
Lithium	1336	511	2136000
Mercury	358	71	297000
Nitrogen	-196	48	201000
Oxygen	-183	51	213000
Sulphuric acid	326	122	510000
Water	100	540	2260000
Zinc	918	475	1986000

Boiling points and specific latent heats of vaporisation of various substances

All liquids have different boiling points, therefore the boiling point is also a characteristic property of matter. See Table 1.5.



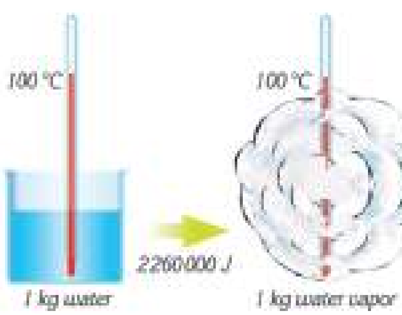


Figure 8.7 2 260 000 kJ energy is needed to convert 1 kg of water at 100 °C into vapour at the same temperature.

The specific latent heat of vaporisation of water is 2 260 000 J/kg, or in thermal units 540 cal/g. That is, we need to supply 2 260 000 J of energy to change 1 kg of water at 100 °C into vapor at the same temperature (Figure 8.7). All liquids have a different specific latent heat of vaporisation, as shown in Table 8.2

What is condensation?

As we know from the preceding sections, gas particles have very high kinetic energies and they are in a state of constant motion. In a container, particles at very high speeds strike the walls of the container and lose some energy. This loss of energy slows them down and cause them to change state from gas into liquid. This is the reverse process of vaporisation and is called condensation. When steam condenses to form water, latent heat (hidden heat) is lost. The specific latent heat of condensation is equal to the specific latent heat of vaporisation:

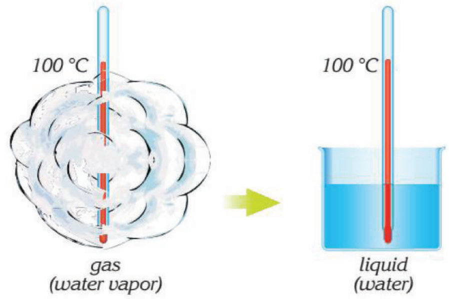


Figure 8.8 Condensation of water vapour

$$L_{vaporisation} = L_{condensation}$$

The temperature of condensation is equal to the temperature of boiling for the same substance. When a gas condenses it liquefies(Figure 8.8). We can give some examples of condensation from the environment. The warm moist air rises from the earth and cools down at high altitudes, where they condense and form clouds (Figure 8.9). Steam from a tea kettle condenses onto cold glass windows forming water droplets.

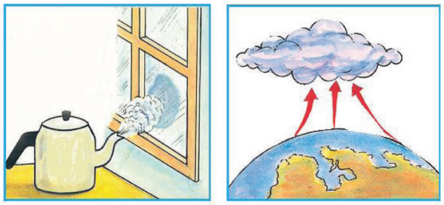


Figure 8.10 Water vapour rising from seas, lakes and living things form clouds.

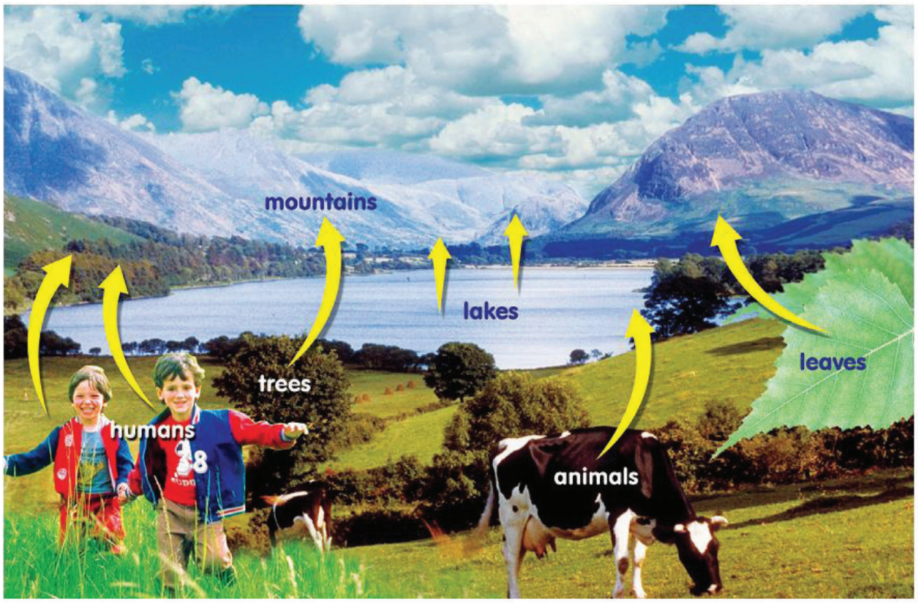
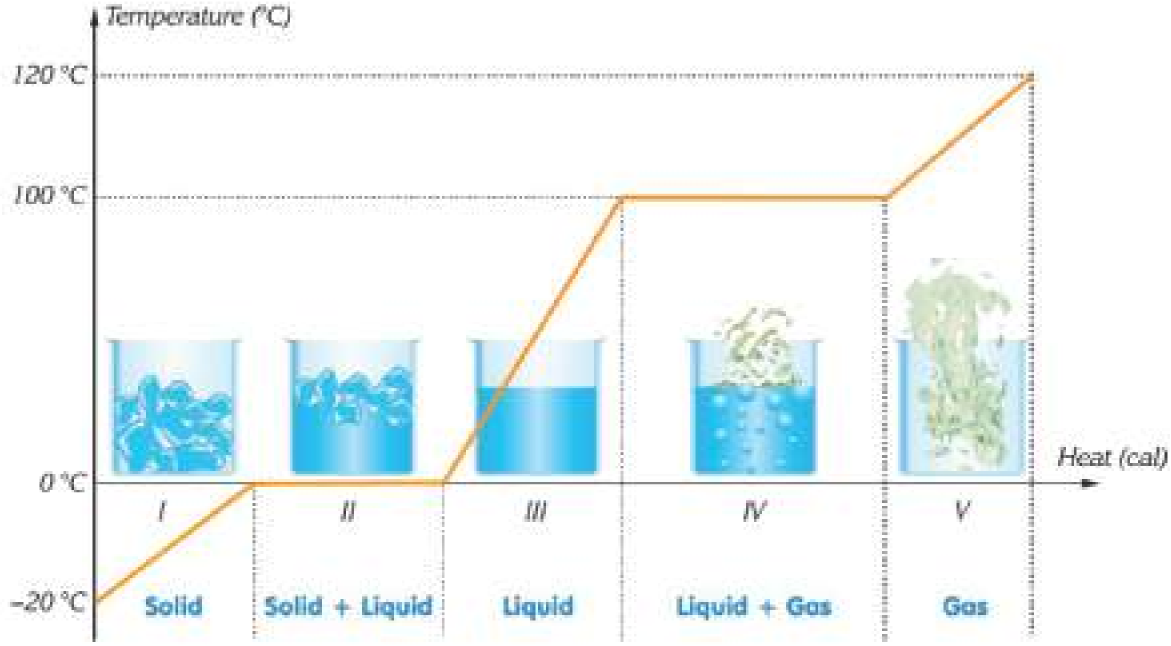


Figure 8.9

A general look at the various states of matter

The following graph illustrates the change in state of water from ice through to gas.



At the beginning ice is at – 20°C. The graph is analysed in five stages:

I. In the first stage ice at –20°C warms up to 0 °C.

II. In the second stage, only ice is present at 0°C but it slowly melts, and transforms into liquid water without any temperature change. Thus, both solid and liquid states of water exist together. The duration of this stage depends on the amount of ice.

III. The third stage begins after all the ice has melted. Only water exists at 0°C, but its temperature slowly increases from 0 to 100°C.

IV. In the fourth stage liquid water at 100 °C changes to vapour at 100 °C. Thus both liquid and gaseous states of water exists at the same time. The duration of this stage also depends on the amount of water.

V. In the fifth stage water exists in its gaseous state, continuous heating raises the temperature.

What is sublimation?

In some cases substances can change directly from solid to vapour or from vapour to solid without passing through the liquid stage. Sublimation is the process by which a solid changes directly into a gas. For example, mothballs, iodine and dry ice (solid carbon dioxide) are some substances that sublimate at room temperature. This process is illustrated in figure 8.11

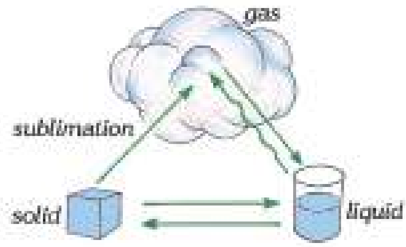


Figure 8.11 Sublimation is the change in state from solid into gas.

Factors affecting the boiling point of liquids

The boiling point of a liquid can be increased by dissolving solids in it. Some of the heat energy is used to break down the attractive forces between the liquid and dissolved solid particles. Therefore the amount of dissolved solid causes an increase in boiling point of a liquid (Figure 8.12). Another important effect on boiling point is pressure. The effect of pressure can be explained by the kinetic theory. The particles, having gained enough kinetic energy to escape from the liquid must also overcome the air pressure above the liquid. If the air pressure is high, the particles leaving the liquid can be condensed back into the liquid form. Only liquid particles with very high energy can change into the gaseous state. By lowering the gas pressure over the liquid, the particles escape more easily from the liquid. Thus we can say that increasing the air pressure increases the boiling point, and decreasing the pressure decreases the boiling point of the liquid. At higher altitudes, for example at the top of mountains, the air pressure is lower so the boiling point of water decreases. For example water boils at 88 °C at the top of Uludaõ in Bursa and at 70 °C at the top of mount Everest. The boiling point of water at various altitudes is shown the figure to the right.

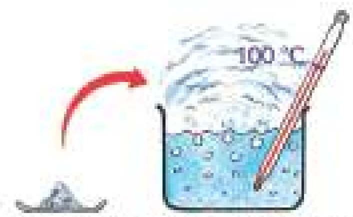


Figure 8.12 Adding salt increases the boiling point of water.

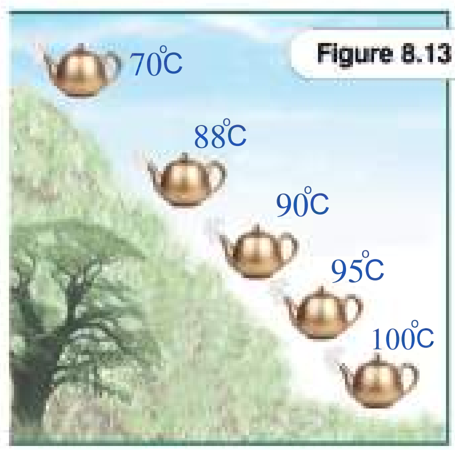


Figure 8.13

In a pressure cooker water boils at a higher temperature, of around 120 °C. Heating the vapour causes a higher pressure. Using pressure cookers, food can be cooked in less time compared to ordinary pans therefore pressure cookers save both energy and time.

Figure 8.14

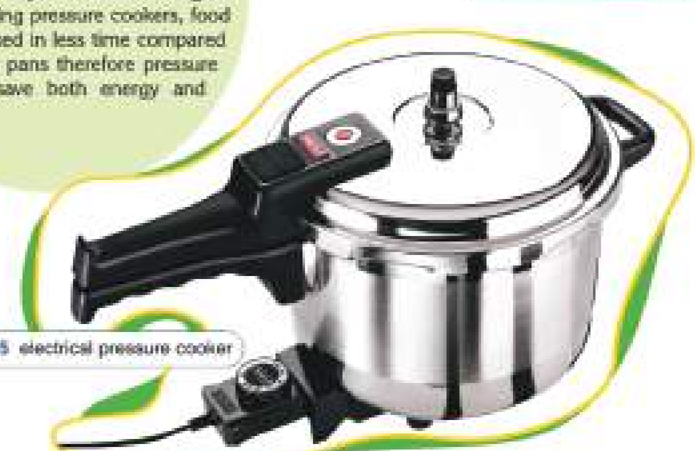


Figure 8.15 electrical pressure cooker

Lowering the freezing and melting points

If a solid is dissolved in a liquid, the liquid freezes at a lower temperature This is because the substance added to the liquid causes it to form a regular arrangement of its molecules at a lower temperature. For example if we dissolve some salt in water, it freezes below 0°C, and also if ice is not pure, it melts at a temperature lower than 0 °C (Figure 8.16). This is why salt is scattered on icy roads in winter. Another example of lowering the freezing point of a substance is to add a special liquid to the car motors in winter to decrease the freezing point, this liquid is called anti-freeze. See figure 8.17.

Figure 8.16 Adding salt decreases the freezing point of water.

Pressure decreases melting point

The ice block stands on two supports. A thin copper wire is placed around the block with a weight suspended from it. The high pressure of the copper wire lowers the melting point, so the ice melts, and the wire slowly falls through. As the wire moves down, the water above it will freeze again, and the ice will be just as solid as it was before. This process of melting by pressure and re-freezing is called regulation.

Figure 8.17

Cooling produced by evaporation

When a liquid evaporates, it absorbs energy from its surroundings; as a result the surroundings cool (Figure 8.18) This is why people feel cool after swimming or having a bath. Some liquids have low boiling points, therefore they can change into the vapour state more easily. Methylated spirits and ether are two examples. If a little ether is poured onto a hand, it evaporates rapidly by absorbing heat from the hand, making the hand feel cooler.

Refrigerators and air conditioners work with liquids that have low boiling points. Usually freon gas is used in refrigerators to carry heat from the cooling unit to the outside . Pipes inside and outside the refrigerator are used to pump the freon around the fridge. An electric pump removes the freon vapour inside the cooling unit and reduces the pressure. Thus the boiling point of the freon is lowered. Evaporating freon, absorbs latent heat from the freezing unit. The pump compresses the vapour into the condensing unit outside the refrigerator. This unit is a high pressure area and freon vapour changes into liquid, losing the latent heat of vaporisation to the surrounding air. The continuous recycling of freon in the pipes keeps the inside of the refrigerator cool. Air conditioning systems also work using the same principle.

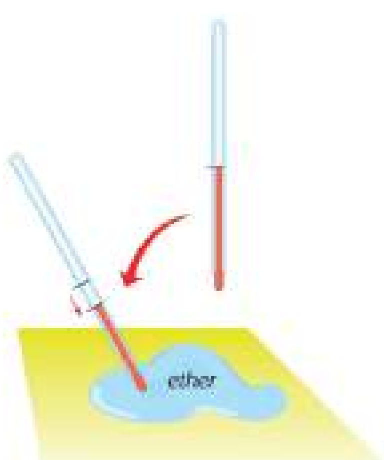


Figure 8.18 When ether evaporates it absorbs heat from the surroundings.

CHAPTER QUESTIONS

Q.1.Choose the correct answer

1. Sublimation is;

a) change of state of matter from solid state to liquid state
b) change of state of matter firstly from solid state to liquid state, then to gaseous state
c) change of state of matter from liquid state to solid state
d) change of state of matter directly from solid state to gaseous state

2. Melting point of ice is 0 °C at;

a) At standard atmospheric pressure

b) Pressure that greater than atmospheric pressure

c) Pressure that less than atmospheric pressure

d) Pressure does not affect

3. Boiling point of water is;

a) 0 °C

b) less than 0°C

c) greater than 0°C

d) water boils at any temperautre

Q.2. The sentences below are True or False. If False correct sentences without changing underlined words.

1. **Meltingis change in state of matter** from liquid state to solid state

2. **Ice at 0°C melts by** heating and applying pressure

3. **Specific latent heat of fusion is the quantity of heat energy needed** to change 1kg mass of a solid into a liquid without any change in temperature.

4. **The specific latent heat of vaporization of water is** 336kj.

5. Condensation **is change in state of matter from gaseous state to liquid state.**

6. Water loses heat **without increasing its temperature.**

7. **Evaporation speeds of substances** are same.

8. **People in Basra have trouble in summer because of** dry air.

9. **Evaporation speed of liquids** increase **when they are exposed to drafts.**

Q.3. Fill in the blanks

1. Specific latent heat of fusion of water at 0°C is ________.

2. Water freezes under 0°C by ________ pressure.

3. Cold water boils by __________ pressure.

4. Evaporation is _________ ____________.

5. When salt is added to water, freezing point of mixture
6. Vapor ____________ heat when it condenses.

Q.4. How does a refrigerator work?

Q.5. Sometimes we observe that cold fizzy drinks freezes after opening cap. Why?

Q.6. Water loses heat during;

a) Evporation
b) Condensation
c) Freezing

Q.7. In cold winter days, glass water bottles blow up. Why?

Q.8. Explain why people tend to feel cold after having bath.

Q.9. Mud caps freeze when they are exposed to drafts. However, if glass caps are used i stead of mud caps, they do not freeze. Explain, why?