GEOGRAPHY
TEST – 4 Part – 1

9TH Science	**Unit 1**	Measurement
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Unit – 1 Measuremet

Introduction

Measurement is the basis of all important scientific study. It plays an important role in our daily life also. While finding your height, buying milk for your family, timing the race completed by your friend and so on, you need to make measurements. Measurement answers questions like, how long, how heavy and how fast? Measurement is about assigning a number to a characteristic of an object or event which can be compared with other objects or events. It is defined as the determination of the size or magnitude of a quantity. In this lesson you will learn about units of measurements and the characteristics of measuring instruments.

Physical Quantities and Units

Physical quantities

Physical quantity is a quantity that can be measured. Physical quantities can be classified into two: fundamental quantities and derived quantities. Quantities which cannot be expressed in terms of any other physical quantities are called fundamental quantities. Example: Length, mass, time, temperature etc. Quantities which can be expressed in terms of fundamental quantities are called derived quantities. Example: Area, volume and density etc.

Physical quantities have a numerical value and a unit of measurement (say, 3 kilogram). Suppose you are buying 3 kilograms of vegetable in a shop. Here, 3 is the numerical value and kilogram is the unit. Let us study about units now.

Units

A unit is a standard quantity with which the unknown quantities are compared. It is defined as a specific magnitude of a physical quantity that has been adopted by law or convention. For example, feet is the unit for measuring length. That means, 10 feet is equal to 10 times the definite pre-determined length, called feet

Earlier, different unit systems were used by people from different countries. Some of the unit systems followed earlier are given below in foot is the singular of feet

System	Length	Mass	Time
CGS	centimetre	gram	Second
FPS	foot	pound	Second
MKS	metre	kilogram	second

But, at the end of the Second World War there was a necessity to use worldwide system of measurement. Hence, SI (International System of Units) system of units was developed and recommended by General Conference on Weights and Measures at Paris in 1960 for international usage.

SI System of Units

SI system of units is the modernised and improved form of the previous system of units. It is accepted in almost all the countries. It is based on a certain set of fundamental units from which derived units are obtained by proper combination. There are seven fundamental units in the SI system of units. They are also known as base units and they are given in **Table 1.2**

The units used to measure the fundamental quantities are called fundamental units and the units which are used to measure the derived quantities are called derived units.

Table 1.2 Fundamental quantities and their units

Fundamental quantities	Unit	Symbol
Length	metre	M
Mass	kilogram	KG
Time	second	S
Eletirc current	ampere	A
Luminous intensity	candela	CD
Amount of substance	mole	MOL

S.No	Physical quantity	Expression	Unit
1	Area	length × breadth	M2
2	Volume	area × height	M2
3	Density	mass / volume	Kgm3
4	Velocity	displacement / time	Ms-1
5	Momentum	mass × velocity	mass × velocity
6	Acceleration	velocity / time	Ms-2
7	Force	mass × acceleration	Kgms-2 or N
8	Pressure	force / area	Nm-2 or Pa
9	Energy (work)	force × distance	Nm or J
10	Surface tension	force / length	Nm–A

In order to measure very large distance (distance of astronomical objects) we use the following units.

- Astronomical unit
- Light year
- Parsec

Astronomical unit (AU): It is the mean distance of the centre of the Sun from the centre of the Earth. 1 AU = 1.496 × 10 11 m (Figure 1.1).

Light year: It is the distance travelled by light in one year in vacuum and it is equal to 9.46 × 1015 m.

Parsec: Parsec is the unit of distance used to measure astronomical objects outside the solar system.
1 Parsec = 3.26 light year.

Larger units	**In metre**
Kilometre (km)	103 m
Astronomical unit(AU)	1.496 × 1011 m
Light year (ly)	9.46 × 1015 m

Parsec (pc)	3.08 × 1016 m

The nearest star alpha centauri is about 1.34 parsec from the sun. Most of the stars visible led eye in the night sky are within 500 parsec distance from the sun.

To measure small distances such as distance between two atoms in a molecule, size of the nucleus and wavelength etc. we use submultiples of ten. These quantities are measured in Angstrom unit (Table 1.5).

Smaller units	In metre
Fermi (f) *	10^{-15} m
Angstrom (A°)*	10^{-10} m
Nanometre (nm)	10^{-9} m
Micron (micrometre μ m)	10^{-6} m
Millimetre (mm)	10^{-3} m
Centimetre (cm)	10^{-2} m

* Unit outside SI system and still accepted for use.
Mass

Mass

Mass is the quantity of matter contained in a body. The SI unit of mass is kilogram (kg). One kilogram is the mass of a particular international prototype cylinder made of platinum-iridium alloy, kept at the International Bureau of Weights and Measures at Sevres, France.

The units gram (g) and milligram (mg) are the submultiples of ten (1/10) of the unit kg. Similarly quintal and metric tonne are multiples of ten (× 10) of the unit kg.

1 g = 1/1000 × 1 kg = 0.001 kg
1 mg = 1/1000000 × 1 kg = 0.000001 kg
1 quintal = 100 × 1 kg = 100 kg
1 metric tonne = 1000 × 1 kg = 10 quintal

Atomic mass unit

Mass of a proton, neutron and electron can be determined using atomic mass unit (amu).

1 amu = (1/12)th of the mass of C12 atom

Time

Time is a measure of duration of events and the intervals between them. The SI unit of time is second. One second is the time required for the light to propagate 29,97,92,458 metres through vacuum. It is also defined as 1/86, 400th part of a mean solar day. Larger units for measuring time are day, month, year and millennium etc. 1 millenium = 3.16 × 109 s.

Temperature

Temperature is the measure of hotness or coldness of a body. SI unit of temperature is kelvin (K). One kelvin is the fraction (1/273.16) of the thermodynamic temperature of the triple point of water (The temperature at which saturated water vapour, pure water and melting ice are in equilibrium). Zero kelvin (0 K) is commonly known as absolute zero. The other units for measuring temperature are degree celsius (°C) and fahrenheit (F).

Unit Prefixes

Unit prefixes are the symbols placed before the symbol of a unit to specify the order of magnitude of a quantity. They are useful to express very large or very small quantities. k(kilo) is the unit prefix in the unit, kilogram. A unit prefix stands for a specific positive or negative power of 10. k stands for 1000 or 103. Some unit prefixes are given in Table-6.

The physical quantities vary in different proportion like from 10-15 m being the diameter of nucleus to 1026 m being the distance between two stars and 9.11 × 10 31 kg being the electron mass to 2.2 × 1041 kg being the mass of the milky way galaxy.

Power of 10	Prefix	Symbol
10^{15}	peta	P
10^{12}	Tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	Kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	Centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	Pico	p
10^{-15}	femto	f

Rules and Conventions for Writing Si Units and their Symbols

1. The units named after scientists are not written with a capital initial letter. E.g. newton, henry, ampere and watt.
2. The symbols of the units named after scientists should be written by the initial capital letter. E.g. N for newton, H for henry, A for ampere and W for watt.

3. Small letters are used as symbols for units not derived from a proper noun. E.g. m for metre, kg for kilogram.
4. No full stop or other punctuation marks should be used within or at the end of symbols. E.g. 50 m and not as 50 m.
5. The symbols of the units are not expressed in plural form. E.g. 10 kg not as kgs.
6. When temperature is expressed in kelvin, the degree sign is omitted. E.g. 283 K not as 283° K (If expressed in Celsius scale, degree sign should be included e.g. 100° C not as 100 C, 108° F not as 108 F).
7. Use of solidus is recommended for indicating a division of one unit symbol by another unit symbol. Not more than one solidus is used. E.g. ms-1 or m/s. J/K/mol should be JK-1 mol-1
8. The number and units should be separated by a space. E.g.15 kgms-1 not as 15kgms-1.
9. Accepted symbols alone should be used. E.g. ampere should not be written as amp and second should not be written as sec.
10. The numerical values of physical quantities should be written in scientific form. E.g. the density of mercury should be written as 1.36 × 104 kg m-3 not as 13600 kg m-3.

Screw Gauge

In our daily life, we use metre scale for measuring lengths. They are calibrated in cm and mm scales. The smallest length which can be measured by metre scale is called least count. Usually the least count of a scale is 1 mm. We can measure the length of objects up to mm accuracy using this scale. But this scale is not sufficient for measuring the size of small spherical objects. So, Vernier caliper and screw gauge are used.

v Can you ask for milligram measures of groceries or gram measures of rice from the nearby shop? Can you ask for millimetre measure of cloth? What are the things that you could buy in smaller measures? Why?

Vernier scale

The diameters of spherical objects such as cricket ball and hollow objects such as a pen cap cannot be measured with a meter scale. For that we use an instrument named Vernier caliper which can measure the inner and outer diameters of objects.

v Pierre Vernier (1580 - 1637) was a French government official. Vernierwas taught mathematics and science by his father who was a lawyer and engineer. He worked much of the time as an engineer, working on the fortifications of various cities. Like many other mathematicians and scientists of that period, Vernier worked on cartography and on surveying. His interest in surveying led him to develop instruments for surveying and this prompted the invention of a precise instrument called Vernier caliper.

Description of Vernier caliper

The Vernier caliper consists of a thin long steel bar graduated in cm and mm. This is the main scale. To the left end of the steel bar an upper and a lowerjaw are fixed perpendicular to the bar. These are named as fixed jaws. To the right of the fixed jaws, a slider with an upper and a lower moveable jaw is fixed. The slider can be moved or fixed to any position using a screw. The Vernier scale is marked on the slider and moves along with the movable jaws and the slider. The lower jaws are used to measure the external dimensions and the upper jaws are used to measure the internal dimensions of objects. The thin bar attached to the right side of the Vernier scale is used to measure the depth of hollow objects.

Usage of Vernier caliper

The first step in using the Vernier caliper is to find out its least count, range and zero error.

Least count

$$\text{Least count of the instrument (L.C)} = \frac{\text{Value of one smallest main scale division}}{\text{Total number of vernier scale division}}$$

The main scale division can easily be obtained by inspecting the main scale. It will be in centimeter, further divided into millimetre. The value of the smallest main scale division is 1 mm. The Vernier scale division is obtained by counting number of division in it. In the Vernier scale there will be 10 divisions.

$$\text{L.C} = \frac{1mm}{10} = 0.1\text{mm} = 0.01\text{cm}$$

Zero error

Unscrew the slider and move it to the left, such that both the jaws touch each other. Check whether the zero marking of the main scale coincides with that of the Vernier scale. If they are not coinciding with each other, the instrument is said to possess zero error. Zero error may be positive or negative. If the zero mark of the Vernier is shifted to the right, it is called positive error. On the other hand, if the Vernier zero is shifted to the left of the main scale zero marking, and then the error is negative.

Positive zero error

Figure 3(a) shows the positive zero error. From the figure you can see that zero of the vernier scale is shifted to the right of zero of the main scale. In this case the reading will be more than the actual reading. Hence, this error should be corrected. In order to correct this error, find out which vernier division is coinciding with any of the main scale divisions. Here, fifth vernier division is coinciding with a main scale division. So, positive zero error = +5 x LC = +5 x 0.01 = 0.05 cm.

Negative zero error

Now look at the Figure 3(b). You can see that zero of the vernier scale is shifted to the left of the zero of the main scale. So, the obtained reading will be less than the actual reading. To correct this error we should first find which vernier division is coinciding with any of the main scale divisions, as we found in the previous case. In this case, you can see that sixth line is coinciding. But, to find the negative error, we can count backward (from 10). So, the fourth line is coinciding. Therefore, negative zero error = –4×LC = –4×0.01 = –0.04 cm.
Example:
Calculate the positive and negative error from the given Figure 4.

Solution:

Case (a): Zero of the vernier scale and zero of the main scale are coinciding with each other. So there is no zero error.
Case (b): The zero of veriner scale is shifted to the right from the zero of the main scale. It is positive error. The 8th division of vernier scale coincides with one of the main scale divisions. So the positive error = (8×0.01cm) = 0.08 cm.

Case (c): The zero of veriner scale is shifted to the left from the zero of main scale. It is negative error. The 4th division of vernier scale (6th from backward) coincides with one of the main scale divisions. So the negative zero error = –(6×0.01cm)= –0.06 cm.
Once you are able to calculate the zero error, you can get the correct reading using the formula:

The correct reading = Main scale reading + (VC × LC) ± (Zero correction)

Zero Correction:

If error is positive the we should subtract that error value. If error is negative, we should add that error value.
For example, let us calculate the correct reading, if the main scale reading is 8 cm, vernier coincidence is 4 and positive zero error is 0.05 cm,

The correct reading = 8 cm + (4 × 0.01cm)- 0.05 cm = 8 + 0.04 - 0.05
= 8 -0.01 =7.99 cm

Let us try another one. The main scale reading is 8 cm and vernier coincidence is 4 and negative zero error is 0.02 cm, then the correct reading:
= 8 cm+(4×0.01 cm)+(0.02 cm)
= 8+0.04+0.02 = 8.06 cm.

We can use Vernier caliper to find different dimensions of any familiar object. If the length, width and height of the object can be measured, volume can be calculated. For example, if we could measure the inner diameter of a beaker (using appropriate jaws) as well as its depth (using the depth probe) we can calculate its inner volume.

Example:
Calculate the diameter of the sphere which is shown in the Figure 5. Assume the scale has no zero error.

The diameter (D) of the sphere = Main scale reading (MSR) + (Vernier scale coincidence (VC) × least count (LC))± ZE. In this case the zero of the vernier scale is right after the main scale reading 1.1. So the main scale reading is 1.1 cm. The vernier scale coincidence is 7. The least count is 0.01 cm. The diameter of the sphere = 1.1 cm + (7 × 0.01cm)−0 = 1.1 + 0.07 = 1.17 cm.

Digital Vernier caliper

Today, we are living in a digital world and the digital version of the vernier callipers are available now. Digital Vernier caliper (Figure 6) has a digital display onthe slider, which calculates and displays the measured value. The user need not manually calculate the least count, zero error etc.

Screw Gauge

Measurements made with a Vernier caliper can be made in centimetre only. Hence to measure the length and thickness of very small objects we use a screw gauge. This instrument can measure the dimensions upto 1/100th of a millimetre or 0.01 mm. With the screw gauge it is possible to measure the diameter of a thin wire and the thickness of thin metallic plates.

Description of screw gauge

The screw gauge consists of a U shaped metal frame. A hollow cylinder is attached to one end of the frame. Grooves are cut on the inner surface of the cylinder through which a screw passes (Figure 7).On the cylinder parallel to the axis of the screw there is a scale which is graduated in millimetre called Pitch Scale (PS). One end of the screw is attached to a sleeve. The head of the sleeve (Thimble) is divided into 100 divisions called the Head scale.

The end of the screw has a plane surface (Spindle). A stud (Anvil) is attached to the other end of the frame, just opposite to the tip of the screw. The screw head is provided with a ratchat arrangement (safety device) to prevent the user from exerting undue pressure.

Using the screw gauge

The screw gauge works on the principal that when a screw is rotated in a nut, the distance moved by the tip of the screw is directly proportional to the number of rotations.

Pitch of the screw

The pitch of the screw is the distance between two successive screw threads. It is also equal to the distance travelled by the tip of the screw for one complete rotation of the head. It is equal to 1 mm in typical screw gauges.

$$\boxed{\text{Pitch of the screw} = \frac{\textit{Distance moved by the Pitch}}{\textit{No.of rotations by Head scale}}}$$

Least count of a screw gauge

The distance moved by the tip of the screw for a rotation of one division on the head scale is called the least count of the screw gauge.

$$\boxed{\begin{array}{l}\text{Least count of the instrument (L.C.)}\\ = \dfrac{\textit{Value of one smallest pitch scale reading}}{\textit{Total number of Head scale division}}\end{array}}$$

LC=— =0.01 mm

Zero Error of a screw gauge

When the plane surface of the screw and the opposite plane stud on the frame area brought into contact, if the zero of the head scale coincides with the pitch scale axis there is no zero error (Figure 8).

Positive zero error

When the plane surface of the screw and the opposite plane stud on the frame are brought into contact, if the zero of the head scale lies below the pitch scale axis, the zero error is positive (Figure 9). For example, the 5th division of the head scale coincides with the pitch scale axis, then the zero error is positive and is given byZ.E = + (n × LC) where 'n' is the head scale coincidence. In this case, Zero error = + (5 × 0.01) = 0.05mm. So the zero correction is – 0.05 mm.

Negative zero error

When the plane surface of the screw and the opposite plane stud on the frame are brought into contact, if the zero of the head scale lies above the pitch scale axis, the zero error is negative (Figure 10). For example, the 95th division coincides with the pitch scale axis, then the zero error is negative and is given by

$$\boxed{\begin{array}{l}ZE = -(100 - n) \times LC\\ ZE = -(100 - 95) \times LC\\ = -5 \times 0.01\\ = -0.05\ \text{mm}\end{array}}$$

The zero correction is + 0.05mm.

F. 8 No zero error	**F. 9 Positive Zero error**	**F.10 Negative Zero Error**

To measure the thickness of a thin coin using a screw gauge

- Determine the pitch, the least count and the zero error of the screw gauge
- Place the coin between the two studs
- Rotate the head until the coin is held firmly but not tightly, with the help of the ratchat
- Note the reading of the pitch scale crossed by the head scale (PSR) and the head scale division that coincides with the pitch scale axis (HSC)
- The width of the coin is given by PSR + CHSR (Corrected HSR). Repeat the experiment for different positions of the coin
- Tabulate the readings
- The average of the last column readings gives the width of the coin

- The shell of an egg is 12%of its mass. A blue whale can weigh as much as 30 elephants and it is as long as 3 large tour buses.

Measuring Mass

We commonly use the term ‘weight’ which is actually the ‘mass’. Many things are measured in terms of ‘mass’ in the commercial world. The SI unit of mass is kilogram. In any case, the units are based on the items purchased. For example, we buy gold in gram or milligram, medicines in milligram, provisions in gram and kilogram and express cargo in tonnes.

Can we use the same instrument for measuring the above listed items? Different measuring devices have to be used for items of smaller and larger masses. In this section we will study about some of the instruments used for measuring mass.

Common (beam) balance

A beam balance compares the sample mass with a standard reference mass. (Standard reference masses are 5g, 10g, 20g, 50g, 100g, 200g, 500g, 1kg, 2kg, 5kg). This balance can measure mass accurately up to 5g (Figure 11).

Two pan balance

This type of balance is commonly used in provision and grocery shops (Figure 12). This balance compares the sample mass with the standard reference mass. The pans rest on top of the beam and can be conveniently placed on a table top. This balance can measure mass accurately upto 5 g.

Physical balance

This balance is used in labs and is similar to the beam balance but it is a lot more sensitive and can measure mass of an object correct to a milligram (Figure 13).The standard reference masses used in this physical balance are 10 mg, 20 mg, 50 mg, 100 mg, 200 mg, 500 mg, 1 g, 2g, 5 g, 10 g, 20 g, 50 g, 100g, and 200 g.

Digital balance

Nowadays for accurate measurements digital balances are used, which measures mass accurately even up to a few milligrams, the least value being 10 mg (Figure 14). This electrical device is easy to handle and commonly used in jewellery shops and labs.

Spring balance

This balance helps us to find the weight of an object. It consists of a spring fixed at one end and a hook attached to a rod at the other end. It works by 'Hooke's law' which explains that the addition of weight produces a proportional increase in the length of the spring (Figure 15). A pointer is attached to the rod which slides over a graduated scale on the right. The spring extends according to the weight attached to the hook and the pointer reads the weight of the object on the scale.
Solve – The mass of 40 apples in a box is 10 kg. (i) Find the mass of a dozen of them (ii) Express the mass of one apple in gram.

Difference between mass and weight

Mass (m) is the quantity of matter contained in a body. Weight (w) is the normal force (N) exerted by the surface on the body to balance against gravitational pull on the object. In the case of spring scale the tension in the spring balances the gravitational pull on the object. When the man is standing on the surface of the earth or floor, the surface exerts a normal force on the body which is equivalent to gravitational force. The gravitational force acting on the object is given by 'mg'. Here m is mass of the object and 'g' is acceleration due to gravity. If a man has a mass 50 kg on the earth, then what is his weight?

Weight (w) = mg
Mass of a man = 50 kg
His weight = 50 × 9.8
w = 490 newton

No	Mass	Weight
1.	Fundamental quantity	Derived quantity
2.	Has magnitude alone-scalar quantity	Has magnitude and direction vector quantity
3.	It is the amount of matter contained in a body	It is the normal force exerted by the surface on the object against gravitational pull
4.	Remains the same	Varies from place to place

5.	It is measured using physical balance	It is measured using spring balance
6.	Its unit is kilogram	Its unit is newton

The pull of gravity on the Moon is 1/6 times weaker than that on the Earth. This causes the weight of the object on the Moon to be less than that on the Earth.Acceleration due to gravity on the Moon = $1.63 m/s^2$. If the mass of a man is 70 kg then his weight on the Earth is 686 N and on the Moon is 114 N. But his mass is still 70 kg on the Moon.

Accuracy in Measurements

When measuring physical quantities, accuracy is important. Accuracy represents how close a measurement comes to a true value. Accuracy in measurement is centre in engineering, physics and all branches of science. It is also important in our daily life. You might have seen in jewellery shops how accurately they measure gold. What will happen if little more salt is added to food while cooking? So, it is important to be accurate when taking measurements.

Faulty instruments and human error can lead to inaccurate values. In order to getaccurate values of measurement, it is always important to check the correctness of the measuring instruments. Also, repeating the measurement and getting the average value can correct the errors and give us accurate value of the measured quantity.

UNIT 2- MOTION

Introduction

Every object undergoes motion, even stationary objects move along with the speed of earth.Hence it becomes necessary to study the state of an object at any instant of time. An object under the influence of forces may either be at rest or in motion.

Rest and Motion

In physics, the objects which do not change their position are said to be at rest, while those which change their position are said to be in motion. Example: A book lying on a table, the walls of a room (at rest) Cars and buses running on the road, birds and aeroplanes flying in air (in motion). Motion is a relative phenomenon. This means that an object appearing to be in motion to one person can appear to be at rest as viewedby another person. For example, trees on roadside would appear to move backward for a person travelling in a car while the same tree would appear to be at rest for a person standing on road side.

Types of Motion

In physics, motion can be classified under the following types for ease of understanding.

Linear motion - where the object moves along a straight line.
Circular motion - where the object moves along a circular path.
Oscillatory motion - where an object describes a repetitive to and fro movement retracing its original path.
Uniform motion - where an object travels equal distance in equal intervals of time.
Random motion - where the motion of the object does not fall in any of the above categories.

Uniform and Non Uniform Motion

Uniform motion

An object is said to be in uniform motion if it covers equal distances in equal intervals of time how so ever big or small these time intervals may be.

For example, suppose a car covers 60 km in first hour, another 60 km in second hour, and again 60 km in the third hour and so on. The motion of the car is uniform. Let us now understand the meaning of the words “how so ever small the time interval may be” used in the definition. In this example, the car travels a distance of 60 km in each hour. In the striker sense, the car should travel 30 km in each half an hour, 15 km in every 15 minutes, 10 km in every 10 minutes, 5 km in every 5 minutes and 1 km in every 1 minute. Only then the motion of the car can be said to be uniform.

Non uniform motion

An object is said to be in non-uniform motion if it covers unequal distances in equal intervals of time.Consider a bus starting from one stop. It proceeds slowly when it passes crowded area of the road. Suppose, it manages to travel merely 100 m in 5 minutes due to heavy traffic, when it gets out and the road is clear, it speeds up and is able to travel about 2 km in 5 minutes.

We say, the motion of the bus is non-uniform i.e. it travels unequal distances in equal intervals of time.

Distance and Displacement

Distance

The actual length of the path travelled by a moving body irrespective of the direction is called the distance travelled by the body. It is measured in metre in SI system. It is a scalar quantity having magnitude only.

Displacement

It is defined as the change in position of a moving body in a particular direction. It isVector quantity having both magnitude and direction. It is also measured in metre in SI system.

Speed Velocity and Acceleration

Speed

Speed is the rate of change of distance or the distance travelled in unit time. It is a scalar quantity. The SI unit of speed is ms-1. Thus,
Speed = Distance travelled / time taken

Velocity

Velocity is the rate of change of displacement. It is the displacement in unit time. It is a vector quantity. The SI unit of velocity is ms-1. Thus,Velocity = Displacement / time taken

Acceleration

Acceleration is the rate of change of velocity or it is the change of velocity in unit time. It is a vector quantity. The SI unit of acceleration is ms-2.

Acceleration = Change in velocity/time
= (Final velocity - initial velocity)/time
$a = (v-u)/t$

Consider a situation in which a body moves in a straight line without reversing its direction.

Case 1: From the above equation if v > u, i.e. if final velocity is greater thaninitial velocity, the velocity increases with time and the value of acceleration is positive.

Case 2: If v < u, i.e. if final velocity is less than initial velocity the velocity decreases with time and the value of acceleration is negative. It is called negative acceleration. If the acceleration has a value of -2 ms"2 when we say that the retardation is 2 ms"2 or deceleration is 2 ms"2.

Case 3: If v = u, then a = 0. This means that the acceleration is zero when the final velocity is equal to initial velocity

Graphical Representation of Motion along a Straight Line

Plotting the distance/displacement or speed/velocity on a graph helps us visuallyunderstand certain things about time and position.

The distance - time graph for uniform motion

The following Table shows the distance walked by Surya at different times.

Time (minute)	Distance (metre)
0	0
5	500
10	1000
15	1500
20	2000
25	2500

A graph is drawn by taking time along X-axis and distance along Y-axis. The graph is known as distance - time graph. When we look at the distance - time graph of Surya's walk, we notice certain things. First, it is a straight line. We also notice that Surya covers equal distances inequal intervals of time. We can therefore conclude that Surya walked at a constant speed. Can you find the speed at which Surya walked, from the graph? Yes, you can. The parameter is referred to as the slope of the line.

Speed at which Surya walked = distance covered / time taken
= BC/AC (From the graph)
= slope of the straight line
= 500/5
= 100 ms^{-1}

Steeper the slope (in other words the larger value) the greater is the speed.

Letustakealookatthe distance-time graphs of three different people - Surya walking, Monica cycling and Hari going in a car, along the same path. We know that cycling can be faster than walking and a car can go faster than a cycle. The distance -time graph of the three would be as given in the following graph. The slope of the line on the distance - time graph becomes steeper and steeper as the speed increases.

The distance time graph for non-uniform motion

We can also plot the distance - time graph for accelerated motion (non-uniform motion). Table given below shows the distance travelled by a car in a time interval of two second.

Note that the graph is not a straight line as we got in the case of uniform motion. This nature of the graph shows non - linear variation of the distance travelled by the car with time. Thus, the graph represents motion with non-uniform speed.

Velocity - Time graph

The variation in velocity of an object with time can be represented by velocity - time graph. In the graph, time is represented along the X - axis and the velocity is represented along the Y - axis. If the object moves at uniform velocity, a straight line parallel toX-axis is obtained. This Graph shows the velocity - time graph for a car moving with uniform velocity of 40 km/hour.

We know that the product of velocity and time gives displacement of an object moving with uniform velocity. The area under the velocity - time graph is equal to the magnitude of the displacement. So the distance (displacement) S covered by the car in a time interval of t can be expressed as

$S = AC \times CD$
S = Area of the rectangle ABCD
(shaded portion in the graph)

We can also study about uniformly accelerated motion by plotting its velocity - time graph. Consider a car being driven along a straight road for testing its engine. Suppose a person sitting next to the driver records its velocity for every 5 seconds from the speedometer of the car. The velocity of the car in ms-1 at different instants of time is shown in the Table below.

Time (Second)	**Velocity of the Car (ms^{-1})**
0	0
5	9
10	18
15	27
20	36
25	45
30	54

In this case, the velocity – time graph for the motion of the car is shown in graph (straight line). The nature of the graph shows that the velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity – time graph is a straight line.

One can also determine the distance moved by the car from its velocity – time graph. The area under the velocity – time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time.

Since the magnitude of the velocity of the car is changing due to acceleration, the distance S travelled by the car will be given by the area ABCDE under the velocity – time graph. That is

S = area ABCDE
= area of the rectangle ABCD + area of the triangle ADE
S = (AB × BC) + ½ (AD × DE)

The area ABCDE can also be calculated by considering the shape as trapezium. Area of the quadrangle ABCDE can also be calculated by calculating the area of trapezium ABCDE. It means

S = area of trapezium ABCDE
= ½ × sum of length of parallel sides × distance between parallel sides
S = ½ × (AB + CE) × BC

The case of non-uniformly accelerated motion, distance – time graph, velocity – time graphs can have any shape as shown in Figure below:

- The magnitude of instantaneous velocity is to the instantaneous speed at the given instant. The speedometer of an automobile measures the instantaneous speed of the automobile. In a uniform motion in dimension, the average velocity = instantaneous velocity. Instantaneous velocity is also called velocity and instantaneous speed also called simply speed.

Equations of Motion

Newton studied the motion of an object and gave a set of three equations of motion. These equations relate the displacement, velocity, acceleration and time of an object under motion. An object is in motion with initial velocity u attains a final velocity v in time t due to acceleration a, with displacement s.The three equations of motion can be written as,

$v = u + at$
$s = ut + \frac{1}{2} a t^2$
$v^2 = u^2 + 2as$

Let us try to derive these equations by graphical method.

Equations of motion from velocity - time graph:

Graph shows the change in velocity with time for an uniformly accelerated object. The object starts from the point D in the graph with velocity u. Its velocity keeps increasing and after time t it reaches the point B on the graph.

The initial velocity of the object = u = OD = EA

The final velocity of the object = v = OC = EB

Time = t = OE = DA

Also from the graph we know that, AB = DC

First equation of motion

By definition, acceleration = change in velocity / time

= (final velocity – initial velocity)/time

= (OC - OD) / OE

= DC/OE

a = DC/t

DC = AB = at

From the graph EB = EA + AB

$\boxed{v = u + at}$

This is first equation of motion. (1)

Second equation of motion

From the graph the distance covered by the object during time t is given by the area of quadrangle DOEB

s = area of the quadrangle DOEB

= area of the rectangle DOEA + area of the triangle DAB

= (AE x OE) + (1/2 x AB x DA)

$\boxed{S = ut + \frac{1}{2} at^2}$

This is second equation of motion. (2)

Third equation of motion

From the graph the distance covered by the object during time t is given by the area of the quadrangle DOEB. Here DOEB is a trapezium. Then

S = area of trapezium DOEB

=½ x sum of length of parallel side x distancebetween parallel sides

= V ½ x (OD + BE) x OE

S = V ½ x (u + v) x t

since a = (v - u) /1 or t = (v - u)/a

Therefore s = ½ x (v + u) x (v - u)/a

$2as = v^2 - u^2$

$$\boxed{v^2 = u^2 + 2as}$$

Thisis third equation of motion (3)

Motion of objects under the influence of gravitational force of the earth - Freely falling body:

In activity , both the stone and the eraser have reached the surface of the earth almost at the same time but in activity 8, the eraser reaches first, the sheet of paper reaches later. In activity 9, the paper crumpled into a ball reaches ground first and plain sheet of paper reaches later, although they have equal mass. Do you know the reason? When all these objects are dropped in the absence of air medium (vacuum), all would have reached the ground at the same time. In air medium, due to friction, air offers resistance to the motion of free falling objects.

The resistance offered by air is negligibly small when compared to the gravitational pull acting on the stone and rubber (in activity). Hence, they reach the ground at the same time. But, in activity 8, the air resistance exerted on the sheet of paper is much higher than that on the eraser. Again in activity 9, the air resistance offered to the plain sheet of paper is much higher than that offered to the paper ball. This is because the magnitude of air resistance depends onthe area of objects exposed to air. If we do experiment in a tall glass jar from which air has been sucked out, both the paper and the eraser would fall at the same rate. Galileo dropped different objects from the top of the Leaning Tower of Pisa in Italy to prove the same. We know that an object experiences acceleration during free fall. This acceleration experienced by an object is independent of mass. This means that all objects hollow or solid, big or small, should fall at the same rate.

- **Can a body have zero velocity and finite acceleration?**

  Yes, when a body is thrown vertically upwards in space, at the highest point, the body has zero velocity and acceleration to the acceleration due to the gravity.

The equation of motion for a freely falling body can be obtained by replacing ‘a’ in equations 1 to 3 with g, the acceleration due to gravity. For an object falling freely, its initial velocity u = 0. Thus we get the following equations

$$\boxed{v = gt,\ s = \tfrac{1}{2} gt^2,\ v^2 = 2gh}$$

when we through an object vertically upwards, it moves against the acceleration due to gravity. Hence g is taken to be –g in such cases.

If you carefully observe, on being released the stone moves along a straight line tangential to the circular path. This is because once the stone is released, it continues to move along the direction it has been moving at that instant. This shows that the direction of motion changed at every point when the stone was moving along the circular path. When an object moves with constant speed along a circular path, the motion is called uniform circular motion. When an object is moving with a constant speed along a circular path, the velocity changes due to the change in direction. Hence it is an accelerated motion.

Examples of uniform circular motion.

1. Revolution of earth around the sun.
2. Revolution of moon around the earth.
3. The tip of the second's hand of a clock.

If an object, moving along a circular path of radius r, takes time T to come back to its starting position, the speed v is given by,

Speed = circumference/time taken
$V = 2\pi r/T$

Giant Wheel moves in a vertical circular path.

2. Centripetal Acceleration and Centripetal Force

A body is said to be accelerated, if the velocity of the body changes either in magnitude or in direction. Hence the motion of a stone in circularpath with constantspeedandcontinuous changes of direction is an accelerated motion. There must be an acceleration acting along the string directed inwards, which makes the stone to move in circular path.

This acceleration is known as centripetal acceleration and the force is known as centripetal force. Since the centripetal acceleration is directed radially towards the centre of the circle, the centripetal force must act on the object radially towards the centre.

Let us consider an object of mass m, moving along a circular path of radius r, with a velocity v, its centripetal acceleration is given by

$$a = v^2/r$$

Hence, the magnitude of centripetal force is given by,

F = mass x centripetal acceleration $F = mv^2/r$

In this activity, a pulling force that acts away from the centre is experienced. This is called as centrifugal force.

Centrifugal Force

Force acting on a body away from the centre of circular path is called centrifugal force. Thus centrifugal force is in a direction opposite to the direction of centripetal force. Its magnitude is same as that of centripetal force. The dryer in a washing machine is an example for the application of centrifugal force.

v **How do we separate cream from milk?**

A separator is a high speed spinner. It acts on the same principle of centrifuge machines. The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream is lighter than other components in milk. Therefore, skimmed milk which is denser than cream is collected at outer wall of the bowl. The lighter part of cream is pushed towards the centre from where it is collected through pipe.

v **When you go for a ride in a merry-go-round in amusement parks, what force do you experience?**

We experience an outward pull as merry-go round rotates about verticalaxis. This is due to centrifugal force.

Spin dryer - centrifugal force

1 -rotating metal drum
2&3 - wet cloth
4 -water droplet
5 -let out of droplets

A spin dryer removes excess water from clothing by rotating a perforated drum at high speed. The water is thrown out through the holes. The clothes keep moving in a circle because the contact force of the drum provides centrifugal force.

UNIT – 3 FLUIDS

Introduction

A small iron nail sinks in water, whereas a huge ship of heavy mass floats on sea water. Astronauts have to wear a special suit while traveling in space. All these have a common reason called 'pressure'. If the pressure increases in a solid, based on its inherent properties, it experiences tension and ultimately deforms or breaks. In the case of fluids it causes them to flow rather than to deform. Although liquids and gases share some common characteristics, they have many distinctive characteristics on their own. It is easy to compress a gas whereas liquids are incompressible. Learning of all these facts helps us to understand pressure better. In this lesson you will study about pressure in fluids, density of fluids and their application in practical life.

Thrust and Pressure

Pushing a pin into a board by its head is difficult. But pushing it by the pointed end is easy. Why? Have you ever wondered why a camel can run in a desert easily? Why a truck or a motorbus has wider tyre? Why cutting tools have sharp edges? In order to answer these questions and understand the phenomena involved, we need to learn about two interrelated physical concepts called thrust and pressure.

In both the cases of the above activity, the force exerted on the sand is the weight of your body which is the same. This force acting perpendicular to the surface is called thrust. When you stand on loose sand, the force is acting on an area equal to the area of your feet. When you lie down, the same force acts on an area of your whole body, which is larger than the area of your feet. Therefore, the effect of thrust, depends on the area on which it acts

The effect of thrust on sand is larger while standing than while lying.
The force per unit area acting on an object concerned is called pressure. Thus, we can say thrust on an unit area is pressure.

$$\text{Pressure} = \frac{Thrust}{Area\ of contact}$$

For the same given force, if the area is large pressure is low and vice versa. This is shown in Figure

In SI units, the unit of thrust is newton (denoted as N). The unit of pressure is newton per square metre or newton metre–2 (denoted as Nm–2). In the honour of the great French scientist, Blaise Pascal, 1 newton per square metre is called as 1 pascal denoted as Pa. 1 Pa = 1 N m–2

If a single nail pricks our body it is very painful. How is it possible for people to lie down on a bed of nails, still remain unhurt? It is because, area of contact is more.

All the flowing substances, both liquids and gases are called fluids. Like solids, fluids also have weight and therefore exert pressure. When filled in a container, the pressure of the fluid is exerted in all directions and at all points of the fluid. Since the molecules of a fluid are in constant, rapid motion, particles are likely to move equally in any direction. Therefore, the pressure exerted by the fluid acts on an object from all directions. It is shown in Figure 3.2. Pressure in fluids is calculated as shown below.

$$\text{Fluid Pressure} = \frac{Totalforceexertedbythefluid}{Areaoverwhichtheforceisexerted} = \frac{F}{A}$$

We shall first learn about the pressure exerted by liquids and then learn about the pressure exerted by gases.

Pressure due to liquids

The force exerted due to the pressure of a liquid on a body submerged in it and on the walls of the container is always perpendicular to the surface. In Figure 3.3(a), we can see the pressure acting on all sides of the vessel.

When an air filled balloon is immersed inside the water in a vessel it immediately comes up and floats on water. This shows that water (or liquid) exerts pressure in the upward direction. It is shown in Figure 3.3(b).

Similarly, liquid pressure acts in lateral sides also. When a bottle having water is pierced on the sides we can see water coming out with a speed as in Figure 3.3(c). This is because liquid exerts lateral pressure on the walls the container.

Factors determining liquid pressure in liquids

Pressure exerted by a liquid at a point is determined by,
(i) depth (h)
(ii) density of the liquid (ρ)
(iii) acceleration due to gravity (g).

From this activity we can infer that pressure varies as depth increases. But, it is same at a particular depth independent of the direction.

Pressure due to a liquid column

A tall beaker is filled with liquid so that it forms a liquid column. The area of cross section at the bottom is A. The density of the liquid is ρ. The height of the liquid column is h. In other words the depth of the water from the top level surface is 'h' as shown in Figure in 3.4

We know that, thrust at the bottom of thecolumn (F) = weight of the liquid.

Therefore, F = mg (1)

We can get the mass of the liquid by multiplying the volume of the liquid and its density.

Mass, m = ρ V (2)
Volume of the liquid column, V
= Area of cross section (A) × Height (h) = Ah (3)

Substituting (3) in (2)
Mass, m = ρAh (4)
Substituting (4) in (1)

Force = mg = ρAhg

Pressure, $P = \frac{Thrust(F)}{Area\ (A)} = \frac{mg}{A} = \frac{p(Ah)g}{A} = \rho hg$

Pressure due to a liquid column, P = hρg

This expression shows that pressure in aliquid column is determined by depth, density of the liquid and the acceleration due to gravity. Interestingly, the final expression for pressure does not have the term area A in it. Thus, pressure in liquid depends on depth only.

Earth is surrounded by a layer of air up to certain height (nearly 300 km) and this layer of air around the earth is called atmosphere of the earth. Since air occupies space and has weight, it also exerts pressure. This pressure is called atmospheric pressure. The atmospheric pressure we normally refer is the air pressure at sea level.

Figure 3.5 shows that air gets 'thinner' with increasing altitude. Hence, the atmospheric pressure decreases as we go up in mountains. On the other hand air gets heavier as we go down below sea level like mines.

Human lung is well adapted to breathe at a pressure of sea level (101.3 k Pa). As the pressure falls at greater altitudes, mountain climbers need special breathing equipments with oxygen cylinders. Similar special equipments are used by people who work in mines where the pressure is greater than that of sea level.

Measurement of atmospheric pressure

The instrument used to measure atmospheric pressure is called barometer. A mercury barometer, first designed by an Italian Physicist Torricelli, consists of a long glass tube (closed at one end, open at the other) filled with mercury and turned upside down into a container of mercury. This is done by closing the open end of the mercury filled tube with the thumb and then opening it after immersing it in to a trough of mercury

The barometer works by balancing the mercury in the glass tube against the outside air pressure. If the air pressure increases, it pushes more of the mercury up into the tub and if the air pressure decreases, more of the mercury drains from the tube. As there is no air trapped in the space between mercury and the closed end, there is vacuum in that space. Vacuum cannot exert any pressure. So the level of mercury in the tube provides a precise measure of air pressure which is called atmospheric pressure. This type of instrument can be used in a lab or weather station.

On a typical day at sea level, the height of the mercury column is 760 mm. Let us calculate the pressure due to the mercury column of 760 mm which is equal to the atmospheric pressure. The density of mercury is 13600 kg m–3.

Pressure, $P = h\rho g$

$= (760\times 10^{-3}\text{m}) \times (13600\ \text{kgm}^{-3}) \times (9.8\ \text{ms}^{-2}) = 1.013 \times 10^{5}$ Pa.

This pressure is called one atmospheric pressure (atm). There is also another unit called (bar) that is also used to express such high values of pressure.

1 atm = 1.013 × 105 Pa.
1 bar = 1 × 105 Pa.
Hence, 1 atm = 1.013 bar.

Expressing the value in kilopascal gives 101.3 k Pa. This means that, on each 1 m2 of surface, the force acting is 1.013 k N.

Gauge pressure and absolute pressure

Our daily activities are happening in the atmospheric pressure. We are so used to it that we do not even realise. When tyre pressure and blood pressure are measured using instruments (gauges) they show the pressure, over the atmospheric pressure. Hence, absolute pressure is zero-referenced against a perfect vacuum and gauge pressure is zeroreferenced against atmospheric pressure.

For pressures higher than atmospheric pressure,
absolute pressure = atmospheric pressure +
gauge pressure

For pressures lower than atmospheric pressure,
absolute pressure = atmospheric pressure –
gauge pressure

We have seen that liquid column exertspressure. So the pressure inside the sea will be more. This is more than twice the atmospheric pressure. Parts of our body, especially blood vessels and soft tissues cannot withstand such high pressure. Hence, scuba divers always wear special suits and equipment to protect them.

In petrol bunks, the tyre pressure of vehicles is measured in a unit called psi. It stands for pascal per inch, an old system of unit for measuring pressure.

Pascal's Law

Pascal's principle is named after Blaise Pascal (1623-1662), a French mathematician and physicist. The law states that the external pressure applied on an incompressible liquid is transmitted uniformly throughout the liquid. Pascal’s law can be demonstrated with the help of a glass vessel having holes all over its surface. Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions (Fig. 3.8). This principle is applied in various machines used in our daily life.

Hydraulic pressPascal's law became the basis for one of theimportant machines ever developed, the hydraulic press. It consists of two cylinders of differentcross-sectional areas as shown in Figure 3.9. They are fitted with pistons of cross-sectional areas “a” and 'A'. The object to be lifted is placed over the piston of large cross-sectional area A. The force F1 is applied on the piston of small cross-sectional area 'a'. The pressure P produced by small piston is transmitted equally to large piston and a force F2 acts on A which is much larger than F_1.

Pressure on piston of small area ‘a’ is given by,

$$P=\frac{f1}{A1} \qquad (1)$$

Applying Pascal’s law, the pressure on large piston of area A will be the same as that on small piston. Therefore, $P=\frac{f2}{A2}$ (2)

Comparing equations (1) and (2),we get

$$\frac{F1}{A1}=\frac{F2}{A2}.\text{or } F2=F1\times\frac{A2}{A1}$$

Since, the ratio $\frac{A2}{A1}$is greater than 1, the force F2 that acts on the larger piston is greater than the force F1 acting on the smaller piston. Hydraulic systems working in this way are known as force multipliers.

To understand density better, let us assume that the mass of the flask be 80 g. So, the mass of the flask filled with water is 330 g and the mass of flask filled with kerosene is 280 g. Mass of water only is 250 g and kerosene only is 200 g. Mass per unit volume of water is 250/250 cm3. This is 1g/cm3. Mass per unit volume of kerosene is 200 g/250 cm3. This is 0.8 g/cm3. The result 1 g/cm3 and 0.8 gcm3 are the densities of water and kerosene respectively. Therefore, the density of a substance is the mass per unit volume of a given substance.
The SI unit of density is kilogram per meter cubic (kg/m3) also gram per centimeter cubic (g/cm3). The symbol for density is rho (ρ).

Relative Density

We can compare the densities of two substances by finding their masses. But, generally density of a substance is compared with the density of water at 4 °C because density of water at that temperature is 1g/cm3. Density of any other substance with respect to the density of
water at 4 °C is called the relative density. Thus relative density of a substance is defined as ratio of density of the substance to density of water at 4 °C. Mathematically, relative density (R.D),

$$= \frac{Densityofthesubstance}{Densityofwaterat\ 4\,°c}$$

We know that, Density $\frac{Mass}{volume}$

∴ Relative density

$$= \frac{massofthesubstance/volumeofthesunstance}{massofwater/volumeofwater}$$

Since the volume of the substance is equal to the volume of water,

Relative density

$$= \frac{massofcertain/volumeofthesunstance}{massofequal/volumeofwaterat\ 4\,°c}$$

Thus, the ratio of the mass of a given volume of a substance to the mass of an equal volume of water at 4°C also denotes relative density.

Measurement of relative density

Relative density can be measured using Pycnometer also called density bottle. It consists of ground glass stopper with a fine hole through it. The function of the hole in a stopper is that, when the bottle is filled and the stopper is inserted, the excess liquid rises through the hole and runs down outside the bottle. By this way the bottle will always contain the same volume of whatever the liquid is filled in, provided the temperature remains constant. Thus, the density of a given volume of a substance to the density of equal volume of referenced substance is called relative density or specific gravity of the given substance. If the referenced substance is water then the term specific gravity is used.

Floating and sinking

Whether an object will sink or float in a liquid is determined by the density of the object compared to the density of the liquid. If the density of a substance is less than the density of the liquid it will float. For example a piece of wood which is less dense than water will float on it. Any substance having more density than water (for example, a stone), will sink into it.

Application of principle of flotation

Hydrometer

A direct-reading instrument used for measuring the density or relative density of the liquid is called hydrometer. Hydrometer is based on the principle of flotation, i.e., the weight of the liquid displaced by the immersed portion of the hydrometer is equal to the weight of the hydrometer.

Hydrometer consists of a cylindrical stem having a spherical bulb at its lower end and a narrow tube at its upper end. The lower spherical bulb is partially filled with lead shots or mercury. This helps hydrometer to float or stand vertically in liquids. The narrow tube has markings so that relative density of a liquid can be read directly.

The liquid to be tested is poured into the glass jar. The hydrometer is gently lowered in to the liquid until it floats freely. The reading against the level of liquid touching the tube gives the relative density of the liquid.

Hydrometers may be calibrated for different uses such as lactometers for measuring the density (creaminess) of milk, saccharometer for measuring the density of sugar in a liquid and alcoholometer for measuring higher levels of alcohol in spirits.

Lactometer

One form of hydrometer is a lactometer, an instrument used to check the purity of milk. The lactometer works on the principle of gravity of milk.
The lactometer consists of a long graduated test tube with a cylindrical bulb with the graduation ranging from 15 at the top to 45 at the bottom. The test tube is filled with air. This air chamber causes the instrument to float. The spherical bulb is filled with mercury to cause the lactometer to sink up to the proper level and to float in an upright position in the milk.

Inside the lactometer there may be a thermometer extending from the bulb up into the upper part of the test tube where the scale is located. The correct lactometer reading is obtained only at the temperature of 60 °F. A lactometer measures the cream content of milk. More the cream, lower the lactometer floats in the milk. The average reading of normal milk is 32. Lactometers are used at milk processing units and dairies.

Buoyancy

We already saw that a body experiences an upward force due to the fluid surrounding, when it is partially or fully immersed in to it. We also know that pressure is more at the bottom and less at the top of the liquid. This pressure difference causes a force on the object and pushes it upward. This force is called buoyant force and the phenomenon is called buoyancy (Fig.3.11).

Most buoyant objects are those with a relatively high volume and low density. If the object weighs less than the amount of water it has displaced (density is less), buoyant force will be more and it will float (such object is known as positively buoyant). But, if the object weighs more than the amount of water it has displaced (density is more), buoyant force is less and the object will sink (such object is known as negatively buoyant).

Salt water provides more buoyant force than fresh water, because, buoyant force depends as much on the density of fluids as on the volume displaced.

Cartesian diver

Cartesian diver is an experiment that demonstrates the principle of buoyancy. It is a pen cap with clay. The Cartesian diver contains just enough liquid that it barely floats in a bath of the liquid; its remaining volume is filled with air. When pressing the bath, the additional water enters the diver, thus increasing the average density of the diver, and thus it sinks

Archimedes Priciple

Archimedes principle is the consequence of Pascal's law. According to legend, Archimedes devised the principle of the 'hydrostatic balance' after he noticed his own apparent loss in weight while sitting in his bath. The story goes that he was so enthused with his discovery that he jumped out of his bath and ran through the town, shouting 'eureka'. Archimedes principle states that 'a body immersed in a fluid experiences a vertical upward buoyant force equal to the weight of the fluid it displaces'.

When a body is partially or completely immersed in a fluid at rest, it experiences an upthrust which is equal to the weight of the fluid displaced by it. Due to the upthrust acting on the body, it apparently loses a part of its weight and the apparent loss of weight is equal to the upthrust.

Thus, for a body either partially or completely immersed in a fluid,
Upthrust = Weight of the fluid displaced = Apparent loss of weight of the body.

Apparent weight of an object
= True weight of an object in air – Upthrust (weight of water displaced)

Laws of flotation

Laws of flotation are:

1. The weight of a floating body in a fluid is equal to the weight of the fluid displaced by the body.

2. The centre of gravity of the floating body and the centre of buoyancy are in the same vertical line.

The point through which the force of buoyancy is supposed to act is known as centre of buoyancy. It is shown in Figure

Flotation therapy uses water that contains Epsom salts rich in magnesium. As a floater relaxes, he or she is absorbing this magnesium through the skin. Magnesium helps the body to process insulin, which lowers a person's risk of developing Type 2 Diabetes.

UNIT-4-Electric charge and Electric current

Introduction

Like mass and length, electric charge also is a fundamental property of all matter. We know that matter is made up of atoms and molecules. Atoms have particles like electrons, protons and neutrons. By nature, electrons and protons have negative and positive charge respectively and neutrons do not have charge. An electric current consists of moving electric charges. Electricity is an important source of energy in the modern times. In this lesson, we will study about electric charges, electric current, electric circuit diagram and the effects of electric current.

Electric charges

Inside each atom there is a nucleus with positively charged protons and chargeless neutrons and negatively charged electrons orbiting the nucleus. Usually there are as many electrons as there are protons and the atoms themselves are neutral.

If an electron is removed from the atom, the atom becomes positively charged. Then it is called a positive ion. If an electron is added in excess to an atom then the atom is negatively charged and it is called negative ion.

When you rub a plastic comb on your dry hair, the comb obtains power to attract small pieces of paper, is it not? When you rub the comb vigorously, electrons from your hair leave and accumulate on the edge of the comb. Your hair is now positively charged as it has lost electrons and the comb is negatively charged as it has gained electrons.

Measuring electric charge

Electric charge is measured in coulomb and the symbol for the same is C. The charge of an electron is numerically a very tiny value. The charge of an electron (represented as e) is the fundamental unit with a charge equal to 1.6 × 10–19 C. This indicates that any charge (q) has to be an integral multiple (n) of this fundamental unit of electron charge (e). q = ne. Here, n is a whole number.

Practically, we have µC (micro coulomb), nC (nano coulomb)and pC (pico coulomb) as units of electric charge.

1 µC = 10-6 C, 1nC=10-9 and 1pC = 10-12C

Electric charge is additive in nature. The total electric charge of a system is the algebraic sum of all the charges located in the system. For example, let us say that a system has two charges +5C and –2C. Then the total or net charge on the system is, (+5C) + (–2C) = +3C.

Electrostatic forces between two point charges obey Newton's third law. The force on one charge is the action and on the other is reaction and vice versa.

Electric force

Among electric charges, there are two types of electric force (F): one is attractive and the other is repulsive. The like charges repel and unlike charges attract. The force existing between the charges is called as 'electric force'. These forces can be experienced even when the charges are not in contact.

Electric field

The region in which a charge experiences electric force forms the 'electric field' around the charge. Often electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed (Fig. 4.2). The direction of the electric field is the direction of the force that would act on a small positive charge. Therefore the lines representing the electric field are called 'electric lines of force'. The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field. Electric lines of force are imaginary lines. The strength of an electric field is represented by how close the field lines are to one another.

For an isolated positive charge the electric lines of force are radially outwards and for an isolated negative charge they are radially inwards.

Electric field at a point is a measure of force acting on a unit positive charge placed at that point. A positive charge will experience force in the direction of electric field and a negative charge will experience in the opposite direction of electric field.

Electric potential

Though there is an electric force (either attractive or repulsive) existing among the charges, they are still kept together, is it not?. We now know that in the region of electric charge there is an electric field. Other charges experience force in this field and vice versa. There is a work done on the charges to keep them together. This results in a quantity called 'electric potential'.

Electric potential is a measure of the work done on unit positive charge to bring it to that point against all electrical forces.

Electric current

When the charged object is provided with a conducting path, electrons start to flow through the path from higher potential to lower potential region. Normally, the potential difference is produced by a cell or battery. When the electrons move, we say that an electric current is produced. That is, an electric current is formed by moving electrons.

Direction of current

Before the discovery of the electrons, scientists believed that an electric current consisted of moving positive charges. Although we know this is wrong, the idea is still widely held, as the discovery of the flow of electronsdid not affect the basic understanding of the electric current. The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'.

In electrical circuits the positive terminal is represented by a long line and negative terminal as a short line.

Measurement of electric current

We can measure the value of current and express it numerically. Current is the rate at which charges flow past a point on a circuit. That is, if q is the quantity of charge passing through a cross section of a wire in time t, quantity of current (I) is represented as,

$$I = q/t$$

The standard SI unit for current is ampere with the symbol A. Current of 1 ampere means that there is one coulomb (1C) of charge passing through a cross section of a wire every one second (1 s).

$$1 \text{ ampere} = 1 \text{ coulomb} / 1 \text{ second (or)}$$
$$1 \text{ A} = 1 \text{ C} / 1 \text{ s} = 1\text{Cs}^{-1}$$

Ammeter is an instrument used to measure the strength of the electric current in an electric circuit.

The ammeter is connected in series in a circuit where the current is to be found. . The current flows through the positive (+) red terminal of ammeter and leaves from the negative (–) black terminal.

Electromotive force (e.m.f)

Imagine that two ends of a water pipe filled with water are connected. Although filled with water, the water will not move or circle around the tube on its own. Suppose, you insert a pump in between and the pump pushes the water, then the water will start moving in the tube. Now the moving water can be used to produce some work. We can insert a water wheel in between the flow and make it to rotate and further use that rotation to operate machinery.

Likewise if you take a circular copper wire, it is full of free electrons. However, they are not moving in a particular direction. You need some force to push the electrons to move in a direction.

Devices like electric cells and other electrical energy sources act like pump, 'pushing' the charges to flow through a wire or conductor. The 'pumping' action of the electrical energy source is made possible by the 'electromotive force, (e.m.f). The electromotive force is represented as (ε). The e.m.f of an electrical energy source is the work done (W) by the source in driving a unit charge (q) around the complete circuit.

ε = W/q where, W is the work done. The SI unit of e.m.f is joules per coulomb (JC-1) or volt (V). In other words the e.m.f of an electrical energy source is one volt if one joule of work is done by the source to drive one coulomb of charge completely around the circuit.

Potential difference (p.d)

One does not just let the circuit connect one terminal of a cell to another. Often we connect, say a bulb or a small fan or any other electrical device in an electric circuit and use the electric current to drive them. This is how a certain amount of electrical energy provided by the cell or any othersource of electrical energy is converted into other form of energy like light, heat, mechanical and so on. For each coulomb of charge passing through the light bulb (or any appliances) the amount of electrical energy converted to other forms of energy depends on the potential difference across the electrical device or any electrical component in the circuit. The potential difference is represented by the symbol V.

$$V = W/q$$

where, W is the work done, i.e., the amount of electrical energy converted into other forms of energy measured in joule and q is amount of charge measured in coulomb. The SI unit for both e.m.f and potential difference is the same i.e., volt (V).

Voltmeter is an instrument used to measure the potential difference. To measure the potential difference across a component in a circuit, the voltmeter must be connected in parallel to it. Say, you want to measure the potential difference across a light bulb, you need to connect the voltmeter.

Note the positive (+) red terminal of the voltmeter is connected to the positive side of circuit and the negative (–) black terminal is connected to the negative side of the circuit across a component (light bulb in the above illustration).

Resistance

The Resistance (R) is the measure of opposition offered by the component to the flow of electric current through it. Different electrical components offer different electrical resistance.

Metals like copper, aluminium etc., have very much negligible resistance. That is why they are called good conductors. On the other hand, materials like nicrome, tin oxide etc., offer high resistance to the electric current. We also have a category of materials called insulators; they do not conduct electric current at all (glass, polymer, rubber and paper). All these materials are needed in electrical circuits to have usefulness and safety in electrical circuits.

The SI unit of resistance is ohm with the symbol (Ω). One ohm is the resistance of a component when the potential difference of one volt applied across the component drives a current of one ampere through it.

We can also control the amount of flow of current in a circuit with the help of resistance. Such components used for providing resistance are called as 'resistors'. The resistors can be fixed or variable.

Fixed resistors have fixed value of resistance, while the variable resistors like rheostats can be used to obtain desired value of resistance.

Electric circuit diagram

To represent an electrical wiring or solve problem involving electric circuits, the circuit diagrams are made.

The four main components of any circuits namely,

(i) cell,
(ii) connecting wire,
(iii) switch and
(iv) resistor or load are given above.

In addition to the above many other electrical components are also used in an actualcircuit. A uniform system of symbols has been evolved to describe them. It is like learning a sign language, but useful in understanding circuit diagrams. Some common symbols in the electrical circuit.

Different electrical circuits

Look at the two circuits, shown in Figure 4.11. In Figure A two bulbs are connected in series and in Figure B they are connected in parallel. Let us look at each of these separately.

Series circuits

Let us first look at the current in a series circuit. In a series circuit the components are connected one after another in a single loop. In a series circuit there is only one pathway through which the electric charge flow. From the above we can know that the current I all along the series circuit remain same. That is in a series circuit the current in each point of the circuit is same.

Parallel circuits

In parallel circuits, the components are connected to the e.m.f source in two or more loops. In a parallel circuit there is more than one path for the electric charge to flow. In a parallel circuit the sum of the individual current in each of the parallel branches is equal to the main current flowing into or out of the parallel branches. Also, in a parallel circuit the potential difference across separate parallel branches are same.

Effects of electric current

When current flows in a circuit it exhibits various effects. The main effects are heating, chemical and magnetic effects.

When the flow of current is 'resisted' generally heat is produced. This is because the electrons while moving in the wire or resistor suffer resistance. Work has to be done to overcome the resistance which is converted in to heat energy. This conversion of electrical energy into heating energy is called 'Joule heating' as this effect was extensively studied by the scientist Joule. This forms the principle of all electric heating appliances like iron box, water heater, toaster etc. Even connecting wires offer a small resistance to the flow of current. That is why almost all electrical appliances including the connecting wires are warm when used in an electric circuit.

So far we have come across the cases in which only the electrons can conduct electricity. But, here when current passes through electrolyte like copper sulphate solution, both the electron and the positive copper ion conduct electricity. The process of conduction of electric current through solutions is called 'electrolysis'. The solution through which the electricity passes is called 'electrolyte'. The positive terminal inserted in to the solution is called 'anode' and the negative terminal 'cathode'. In the above experiment, copper wire is anode and carbon rod is cathode.

Extremely weak electric current is produced in the human body by the movement of charged particles. These are called synaptic signals. These signals are produced by electro-chemical process. They travel between brain and the organs through nervous system.

Magnetic effect of electricity

A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current. This is called magnetic effect of current. The discovery of the scientist Oersted and the 'right hand thumb rule' are detailed in the chapter on Magnetism and Electromagnetism in this book.
Direction of current is shown by the right hand thumb and the direction of magnetic field is shown by other fingers of the same right hand.

Types of current

There are two distinct types of electric currents that we encounter in our everyday life: direct current (dc) and alternating current (ac).

Direct current

We know current in electrical circuits is due to the motion of positive charge from higher potential to lower potential or electron from lower to higher electrical potential. Electrons move from negative terminal of the battery to positive of the battery. Battery is used to maintain a potential difference between the two ends of the wire. Battery is one of the sources for dc current. The dc is due to the unidirectional flow of electric charges. Some other sources of dc are solar cells, thermocouples etc.

Many electronic circuits use dc. Some examples of devices which work on dc are cell phones, radio, electric keyboard, electric vehicles etc.

Alternating current

If the direction of the current in a resistor or in any other element changes its direction alternately, the current is called an alternating current. The alternating current varies sinusoidally with time. This variation is characterised by a term called as frequency. Frequency is the number of complete cycle of variation, gone through by the ac in one second. In ac, the electrons do not flow in one direction because the potential of the terminals vary between high and low alternately. Thus, the electrons move to and fro in the wire carrying alternating current. It is diagrammatically represented.

Domestic supply is in the form of ac. When we want to use an electrical device in dc, then we have to use a device to convert ac to dc. The device used to convert ac to dc is called rectifier. Colloquially it is called with several names like battery eliminator, dc adaptor and so on. The device used to convert dc into ac is called inverter.

Advantages of ac over dc

The voltage of ac can be varied easily using a device called transformer. The ac can be carried over long distances using step up transformers. The loss of energy while distributing current in the form of ac is negligible. Direct current cannot be transmitted as such. The ac can be easily converted into dc and generating ac is easier than dc. The ac can produce electromagnetic induction which is useful in several ways.

Advantage of dc

Electroplating, electro refining and electrotyping can be done only using dc. Electricity can be stored only in the form of dc.

In India, the voltage and frequency of ac used for domestic purpose is 220 V and 50 Hz respectively where as in United States of America it is 110 V and 60 Hz respectively.

Dangers of electricity and precautions to be taken

The following are the possible dangers as for as electric current is concerned.

Damaged insulation:

Do not touch the bare wire. Use safety glows and stand on insulating stool or rubber slippers while handling electricity.

Overload of power sockets:

Do not connect too many electrical devices to a single electrical socket.

Inappropriate use of electrical appliances:

Always use the electrical appliances according to the power rating of the device like ac point, TV point, microwave oven point etc.

Environment with moisture and dampness:

Keep the place, where there is electricity, out of moisture and wetness as it will lead to leakage of electric current.

Beyond the reach of children:

The electrical sockets are to be kept away from the reach of little children who do not know the dangers of electricity.

Resistance of a dry human body is about 1,00,000 ohm. Because of the presence of water in our body the resistance is reduced to few hundred ohm. Thus, a normal human body is a good conductor of electricity. Hence, precautions are required while doing electrical work.

UNIT-5 - Magnetism and Electromagnetism

Introduction

Have you ever played with magnets? Do you wonder why it attracts iron? Magnets are always attractive objects for the humans. In fact famous scientist Einstein has mentioned that he was always attracted by magnets in his childhood. In the olden days magnets were used in the ships. Captains of the ships effectively used the magnets to identify the direction of the ship in the sea.

There are two kinds of magnets that we can see around us: Natural magnet and Artificial magnet. Natural magnets exist in the nature. These kind of magnets can be found in rocks and sandy deposits in various parts of the world. The strongest natural magnet is lodestone magnetite.

The magnetic property in the natural magnets is permanent. It never gets destroyed. The lodestones were used to make compassesin the olden days. Artificial magnets are made by us. The magnets available in the shops are basically artificial magnets. In this lesson we shall study about properties of magnets, magnetic effect of current, electromagnetic induction and applications of electromagnets.

Magnetic field (B)

From the above activity we notice that magnets have an invisible field all around them which attracts magnetic materials.

In this space we can feel the force of attraction or repulsion due to the magnet. Thus, magnetic field is the region around the magnet where its magnetic influence can be felt. It is denoted by B and its unit is Tesla.

The direction of the magnetic field around a magnet can be found by placing a small compass in the magnetic field

Magnetic field can penetrate through all kinds of materials, not just air. The Earth produces its own magnetic field, which shields the earth's ozone layer from the solar wind and it is important for navigation also.

Magnetic Field Lines

A magnetic field line is defined as a curve drawn in the magnetic field in such a way that the tangent to the curve at any point gives the direction of the magnetic field. They start at north pole and ends at south pole. The arrow mark indicates the direction of magnetic field at points A, B and C. Note carefully that the magnetic field at a point is tangential to the magnetic field lines.

agnetic flux

Magnetic flux is the number of magnetic field lines passing through a given area. It is denoted by ϕ and its unit is weber (Wb).

The number of magnetic field lines crossing unit area kept normal to the direction of field lines is called magnetic flux density.

Magnetic flux density

Some sea turtles (loggerhead sea turtle) return to their birth beach many decades after they were born, to nest and lay eggs. In a research, it is suggested that the turtles can perceive variations in magnetic parameters of Earth such as magnetic field intensity and remember them. This memory is what helps them in returning to their homeland.

Properties of magnetic lines of force

- Magnetic lines of force are closed, continuous curves, extending through the body of the magnet.
- Magnetic lines of force start from the North Pole and end at the South Pole.
- Magnetic lines of force never intersect.
- They will be maximum at the poles than at the equator.
- The tangent drawn at any point on the curved line gives the direction of magnetic field.

Magnetic effect of current

It was on 21st April 1820, Hans Christian Oersted, a Danish Physicist was giving a lecture. He was demonstrating electrical circuits in that class. He had to often switch on and off the circuit during the lecture. Accidentally, he noticed the needle of the magnetic compass that was on the table. It deflected whenever he switched on and the current was flowing through the wire. The compass needle moved only slightly, so that the audience didn't even notice. But, it was clear to Oersted that something significant was happening. He conducted many experiments to find out a startling effect, the magnetic effect of current.

Oersted aligned a wire XY such that they were exactly along the North-South direction. He kept one magnetic compass above the wire at A and another under the wire at B. When the circuit was open and no current was flowing through it, the needle of both the compass was pointing to north. Once the circuit was closed and electric current was flowing, the needle at A pointed to east and the needle at B to the west as shown in Figure 5.5. This showed that current carrying conductor produces magnetic field around it.

The direction of the magnetic lines around a current carrying conductor can be easily understood using the right hand thumb rule. Hold the wire with four fingers of your right hand with thumbs-up position. If the direction of the current is towards the thumb then the magnetic lines curl in the same direction as your other four fingers as shown in Figure 5.6. This shows that the magnetic field is always perpendicular to the direction of current.

The strength of the magnetic field at a point due to current carrying wire depends on:

I. the current in the wire,
II. distance of the point from the wire,
III. the orientation of the point from the wire and
IV. The magnetic nature of the medium.

The magnetic field lines are stronger near the current carrying wire and it diminishes as you go away from it. This is represented by drawing magnetic field lines closer together near the wire and farther away from the wire.

Force on a current carrying conductor in a magnetic field

H.A.Lorentz found that a charge moving in a magnetic field, in a direction other than the direction of magnetic field, experiences a force. It is called the magnetic Lorentz force. Since charge in motion constitutes a current, a conductor carrying moving charges, placed in magnetic field other than the direction of magnetic field, will also experience a force and can produce motion in the conductor.

From this activity, we infer that current carrying wire has a magnetic field perpendicular to the wire (by looking at the deflection of the compass needle in the vicinity of a current carrying conductor). The deflection of the needle implies that the current carrying conductor exerts a force on the compass needle. In 1821, Michael Faraday discovered that a current carrying conductor also gets deflected when it is placed in a magnetic field. In Figure 5.7, we can see that the magnetic field of the permanent magnet and the magnetic field produced by the current carrying conductor interact and produce a force on the conductor.

If a current, I is flowing through a conductor of length, L kept perpendicular to the magnetic field B, then the force F experienced by it is given by the equation,

$$F = I L B$$

The above equation indicates that the force is proportional to current through the conductor, length of the conductor and the magnetic field in which the current carrying conductor is kept.

The angle of inclination between the current and magnetic field also affects the magnetic force. When the conductor is perpendicular to the magnetic field, the force will be maximum (=BIL). When it is parallel to the magnetic field, the force will be zero.

The force is always a vector quantity. A vector quantity has both magnitude and direction. It means we should know the direction in which the force would act. The direction is often found using what is known as Fleming's Left hand Rule (formulated by the scientist John Ambrose Fleming).

The law states that while stretching the three fingers of left hand in perpendicularmanner with each other, if the direction of the current is denoted by the middle finger of the left hand and the second finger is for direction of the magnetic field, then the thumb of the left hand denotes the direction of the force or movement of the conductor.

Force on parallel current carrying conductors

We have seen that a current carrying conductor has a magnetic field around it. If we place another conductor carrying current parallel to the first one, the second conductor will experience a force due to the magnetic field of the first conductor. Similarly, the first conductor will experience a force due to the magnetic field of the second conductor. These two forces will be equal in magnitude and opposite in direction.

Using Fleming's left hand rule we can find that the direction of the force on each wire would be towards each other when the current in both of them are flowing in the same direction, i.e., the wires would experience an attractive force. However, if the direction of the flow of current is in opposite direction, then the force on each of the wire will be in opposite direction.

Connection between Electricity and Magnetism:

Before 18th century people thought that magnetism and electricity were separate subjects of study. After Oersted's experiment the electricity and magnetism were united and became a single subject called 'Electromagnetism'.

When there is current, the magnetic field is produced and the current carrying conductor behaves like a magnet. You may now wonder how was it possible for a lodestone to behave like a magnet when there was no current passing through it. Only in the twentieth century, we understood that the magnetic property arises due to the motion of electrons in the lodestone. In the circuit the electrons flow from negative of the battery to positive of the battery and constitutes current. As a result it produces magnetic field. In natural magnets and artificial magnets that we buy in shops, the electrons move around the nucleus constitutescurrent which leads to magnetic property. Here, every orbiting electron in its orbit is like a current carrying loop. Even though in all the materials electrons orbit around the nucleus, only for certain special type of material called magnetic material the motion of electrons around the nucleus gets added up and as a result we have permanent magnetic field.

Electric motor

An electric motor is a device which converts electrical energy into mechanical energy. Electric motors are crucial in modern life. They are used in water pump, fan, washing machine, juicer, mixer, grinder etc. We have already seen that when electric current is passed through a conductor placed normally in a magnetic field, a force is acting on the conductor and this force makes the conductor to move. This is harnessed to construct an electric motor. To understand how a motor works, we need to understand how a current carrying coil experiences a turning effect when placed inside a permanent magnetic field.

In figure 5.12.a simple coil is placed inside two poles of a magnet. Now look at the current carrying conductor segment AB. The direction of the current is towards B, whereas in the conductor segment CD the direction is opposite. As the current is flowing in opposite directions in the segments AB and CD, the direction of the motion of the segments would be in opposite directions according to Fleming's left hand rule. When two ends of the coil experience force in opposite direction, they rotate

If the current flow is along the line ABCD, then the coil will rotate in clockwise direction first and then in anticlockwise direction. If we want to make the coil rotate in any one direction, say clockwise, then the direction of the current should be along ABCD in the first half of the rotation and along DCBA in the second half of the rotation. To change the direction of the current, a small device called split ring commutator is used.

When the gap in the split ring commutator is aligned with terminals X and Y, there is no flow of current in the coil. But, as the coil is moving, it continues to move forward bringing one of the split ring commutator in contact with the carbon brushes X and Y. The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil.

The speed of rotation of coil can be increased by:

- increasing the strength of current in the coil.
- increasing the number of turns in the coil.
- increasing the area of the coil and
- increasing the strength of the magnetic field.

Electromagnetic Induction
Experiment 1

In this experiment, two coils were wound on a soft iron ring (separated from each other). The coil on the left is connected to a battery and a switch K. A galvanometer is attached to the coil on the right. When the switch is put 'on', at that instant, there is a deflection in the galvanometer. Likewise, when the switch is put 'off', again there is a deflection – but in the opposite direction. This proves the generation of current.

Experiment 2

In this experiment, current (or voltage) is generated by the movement of the magnetin and out of the coil. The greater the number of turns, the higher is the voltage generated

Experiment 3

In this experiment, the magnet is stationary, but the coil is moved in and out of the magnetic field (indicated by the magnetic lines of force). Here also, current is induced.

All these observations made Faraday to conclude that whenever there is a change in the magnetic flux linked with a closed circuit an emf is produced and the amount of emfinduced varies directly as the rate at which the flux changes. This emf is known as induced emf and the phenomenon of producing an induced emf due to change in the magnetic flux linked with a closed circuit is known as electromagnetic induction.

Note: The direction of the induced current was given by Lenz's law, which states that the induced current in the coil flows in such a direction as to oppose the change that causes it. The direction of induced current can also be given by another rule called Fleming's Right Hand Rule.

Michael Faraday (22nd Sep,1791–25th Aug, 1867) was a British Scientist who contributed to the study of electromagnetism and electrochemistry. His main discoveries include the principles underlying electromagnetic induction, diamagnetism and electrolysis.

Fleming's Right Hand Rule

Stretch the thumb, fore finger and middle finger of your right hand mutually perpendicular to each other. If the fore finger indicates the direction of magnetic field and the thumb indicates the direction of motion of the conductor, then the middle finger will indicate the direction of induced current. Fleming's Right hand rule is also called 'generator rule'.

Electric generator

An alternating current (AC) generator, as shown in Figure 5.18, consists of a rotating rectangular coil ABCD called armature placed between the two poles of a permanent magnet. The two ends of this coil are connected to two slip rings S1 and S2. The inner sides of these rings are insulated. Two conducting stationary brushes B1 and B2 are kept separately on the rings S1 and S2 respectively. The two rings S1 and S2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field. Outer ends of the two brushes are connected to the external circuit.
When the coil is rotated, the magnetic flux linked with the coil changes. This change in magnetic flux will lead to generation of induced current. The direction of the induced current, as given by Fleming's Right Hand Rule, is along ABCD in the coil and in the outer

circuit it flows from B2 to B1. During the second half of rotation, the direction of current is along DCBA in the coil and in the outer circuit it flows from B1 to B2. As the rotation of the coil continues, the induced current in the external circuit is changing its direction for every half a rotation of the coil.
To get a direct current (DC), a split ring type commutator must be used. With this arrangement,

one brush is at all times in contact with the arm moving up in the field while the other is in contact with the arm moving down. Thus, a unidirectional current is produced. The generator is thus called a DC generator .

Transformer

Transformer is a device used for converting low voltage into high voltage and high voltage into low voltage. It works on the principle of electromagnetic induction. It consists of primary and secondary coil insulated from each other. The alternating current flowing through the primary coil induces magnetic field in the iron ring. The magnetic field of the iron ring induces a varying emf in the secondary coil.

Depending upon the number of turns in the primary and secondary coils, we can step-up or step-down the voltage in the secondary coil as shown in Figure 5.20.

Step up transformer:

The transformer used to change a low alternativing voltage to a high alternating voltage is called a step up transformer. ie Vs > Vp. In a step up transformer, the number of turns in the secondary coil is more than the number of turns in the primary coil (Ns > Np).

Step down transformer:

The transformer used to change a high alternating voltage to a low alternating voltage is called a step down transformer (Vs <Vp). In a step down transformer, the number of turns in the secondary coils are less than the number of turns in the primary coil (Ns < Np).
The formulae pertaining to the transformers are given in the following equations.

Number of primary turns Np Primary voltage Vp
Number of secondary turns Ns = Secondary voltage Vs
Number of secondary turns Ns Primary current Ip
Number of primary turns Np = Secondary current Is

A step up transformer increases the voltage but it decreases the current and vice versa. Basically there will be loss of energy in a transformer in the form of heat, sound etc.

A transformer cannot be used with the direct current (DC) source because, current in the primary coil is constant (ie. DC). Then there will be no change in the number of magnetic field lines linked with the secondary coil and hence no emf will be induced in the secondary coil.

Applications of Electromagnets

Electromagnetism has created a great revolution in the field of engineering applications. In addition, this has caused a great impact on various fields such as medicine, industries, space etc.

Speaker Inside the speaker, an electromagnet is placed in front of a permanent magnet. The permanent magnet is fixed firmly in position whereas the electromagnet is mobile. As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed. This means that it is in turn attracted to and repelled from the permanent magnet vibrating back and forth. The electromagnet is attached to a cone made of a flexible material such as paper or plastic which amplifies these vibrations, pumping sound waves into the surrounding air towards our ears.

Magnetic Levitation Trains

Magnetic levitation (Maglev) is a method by which an object is suspended with no support other than magnetic fields. In maglev trains two sets of magnets are used, one set to repel and push the train up off the track, then another set to move the floating train ahead at great speed without friction. In this technology, there is no moving part. The train travels along a guideway of magnets which controls the train's stability and speed using the basic principles of magnets. Figure.

Medical System

Nowadays electromagnetic fields play a key role in advanced medical equipments such as hyperthermia treatments for cancer, implants and magnetic resonance imaging (MRI). Sophisticated equipments working based on electromagnetism can scan even minute details of the human body. Figure 5.22 MRI Scanning machine Many of the medical equipments such as scanners, x-ray equipments and other equipments also use the principle of electromagnetism for their functioning.

UNIT- 6 –LIGHT

Introduction

Light is a form of energy which travels as electromagnetic waves. The branch of physics that deals with the properties and applications of light is called optics. In our day to day life we use number of optical instruments. Microscopes are inevitable in science laboratories. Telescopes, binoculars, cameras and projectors are used in educational, scientific and entertainment fields. In this lesson, you will learn about spherical mirrors (concave and convex). Also, you will learn about the properties of light, namely reflection and refraction and their applications.

Reflection of Light

Light falling on any polished surface such as a mirror, is reflected. This reflection of light on polished surfaces follows certain laws and you have studied about them in your lower classes. Let us study about them little elaborately here.

Laws of reflection

Consider a plane mirror MM′ as shown in Figure 6.1. Let AO be the light ray incident on the plane mirror at O. The ray AO is called incident ray. The plane mirror reflects the incident ray along OB. The ray OB is called reflected ray. Draw a line ON at O perpendicular to MM′. This line ON is called normal.

The angle made by the incident ray with the normal (i = angle AON) is called angle of incidence. The reflected ray OB makes an angle (r = angle NOB) with the normal and this is called angle of reflection. From the figure you can observe that the angle of incidence is equal to the angle of reflection. i.e., i = r. Also, the incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane. These are called the laws of reflection. Laws of reflection are given as: The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

The angle of incidence is equal to angle of reflection.

The most common usage of mirror writing can be found on the front of ambulances, where the word "AMBULANCE" is often written in very large mirrored text.

Lateral inversion

You might have heard about inversion. But what is lateral inversion? The word lateral comes from the Latin word latus which means side. Lateral inversion means sidewise inversion. It is the apparent inversion of left and right that occurs in a plane mirror. Why do plane mirrors reverse left and right, but they do not reverse up and down? Well, the answer is surprising. Mirrors do not actually reverse left and right and they do not reverse up and down also. What actually mirrors do is reverse inside out. Look at the image below (Figure 6.2) and observe the arrows, which indicate the light ray from the object falling on the mirror. The arrow from the object's head is directed towards the top of the mirror and the arrow from the feet is directed towards the bottom. The arrow from left hand goes to the left side of the mirror and the arrow from the right hand goes to the right side of the mirror. Here, you can see that there is no switching. It is an optical illusion. Thus, the apparent lateral inversion we observe is not caused by the mirror but the result of our perception.

Real and Virtual Image

If the light rays coming from an object actually meet, after reflection, the image formed will be a real image and it is always inverted. A real image can be produced on a screen. When the light rays coming from an object do not actually meet, but appear to meet when produced backwards, that image will be virtual image. The virtual image is always erect and cannot be caught on a screen (Figure
binoculars, cameras and projectors are used in educational, scientifi c and entertainment fields.

In this lesson, you will learn about spherical mirrors (concave and convex). Also, you will learn about the properties of light, namely refl ection and refraction and their applications.

Curved Mirrors

We studied about laws of reflection. These laws are applicable to all types of reflecting surfaces including curved surfaces. Let us learn about image formation in curved surfaces in this part.

In your earlier classes, you have studied that there are many types of curved mirrors, such as spherical and parabolic mirrors. The most commonly used type of curved mirror is spherical mirror. The curved surfaces of a shining spoon could also be considered as a curved mirror.

Take a hemispherical spoon. It has an inner and outer surface like the inside and outside of the ball. See your face on these surfaces? How do they look?

Move the spoon slowly away from your face. Observe the image. How does it change? Reverse the spoon and repeat the activity. How does the image look like now?

Spherical mirrors

In curved mirrors, the reflecting surface can be considered to form a part of the surface of a sphere. Such mirrors whose reflecting surfaces are spherical are called spherical mirrors.

In some spherical mirrors the reflecting surface is curved inwards, that is, it faces towards the centre of the sphere. It is called concave mirror. In some other mirrors, the reflecting surface is curved outward. It is called convex mirror and are shown in Figure 2.

In order to understand reflection of light at curved surfaces, we need to know the following.

Centre of curvature (C): The centre of the hollow sphere of which the spherical mirror forms a part.

Pole (P): The geometrical centre of the spherical mirror.

Principal axis (PC): The perpendicular line joining the pole and the centre of curvature of the mirror.

Radius of curvature(R): The distance between the pole and the centre of curvature of the spherical mirror.

Principal focus (F): The point on the principal axis of the spherical mirror where the rays of light parallel to the principal axis meet or appear to meet after reflection from the spherical mirror.

Focal length(f): The distance between the pole and the principal focus.
Radius of curvature and focal length are related to each other by the formula: R=2f. All these are depicted in Figure 3.

Image Formed by Curved Mirrors

We have seen that the parallel rays of sun light (Figure 4) could be focused at a point using a concave mirror. Now let us place a lighted candle and a white screen in front of the concave mirror. Adjust the position of the screen. Move the screen front and back. Note the size of the image and its shape. Is it inverted? Is it small?

Next, slowly bring the candle closer to the mirror. What do you observe? As you bring the object closer to the mirror the image becomes bigger. Try to locate the image when you bring the candle very close to the mirror. Are you able to see an image on the screen? Now look inside the mirror. What do you see? An erect magnified image of the candle is seen. In some positions of the object an image is obtained on the screen. However at some position of the object no image is obtained. It is clear that the behaviour of the concave mirror is much more complicated than the plane mirror.

However, with the use of geometrical technique we can simplify and understand the behaviour of the image formed by a concave mirror. In the earlier case of plane mirror, we used only two rays to understand how to get full image of a person. But for understanding the nature of image formedby a concave mirror we need to look at four specific rules.

Rules for the construction of image formed by spherical mirrors

From each point of an object, number of rays travel in all directions. To find the position and nature of the image formed by a concave mirror, we need to know the following rules.

Rule 1: A ray passing through the centre of curvature is reflected back along its own path (Figure 5).

Rule 2: A ray parallel to the principal axis passes through the principal focus after reflection (Figure 6).

Rule 3: A ray passing through the focus gets reflected and travels parallel to the principal axis (Figure 7).

Rule 4: A ray incident at the pole of the mirror gets reflected along a path such that the angle of incidence (APC) is equal to the angle of reflection (BPC) (Figure 8).

Concave Mirror

Ray diagrams for the formation of images

We shall now find the position, size and nature of image by drawing the ray diagram for a small linear object placed on the principal axis of a concave mirror at different positions.

Case-I: When the object is far away (at infinity), the rays of light reaching the concave mirror are parallel to each other (Figure 10).

Position of the Image: The image is at the principal focus F.
Nature of the Image: It is (i) real, (ii) inverted and (iii) highly diminished in size.

Case-II: When the object is beyond the centre of curvature (Figure 11).
Position of the image: Between the principal focus F and centre of curvature C.

Nature of the image: Real, inverted and smaller than object.
Case – III: When the object is at the centre of curvature (Figure 12).
Position of the image: The image is at the centre of curvature itself.
Nature of the image: It is i) Real, ii) inverted and iii) same size as the object.

Case – IV: When the object is in between the centre of curvature C and principal focus F (Figure 13).
Position of the image: The image is beyond C

Nature of the image: It is i)Real ii) inverted and iii) magnified.

Case – V: When the object is at the principal focus F (Figure 14).
Position of the image: Theoretically, the image is at infinity.
Nature of the image: No image can be captured on a screen nor any virtual image can be seen.

Case – VI: When the object is in between the focus F and the pole P (Figure 15). Position of the image: The image is behind the mirror.
Nature of the image: It is virtual,erect and magnified.

S. No	Position of Object	Ray Diagram	Position of Image	Size of Image	Nature of Image
1.	At infinity		At the principal focus	Point size	Real and Inverted
2.	Beyond the Centre of Curvature C		Between F and C	Smaller than the object	Real and Inverted
3.	At the Centre of Curvature C		A to C	Same size	Real and Inverted
4.	Between C and F		Beyond C	Magnified	Real and inverted
5.	At the principal focus F		At infinity	Infinitely large	Real and Inverted
6.	Between the principal focus F and the pole P of the mirror		Behind the mirror	Magnified	Virtual and Erect

Sign convention for measurement of distances

We follow a set of sign conventions called the cartesian sign convention. In this convention the pole (P) of the mirror is taken as the origin. The principal axis is taken as the x axis of the coordinate system (Figure 16).The object is always placed on the left side of the mirror.
All distances are measured from the pole of the mirror.

- § Distances measured in the direction of incident light are taken as positive and those measured in the opposite direction are taken as negative.
- § All distances measured perpendicular to and above the principal axis are considered to be positive.
- § All distances measured perpendicular to and below the principal axis are considered to be negative.

Type of	u	v	f	R	Height of the	Height of the image

mirror						subject		
		real	virtual				real	virtual
Concave mirror	-	-	+	-	-		-	+
Convex mirror	-	No real image	+	+	+		No real image	+

Mirror equation

The expression relating the distance of the object u, distance of image v and focal length f of a spherical mirror is called the mirror equation. It is given as:

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

Linear magnification (m)

Magnification produced by a spherical mirror gives the how many times the image of an object is magnified with respect to the object size.
It can be defined as the ratio of the height of the image (//.) to the height of the object (h).

$$m=\frac{h_i}{h_o}$$

The magnification can be related to object distance (u) and the image distance (v)

$$m=-\frac{v}{u}$$
$$\therefore m=\frac{h_i}{h_o}=-\frac{v}{u}$$

Note: A negative sign in the value of magnification indicates that the image is real. A positive sign in the value of magnification indicates that the virtual image.

Uses of concave mirror

Dentist's head mirror:

In dentist's head mirror, a parallel beam of light is made to fall on the concave mirror. This mirror focuses the light beam on a small area of the body (such as teeth, throat etc.).

Make-up mirror:

When a concave mirror is held near the face, an upright and magnified image is seen. Here, our face will be seen magnified.

Other applications:

Concave mirrors are also used as reflectors in torches, head lights in vehicles and search lights to get powerful beams of light. Large concave mirrors are used in solar heaters.

Stellar objects are at an infinite distance. Therefore, the image formed by a concave mirror would be diminished, and inverted. Yet, astronomical telescopes use concave mirrors

Convex Mirror

Image Formation

Any two rays can be chosen to draw the position of the image in a convex mirror (Figure 6.10): a ray that is parallel to the principal axis (rule 1) and a ray that appears to pass through the centre of curvature (rule 2).

Note: All rays behind the convex mirror shall be shown with dotted lines.

The ray OA parallel to the principal axis is reflected along AD. The ray OB retraces its path. The two reflected rays diverge but they appear to intersect at I when produced backwards. Thus II′ is the image of the object OO′. It is virtual, erect and smaller than the object.

Uses of convex mirrors

Convex mirrors are used as rear-view mirrors in vehicles. It always forms a virtual, erect, small-sized image of the object. As the vehicles approach the driver from behind, the size of the image increases. When the vehicles are moving away from the driver, then image size decreases. A convex mirror provides a much wider field of view (it is the observable area as seen through eye / any optical device such as mirror) compared to plane mirror. Convex mirrors are installed on public roads as traffic safety device. They are used in acute bends of narrow roads such as hairpin bends in mountain passes where direct view ofoncoming vehicles is restricted. It is also used in blind spots in shops.

In the rear view mirror, the following sentence is written. “Objects in the mirror are closer than they appear”. Why?

Speed of light

In early seventeenth century the Italian scientist Galileo Galilee (1564–1642) tried to measure the speed of light as it travelled from a lantern on a hill top about a mile (1.6 km) away from where he stood. His attempt was bound to fail, because he had no accurate clocks or timing instruments.

In 1665 the Danish astronomer Ole Roemer first estimated the speed of light by observing one of the twelve moons of the planet Jupiter. As these moons travel around the planet, at a set speed, it would take 42 hours to revolve around Jupiter. Roemer made a time schedule of the eclipses for the whole year. He made first observation in June and second observation in December. Roemer estimated the speed of light to be about 220,000 km per second.

In 1849 the first land based estimate was made by Armand Fizeau. Today the speed of light in vacuum is known to be almost exactly 300,000 km per second.

Refraction of light

This activity explains the refraction of light. The bending of light rays when they pass obliquely from one medium to another medium is called refraction of light.

Cause of refraction

Light rays get deviated from their original path while entering from one transparentmedium to another medium of different optical density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light in a rarer medium (low optical density) is more than in a denser medium (high optical density).

Refraction of light from a plane transparent surface

When a ray of light travels from optically rarer medium to optically denser medium, it bends towards the normal. (Figure 22)

When a ray of light travels from an optically denser medium to an optically rarer medium it bends away from the normal. (Figure 23)

A ray of light incident normally on a denser medium goes without any deviation. (Figure 24).

The laws of refraction of light

The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is the angle of refraction, then

$$\boxed{\frac{\sin i}{\sin r} = \text{constant}}$$

This constant is called the refractive index of the second medium with respect to the first medium. It is generally represented by the Greek letter, ${}_1\mu_2$ (mew)

Note: The refractive index has no unit as it is the ratio of two similar quantities

Verification of laws of refraction

Speed of light in different media

Light has the maximum speed in vacuum and it travels with different speeds in different media. The speed of light in some media is given below.

Note: The refractive index of a medium is also defined in terms of speed of light in different media

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

in general, $1\mu 2 = \frac{speedoflightinmedium\ 1}{\text{speed of light in medium 2}}$

Total internal reflection

When light travels from denser medium into a rarer medium, it gets refracted away from the normal. While the angle of incidence in the denser medium increases the angle of refraction also increases and it reaches a maximum value of r = 90° for a particular value. This angle of incidence is called critical angle (Figure 6.12). The angle of incidence at which the angle of refraction is 90° is called the critical angle. At this angle, the refracted ray grazes the surface of separation between the two media.

When the angle of incidence exceeds the value of critical angle, the refracted ray is not possible. Since r > 90° the ray is totally reflected back to the same medium. This is called as total internal reflection.

Conditions to achieve total internal reflection

In order to achieve total internal refelection the following conditions must be met.

- Light must travel from denser medium to rarer medium. (Example: From water to air).
- The angle of incidence inside the denser medium must be greater than that of the critical angle.

Total internal reflection in nature

Mirage:

On hot summer days, patch of water may be on the road. This is an illusion. In summer, the air near the ground becomes hotter than the air at higher levels. Hotter air is less dense, and has smaller refractive index than the cooler air. Thus, a ray of light bends away from the normal and undergoes total internal reflection. Total internal reflection is the main cause for the spectacular brilliance of diamonds and twinkling of stars.

Optical fibres:

Optical fibres are bundles of high-quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. Optical fibres work on the phenomenon of total internal reflection. When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflection along the length of the fibre and finally comes out at the other end. Optical fibres are extensively used for transmitting audio and video signals through long distances. Moreover, due to their flexible nature, optical fibers enable physicians to look and work inside the body through tiny incisions without having to perform surgery.

An Indian-born physicist Narinder Kapany is regarded as the Father of Fibre Optics.

Unit – 7 – Heat

Introduction

All substances in our surrounding are made up of molecules. These molecules are generally at motion and posses kinetic energy. At the same time each molecule exerts a force of attraction on other molecules and so they posses potential energy. The sum of the kinetic and potential energy is called the internal energy of the molecules. This internal energy, when flows out, is called heat energy. This energy is more in hot substances and less in cold substances and flows from hot substances to cold substances. In this lesson you will study about how this heat transfer takes place. Also you will study about the effect of heat, heat capacity, change of state and latent heat.

Effects of Heat

When a substance is heated, the following things can happen.

Expansion: When heat is added to a substance, the molecules gain energy and vibrate and force other molecules apart. As a result, expansion takes place. You would have seen some space being left in railway tracks. It is because, during summer time, more heat causes expansion in tracks. Expansion is greater for liquids than solids and it is maximum in gases.

Change in State: When you heat ice cubes, they become water and water on further heating changes into vapour. So, solid becomes liquid and liquid becomes gas, when heat is added. The reverse takes place when heat is removed.

Change in Temperature: When heat energy is added to a substance, the kinetic energy of its particles increases and so the particles move at higher speed. This causes rise in temperature. When a substance is cooled, that is, when heat is removed, the molecules lose heat and its temperature falls.

Chemical changes: Since heat is a form of energy it plays a major role in chemical changes. In some cases, chemical reactions need heat to begin and also heat determines the speed at which reactions occur. When we cook food, we light the wood and it catches fire and the food particles become soft because of the heat energy. These are all the chemical changes taking place due to heat.

Transfer of Heat

Heat does not stay where we put it. Hot things get colder and cold things get hotter. Heat is transferred from one place to another till their temperatures become equal. Heat transfer takes place when heat energy flows from an object with higher temperature to an object with lower temperature (Fig. 7.2).

When a dog keeps out its tongue and breathes hard, the moisture on the tongue turns into water and it evaporates. Since, heat energy is needed to turn a liquid into a gas, heat is removed from dog's tongue. This helps to cool the body of the dog.

Heat transfer takes place in three ways:

i. Conduction,
ii. Convection,
iii. Radiation

Conduction

In solids, molecules are closely arranged so that they cannot move freely. When one end of the solid is heated, molecules at that end absorb heat energy and vibrate fast at their own positions. These molecules in turn collide with the neighboring molecules and make them vibrate faster and so energy is transferred. This process continues till all the molecules receive the heat energy.

The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.

Conduction in daily life

i. Metals are good conductors of heat. So, aluminium is used for making utensils to cook food quickly.
ii. Mercury is used in thermometers because, it is a good conductor of heat.
iii. We wear woolen clothes is winter to keep ourselves warm. Air, which is a bad conductor, does not allow our body heat to escape.

Convection

In this activity, water molecules at the bottom of the beaker receive heat energy and move upward and replace the molecules at the top. Same thing happens in air also. When air is heated, the air molecules gain heat energy allowing them to move further apart. Warm air being less dense than cold air will rise. Cooler air moves down to replace the air that has risen. It heats up, rises and is again replaced by cooler air, creating a circular flow.

Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.
Convection in daily life

Hot air balloons: Air molecules at the bottom of the balloon get heated by a heat source and rise. As the warm air rises, cold air is pushed downward and it is also heated. When the hot air is trapped inside the balloon, it rises.

Breezes: During day time, the air in contact with the land becomes hot and rises. Now the cool air over the surface of the sea replaces it. It is called sea breeze. During night time, air above the sea is warmer. As the warmer air over the surface of the sea rises, cooler air above the land moves towards the sea. It is called land breeze.

Winds: Air flows from area of high pressure to area of low pressure. The warm air molecules over hot surface rise and create low pressure. So, cooler air with high pressure flows towards low pressure area. This causes wind flow.

Chimneys: Tall chimneys are kept in kitchen and industrial furnaces. As the hot gases and smoke are lighter, they rise up in the atmosphere.

7.2.3 Radiation

Radiation is a method of heat transfer that does not require particles to carry the heat energy. In this method, heat is transferred in the form of waves from hot objects in all direction. Radiation can occur even in vacuum whereas conduction and convection need matter to be present. Radiation consists of electromagnetic waves travelling at the speed of light. Thus, radiation is the flow of heat from one place to another by means of electromagnetic waves. Transfer of heat energy from the sun reaches us in the form of radiation. Radiation is emitted by all bodies above 0 K. Some objects absorb radiation and some other objects reflect them.

While firing wood, we can observe all the three ways of heat transfer. Heat in one end of the wood will be transfered to other end due to conduction. The air near the wood will become warm and replace the air above. This is convection. Our hands will be warm because heat reaches us in the form of radiation.

Radiation in daily life

i. White or light colored cloths are good reflectors of heat. They keep us cool during summer.

ii. Base of cooking utensils is blackened because black surface absorbs more heat from the surrounding.

iii. Surface of airplane is highly polished because it helps to reflect most of the heat radiation from the sun.

Concept of temperature

Temperature is the degree of hotness or coolness of a body. Hotter the body, higher is its temperature.

Unit of Temperature

The SI unit of temperature is kelvin (K). For day to day applications, Celsius (°C) is used. Temperature is measured with a thermometer.

Temperature scales

There are three scales of temperature.

i. Fahrenheit scale
ii. Celsius or Centigrade scale
iii. Kelvin or Absolute scale

Fahrenheit scale

In Fahrenheit scale, 32 °F and 212 °F are the freezing point and boiling point respectively. Interval has been divided into 180 parts.

Celsius temperature scale

In Celsius scale, also called centigrade scale, 0°C and 100 °C are the freezing point and boiling point respectively. Interval has been divided into 100 parts. The formula to convert a Celsius scale to Fahrenheit scale is:

$F=\frac{9}{5}C+32$

The formula for converting a Fahrenheit scale to Celsius scale is:

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

Kelvin scale (Absolute scale)

Kelvin scale is known as the absolute scale. On the Kelvin scale 0 K represents absolute zero, the temperature at which the molecules of a substance have their lowest possible energy. The solid, liquid, gaseous

The temperature at which the pressure and volume of a gas theoretically reaches zero is called absolute zero. This is shown in Figure 7.7.

For all gases, the pressure extrapolates to zero at the temperature –273.15 °C. It is known as absolute zero or 0 K. Some base linetemperatures in the three temperature scales are shown in Table 7.1.

Temperature	Kelvins (K)	Degre Celcius (°C)	Degrees Fahrenheit (°F)
Boiling point of water	373.15	100	212
Melting point of ice	273.15	0	32
Absolute zero	0	-273	-460

Specific Heat Capacity

ou might have felt that the land is cool in the morning and hot during day time. But, water in a lake will be almost at a particular temperature both in the morning as well as in the afternoon. Both are subjected to same amount of heat energy from the Sun, but they react differently. It is because both of them have different properties. In general, the amount of heat energy absorbed or lost by a body is determined by three factors.

1. Mass of the body
2. Change in temperature of the body
3. Nature of the material of the body

We can understand this from the following observations.

Observation:1

Quantity of heat required to raise the temperature of 1 litre of water will be more than the heat required to raise the temperature of 500 ml of water. If Q is the quantity of heat absorbed and m is the mass of the body, then $Q \propto m$ (7.1)

Observation: 2

Quantity of heat energy (Q) required to raise the temperature of 250 ml of water to 100°C is more than the heat energy required to raise the temperature to 50 °C. Here, $Q \propto \Delta T$, where ΔT is the change in temperature of the body.

Thus, heat lost or gained by a substance when its temperature changes by ΔT is,

$Q \propto m\Delta T$
$Q = mC\Delta T$ (7.2)

From the above equations, the absolute temperature and energy of a system are proportional to each other. The proportionality constant is the specific heat capacity (C) of the substance.

$\therefore C = Q/m\Delta T$

Thus, specific heat capacity of a substance is defined as the amount of heat required to raise the temperature of 1 kg of the substance by 10C or 1 K. The SI unit of specific heat capacity is Jkg-1 K-1. The most commonly used units of specific heat capacity are J/kg°C and J/g°C.

Among all the substances, water has the highest specific heat capacity and its value is4200 J/kg°K. So, water absorbs a large amount of heat for unit rise in temperature. Thus, water is used as a coolant in car radiators and factories to keep engines and other machinery parts cool. It is because of this same reason, temperature of water in the lake does not change much during day time.

Water in its various form, has different specific heat capacities.
Water (Liquid state) = 4200 $JKg^{-1} K^{-1}$
Ice (Solid state) = 2100 $JKg^{-1} K^{-1}$
Steam (Gaseous state) = 460 $JKg^{-1} K^{-1}$

Heat capacity or Thermal capacity

Now, you are familiar with specific heat capacity. It is the heat required to raise the temperature of a unit mass of a body by 1°C. But, heat capacity is the heat required to raise the temperature of the entire mass of the body by 1°C. Thus, heat capacity or thermal capacity is defined as the amount of heat energy required to raise the temperature of a body by 1°C. It is denoted by C′.

Heat Capacity $=\frac{Quantityofheatrequired}{RaiseinTemperature}$

$C^I = Q/T$

SI unit of heat capacity is J/K. It is also expressed in cal/oC, kcal/oC or J/oC.

Change of state

The process of changing of a substance from one physical state to another at a definite temperature is known as change of state. For example, water molecules are in liquid state at normal temperature. When water is heated to 100°C, it becomes steam which is a gaseous state of matter. On reducing the temperature of the steam it becomes water again. If we reduce the temperature further to 0 °C, it becomes ice which is a solid state of water. Ice on heating, becomes water again. Thus, water changes its state when there is a change in temperature. There are different such processes in the change of state in matter. Figure 7.8 shows various processes of change of state.

Melting – Freezing

The process in which a solid is converted to liquid by absorbing heat is called melting or fusion. The temperature at which a solid changes its state to liquid is called melting point. The reverse of melting is freezing. The process in which a liquid is converted to solid by releasing heat is called freezing. The temperature at which a liquid changes its state to solid is called freezing point. In the case of water, melting and boiling occur at 0°C.

Boiling-Condensation

The process in which a liquid is converted to vapor by absorbing heat is called boiling or vaporization. The temperature at which a liquid changes its state to gas is called boiling point. The process in which a vapor is converted to liquid by releasing heat is called condensation. The temperature at which vapour changes its state to liquid is called condensation point. Boiling point as well as condensation point of water is 100°C.

Sublimation

Some solids like dry ice, iodine, frozen carbon dioxide and naphthalene balls change directly from solid state to gaseous state without becoming liquid. The process in which a solid is converted to gaseous state is called sublimation. Various stages of conversion of state of matter by heat with the corresponding change in temperature is shown in Figure 7.9

Latent heat

The word, ‘latent’ means hidden. So, latent heat means hidden heat or hidden energy. In order to understand latent heat, let us do the activity given belowIn the above activity, temperature is constant at 0°C until entire ice is converted into liquid and again constant at 100°C until all the ice is converted into vapor. Why? It is because, when a substance changes from one state to another, a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat. Thus, latent heat is the amount of heat energy absorbed or released by a substance during a change in its physical states without any change in its temperature. Heat energy is absorbed by the solid during melting and an equal amount of heat energy is liberated by the liquid during freezing, without any temperature change. It is called latent heat of fusion. In the same manner, heat energy is absorbed by a liquid during vaporization and an equal amount of heat energy is liberated by the vapor during condensation, without anytemperature changes. This is called latent heat of vaporization.

Specific latent heat

Latent heat, when expressed per unit mass of a substance, is called specific latent heat. It is denoted by the symbol L. If Q is the amount of heat energy absorbed or liberated by ‘m’ mass of a substance during its change of phase at a constant temperature, then specific latent heat is given as $L = Q/m$. Thus, specific latent heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change in temperature. The SI unit of specific latent heat is J/kg.

Unit – 8 – Sound

Introduction

Sound is a form of energy which produces sensation of hearing in our ears. Some sounds are pleasant to hear and some others are not. But, all sounds are produced by vibrations of substances. These vibrations travel as disturbances in a medium and reach our ears as sound. Human ear can hear only a particular range of frequency of sound that too with a certain range of energy. We are not able to hear sound clearly if it is below certain intensity. The quality of sound also differs from one another. What are the reasons for all these? It is because sound has several qualities. In this lesson we are going to learn about production and propagation of sound along with its various other characteristics. We will also study about ultrasonic waves and their applications in our daily life.

Production of sound

In your daily life you hear different sounds from different sources. But, have you ever thought how sound is produced? To understand the production of sound, let us do an activity.

When you strike the tuning fork on the rubber pad, it starts vibrating. These vibrations cause the nearby molecules to vibrate. Thus, vibrations produce sound.

Propagation of Sound Waves

Sound needs a medium for propagation

Sound needs a material medium like air, water, steel etc., for its propagation. It cannot travel through vacuum. This can be demonstrated by the Bell – Jar experiment.

An electric bell and an airtight glass jar are taken. The electric bell is suspended inside the airtight jar. The jar is connected to a vacuum pump, as shown in Figure 8.1. If the bell is made to ring, we will be able to hear the sound of the bell. Now, when the jar is evacuated with the vacuum pump, the air in the jar is pumped out gradually and the sound becomes feebler and feebler. We will not hear any sound, if the air is fully removed (if the jar has vacuum).

Sound is a wave

Sound moves from the point of generation to the ear of the listener through a medium. When an object vibrates, it sets the particles of the medium around to vibrate. But, the vibrating particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is displaced from its equilibrium position. It then exerts a force on an adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches our ears. It is to be noted that only the disturbance created by a source of sound travels through the medium not the particles of the medium. All the particles of the medium restrict themselves with only a small to and fro motion called vibration whichenables the disturbance to be carried forward. This disturbance which is carried forward in a medium is called wave.

Longitudinal nature of sound waves

From the above activity you can see that in some parts of the coil, the turns are closer together. These are regions of compressions. In between these regions of compressions we have regions where the coil turns are far apart called rarefactions. As the coil oscillates, the compressions and rarefactions move along the coil. The waves that propagates with compressions and rarefactions are called longitudinal waves. In longitudinal waves the particles of the medium move to and fro along the direction of propagation of the wave. Sound also is a longitudinal wave. Sound can travel only when there are particles which can be compressed and rarefied. Compressions are the regions where particles are crowded together. Rarefactions are the regions of low pressure where particles are spread apart. A sound wave is an example of a longitudinal mechanical wave. Figure 8.2 represents the longitudinal nature of sound wave in the medium.

Characteristics of a Sound Wave

A sound wave can be described completely by five characteristics namely amplitude, frequency, time period, wavelength and velocity or speed.

Amplitude (A)

The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave. If the vibration of a particle has large amplitude, the sound will be loud and if the vibration has small amplitude, the sound will be soft. Amplitude is denoted as A. Its SI unit is meter (m).

Frequency (n)

The number of vibrations (complete waves or cycles) produced in one second is calledfrequency of the wave. It is denoted as n. The SI unit of frequency is s–1 (or) hertz (Hz). Human ear can hear sound of frequency from 20 Hz to 20,000 Hz. Sound with frequency less than 20 Hz is called infrasonic sound. Sound with frequency greater than 20,000 Hz is called ultrasonic sound. Human beings cannot hear infrasonic and ultrasonic sounds.

Time period (T)

The time required to produce one complete vibration (wave or cycle) is called time period of the wave. It is denoted as T. The SI unit of time period is second (s). Frequency and time period are reciprocal to each other.

Wavelength (λ)

The minimum distance in which a sound wave repeats itself is called its wavelength. In a sound wave, the distance between the centers of two consecutive compressions or two consecutive rarefactions is also called wavelength. The wavelength is usually denoted as λ (Greek letter, lambda). The SI unit of wavelength is metre (m).

Velocity or speed (v)

The distance travelled by the sound wave in one second is called velocity of the sound. The SI unit of velocity of sound is m s–1.

Distinguishing different Sounds

Sounds can be distinguished from one another in terms of the following three different factors.

1. Loudness
2. Pitch
3. Timbre (or quality)

1. Loudness and Intensity

Loudness is a quantity by virtue of which a sound can be distinguished from another one, both having the same frequency. Loudness or softness of sound depends on the amplitudeof the wave. If we strike a table lightly, we hear a soft sound because we produce a sound wave of less amplitude. If we hit the table hard we hear a louder sound. Loud sound can travel a longer distance as loudness is associated with higher energy. A sound wave spreads out from its source. As it move away from the source its amplitude decreases and thus its loudness decreases. Figure 8.4 shows the wave shapes of a soft and loud sound of the same frequency.

The loudness of a sound depends on the intensity of sound wave. Intensity is defined as the amount of energy crossing per unit area per unit time perpendicular to the direction of propagation of the wave.

The intensity of sound heard at a place depends on the following five factors.

i. Amplitude of the source.
ii. Distance of the observer from the source.
iii. Surface area of the source.
iv. Density of the medium.
v. Frequency of the source.

The unit of intensity of sound is decibel (dB). It is named in honour of the Scottish-born scientist Alexander Graham Bell who invented telephone.

2. Pitch

Pitch is one of the characteristics of sound by which we can distinguish whether a sound is shrill or base. High pitch sound is shrill and low pitch sound is flat. Two music sounds produced by the same instrument with same amplitude, will differ when their vibrations are of different frequencies. Figure 8.6 consists of two waves representing low pitch and high pitch sounds.

3. Timbre or Quality

Timbre is the characteristic which distinguishes two sounds of same loudness and pitch emitted by two different instruments. A sound of single frequency is called a tone and a collection of tones is called a note. Timbre is then a general term for the distinguishable characteristics of a tone.

Speed of Sound

The speed of sound is defined as the distance travelled by a sound wave per unit time as it propagates through an elastic medium.

speed(v)= $\frac{Distance}{Time}$

If the distance traveled by one wave is taken as one wavelength (λ), and the time taken for this propagation is one time period (T), then

speed (V) = $\frac{onewavelengh\ (\gamma)}{onetimeperiod\ (T)}$ (or) v = $\frac{\gamma}{T}$

As, T = $\frac{1}{n}$, the speed (v) of sound is also written as, v = n λ.

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

Speed of sound in different media

Sound propagates through a medium at a finite speed. The sound of thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels.

The speed of sound is less in gaseous medium compared to solid medium. In any medium the speed of sound increases if we increase the temperature of the medium. For example the speed of sound in air is 330 m s–1 at 0 °C and 340 m s–1 at 25 °C. The speed of sound at a particular temperature in various media is listed in Table 8.1.

State	Medium	Speed in m s-1
	Aluminum	6420

solids	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980
Liquids	Water	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316
	Sulphur dioxide	213

Sound travels about 5 times faster in water than in air. Since the speed of sound in sea water is very large (being about 1530 m s-1 which is more than 5500 km/h-1), two whales in the sea which are even hundreds of kilometres away can talk to each other very easily through the sea water.

Reflection of Sound

Sound bounces off a surface of solid or a liquid medium like a rubber ball that bounces off from a wall. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves. The laws of reflection are:
The angle in which the sound is incident is equal to the angle in which it is reflected.

Direction of incident sound, the reflected sound and the normal are in the same plane.

Uses of multiple reflections of sound

Musical instruments

Megaphones, loud speakers, horns, musical instruments such as nathaswaram, shehnai and trumpets are all designed to send sound in a particular direction without spreading it in all directions. In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

Stethoscope

Stethoscope is a medical instrument used for listening to sounds produced in the body. In stethoscopes, these sounds reach doctor's ears by multiple reflections that happen in the connecting tube.

Echo

When we shout or clap near a suitable reflecting surface such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1s.

Hence, to hear a distinct echo the time interval between the original sound and the reflected sound must be at least 0.1s. Let us consider the speed of sound to be 340 m s–1 at 25° C.The sound must go to the obstacle and return to the ear of the listener on reflection after 0.1 s. The total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 m s–1 × 0.1 s = 34 m.

Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance i.e. 17 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections. The roaring of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds at different heights and the land.

Reverberation

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound absorbing materials like compressed fiberboard, flannel cloths, rough plaster and draperies. The seat materials are also selected on the basis oftheir sound absorbing properties. There is aseparate branch in physics called acoustics which takes these aspects of sound in to account while designing auditoria, opera halls, theaters etc.

Ultrasonic Sound or Ultrasound

Ultrasonic sound is the term used for soundwaves with frequencies greater than 20,000 Hz.These waves cannot be heard by the human ear, but the audible frequency range for other animals includes ultrasound frequencies. For example, dogs can hear ultrasonic sound. Ultrasonic whistles are used in cars to alert deer to oncoming traffic so that they will not leap across the road in front of cars.

An important use of ultrasound is inexamining inner parts of the body. The ultrasonic waves allow different tissues such as organs and bones to be ‘seen’ or distinguished by bouncing of ultrasonic waves by the objects examined. The waves are detected, analysed and stored in a computer. An echogram is an image obtained by the use of reflected ultrasonic waves. It is usedas a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

Applications of ultrasonic waves

- Ultrasounds can be used in cleaning technology. Minute foreign particles can be removed from objects placed in a liquid bath through which ultrasound is passed.
- Ultrasounds can also be used to detect cracks and flaws in metal blocks.
- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echo cardiography'.
- Ultrasound may be employed to break small 'stones' formed in the kidney into fine grains. These grains later get flushed out with urine.

SONAR

SONAR stands for sound Navigation and Ranging. Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. Sonar consists of a transmitter and a detector and is installed at the bottom of boats and ships.

The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound.
Let the time interval between transmission and reception of ultrasound signal be 't'. Then, the speed of sound through sea water is $2d / t = v$

This method is called echo-ranging. Sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarine, icebergs etc.

Electrocardiogram (ECG)

The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. It can provide a wealth of useful information and remains an essential part of the assessment of cardiac patients. In ECG, the sound variation produced by heart is converted into electric signals. Thus, an ECG is simply a representation of the electrical activity of the heart muscle as it changes with time. Usually it is printed on paper for easy analysis. The sum of this electrical activity, when amplified and recorded for just a few seconds is known as an ECG.

Structure of Human Ear

How do we hear? We are able to hear with the help of an extremely sensitive device called the ear. It allows us to convert pressure variations in air with audible frequencies into electric signals that travel to the brain via the auditory nerve. The auditory aspect of human ear is discussed below.

The outer ear is called ‘pinna’. It collects the sound from the surroundings. The collected sound passes through the auditory canal. At the end of the ear is eardrum or tympanic membrane. When a compression of the medium reaches the eardrum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches it. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interrupts them as sound.

Unit – 9 – Universe

Introduction

In the earlier days, before the invention of astronomical instruments, people thought that Earth is the centre of all the objects in the space. This was known as the geocentric model, held by Greek astronomer Ptolemy (2nd Century), Indian astronomer Aryabhatta (5th Century) and many astronomers around the world. Later Polish astronomer Nicolaus Copernicus proposed the heliocentric model (helios = Sun), with Sun at the centre of the solar system. Invention of the telescope in the Netherlands, in 1608, created a revolution in astronomy. In this lesson, we will study about the building blocks of the universe, Kepler's laws of motion, time period of satellites and International Space Station (ISS).

Building block of the Universe

The basic constituent of the universe is luminous matter i.e., galaxies which are really the collection of billionsof stars. The universe contains everything that exists including the Earth, planets, stars, space, and galaxies. This includes all matter, energy and even time. No one knows how big the universe is. It could be infinitely large. Scientists, however, measure the size of the universe by what they can see. This is called the 'observable universe'. The observable universe is around 93 billion light years (1 light year = the distance that light travels in one year, which is 9.4607 × 1012 km) across.

One of the interesting things about the universe is that it is currently expanding. It is growing larger and larger all the time. Not only is it growing larger, but the edge of the universe is expanding at a faster and faster rate. However, most of the universe what we think of is empty space. All the atoms together only make up around four percent of the universe. The majority of the universe consists of something scientists call dark matter and dark energy.

Age of the Universe

Scientists think that the universe began with the start of a massive explosion called the Big Bang. According to Big Bang theory, all the matter in the universe was concentrated in a single point of hot dense matter. About 13.7 billion years ago, an explosion occurred and all the matter were ejected in all directions in the form of galaxies. Nearly all of the matter in the universe that we understand is made of hydrogen and helium, the simplest elements, created in the Big Bang. The rest, including the oxygen, the carbon, calcium, and iron, and silicon are formed in the cores of stars. The gravity that holds these stars together generally keeps these elements deep inside their interiors. When these stars explode, these fundamental building blocks of planetary systems are liberated throughout the universe.

Galaxies

Immediately after the Big Bang, clouds of gases began to compress under gravity to form the building blocks of galaxies. A galaxy is a massive collection of gas, dust, and billions of stars and their solar systems. Scientists believe that there are one hundred billion (1011) galaxies in the observable universe. Galaxies are also in different shapes. Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular. Galaxies occur alone or in pairs, but they are more often parts of groups, clusters, and super clusters. Galaxies in such groups often interact and even merge together.

Our Sun and all the planets in the solar system are in the Milky Way galaxy. There are many galaxies besides our Milky Way. Andromeda galaxy is our closest neighboring galaxy. The Milky Way galaxy is spiral in shape.

It is called Milky Way because it appears as a milky band of light in the sky. It is made up of approximately 100 billion stars and its diameter is 1,00,000 light years. Our solar system is 25,000 light years away from the centre of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the centre of the galaxy and it takes 250 million years to do that.

The distance of Andromeda, our nearest galaxy is approximately 2.5 million light-years. If we move at the speed of the Earth (30 km/s), it would take us 25 billion years to reach it!

Stars

Stars are the fundamental building blocks of galaxies. Stars were formed when the galaxies were formed during the Big Bang. Stars produce heat, light, ultraviolet rays, x-rays, and other forms of radiation. They are largely composed of gas and plasma (a superheated state of matter). Stars are built by hydrogen gases. Hydrogen atoms fuse together to form helium atoms and in the process they produce large amount of heat. In a dark night we can see nearly 3,000 stars with the naked eye. We don't know how many stars exist. Our universe contains more than 100 billion galaxies, and each of those galaxies may have more than 100 billion stars. Though the stars appear to be alone, most of the stars exist as pairs. The brightness of a star depends on their intensity and the distance from the Earth. Stars also appeartobe in different colours depending on their temperature. Hot stars are white or blue, whereas cooler stars are orange or red in colour. They also occur in many sizes.

A group of stars forms an imaginary outline or meaningful pattern on the space. They represent an animal, mythological person or creature, a god, or an object. This group of stars is called constellations. People in different cultures and countries adopted their own sets of constellation outlines. There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

The Solar System Sun and the celestial bodies which revolve around it form the solar system. It consists of large number of bodies such as planets, comets, asteroids and meteors. The gravitational force of attraction between the Sun and these objects keep them revolving around it.

The Sun

The Sun is a medium sized star, a very fiery spinning ball of hot gases. Three quarters of the Sun has hydrogen gas and one quarter has helium gas. It is over a million times as big as the Earth. Hydrogen atoms combine or fuse together to form helium under enormous pressure. This process, called nuclear fusion releases enormous amount of energy as light and heat. It is this energy which makes Sun shine and provide heat. Sun is situated at the centre of the solar system. The strong gravitational fields cause other solar matter, mainly planets, asteroids, comets, meteoroids and other debris, to orbit around it. Sun is believed to be more than 4.6 billion years old.

Formation of the Sun

At the time of the Big Bang, hydrogen gas condensed to form huge clouds, which later concentrated and formed the numerous galaxies. Some of the hydrogen gas was left free and started floating around in our galaxy. With time, due to some changes, this free-floating hydrogen gas concentrated and paved way for the formation of the Sun and solar system. Gradually, the Sun and the solar system turned into a slowly spinning molecular cloud, composed of hydrogen and helium along with dust. The cloud started to undergo the process of compression, as a result of its own gravity. Its excessive and high-speed spinning ultimately resulted in its flattening into a giant disc.

Planets

A planet revolves around the Sun along a definite curved path which is called an orbit. It is elliptical. The time taken by a planet to complete one revolution is called its period of revolution.

Besides revolving around the Sun, a planet also rotates on its own axis like a top. The time taken by a planet to complete one rotation is called its period of rotation. The period of rotation of the Earth is 23 hours and 56 minutes and so the length of a day on Earth is taken as 24 hours. Table 9.1 tells about the length of a day on each planet.

The planets are spaced unevenly. The first four planets are relatively close together and close to the Sun. They form the inner solar

Planets	**Length of a day**
Mercury	58.65 days
Venus	243 days
Earth	23.93 hours
Mars	24.62 hours
Jupiter	9.92 hours
Saturn	10.23 hours
Uranus	17 hours
Neptune	18 hours

system. Farther from the Sun is the outer solar system, where the planets are much more spread out. Thus the distance between Saturn and Uranus is much greater (about 20 times) than the distance between the Earth and the Mars.

The four planets grouped together in the inner solar system are Mercury, Venus, Earth and Mars. They are called inner planets. They have a surface of solid rock crust and so are called terrestrial or rocky planets. Their insides, surfaces and atmospheres are formed in a similar way and form similar pattern. Our planet, Earth can be taken as a model of the other three planets.

The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system and slowly orbit the Sun are called outer planets. They are made of hydrogen, helium and other gases in huge amounts and have very dense atmosphere. They are known as gas giants and are called gaseous planets. The four outer planets Jupiter, Saturn, Uranus and Neptune have rings whereas the four inner planets do not have any rings. The rings are actually tiny pieces of rock covered with ice. Now let us learn about each planet in the solar system.

Mercury: Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. Mercury can be easily observed thorough telescope than naked eye since it is very faint and small. It always appears in the eastern horizon or western horizon of the sky.

Venus: Venus is a special planet from the Sun, almost the same size as the Earth. It is the hottest planet in our solar system. After our moon, it is the brightest heavenly body in our night sky. This planet spins in the opposite direction to all other planets. So, unlike Earth, the Sun rises in the west and sets in the east here. Venus can be seen clearly through naked eye. It always appears in the horizon of eastern or western sky

The Earth: The Earth where we live is the only planet in the solar system which supports life. Due to its right distance from the Sun it has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone. All these have made continuation of life possible on the Earth. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

Mars: The first planet outside the orbit of the Earth is Mars. It appears slightly reddish and therefore it is also called the red planet. It has two small natural satellites (Deimos and Phobos).

Jupiter: Jupiter is called as Giant planet. It is the largest of all planets (about 11 times larger and 318 times heavier than Earth). It has 3 rings and 65 moons. Its moon Ganymede is the largest moon of our solar system.

Saturn: Known for its bright shiny rings, Saturn appears yellowish in colour. It is the second biggest and a giant gas planet in the outer solar system. At least 60 moons are present - the largest being Titan. Titan is the only moon in the solar system with clouds. Having least density of all (30 times less than Earth), this planet is so light.

Uranus: Uranus is a cold gas giant and it can be seen only with the help of large telescope. It has a greatly tilted axis of rotation. As a result, in its orbital motion it appears to roll on its side. Due to its peculiar tilt, it has the longest summers and winters each lasting 42 years.

Neptune: It appears as Greenish star. It is the eighth planet from the Sun and is the windiest planet. Every 248 years, Pluto crosses its orbit. This situation continues for 20 years. It has 13 moons – Triton being the largest. Triton is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.

Other Bodies of the Solar System

Besides the eight planets, there are some other bodies which revolve around the Sun. They are also members of the solar system.

Asteroids

There is a large gap in between the orbits of Mars and Jupiter. This gap is occupied by a broad belt containing about half a million pieces of rocks that were left over when the planets were formed and now revolve around the Sun. These are called asteroids. The biggest asteroid is Ceres – 946 km across. Every 50 million years, the Earth is hit by an asteroid nearing 10 km across. Asteroids can only be seen through large telescope.

Comets

Comets are lumps of dust and ice that revolve around the Sun in highly elliptical orbits. Their period of revolution is very long. When approaching the Sun, a comet vaporizes and forms a head and tail. Some of the biggest comets ever seen had tails 160 million (16 crores) km long. This is more than the distance between the Earth and the Sun. Many comets are known to appear periodically. One such comet is Halley's Comet, which appears after nearly every 76 years. It was last seen in 1986. It will next be seen in 2062.

Meteors and Meteorites

Meteors are small piece of rocks scattered throughout the solar system. Traveling with high speed, these small pieces come closer to the Earth's atmosphere and are attracted by the gravitational force of Earth. Most of them are burnt up by the heat generated due to friction in the Earth's atmosphere. They are called meteors. Some of the bigger meteors may not be burnt completely and they fall on the surface of Earth. These are called meteorites.

Satellites

A body moving in an orbit around a planet is called satellite. In order to distinguish them from the man made satellites (called as artificial satellites), they are called as natural satellites or moons. Satellite of the Earth is called Moon (other satellites are written as moon). We can see the Earth's satellite Moon, because it reflects the light of the Sun. Satellite moves around the planets due to gravity, and the centripetal force. Among the planets in the solar system all the planets have moons except Mercury and Venus.

The Sun travelling at a speed of 250 km per second (9 lakh km/h) takes about 225 million years to complete one revolution around the Milky Way. This period is called a cosmic year.

Orbital Velocity

We saw that there are natural satellites moving around the planets. There will be gravitational force between the planet and satellites. Nowadays many artificial satellites are launched into the Earth's orbit. The first artificial satellite Sputnik was launched in 1956. India launched its first satellite Aryabhatta on April 19, 1975. Artificial satellites are made to revolve in an orbit at a height of few hundred kilometres. At this altitude, the friction due to air is negligible. The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit.

The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called orbital velocity.

The orbital velocity of the satellite depends on its altitude above Earth. Nearer the object to the Earth, the faster is the required orbital velocity. At an altitude of 200 kilometres, the required orbital velocity is little more than 27,400 kph. That orbital speed and distance permit the satellite to make one revolution in 24 hours. Since Earth also rotates once in 24 hours, a satellite stays in a fixed position relative to a point on Earth's surface. Because the satellite stays over the same spot all the time, this kind of orbit is called 'geostationary'. Orbital velocity can be calculated using the following formula.

$v = \frac{\sqrt{GM}}{(R+h)}$ where,

G = Gravitational constant (6.673 × 10–11 Nm2kg-2)
M = Mass of the Earth (5.972 × 1024 kg)
R = Radius of the Earth (6371 km)
h = Height of the satellite from the surface of the Earth.

Microgravity is the condition in which people or objects appear to be weightless. The effects of microgravity can be seen when astronauts and objects float in space. Micro- means very small, so microgravity refers to the condition where gravity 'seems' to be very small.

Time period of a Satellite

Time taken by a satellite to complete one revolution round the Earth is called time period.

Time period, $T = \frac{Distance\ covered}{Orbital\ Velcity}$

$T = \frac{2\pi r}{V}$

Substituting the value of v, we get

$$T=\frac{2\pi r(R+h)}{\frac{\sqrt{GM}}{(R+h)}}$$

All stars appear to us as moving from east to west, where as there is one star which appears to us stationary in its position. It has been named as Pole star. The pole star appears to us as fixed in space at the same place in the sky in the north direction because it lies on the axis of rotation of the Earth which itself is fixed and does not change its position in space. It may be noted that the pole star is not visible from the southern hemisphere.

Kepler's Laws

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor, Tycho Brahe with three statements that described the motion of planets in a Sun-centered solar system. Kepler's efforts to explain the underlying reasons for such motions are no longer accepted; nonetheless, the actual laws themselves are still considered an accurate description of the motion of any planet and any satellite. Kepler's three laws of planetary motion can be described as below.

First Law – The Law of Ellipses

All planets revolve around the Sun in elliptical orbits with Sun at one of their foci.

Second Law – The Law of Equal Areas

The line connecting the planet and the Sun covers equal areas in equal intervals of time.

Third Law – The Law of Harmonies

The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the distance between sun and the planets.

International Space Station

ISS is a large spacecraft which can house astronauts. It goes around in low Earth orbit at approximately 400 km distance. It is also a science laboratory. Its very first part was placed in orbit in 1998 and its core construction was completed by 2011. It is the largest man-made object in space which can also be seen from the Earth through the naked eye. The first human crew went to the ISS in 2000. Ever since that, it has never been unoccupied by humans. At any given instant, at least six humans will be presentin the ISS. According to the current plan, ISS will be operated until 2024, with a possible extension until 2028. After that, it could be deorbited, or recycled for future space stations.

Benefits of ISS

According to NASA, the following are some of the ways in which the ISS is already benefitting us or will benefit us in the future.

Supporting water-purification efforts

Using the technology developed for the ISS, areas having water scarcity can gain access to advanced water filtration and purification systems. The water recovery system (WRS) and the oxygen generation system (OGS) developed for the ISS have already saved a village in Iraq from being deserted due to lack of clean water.

Eye tracking technology

The Eye Tracking Device, built for a microgravity experiment, has proved ideal to be used in many laser surgeries. Also, eye tracking technology is helping disabled people with limited movement and speech. For example, a kid who has severe disability in body movements can use his eye-movements alone and do routine tasks and lead an independent life.

Robotic arms and surgeries

Robotic arms developed for research in the ISS are providing significant help to the surgeons in removing inoperable tumours (e.g., brain tumours) and taking biopsies with great accuracies. Its inventors say that the robot could take biopsies with remarkable precision and consistency.

Apart from the above-mentioned applications, there are many other ways in which the researches that take place in the ISS are helpful. They are: development of improved vaccines, breast cancer detection and treatment, ultrasound machines for remote regions etc,.

ISS and International Cooperation

As great as the ISS' scientific achievements are, no less in accomplishment is the international co-operation which resulted in the construction of the ISS. An international collaboration of five different space agencies of 16 countries provides, maintains and operates the ISS. They are: NASA (USA), Roskosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Cananda). Belgium, Brazil, Denmark, France, Germany, Italy, Holland, Norway, Spain, Sweden, Switzerland and the UK are also part of the consortium.

Unit – 10 – Matter around us

Introduction

We use the term matter to cover all substances and materials from which the universe is composed. Matter is everything around us. The air we breathe, the food we eat, the pen we write, clouds, stones, plants, animals, a drop of water or a grain of sand everything is matter. Samples of any of these materials have two properties in common. They have mass and they occupy space.

Thus, we say that matter is anything that has mass and occupies space.

Classification of Matter

In class VIII, You have studied the classification of matter on the basis of their physical states. Now let us see how we can classify matter on the basis of chemical composition.Broadly speaking, it has been classified into pure substances and mixtures. From the point of view of chemistry, pure substances are those which contain only one kind of particles whereas impure substances (mixtures) contain more than one kind of particles.

The flow chart given below will help us to understand the chemical classification of matter in detail.

Not all things that we see or feel are matter. For example, sunlight, sound, force and energy neither occupy space nor have any mass. They are not matter.

Elements

Most of you may be interested in music, and some of you may know how it is composed. Music is the combination of a few basic musical notes i.e., Sa, Re, Ga,…Thus, the building blocks of music are the musical notes.

Sa, Re, Ga, Ma, Pa...	Building blocks of music

Likewise , all substances on earth are made up of certain simple substances called elements. Plants, cats, apples, rocks, cars and even our bodies contain elements. Thus, elements are the building block of all materials.

In the modern periodic table there are 118 elements known to us, 92 of which are naturally occurring while the remaining 26 have been artificially created. But from these 118 elements, billions of compounds are formed-some naturally occurring and some artificial. Isn't that amazing?

H, He, Li……. 118 lements

Building block of all materials

Robert boyle used the name element for any substance that cannot be broken down further, into a simpler substance. This definition can be extended to include the fact that each element is made up of only one kind of atom. For example, aluminium is an element which is made up of only aluminium atoms. It is not possible to obtain a simpler substance chemically from the aluminium atoms. You can only make more complicated substances from it, such as aluminium oxide, aluminium nitrate and aluminum sulphate.

Atom: The smallest unit of an element which may or may not have an independent existence, but always takes part in a chemical reaction is called atom.

Molecules: The smallest unit of a pure substance, which always exists independently and can retain physical and chemical properties of that substance is called a molecule.

Examples:

Hydrogen molecule consists of two atoms of hydrogen (H2)
Oxygen molecule consists of two atoms of oxygen (O2)
All elements can be classified according to various properties. A simple way to do this is to classify them as metals, non metals and metalloids.

Compounds

When two or more elements combine chemically to form a new substance, the new substance is called a compound. For example, cane sugar is made up of three elements carbon, hydrogen and oxygen. The chemical forumula of cane sugar is $C_{12}H_{22}O_{11}$. A compound has properties that are diff erent from those of the elements from which it is made. Common salt, also known as sodium chloride, is a compound. It is added to give taste to our food. It is a compound made up of a metal, sodium, that reacts violently with water and a non-metal, chlorine.

Compounds of phosphorous, nitrogen and potassium are used in fertilizers. Silicon compounds are of immense importance in the computer industry. Compounds of fluorine are used in our toothpastes as they strengthen our teeth.

Element	Compound
Made up of only one kind of atom.	Made up of more than one kind of atom.
The smallest particle that retains all its properties is the atom.	The smallest particle that retains all its properties is the molecule.
Cannot be broken down into simpler substances.	Can be broken down into elements by chemical methods.

Mixtures

A mixture is an impure substance. It contains two or more kinds of elements or compounds or both physically mixed together in any ratio.For example, tap water is a mixture of water and some dissolved salts. Lemonade is a mixture of lemon juice, sugar and water. Air is a mixture of nitrogen, oxygen, carbon dioxide, water vapour and other gases. Soil is a mixture of clay, sand and various salts. Milk, ice cream, rock salt, tea, smoke, wood, sea water, blood, tooth paste and paint are some other examples of mixtures. Alloys are mixtures of metals.

Differences Between Compound and Mixture

There are differences between compounds and mixtures. This can be shown by the following activity.

The black compound is Iron (II) sulphide.

Iron + sulphur $\xrightarrow{heat}$ Iron sulphide

The Iron sulphide formed has totally different properties to the mixture of iron and sulphur as tabulated below:

Substance	Appearance	Effect of magnet
Iron (element)	Dark grey powder	Attracted to it
Sulphur (element)	Yellow powder	None
Iron + Sulphur (Mixture)	Dirty yellow powder	Iron powder attracted to it
Iron sulphide (compound)	Black solid	No effect

From the above experiment, we can summarise the major differences between mixtures and compounds:

Blood is not a pure substance. It is a mixture of various components such as platelets, red and white blood corpuscles and plasma.

Mixture	Compound
It contains two or more substances	It is a single Substance
The constituent may be present in any Proportion	The constituents are present in definite proportions.
They show the properties of their constituents.	They do not show the properties of the constituent elements.
The components may be separated easily by physical methods.	The constituents can only be separated by one or more chemical reactions.

Types of Mixtures

Most of the substances that we use in our daily life are mixtures. In some we will be able to see the components with our naked eyes but in most others the different components are not visible. Based on this mixture can be classified as below.

Homogeneous and Heterogeneous mixture

A mixture in which the components cannot be seen separately is called a homogeneous mixture. It has a uniform composition and every part of the mixture has the same properties. Tap water, milk, air, ice cream, sugar syrup, ink, steel, bronze and salt solution (Figure 10.4a) are homogeneous mixtures. A mixture in which the components can be seen separately is called a heterogeneous mixture. It does not have a uniform composition and properties. Soil, a mixture of iodine and common salt, a mixture of sugar and sand, a mixture of oil and water, a mixture of sulphur and iron fi lings and a mixture of milk and cereals (Figure 10.4b) are heterogeneous mixture.

Separation of mixtures

Many mixtures contain useful substances mixed with unwanted material. In order to obtain these useful substances, chemists oft en have to separate them from the impurities. The choice of a particular method to separate components of a mixture will depend on the properties of the components of the mixture as well as their physical states (as shown in Table 10.3).

Sublimation

Certain solid substances when heated change directly from solid to gaseous state without attaining liquid state. The vapourswhen cooled give back the solid substance. This process is known as sublimation. Examples: Iodine, camphor, ammonium chloride etc., The powdered mixture of Ammonium chloride and sand is taken in a china dish and covered with a perforated asbestos sheet. An inverted funnel is placed over the asbestos sheet as shown in Figure 10.5. The open end of the stem of the funnel is closed using cotton wool and the china dish is heated. The pure vapours of the volatile solid pass through the holes in the asbestos sheet and condense on the inner sides of the funnel. The non-volatile impurities remain in the china dish.

Type of mixtures	**Mixtures**	**Methods of separation**
Heterogeneous	Solid and solid	Handpicking, sieving, winnowing, magnetic separation, sublimation.
	Insoluble solid and liquid	Sedimentation and decantation, loading, filtration, centrifugation
	Two immiscible liquids	Decantation, separating funnel
Homogeneous	Soluble solid and liquid	Evaporation, distillation, crystallisation
	Two miscible liquids	Fractional distillation
	Solution of two or more solids in a liquid	Chromatography

Centrifugation

Centrifugation is the process by which fine insoluble solids from a solid- liquid mixture can be separated in a machine called a centrifuge. A centrifuge rotates at a very high speed. On being rotated by centrifugal force, the heavier solid particles move down and the lighter liquid remains at the top. In milk diaries, centrifugation is used to separate cream from milk. In washing machines, this principle is used to squeeze out water from wet clothes. Centrifugation is also used in pathological laboratories to separate blood cells from a blood sample.

Solvent extraction

Two immiscible liquids can be separated by solvent extraction method. This method works on the principle of difference in solubility of two immiscible liquids in a suitable solvent. For example, mixture of water and oil can be separated using a separating funnel. Solvent extraction method is used in pharmaceutical and petroleum industries.

Solvent extraction is an old practice done for years. It is the main process in perfume development and it is also used to obtain dyes from various sources.

Simple distillation

Distillation is a process of obtaining pure liquid from a solution. It is actually a combination of evaporation and condensation i.e Distillation = Evaporation + Condensation In this method, a solution is heated in order to vapourise the liquid. The vapours of the liquid on cooling, condense into pure liquid. For example, sea water in many countries is converted into drinking water by distillation. This method is also used to separate two liquids whose boiling points differ more than 25 K.

Fractional distillation

To separate two or more miscible liquids which do not differ much in their boiling points (difference in boiling points is less than 25 K) fractional distillation is employed. Fractional distillation is used in petrochemical industry to obtain different fractions of petroleum, to separate the different gases from air, to distil alcohols etc.

Chromatography

Before we discuss the technique we will take a look at the difference between the two important terms: Absorption and Adsorption Adsorption is the process in which the particles of a substance is concentrated only at the surface of another substance. Absorption is the process in which the substance is uniformly distributed throughout the bulk of another substance. For example, when a chalk stick is dipped in ink, the surface retains the colour of the ink due to adsorption of coloured molecules while the solvent of the ink goes deeper into the stick due to absorption. Hence, on breaking the chalk stick, it is found to be white from inside. Chromatography is also a separation technique. It is used to separate different components of a mixture based on their different solubilities in the same solvent. There are several types of chromatographybased on the above basic principles. The simplest type is paper chromatography.

Paper chromatography

This method is used to separate the different coloured dyes in a sample of ink. A spot of the ink (e.g. black ink) is put on to a piece of chromatography paper. This paper is then set in a suitable solvent as shown in figure 10.10. The black ink separates into its constituent dyes. As the solvent moves up the paper, the dyes are carried with it and begin to separate. They separate because they have different solubility in the solvent and are adsorbed to different extents by the chromatography paper. The chromatogram shows that the black ink contains three dyes.

Solutions

A solution is a homogeneous mixture of two or more substances. In a solution, the component present in lesser amount by weight is called solute and the component present in larger amount by weight is called solvent. In short, a solution can be represented as follows: solute + solvent solution Example: salt + water salt solution

Types of solution

Based on the particle size of the substance, the solutions are divided into three types. Let us study them through an activity.

We can see that in the case of sugar we get a clear solution and the particles never settle down. This mixture is called as true solution. In the case of starch and water we get a cloudy mixture. This mixture is called as colloidial solution In the case of wheat flour mixed with water we get a very turbid mixture and fine particles slowly settle down at the bottom after some time. This mixture is called as suspension.

Colloidal Solutions

A colloidal solution is a heterogeneous system consisting of the dispersed phase and the dispersion medium. Dispersed phase or the dispersion medium can be a solid, or liquid or gas. There are eight different combinations possible (Table 10.4). The combination of gas in gas is not possible because gas in gas always forms a true solution. Brownian movement When colloidal solution are viewed under powerful microscope, it can be seen that colloidal particles are moving constantly and rapidly in zig-zag directions. The Brownian movement of particles is due to the unbalanced bombardment of the particles by the molecules of dispersion medium. Tyndall effect Tyndall (1869) observed that when a strong beam of light is focused on a colloidal solution the path of the beam becomes visible. This phenomenon is known as Tyndall effect and the illuminated path is called Tyndall cone. This phenomenon is not observed in case of true solution

S.no.	Dispersed Phase	Dispersion Medium	Name	Examples
1.	Solid	Solid	Solid	Alloys, gems, coloured glass
2.	Solid	Liquid	Sol	Paints, inks, egg white
3.	Solid	Gas	Aerosol	Smoke, dust
4.	Liquid	Solid	Gel	Curd, Cheese, jelly
5.	Liquid	Liquid	Emulsion	Milk, butter, oil in water
6.	Liquid	Gas	Aerosol	Mist, fog, clouds
7.	Gas	Solid	Solid foam	Cake, bread
8.	Gas	Liquid	Foam	Soap lather, Aerated water

Property	Suspension	Colloidal sol.	Solution
Particle	>100nm	1 to 100nm	<100nm
Filtration Separation	Possible	impossible	impossible
Setting of particles	Settle on their own	Settle on centrifugation	Do not settle
Appearance	Opaque	Translucent (or) Semi transparent	Transparent
Tyndall effect	Shows	Shows	Does not show
Diffusion of particles	Do not diffuse	Diffuse slowly	Diffuse rapidly
Brownian movement	May show	Shows	May or may not show
Nature	Heterogeneous	Heterogeneous	Homogeneous

Emulsions - a special kind of colloids

An emulsion is a colloid of two or more immiscible liquids where one liquid is dispersed in another liquid. This means one type of liquid particles get scattered in another liquid. In other words, an emulsion is a special type of mixture made by combining two liquids that normally don’t mix. The word emulsion comes from theLatin word meaning “to milk” (milk is one example of an emulsion of fat and water). The process of turning a liquid mixture into an emulsion is called emulsification. Milk, butter, cream, egg yolk, paints, cough syrups, facial creams, pesticides etc. are some common examples of emulsions.

Types of emulsions

The two liquids mixed can form different types of emulsions. For example, oil and water can form an oil in water emulsion (O/W -e.g. cream), where the oil droplets are dispersed in water, or they can form a water in oil emulsion (W/O -e.g. butter), with water dispersed in oil.

Emulsions find wide applications in food processing, pharmaceuticals, metallurgy and many other important industries.

Unit 11- Atomatic Structure

Introduction

Just as a small child wants to take a toy apart to find out what is inside, scientists have for long been curious about the internal structure of an atom. They wanted to find out what are the particles present inside an atom and how are these particles arranged in an atom. For explaining this many scientists proposed various atomic models. We have learnt Dalton's atomic theory and J.J. Thomson's model in class VIII. Now we will learn about sub-atomic particles and the other atomic models to explain how these particles are arranged within an atom.

Discovery of Nucleus

In 1911, Lord Rutherford, a scientist from New Zealand, performed his famousexperiment of bombarding a thin gold foil with very small positively charged particles called alpha(α) particles. He selected a gold foil because, he wanted as thin layer as possible and gold is the most malleable metal.

He observed that:

1. Most of the alpha particles passed straight through the foil.
2. Some alpha particles were slightly deflected from their straight path.
3. Very few alpha particles completely bounced back.

Later, Rutherford generalized these results of alpha particles scattering experiment and suggested a model of the atom that is known as Rutherford's Atomic model.

Rutherford's Atomic model

According to this model :

i. The atom contains large empty space.
ii. There is a positively charged mass at the centre of the atom, known as nucleus.
iii. The size of the nucleus of an atom is very small compared to the size of an atom.
iv. The electrons revolve around the nucleus in close circular paths called orbits.
v. An atom as a whole is electrically neutral, i.e., the number of protons and electrons in an atom are equal.

Rutherford's model of atomic structure is similar to the structure of the solar system. Justas in the solar system, the Sun is at the centre and the planets revolve around it, similarly in an atom the nucleus contains the main mass and the electrons revolve around it in orbits or shells.

Limitations in Rutherford's model

According to Electromagnetic theory, a moving electron should accelerate and continuously lose energy. Due to the loss of energy, path of electron may reduce and finally the electron should fall into the nucleus. If it happens so, atom becomes unstable. But atoms are stable. Thus, Rutherford's model failed to explain the stability of an atom.

Bohr's model of an atom

In 1913, Neils Bohr, a Danish physicist, explained the causes of the stability of the atom in a different manner. The main postulates are:

i. In atoms, the electron revolve around the nucleus in stationary circular paths called orbits or shells or energy levels.

ii. While revolving around the nucleus in an orbit, an electron neither loses nor gains energy.

iii. An electron in a shell can move to a higher or lower energy shell by absorbing or releasing a fixed amount of energy.

iv. The orbits or shells are represented by the letters K,L,M,N,… or the numbers, n= 1,2,3,4,…. The orbit closest to the nucleus is the K shell. It has the least amount of energy and the electrons present in it are called K electrons, and so on with the successive shells and their electrons. These orbits are associated with fixed amount of energy , so Bohr called them as energy level or energy shells.

Limitations of Bohr's model

One main limitation was that this model was applicable only to hydrogen and hydrogen like ions (example, He+, Li2+, Be3+, and so on). It could not be extended to multi electron nucleus.

Discovery of Neutrons

In 1932 James Chadwick observed when Beryllium was exposed to alpha particles, particles with about the same mass as protons were emitted.

Beryllium + alpha ray→ carbon + neutron

These emitted particles carried no electrical charges. They were called as neutrons. It is denoted by 0n1. The superscript 1 represents its mass and subscript 0 represents its electric charge.

Properties of Neutrons

1. This particle was not found to be deflected by any magnetic or electric field, proving that it is electrically neutral.

2. Its mass is equal to 1.676 × 10−24 g (1 amu).c

In 1920 Rutherford predicted the presence of another particle in the nucleus as neutral. James Chadwick, the inventor of neutron was student of Rutherford

Characteristics of Fundamental particles

The atom is built up of a number of sub- atomic particles. The three sub-atomic particles of great importance in understanding the structure of an atom are electrons, protons and neutrons, the properties of which are given in Table 11.1

Particle	Symbol	Charge (electronic units)	Mass (amu)	Mass (grams)
Electron	-1e0	-1	1\1837	9.1× 1028
Proton	$_1H^1$	+1	1	1.6 × 10^{-24}
Neutron	$_0n^1$	0	1	1.6 × 10^{-24}

There are two structural parts of an atom, thenucleus and the empty space in which there are imaginary paths called orbits.

Nucleus: The protons and neutrons [collectively called nucleons]are found in the nucleus of an atom.
Orbits: Orbit is defined as the path, by which electrons revolve around he nucleus.

Besides the fundamental particles like protons, electrons and neutrons some more particles are discovered in the nucleus of an atom. They include mesons, neutrino, antineutrino, positrons etc.

Atomic number and Mass number

Only hydrogen atoms have one proton in their nuclei. Only helium atoms have two protons. Indeed, only gold atoms have 79 protons. This shows that the number of protons in the nucleus of an atom decides which element it is. This very important number is known as the atomic number (proton number, given the symbol Z) of an atom.

Atomic number(Z) = Number of protons = Number of electrons

Protons alone do not make up all of the mass of an atom. The neutrons in the nucleus also contribute to the total mass. The mass of the electron can be regarded as so small that it can be ignored. As a proton and a neutron have the same mass, the mass of a particular atom depends on the total number of protons and neutrons present. This number is called the mass number (or nucleon number, given the symbol A) of an atom.

Mass number = Number of protons + Number of neutrons

For any element, the atomic numbers are shown as subscripts and mass number are shown as superscripts.

Here 7 is its atomic number and 14 is its mass number.

The difference between the mass number of an element and its atomic number gives the number of neutrons present in one atom of the element.

Number of neutrons (n) = Mass number (A) – Atomic number (z)

For example, the number of neutrons in one

atom of $^{24}_{12}$ Mg is

Number of neutrons (n) =24 - 12 = 12
(A) (Z)

Atomic number is designated as Z why?
Z stands for Zahl, which means NUMBER in German.
Z can be called Atomzahl or atomic number
A is the symbol recommened in the ACS style guide instead of M (massenzahl in German).

Electronic configuration of atoms

You already know that electrons occupy different energy levels called orbits or shells. The distribution of electrons in different shells is called electronic configuration. This distribution of electrons is governed by certain rules or conditions, known as Bohr and Bury Rules of electronic configuration.

Rule 1: The maximum number of electrons that can be accommodated in a shell is equal to 2n2 where 'n' is the serial number of the shell from the nucleus.

Shell	Value of (n)	Maximum number of electrons (2n2)
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

Rule 2: Shells are filled in a stepwise manner in the increasing order of energy.

Rule 3: The outermost shell of an atom cannot have more than 8 electrons , even if it has capacity to accomodate more electrons.

For example, electronic arrangement in calcium having 20 electrons is,

KL M N
2 8 8 2

The forces between the protons and the neutrons in the nucleus are of special kind called Yukawa forces. This strong force is more powerful than gravity.

Geometric Representation of atomic structure of elements

Knowing the mass number and atomic number of an element we can represent atomic structure.

Example:
Geometric Representation of oxygen atom 816 O
Mass number A = 16
Atomic number Z = 8
Number of neutrons = A − Z = 16 − 8 = 8
Number of protons = 8
Number of electron = 8
Electronic configuration = 2, 6

Atoms are so tiny their mass number cannot be expressed in grams but expressed in amu (atomic mass unit). New unit is U Size of an atom can be measured in nano metre (1 nm = 10−9 m)Even though atom is an invisible tiny particle now-a-days atoms can be viewed through SEM that is Scanning Electron Microscope.

Valence electrons

In the above example, we can see that there are six electrons in the outermost shell of oxygen atom. These six electrons are called as valence electrons.

The outermost shell of an atom is called valence shell and the electrons present in the valence shell are known as valence electrons. The chemical properties of elements are decided by these valence electrons, since they are the ones that take part in chemical reaction.

The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties. Elements, which have valence electrons 1 or 2 or 3 (except Hydrogen) are metals.

Elements with 4 to 7 electrons in their valence shell are non-metals.

Valency

Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a chemical reaction. Valency of the elements having valence electrons 1, 2, 3, 4 is 1, 2, 3, 4 respectively.

Valency of an element with 5, 6 and 7 valence electrons is 3, 2 and 1 (8–valence electrons) respectively. Because 8 is the number of electrons required by an element to attain stable electronic configuration. Elements having completely filled outermost shell show Zero valency.

For example: The electronic configuration of Neon is 2,8 (completely filled). So valency is 0.

Elements	**Symbol**	**Atomic No (Z) No. of protons / No. of electrons**	**Mass No. (A) No. of protons + neutrons**	**No. of neutrons (A – Z)**	**Electronic configuration**				**Valency**	**Metal/ non-metal / 1st or noble gas**
					1st or K-shell	**2nd or L-shell**	**3rd or M-shell**	**4th or N-shell**		
Hydrogen	H	1	1	-	1				1	Non-metal
Helium	He	2	4	2	2				0	Noble gas
Lithium	Li	3	7	4	2	1			1	Metal
Beryllium	Be	4	9	5	2	2			2	Metal
Boron	B	5	11	6	2	3			3	Non-metal
Carbon	C	6	12	6	2	4			4	Non-metal
Nitrogen	N	7	14	7	2	5			3	Non-metal
Oxygen	O	8	16	8	2	6			2	Non-metal
Fluorine	F	9	19	10	2	7			1	Non-metal
Neon	Ne	10	20	10	2	8			0	Noble gas
Sodium	Na	11	23	12	2	8	1		1	Metal
Magnesium	Mg	12	24	12	2	8	2		2	Metal
Aluminium	Al	13	27	14	2	8	3		3	Metal
Silicon	Si	14	28	14	2	8	4		4	Non-metal
Phosphorus	P	15	31	16	2	8	5		3	Non-metal
Sulphur	S	16	32	16	2	8	6		2	Non-metal
Chlorine	Ci	17	35,37	18,20	2	8	7		1	Non-metal

Argon	Ar	18	40	22	2	8	8		0	Non-metal
Potassium	K	19	39	20	2	8	8	1	1	Metal
Calcium	Ca	20	40	20	2	8	8	2	2	Metal

Isotopes, Isobars and Isotones

Isotopes

In nature, a number of atoms of some elements have been identified, which have the same atomic number but different mass numbers. For example, take the case of hydrogen atom, it has three atomic species as shown below:

The atomic number of all the three isotopes is 1, but the mass number is 1, 2 and 3, respectively. Other such examples are:

i). Carbon, $^{12}_{6}C$ $^{13}_{6}C$ ii) Chlorine $^{35}_{17}Cl$ $^{37}_{17}Cl$

On the basis of these examples, isotopes are defined as the atoms of the same element, having the same atomic number but different mass numbers. There are two types of isotopes: those which are stable and those which are unstable. The isotopes which are unstable, as a result of the extra neutrons in their nuclei are radioactive and are called radioisotopes.
For example, uranium-235, which is a source of nuclear reactors, and cobalt-60, which is used in radiotherapy treatment are both radioisotopes.

Isobars
Let us consider two elements – calcium (atomic number 20), and argon (atomic number 18).

They have (Fig. 11.10) different number of protons and electrons. But, the mass number of both these elements is 40. It follows that the total number of nucleons in both the atoms are the same. They are called isobars. Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.

No of neutrons in boron = 11 – 5 = 6
No of neutrons in carbon = 12 – 6 = 6

The above pair of elements Boron and Carbon has the same number of neutrons but different number of protons and hence different atomic numbers. Atoms of different elements with different atomic numbers and different mass numbers, but with same number of neutrons are called isotones

Laws of chemical combination

In the seventeenth century, scientists had been trying to find out methods for converting one substance into another. During their studies of chemical changes, they made certain generalisations. These generalisations are known as laws of chemical combination. These are :

Law of conservation of mass
Law of constant proportions
Law of multiple proportions
Law of reciprocal proportions
Gay Lussac's law of gaseous volumes

Out of these five laws you have already learnt the first two laws in class VIII. Let us see the next three laws in detail in this chapter.

Law of multiple proportions

This law was proposed by John Dalton in 1804. It states that, "When two elements A and B combine together to form more than one compound, then masses of A which separately combines with a fixed mass of B are in simple ratio".

To illustrate the law let us consider the following example.

Carbon combines with oxygen to form two different oxides, carbon monoxide(CO) and carbon dioxide (CO2). The ratio of masses of oxygen in CO and CO2 for fixed mass of carbon is 1: 2.

	Mass of carbon (g)	**Mass of oxygen (g)**	**Ratio of O in CO to O in CO_2**
CO	12	16	1:2
CO_2	12	32	

Let us take one more example, Sulphur combines with oxygen to form sulphur dioxide and sulphur trioxide. The ratio of masses of oxygen in SO2 and SO3 for fixed mass of Sulphur is 2:3.

Law of Reciprocal Proportions

The law of reciprocal proportions was proposed by Jeremias Ritcher in 1792.
It states that, "If two different elements combine separately with the same weight of a third element, the ratios of the masses in which they do so are either the same or a simple multiple of the mass ratio in which they combine."

Consider the three elements hydrogen, oxygen and water as shown below:

Here, hydrogen and oxygen combine separately with the same weight of carbon to form methane (CH_4) and carbon dioxide (CO_2)

Compounds	Combining elements		Combining weights	
CH_4	C	H	12	4
CO_2	C	O	12	32

Ratio of different mass of hydrogen (4g) and oxygen (32g) that combines with same mass of carbon	4:32 (OR) 1:8

Now, hydrogen and oxygen combine to form water(H2O).

Ratio of mass of hydrogen to oxygen = 2:16 (or) 1:8 ---(2)

From 1 and 2, the ratio is the same as that of the first obtained. Thus, the law of reciprocal proportion is illustrated.

Gay Lussac's Law of Combining Volumes

According to Gay Lussac's Law, Whenever gases react together, the volumes of the reacting gases as well as the products bear a simple whole number ratio, provided all the volumes are measured under similar conditions of temperature and pressure.

This law may be illustrated by the following example.
It has been experimentally observed that two volumes of hydrogen reacts with one volume of oxygen to form two volumes of water as shown in the figure 11.12.
The ratio of volume which gases bears is 2:1:2 which is a simple whole number ratio.

Quantum Numbers

When you specify the location of a building, you usually list which country it is in, which state and city it is in that country.

Just like we have four ways of defining the location of a building (country, state, city, and street address), we have four ways of defining the properties of an electron, i.e.four quantum numbers.

Thus, the numbers which designate and distinguish various atomic orbitals and electrons present in an atom are called quantum numbers.
Four types of Quantum number are as follows:

Quantum Number	**Symbol**	**Information Conveyed**

Principal quantum number	n	Main energy level
Azimuthal quantum number	l	Sub shell/ shape of orbital
Magnetic quantum number	m	Orientation of orbitals
Spin quantum number	s	Spin of the electron

You will learn more details about this in higher classes.

Unit – 12 – Periodic classification of Element

Introduction

We live in the world of substances with great diversity. Substances are formed by the combination of various elements. All the elements are unique in their nature and property. To categorize these elements according to their properties, scientists started to look for a way. In 1800, there were only 31 known elements. By 1865, their number became 63. Now 118 elements have been discovered. As different elements were being discovered, scientists gathered more and more information about the properties of these elements. They found it difficult to organize all that was known about the elements. They started looking for some pattern in their properties, on the basis of which they could study such a large number of elements with ease. Let us discuss the concepts of classification of elements proposed by various scientists from early to modern period.

Dobereiner's Triads

In 1817, Johann Wolfgang Dobereiner, a German chemist, suggested a method of grouping elements based on their relative atomic masses. He arranged the elements into groups containing three elements each. He called these groups as 'triads' (tri – three).

Dobereiner showed that when the three elements in a triad are arranged in the ascending order of their atomic masses, the atomic mass of the middle element is nearly the same as average of atomic masses of other two elements. This statement is called the Dobereiner's law of triads. Table 12.1 shows the law of triads proposed by Dobereiner.

Example: In the triad group (1), arithmetic mean of atomic masses of 1st and 3rd elements,

Triad Group (1)		**Triad Group (2)**		**Triad Group (3)**	
Element	Atomic Mass	Element	Atomic Mass	Element	Atomic Mass
Li	6.9	Cl	35.5	Ca	40.1
Na	23	Br	79.9	Sr	87.6
K	39.1	I	126.9	Ba	137.3

(6.9 + 39.1)/2 = 23. So the atomic mass of Na (middle element) is 23.

Limitations:

- Dobereiner could identify only three triads from the elements known at that time and all elements could not be classified in the form of triads.
- The law was not applicable to elements having very low and very high atomic mass.

Newlands' Law of Octaves

In 1866, John Newlands arranged 56 known elements in the increasing order of their atomic mass. He observed that every eighth element had properties similar to those of the first element like the eighth note in an octave of music is similar to the first. This arrangement was known as 'law of octaves'.

The octave of Indian music system is sa, re, ga, ma, pa, da, ni, sa. The first and last notes of this octave are same i.e. sa. Likewise, in the Newlands' table of octaves, the element 'F' is eighth from the element 'H', thus they have similar properties.

Limitations:

- There are instances of two elements being fitted into the same slot, e.g. cobalt and nickel
- Some elements, totally dissimilar in their properties, were fitted into the same group. (Arrangement of Co, Ni, Pd, Pt and Ir in the row of halogens)
- The law of octaves was not valid for elements that had atomic masses higher than that of calcium.
- Newlands' table was restricted to only 56 elements and did not leave any room for new elements.
- Discovery of inert gases (Neon. Argon….) at later stage made the 9th element similar to the first one. Eg: Neon between Fluorine and Sodium.

Mendeleev's Periodic Table

In 1869, Russian chemist, Dmitri Mendeleev observed that the elements of similar properties repeat at regular intervals when the elements are arranged in the order of their atomic masses. Based on this, he proposed the law of periodicity which states that "the physical and chemical properties of elements are the periodic functions of their atomic masses". He arranged 56 elements known at that time according to his law of periodicity. This was best known as the short form of periodic table.

(a) Features of Mendeleev's Periodic Table:

- It has eight vertical columns called 'groups' and seven horizontal rows called 'period'.
- Each group has two subgroups 'A' and 'B'. All the elements appearing in a group were found to have similar properties.
- For the first time, elements were comprehensively classified in such a way that elements of similar properties were placed in the same group.

No.	No.	No.	No.	No.	No.	No.	No.

H	1	F	8	Cl	15	CO& Ni	22	Br	29	Pd	36	I	42	Pt&Ir	50
Li	2	Na	9	k	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce& La	33	U	40	Ta	46	Ti	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Di & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro & Ru	35	To	43	Au	49	Th	56

- It was noticed that certain elements could not be placed in their proper groups in this manner. The reason for this was wrongly determined atomic masses. Consequently those wrong atomic masses were corrected. Eg: The atomic mass of beryllium was known to be 14. Mendeleev reassessed it as 9 and assigned beryllium a proper place.
- Columns were left vacant for elements which were not known at that time and their properties also were predicted. This gave motivation to experiment in Chemistry. Eg: Mendeleev gave names Eka Aluminium and Eka Silicon to those elements which were to be placed below Aluminium and Silicon respectively in the periodic table and predicted their properties. The discovery of Germanium later on, during his life time, proved him correct.

(**b) Limitations**:

Elements with large difference in properties were included in the same group. Eg: Hard metals like copper (Cu) and silver (Ag) were included along with soft metals like sodium (Na) and potassium (K).

- No proper position could be given to the element hydrogen. Non-metallic hydrogen was placed along with metals like lithium (Li), sodium (Na) and potassium (K).
- The increasing order of atomic mass was not strictly followed throughout. Eg. Co & Ni, Te & I.
- No place for isotopes in the periodic table.
-

Property	**Mendeleev's prediction (1871**)	**Actual property (1886**)
Atomic Mass	About 72	72.59
Specific Gravity	5.5	5.47
Colour	Dark grey	Dark grey
Formula of Oxide	EsO_2	GeO_2
Nature of Chloride	$EsCl_4$	$GeCl_4$

Modern Periodic Table

In 1913, the English Physicist Henry Moseley, through his X-ray diffraction experiments, proved that the properties of elements depend on the atomic number and not on the atomic mass. Consequently, the modern periodic table was prepared by arranging elements in the increasing order of their atomic number.

This modern periodic table is the extension of the original Mendeleev's periodic table and known as the long form of periodic table.

Modern Periodic Law

Atomic number of an element (Z) indicates the number of protons (positive charge) or the number of electrons (negative charge). The physical and chemical properties of elements depend not only on the number of protons but also on the number of electrons and their arrangements (electronic configuration) in atoms. Hence, the modern periodic law can be stated as follows: "The chemical and physical properties of elements are periodic functions of their atomic numbers". Based on the modern periodic law, the modern periodic table is derived.

Features of Modern Periodic Table

- All the elements are arranged in the increasing order of their atomic number.
- The horizontal rows are called periods. There are seven periods in the periodic table.
- The elements are placed in periods based on the number of shells in their atoms.
- Vertical columns in the periodic table starting from top to bottom are called groups. There are 18 groups in the periodic table.
- Based on the physical and chemical properties of elements, they are grouped into various families.

Group	Families
1	Alkali metals
2	Alkaline earth metals
3 to 12	Transition metals
13	Boron Family
14	Carbon Family
15	Nitrogen Family
16	Oxygen Family (or) Chalcogen Family
17	Halogens
18	Noble gases

Classification of elements into blocks

We know that the electrons in an atom are accommodated in shells around the nucleus. Each shell consists of one or more subshells in which the electrons are distributed in certainmanner. These subshells are designated as s, p, d, and f. Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks namely s, p, d and f blocks.

(1) s-Block Elements: It includes group 1 (alkali metals) and group 2 (alkaline earth metals) elements. They are also called as representative elements. The elements of group 1 (except hydrogen) are metals. They react with water to form solutions that change the colour of a vegetable dye from red to blue. These solutions are said to be highly alkaline or basic. Hence they are called alkali metals.

The elements of group 2 are also metals. They combine with oxygen to form oxides, formerly called 'earths', and these oxides produce alkaline solutions when they are dissolved in water. Hence, these elements are called alkaline earth metals.

(2) p-Block Elements: These elements are in group 13 to 18 in the periodic table. They include boron, carbon, nitrogen, oxygen, fluorine families in addition to noble gases (Except helium). They are also called as representative elements. The p-block is home to the biggest variety of elements and is the only block that contains all three types of elements: metals, nonmetals, and metalloids.

(3) d-Block Elements: It includes group 3 to group 12 elements. They are found in the centre of the periodic table. Their properties are intermediate to that of s block and p block elements and so they are called transition elements.

(4) f – Block Elements: It includes 14 elements after (Lanthanum) La (57), called Lanthanoides and 14 elements after (Actinium) Ac (89), called Actinoides. They are placed at the bottom of the periodic table. They are also called as inner Transition elements.

Advantages of the Modern Periodic Table

- The table is based on a more fundamental property i.e., atomic number.
- It correlates the position of the element with its electronic configuration more clearly.
- The completion of each period is more logical. In a period, as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached.
- It is easy to remember and reproduce.
- Each group is an independent group and the idea of subgroups has been discarded.
- One position for all isotopes of an element is justified, since the isotopes have the same atomic number.
- The position of the eighth group (in Mendeleev‘s table) is also justified in this table. All transition elements have been brought in the middle as the properties of transition elements are intermediate between left portion and right portion elements of the periodic table.
- The table completely separates metals from nonmetals. The nonmetals are present in upper right corners of the periodic table.

- The positions of certain elements which were earlier misfit (interchanged) in the Mendeleev's periodic table are now justified because it is based on atomic number of the elements.
- Justification has been offered for placing lanthanides and actinides at the bottom of the periodic table.

Position of hydrogen in the periodic table

Hydrogen is the lightest, smallest and first element of the periodic table. Its electronic configuration (1s1) is the simplest of all the elements. It occupies a unique position in the periodic table. It behaves like alkali metals as well as halogens in its properties.

Shell number (Symbol)	**1 (K)**	**2 (L)**		**3 (M)**			**4 (N)**			
Sub shell	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f
Maximum number of electrons in each sub shell	2	2	6	2	6	10	2	6	14	14
Maximum number of electrons in each shell	2	8		18			32			

In the periodic table, it is placed at the top of the alkali metals.

(i) Hydrogen can lose its only electron to form a hydrogen ion (H+) like alkali metals.

(ii) It can also gain one electron to form the hydride ion (H-) like halogens.

(iii) Alkali metals are solids while hydrogen is a gas.

Hence the position of hydrogen in the modern periodic table is still under debate as the properties of hydrogen are unique.

Position of Rare Gases

The elements Helium, Neon, Argon, Krypton, Xenon and Radon of group 18 in the periodic table are called as Noble gases or Rare gases. They are monoatomic gases and do not react with other substances easily, due to completely filled subshells. Hence they are called as inert gases. They are found in very small quantities and hence they are called as rare gases.

Metals, Non-Metals and Metalloids

Metals

Metals are typically hard, shiny, malleable (can be made as sheet), fusible and ductile (can be drawn into wire) with good electrical and thermal conductivity. Except mercury, most of the metals are solids at room temperature. Metals occupy larger area in the periodic table and are categorized as:

i) Alkali metals. e.g. Lithium to Francium (top to bottom)

(ii) Alkaline earth metals. e.g: Beryllium to Radium (top to bottom)

(iii) Transition Metals. Group III B to II A
(iv) P-Block metals. e.g: Al, Ga, In, Tl, Sn, Pb and Bi.

Non-metals

A non-metal is an element that does not have the characters like hardness, shiny, malleable, suitable and ductile. In other words, a non-metal is an element that does not have the properties of metal. e.g. All non metals are arranged in P-Block only. P-Block non metals: C, N O, P, S, Se, Halogen (F, Cl, Br and I) and inert gases (Heyo Rn).

Metalloids

Elements which have the properties of both metals and non-metals are called as metalloids. (eg) Boron, Arsenic.

Alloys

During 3500 BC(BCE), people used an alloy named ‘bronze’. The idea of making an alloy was quite old. The majority of the metallic substances used today are alloys. Alloys are mixtures of two or more metals and are formed by mixing molten metals thoroughly. Rarely non - metals are also mixed with metals to produce alloys.

It is generally found that alloying produces a metallic substance that has more useful properties than the original pure metals from which it is made. For example, the alloy brass is made from copper and zinc.

Advantages of alloys

- Alloys do not get corroded or get corroded to very less extent.
- They are harder and stronger than pure metals (Example: Gold is mixed with copper and it is harder than pure gold).
- They have less conductance than pure metals (Example: Copper is good conductor of heat and electricity whereas brass and bronze are not good conductors).
- Some alloys have lower melting point than pure metals (Example: Solder is an alloy of lead and tin which has lower melting point than each of the metals).
- When metal is alloyed with mercury, it is called amalgam.

Unit – 13 – Chemical Bonding

Introduction

We already know that atoms are the building blocks of matter. Under normal conditions no atom exists as an independent (single) entity in nature, except noble gases. However, a group of atoms is found to exist together as one species. Such a group of atoms is called molecule. Obviously there should be a force to keep the constituent atoms together as the thread holds the flowers together in a garland. This attractive force which holds the atoms together is called a bond.

A chemical bond may be defined as the force of attraction between the atoms that binds them together as a unit called molecule In this unit, we will study about Kossel- Lewis approach to chemical bonds, Lewis dot structure and different types of reactions.

Kossel – Lewis approach to chemical bonds

Octet rule

Atoms of various elements combine together in different ways to form chemical compounds. This phenomenon raised many questions.

- Why do atoms combine?
- How do atoms combine?
- Why do certain atoms combine while others do not?

To answer such questions different theories have been put forth from time to time and one of such theories which explained the formation of molecules is Kossel-Lewis theory.

Kossel and Lewis gave successful explanation based upon the concept of electronic configuration of noble gases about why atoms combine to form molecules. Atoms of noble gases have little or no tendency to combine with each other or with atoms of other elements. This means that these atoms must be having stable electronic configurations. The electronic configurations of noble gases are given in Table 13.1.

Name of the element	Atomic number	Shell electronic configuration
Helium (He)	2	2
Neon (Ne)	10	2,8
Argon (Ar)	18	2,8,8
Krypton (Kr)	36	2,8,18,8
Xenon (Xe)	54	2,8,18,18,8
Radon (Rn)	86	2,8,18,32,18,8

Except Helium, all other noble gases have eight electrons in their valence shell. Even helium has its valence shell completely filled and hence no more electrons can be added. Thus, by having stable valence shell electronic configuration, the noble gas atoms neither have any tendency to gain nor to lose electrons and hence their valency is zero. They are so inert that they even do not form diatomic molecules and exist as monoatomic gaseous atoms.

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Based on the noble gas electronic configuration, Kossel and Lewis proposed a theory in 1916 to explain chemical combination between atoms and this theory is known as 'Electronic theory of valence' or Octet rule. According to this, atoms of all elements, other than inert gases, combine to form molecules because they have incomplete valence shell and tend to attain a stable electronic configuration similar to noble gases. Atoms can combine either by transfer of valence electrons from one atom to another or by sharing of valence electrons in order to achieve the stable outer shell of eight electrons.

The tendency of atoms to have eight electrons in the valence shell is known as the 'Octet rule' or the 'Rule of eight'

For example, sodium with atomic number 11 will readily loose one electron to attain neon's stable electronic configuration (Figure 13.3). Similarly, chlorine has electronic configuration 2,8,7. To get the nearest noble gas (i.e. argon) configuration, it need one more electron. So, chlorine readily gains one electron

from other atom and obtains stable electronic configuration (Figure 13.4). Thus elements tend to have stable valence shell (eight electrons) either by losing or gaining electrons.

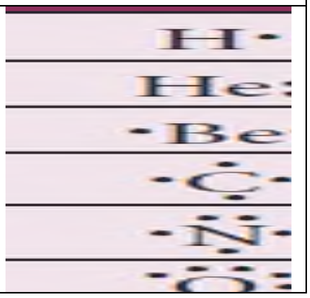
Which atoms tend to lose electrons? Which are tend to gain electrons? Atoms that have 1, 2, 3 electrons in their valence shell tend to lose electrons whereas atoms having 5, 6, 7 valence electrons tend to gain electrons.

Element	**Atomic number**	**Electron distribution**	**Valence electrons**
Boron	5	2,3	3
Nitrogen	7	2, 5	5
Oxygen	8	2, 6	6
Sodium	11	2, 8 ,1	1

Lewis dot structure

When atoms combine to form compounds, their valence electrons involve in bonding. Therefore, it is helpful to have a method to depict the valence electrons in the atoms. This can be done using Lewis dot symbol method. The Lewis dot structure or electron dot symbol for an atom consists of the symbol of the element surrounded by dots representing the electrons of the valence shell of the atom. The unpaired electron in the valence shell is represented by a single dot whereas the paired electrons are represented by a pair of dots.

Symbols other than dots, like crosses or circles may be used to differentiate the electrons of the different atoms in the molecule.

Element	Atomic number	Electron distribution	Valence electrons	Lewis dot Structure
Hydrogen	1	1	1	
Helium	2	2	2	
Beryllium	4	2, 2	2	
Carbon	6	2, 4	4	
Nitrogen	7	2,5	5	
Oxygen	8	2, 6	6	

Types of chemical bond

All the elements have different valence shell electronic configuration. So the way in which they combine to form compounds also differs. Hence, there are different types of chemical bonding possible between atoms which make the molecules. Depending on the type of bond, they show different characteristics or properties. Such types of bonding, that are considered to exist in molecules, are categorized as shown Figure 13.5. Among these, let us learn about the Ionic bond, Covalent bond and Coordinate bond in this chapter and other types of bond in the higher classes.

Ionic (or) Electrovalent bond

An ionic bond is a chemical bond formed by the electrostatic attraction betweenpositive and negative ions. The bond is formed between two atoms when one or more electrons are transferred from the valence shell of one atom to the valence shell of the other atom. The atom that loses electrons will form a cation (positive ion) and the atom that gains electrons will form an anion (negative ion). These oppositely charged ions come closer to each other due to electrostatic force of attraction and thus form an ionic bond. As the bond is between the ions, it is called Ionic bond and the attractive forces being electrostatic, the bond is also called Electrostatic bond. Since the valence concept has been explained in terms of electrons, it is also called as Electrovalent bond.

Formation of ionic bond

Let us consider two atoms A and B. Let atom A has one electron in excess and atom B has one electron lesser than the stable octet electronic configuration. If atom A transfer one electron to atom B, then both the atoms will acquire stable octet electronic configuration. As the result of this electron transfer, atom A will become positive ion (cation) and atom B will become negative ion (anion). These oppositely charged ions are held together by electrostatic force of attraction which is called Ionic bond or Electrovalent bond.

In general, ionic bond is formed between a metal and non-metal. The compounds containing ionic bonds are called ionic compounds. Elements of Group 1 and 2 in periodic table, i.e. alkali and alkaline earth metals form ionic compounds when they react with non-metals.

Illustration 1 – Formation of ionic bonding in sodium chloride (NaCl)

The atomic number of Sodium is 11 and its electronic configuration is 2, 8, 1. It has one electron excess to the nearest stable electronic configuration of a noble gas - Neon. So sodium has a tendency to lose one electron from its outermost shell and acquire a stable electronic configuration forming sodium cation (Na+).

The atomic number of chlorine is 17 and its electronic configuration is 2, 8, 7. It has one electron less to the nearest stable electronic configuration of a noble gas - Argon. So chlorine has a tendency to gain one electron to acquire a stable electronic configuration forming chloride anion (Cl^-).

When an atom of sodium combines with an atom of chlorine, an electron is transferred from sodium atom to chlorine atom forming sodium chloride molecule thus both the atoms attain stable octet electronic configuration.

Illustration 2 – Formation of ionic bond in magnesium chloride (MgCl2)

The atomic number of magnesium is 12 and the electronic configuration is 2, 8, 2. It has two electron excess to the nearest stable electronic configuration of a noble gas - Neon. So magnesium has a tendency to lose two electrons from its outermost shell and acquire a stable electronic configuration forming magnesium cation (Mg2+).

As explained earlier two chlorine atoms will gain two electrons lost by the magnesium atom forming magnesium chloride molecule (MgCl2) as shown in Figure 13.7.

Characteristics of Ionic compounds

The nature of bonding between the atoms of a molecule is the primary factor that determines the properties of compounds. By this way, in ionic compounds the atoms are held together by a strong electrostatic force that makes the compounds to have its characteristic features as follows:

Physical state: These compounds are formed because of the strong electrostatic force between cations and anions which are arranged in a well-defined geometrical pattern. Thus ionic compounds are crystalline solids at room temperature.

Electrical conductivity: Ionic compounds are crystalline solids and so their ions are tightly held together. The ions, therefore, cannot move freely, and they do not conduct electricity in solid state. However, in molten state their aqueous solutions conduct electricity.

Melting point: The strong electrostatic force between the cations and anions hold the ions tightly together, so very high energy is required to separate them. Hence ionic compounds have high melting and boiling points.

Solubility: Ionic compounds are soluble in polar solvents like water. They are insoluble in non-polar solvents like benzene (C_6H_6), carbon tetra chloride (CCl_4).
Density, hardness and brittleness: Ionic compounds have high density and they are quite hard because of the strong electrostatic force between the ions. But they are highly brittle.

Reactions: Ionic compounds undergo ionic reactions which are practically rapid and instantaneous.

Covalent bond

Atoms can combine with each other by sharing the unpaired electrons in their outermost shell. Each of the two combining atoms contributes one electron to the electron pair which is needed for the bond formation and has equal claim on the shared electron pair. According to Lewis concept, when two atoms form a covalent bond between them, each of the atoms attains the stable electronic configuration of the nearest noble gas. Since the covalent bond is formed because of the sharing of electrons which become common to both the atoms, it is also called as atomic bond.

Formation of Covalent bond

Let us consider two atoms A and B. Let atom A has one valence electron and atom B has seven valence electrons. As these atoms approach nearer to each other, each atom contributes one electron and the resulting electron pair fills the outer shell of both the atoms. Thus both the atoms acquire a completely filled valence shell electronic configuration which leads to stability.

Illustration 1 – Formation of hydrogen molecule (H_2)

Hydrogen molecule is formed by two hydrogen atoms. While forming the molecule, both hydrogen atoms contribute one electron each to the shared pair and both atoms acquire stable and completely filled electronic configuration (resembly He).

Illustration 2 – Formation of chlorine molecule (Cl_2)

Chlorine molecule is formed by two chlorine atoms. Each chlorine atom has seven valence electrons (2,8,7). These two atoms achieve a stable completely filled electronic configuration (octet) by sharing a pair of electrons.

Illustration 3 – Formation of methane molecule (CH_4)

Methane molecule is formed by the combination of one carbon and four hydrogen atoms. The carbon atom has four valence electrons (2, 4). These four electrons are shared with four atoms of hydrogen to achieve a stable electronic configuration (octet) by sharing a pair of electrons.

Illustration 4 – Formation of oxygen molecule (O2)

Oxygen molecule is formed by two oxygen atoms. Each oxygen atom has six valence electrons (2, 6). These two atoms achieve a stable electronic configuration (octet) by sharing two pair of electrons. Hence a double bond is formed in between the two atoms.

Illustration 5 – Formation of nitrogen molecule (N2)

Nitrogen molecule is formed by two nitrogen atoms. Each nitrogen atom has five valence electrons (2, 5). These two atoms achieve a stable completely filled electronic configuration (octet) by sharing three pair of electrons. Hence a triple bond is formed in between the two atoms.

Characteristics of Covalent compounds

As said earlier, the properties of compounds depend on the nature of bonding between their constituent atoms. So the compounds containing covalent bonds possess different characteristics when compared to ionic compounds.

Physical state: Depending on force of attraction between covalent molecule the bond may be weaker or stronger. Thus covalent compounds exists in gaseous, liquid and solid form. Eg. Oxygen-gas; Water-liquid: Diamond-solid.
Electrical conductivity: Covalent compounds do not contain charged particles (ions), so they are bad conductors of electricity.

Melting point: Except few covalent compounds (Diamond, Silicon carbide), they have relatively low melting points compared to ionic compounds.

Solubility: Covalent compounds are readily soluble in non-polar solvents like benzene (C6H6), carbon tetra chloride (CCl4). They are insoluble in polar solvents like water.
Hardness and brittleness: Covalent compounds are neither hard nor brittle. But they are soft and waxy.
Reactions: Covalent compounds undergo molecular reactions in solutions and these reactions are slow.

Fajan's Rule:

As we know, a metal combines with a non-metal through ionic bond. The compounds so formed are called ionic compounds. A compound is said to be ionic when the charge of the cation and anion are completely separated. But in 1923, Kazimierz Fajans found, through his X-Ray crystallographic studies, that some of the ionic compounds show covalent character. Based on this, he formulated a set of rules to predict whether a chemical bond is ionic or covalent. Fajan's rules are formulated by considering the charge of the cation and the relative size of the cation and anion.

Ionic	Covalent
Low positive charge	High positive charge
Large cation	Small cation
Small cation	Large cation

- When the size of the cation is small and that of anion is large, the bond is of more covalent character
- Greater the charge of the cation, greater will be the covalent character

For example, in sodium chloride, low positive charge (+1), a fairly large cation and relatively small anion make the charges to separate completely. So it is ionic. In aluminium triiodide, higher is the positive charge (+3), larger is the anion and thus no complete charge separation. So is covalent. The following picture depicts the relative charge separation of ionic compounds:

Coordinate covalent bond

In the formation of normal covalent bond each of the two bonded atoms contribute one electron to form the bond. However, in some compounds, the formation of a covalent bond between two atoms takes place by the sharing of two electrons, both of which comes from only one of the combining atoms. This bond is called Coordinate covalent bond or Dative bond.

Mostly the lone pair of electrons from an atom in a molecule may be involved in the dative bonding. The atom which provides the electron pair is called donor atom while the other atom which accepts the electron pair is called acceptor atom. The coordinate covalent bond is represented by an arrow (→) which points from the donor to the acceptor atom.

Formation of coordinate covalent bond

Let us consider two atoms A and B. Let atom A has an unshared lone pair of electrons and atom B is in short of two electrons than the octet in its valence shell. Now atom A donates its lone pair while atom B accepts it. Thus the lone pair of electrons originally belonged to atom A are now shared by both the atoms and the bond formed by this mutual sharing is called Coordinate covalent bond. (A→B)
Examples (NH^{4+}, $NH_3 \rightarrow BF_3$)

Illustration 1 – Formation of coordinate covalent bond between NH3→BF3 molecules

In some cases, the donated pair of electrons comes from a molecule as a whole which is already formed to another acceptor molecule. Here the molecule ammonia (NH_3) gives a lone pair of electrons to Boron tri fluoride (BF_3) molecule which is electron deficient. Thus, a coordinate covalent bond is formed between NH3 (donor molecule) and BF_3 (acceptor molecule) and is represented by $NH_3 \rightarrow BF_3$.

Characteristics of coordinate covalent compounds

The compounds containing coordinate covalent bonds are called coordinate compounds.

Physical state: These compounds exist as gases, liquids or solids.

Electrical conductivity: Like covalent compounds, coordinate compounds also do not contain charged particles (ions), so they are bad conductors of electricity.

Melting point: These compounds have melting and boiling points higher than those of purely covalent compounds but lower than those of purely ionic compounds.

Solubility: Insoluble in polar solvents like water but are soluble in non-polar solvents like benzene, CCl4, and toluene.

Reactions: Coordinate covalent compounds undergo molecular reactions which are slow.

Oxidation, Reduction and Redox reactions

When an apple is cut and left for sometimes, its surface turns brown. Similarly, iron bolts and nuts in metallic structures get rusted. Do you know why these are happening? It is because of a reaction called oxidation.

Oxidation: The chemical reaction which involves addition of oxygen or removal of hydrogen or loss of electrons is called oxidation.

$2\,Mg + O_2 \rightarrow 2\,MgO$ (addition of oxygen)
$CaH_2 \rightarrow C_a + H_2$ (removal of hydrogen)
$Fe_2+ \rightarrow Fe_3+ + e^-$ (loss of electron)

Reduction: The chemical reaction which involves addition of hydrogen or removal of oxygen or gain of electrons is called reduction.

$2\,Na + H_2 \rightarrow 2\,NaH$ (addition of hydrogen)
$CuO + H_2 \rightarrow Cu + H_2O$ (removal of oxygen)
$Fe_3++ e^- \rightarrow Fe_2+$ (gain of electron)

Redox reactions: Generally, the oxidation and reduction occurs in the same reaction (simultaneously). If one reactant gets oxidised, the other gets reduced. Such reactions are called oxidation-reduction reactions or Redox reactions.

$2\,PbO + C \rightarrow 2\,Pb + CO_2$
$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$

Oxidation	Addition of oxygen
	Removal of hydrogen
	Loss of electron
Reduction	Removal of oxygen
	Addition of hydrogen
	Gain of electron

Oxidising agents and Reducing agents

Substances which have the ability to oxidise other substances are called oxidising agents. These are also called as electron acceptors because they remove electrons from other substances.

Example: H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$

Substances which have the ability to reduce other substances are called Reducing agents. These are also called as electron donors because they donate electrons to other substances.

Example: $NaBH_4$, $LiAlH_4$ and metals like Palladium, Platinum.

Oxidation reactions in daily life:

In nature, the oxygen present in atmospheric air oxidises many things, starting from metals to living tissues.

- The shining surface of metals tarnishes due to the formation of respective metal oxides on their surfaces. This is called corrosion.
- The freshly cut surfaces of vegetables and fruits turns brown after some time because of the oxidation of organic compounds present in them.
- The oxidation reaction in food materials that were left open for a long period is responsible for spoiling of food. This is called Rancidity.

Oxidation number

Oxidation number of an element is defined as the formal charge which an atom of that element appears to have when electrons are counted.

Oxidation number also called oxidation state is the total number of electrons that an atom either gains or losses in order to form a chemical bond with another atom.The sum of oxidation numbers of all the atoms in the formula for a neutral compound is ZERO. The sum of oxidation numbers of an ion is the same as the charge on that ion. Negative oxidation number in compounds of two unlike atoms is assigned to the more electronegative atom.

Example:

- Oxidation number of K and Br in KBr molecule is +1 and –1 respectively.

- Oxidation number of N in NH3 molecule is –3.
- Oxidation number of H is +1 (except hydrides).
- Oxidation number of oxygen in most cases is –2.

Problems on determination of Oxidation Number
ON (Oxidation Number) of neutral molecule is always zero

Illustration 1
Oxidation Number of H and O in H2O
Let us take ON of H = +1 and ON of O = –2
$2 \times (+1) + 1 \times (-2) = 0$
$(+2) + (-2) = 0$
Thus, ON of H is +1 and ON of O is –2

Illustration 2
Oxidation Number of S in H2SO4
Let ON of S be x and we know ON of H = +1 and O = –2
$2 \times (+1) + x + 4 \times (-2) = 0$
$(+2) + x + (-8) = 0$
$x = +6$ Therefore, ON of S is +6

Illustration 3
Oxidation Number of Cr in K2Cr2O7
Let ON of Cr be x and we know ON of K = +1 and O = –2
$2 \times (+1) + 2 \times x + 7 \times (-2) = 0$
$(+2) + 2x + (-14) = 0$
$2x = +12$
$x = +6$ Therefore, ON of Cr in K2Cr2O7 is +6

Illustration 4
Oxidation Number of Fe in FeSO4
Let ON of Fe be x and we know ON of S = +6 and O = –2
$x + 1 \times (+6) + 4 \times (-2) = 0$
$x + (+6) + (-8) = 0$
$x = +2$ Therefore, ON of Fe in $FeSO_4$ is +2

Problems:
1. Find the oxidation number of Mn in $KMnO_4$
2. Find the oxidation number of Cr in $Na_2Cr_2O_7$
3. Find the oxidation number of Cu in $CuSO_4$
4. Find the oxidation number of Fe in FeO

Unit – 14 – Acids, Bases and salts

Introduction

We know that the physical world around us is made of large number of chemicals. Soil, air, water, all the life forms and the materials that they use are all consist of chemicals. Out of such chemicals, acids, bases and salts are mostly used in everyday life. Let it be a fruit juice or a detergent or a medicine, they play a key role in our day-to-day activities. Our body metabolism is carried out by means of hydrochloric acid secreted in our stomach. An acid is a the compound which is capable of forming hydrogen ions (H+) in aqueous solution whereas a base is a compound

that forms hydroxyl ions (OH–) in solution. When an acid and a base react with each other, a neutral product is formed which is called salt. In this lesson let us discuss about them in detail.

Acids

Look at the pictures of some of the materials used in our daily life, given below:

All these edible items taste similar i.e. sour. What causes them to taste sour? A certain type of chemical compounds present in them gives sour taste. These are called acids. The word 'acid' is derived from the Latin name "acidus"
which means sour taste. Substances with sour taste are called acids.

Source	Acid Present
Apple	Malic acid
Lemon	Citric acid
Grape	Tartaric acid
Tomato	Oxalic acid
Vinegar	Acetic acid
Curd	Lactic acid
Orange	Ascorbic acid
Tea	Tannic acid
Stomach juice	Hydrochloric acid
Ant, Bee	Formic acid

In 1884, a Swedish chemist Svante Arrhenius proposed a theory on acids and bases. According to Arrhenius theory, an acid is a substance which furnishes H+ ions or H3O+ ions in aqueous solution. They contain one or more replaceable hydrogen atoms. For example, when hydrogen chloride is dissolved in water, it gives H1 and Cl2 ions in water.

$HCl_{(aq)} \rightarrow H1_{(aq)} + Cl2_{(aq)}$

What happens to an acid or a base in water? Do acids produce ions only in aqueous solution? Hydrogen ions in HCl are produced in the presence of water. The separation of H+ ion from HCl molecules cannot occur in the absence of water.

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Hydrogen ions cannot exist alone, but they exist in combined state with water molecules. Thus, hydrogen ions must always be H+ (or) Hydronium (H3O+).

$H^+ + H_2O \rightarrow H_3O^+$

All acids essentially contain one or more hydrogens. But all the hydrogen containing substances are not acids. For example, methane (CH4) and ammonia (NH3) also contain hydrogen. But they do not produce H+ ions in aqueous solution.

The following table enlists various acids and the ions formed by them in water.

Acid	Molecular Formula	Ions formed		No. of replaceable hydrogen
Acetic Acid	$CH\text{-}{}_3COOH$	H+	$CH\text{-}{}_3COO^-$	1
Formic Acid	HCOOH	H+	$HCOO^-$	1
Nitric Acid	HNO_3	H+	NO_3^-	1
Sulphuric Acid	H_2SO_4	2H+	SO_4^{2-}	2
Phosphoric Acid	H_3PO_4	3H+	PO_4^{3-}	3

Classification of Acids

Acids are classified in different ways as given below:

(a) Based on their sources:

Organic Acids: Acids present in plants and animals (living things) are organic acids. Example: HCOOH, CH_3COOH

Inorganic Acids: Acids prepared from rocks and minerals are inorganic acids or mineral acids. Example: HCl, HNO_3, $H2SO_4$

(b) Based on their Basicity

Monobasic Acid: Acid that contain only one replaceable hydrogen atom per molecule is called monobasic acid. It gives one hydrogen ion per molecule of the acid in solution. Example: HCl, HNO_3

For acids, we use the term basicity that refers to the number of replaceable hydrogen atoms present in one molecule of an acid. For example, acetic acid (CH3COOH) has four hydrogen atoms but only one can be replaced. Hence it is monobasic.

Dibasic Acid: An acid which gives two hydrogen ions per molecule of the acid in solution. Example: H_2SO_4, H_2CO_3

Tribasic Acid: An acid which gives three hydrogen ions per molecule of the acid in solution. Example: H3PO4

(c) Based on Ionisation

Acids get ionised in water (produce H+ ions) completely or partially. Based on the extent of ionisation acids are classified as below.

Strong Acids: These are acids that ionise completely in water. Example: HCl

Weak Acids: These are acids that ionise partially in water. Example: CH_3COOH.

Ionisation is the condition of being dissociated into ions by heat or radiation or chemical reactions or electrical discharge.

(d) Based on Concentration

Concentrated Acid: It has relatively large amount of acid dissolved in a solvent.

Dilute Acid: It has relatively smaller amount of acid dissolved in solvent.

Properties of Acids
a) They have sour taste.
b) Their aqueous solutions conduct electricity since they contain ions.
c) Acids turns blue litmus red.
d) Acids react with active metals to give hydrogen gas.

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2 \uparrow$
$Zn + 2HCl \rightarrow ZnCl_2 + H_2 \uparrow$

Few metals do not react with acid and liberate hydrogen gas. For example: Ag, Cu.

e) Acids react with metal carbonate and metal hydrogen carbonate to give carbon dioxide.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \uparrow$
$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2 \uparrow$

f) Acids react with metallic oxides to give salt and water.
CaO + H2SO4 → CaSO4 + H2O
g) Acids react with bases to give salt and water.
HCl + NaOH → NaCl + H2O

Uses of Acids

- Sulphuric acid is called King of Chemicals because it is used in the preparation of many other compounds. It is used in car batteries also.
- Hydrochloric acid is used as a cleansing agent in toilets.
- Citric acid is used in the preparation of effervescent salts and as a food preservative.
- Nitric acid is used in the manufacture of fertilizers, dyes, paints and drugs.
- Oxalic acid is used to clean iron and manganese deposits from quartz crystals. It is also used as bleach for wood and removing black stains.
- Carbonic acid is used in aerated drinks.
- Tartaric acid is a constituent of baking powder.

Role of water in acid solution

Acids show their properties only when dissolved in water. In water, they ionise to form H+ ions which determine the properties of acids. They do not ionise in organic solvents. For example, when HCl is dissolved in water it produces H+ ions and Cl_ ions whereas in organic solvents like ethanol they do not ionise and remain as molecule.

Aquaregia

We know that metals like gold and silver are not reactive with either HCl or HNO3. But the mixture of these two acids can dissolve gold. This mixture is called Aquaregia. It is a mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3:1. It is a yellow-orange fuming liquid. It is a highly corrosive liquid, able to attack gold and other substances.

Chemical formula : 3 HCL + HNO_3
Solubility in water : Miscible in water
Melting point : - 42°C (- 44°F, 231K)
Boiling point : 108°C (226°F, 381K)

The term aquaregia is a Latin phrase meaning ‘King’s Water’. The name reflects the ability of aquaregia to dissolve the noble metals such as gold, platinum and palladium.

Uses of Aquaregia

It is used chiefly to dissolve metals such as gold and platinum.
It is used for cleaning and refining gold.

Bases

According to Arrhenius theory, bases are substances that ionise in water to form hydroxyl ions (OH–). There are some metal oxides which give salt and water on reaction with acids. These are also called bases. Bases that are soluble in water are called alkalis. A base reacts with an acid to give salt and water only.

Base + Acid → Salt + Water

For example, zinc oxide (ZnO) reacts with HCl to give the salt zinc chloride and water.

$ZnO_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl2_{(aq)} + H2O_{(l)}$

Similarly, sodium hydroxide ionises in water to give hydroxyl ions and thus get dissolved in water. So it is an alkali.

$NaOH_{(aq)} \rightarrow Na^{+}(_{aq}) + OH^{-}(_{aq})$

Bases contain one or more replaceable oxide or hydroxyl ions in solution. Table 14.3 enlists various bases and ions formed by them in water.

All alkalis are bases but not all bases are alkalis. For example: NaOH and KOH are alkalis whereas Al(OH)3 and Zn(OH)2 are bases.

Base	Molecular Formula	Ions formed		No. of replaceable hydroxyl ion
Calcium oxide	CaO	Ca^{2+}	O^{2-}	1
Sodium oxide	Na_2O	$2Na^{+}$	O^{2-}	1
Potassium hydroxide	KOH	K^{+}	OH^{-}	1
Calcium hydroxide	$Ca(OH)_2$	$Ca2^{+}$	OH^{-}	2
Aluminium hydroxide	$Al(OH)_3$	Al^{3+}	OH^{-}	3

Classification of Bases

(a) Based on their Acidity

Monoacidic Base: It is a base that ionises in water to give one hydroxide ion per molecule. Example: NaOH, KOH

Diacidic Base: It is a base that ionises in water to give two hydroxide ions per molecule. Example: Ca(OH)2. Mg(OH)2

Triacidic Base: It is a base that ionises in water to give three hydroxide ions per molecule. Example: Al(OH)3, Fe(OH)3

(b) Based on concentration

Concentrated Alkali: It is an alkali having a relatively high percentage of alkali in its aqueous solution.

Dilute Alkali: It is an alkali having a relatively low percentage of alkali in its aqueous solution.

(c) Based on Ionisation

Strong Bases: These are bases which ionise completely in aqueous solution.
Example: NaOH, KOH

Weak Bases: These are bases that ionise partially in aqueous solution.
Example: NH4OH, Ca(OH)2

The term acidity is used for base, which means the number of replaceable hydroxyl groups present in one molecule of a base.

Properties of Bases

a) They have bitter taste.

b) Their aqueous solutions have soapy touch.

c) They turn red litmus blue.

d) Their aqueous solutions conduct electricity.

e) Bases react with metals to form salt with the liberation of hydrogen gas.

$$Zn + 2\ NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$$

f) Bases react with non-metallic oxides to produce salt and water. Since this is similar to the reaction between a baseand an acid, we can conclude that non-metallic oxides are acidic in nature.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

g) Bases react with acids to form salt and water.

$$KOH + HCl \rightarrow KCl + H2O$$

The above reaction between a base and an acid is known as Neutralisation reaction.
h) On heating with ammonium salts, bases give ammonia gas.

$$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_3\uparrow$$

Few metals do not react with sodium hydroxide. Example: Cu, Ag, Cr

In the above activity you can observe that the bulb will start glowing only in the case of acids. But, you will observe that glucose and alcohol solution do not conduct electricity. Glowing of the bulb indicates that there is a flow of electric current through the solution. The electric current is carried through the solution by ions. Repeat the same activity using alkalis such as sodium hydroxide and calcium hydroxide.

Uses of Bases

(i) Sodium hydroxide is used in the manufacture of soap.
(ii) Calcium hydroxide is used in white washing of building.
(iii) Magnesium hydroxide is used as a medicine for stomach disorder.
(iv) Ammonium hydroxide is used to remove grease stains from cloths.

Tests for Acids and Bases

a) Test with a litmus paper:

An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

b) Test with an indicator Phenolphthalein:

In acid medium, phenolphthalein is colourless. In basic medium, phenolphthalein is pink in colour.

c) Test with an indicator Methyl orange:

In acid medium, methyl orange is pink in colour. In basic medium, methyl orange is yellow in colour.

Indicator	Colour in acid	Colour in acid
Litmus	Blue to Red	Red to Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Pink	Yellow

Strenght of Acidic or Basic solutions

pH Scale

A scale for measuring hydrogen ion concentration in a solution is called pH scale. The 'p' in pH stands for 'potenz' in German meaning power. pH scale is a set of numbers from 0 to 14 which is used to indicate whether a solution is acidic, basic or neutral.

- Acids have pH less than 7
- Bases have pH greater than 7
- A neutral solution has pH equal to 7

Salts

When you say salt, you may think of the common salt. Sea water contains many salts dissolved in it. Sodium chloride is separated from these salts. There are many other salts used in other fields. Salts are the products of the reaction between acids and bases. Salts produce positive ions and negative ions when dissolved in water.

Types of Salts

Normal Salts: A normal salt is obtained by complete neutralization of an acid by a base.

$NaOH + HCl \rightarrow NaCl + H2O$

Acid Salts: It is derived from the partial replacement of hydrogen ions of an acid by a metal. When a calculated amount of a base is added to a polybasic acid, acid salt is obtained.

$NaOH + H2SO_4 \rightarrow NaHSO_4 + H_2O$

Basic Salts: Basic salts are formed by the partial replacement of hydroxide ions of a diacidic or triacidic base with an acid radical.

$Pb(OH)2 + HCl \rightarrow Pb(OH)Cl + H2O$

Double Salts: Double salts are formed by the combination of the saturated solution of two simple salts in equimolar ratio followed by crystallization. For example, potash alum is a mixture of potassium sulphate and aluminium sulphate. $KAl(SO_4)_2 \cdot 12H2O$

Properties of Salts

- Salts are mostly solids which melt as well as boil at high temperature.
- Most of the salts are soluble in water. For example, chloride salts of potassium and sodium are soluble in water. But, silver chloride is insoluble in water
- They are odourless, mostly white, cubic crystals or crystalline powder with salty taste.
- Salt is hygroscopic in nature.

Water of Crystallisation

Many salts are found as crystals with water molecules. These water molecules are known as water of crystallisation. Salts that contain water of crystallisation are called hydrated salts. The number of molecules of water hydrated to a salt is indicated after a dot in its chemical formula. For example, copper sulphate crystal have five molecules of water for each molecule of copper sulphate. It is written as CuSO4.5H2O and named as copper sulphate pentahydrate. This water of crystallisation makes the copper sulphate blue. When it is heated, it loses its water molecules and becomes white.

Salts that do not contain water of crystallisation are called anhydrous salt. They are generally found as powders. Fill in the blanks in the following table based on the concept of water of crystallisation.

Identification of Salts

(i) Physical examination of the salt.

The physical examination of the unknown salt involves the study of colour, smell and density. This test is not much reliable.

(ii) Dry heating Test.

This test is performed by heating a small amount of salt in a dry test tube. After all the water get evaporated, the dissolved salts are sedimented in the container.

(iii) Flame Test.

Certain salts on reacting with concentrated hydrochloric acid (HCl) form their chlorides. The paste of the mixture with con. HCl is introduced into the flame with the help of platinum wire.

Colour of the flame	Inference
Brick red	Ca^{2+}
Golden Yellow	Na^{2+}
Pink Violet	K^{+}
Green Fleshes	Zn^{2+}

(iv) When HCl is added with a carbonate salt, it gives off CO2 gas with brisk effervescence.

Uses of Salts

Common Salt (Sodium Chloride - NaCl)
It is used in our daily food and used as a preservative.

Washing Soda (Sodium Carbonate-Na2CO3)

i. It is used in softening hard water.
ii. It is used in glass, soap and paper industries.

Baking Soda (Sodium bicarbonate -NaHCO3)

i. It is used in making of baking powder which is a mixture of baking soda and tartaric acid.
ii. It is used in soda-acid fire extinguishers.
iii. Baking powder is used to make cakes and bread, soft and spongy.
iv. It neutralizes excess acid in the stomach and provides relief.

Bleaching powder (Calcium Oxychloride - $CaOCl_2$)

i. It is used as disinfectant.
ii. It is used in textile industry for bleaching cotton and linen.

Plaster of Paris (Calcium Sulphate Hemihydrate - $CaSO_4 \cdot \frac{1}{2} H_2O$)

i. It is used for plastering bones.
ii. It is used for making casts for statues.

Unit – 15 Carbon and its Compounds

Introduction

Carbon is one of the most important non-metallic element. Antoine Lavoisier named Carbon from the Latin word 'Carbo' meaning coal. This is because carbon is the main constituent of coal. Coal is a fossil fuel developed from prolonged decomposition of buried plants and animals. So, it is clear that all the life forms contain carbon. The earth's crust contains only 0.032% of carbon (i.e.320 parts per million by weight) in the form of minerals like carbonates, coal and petroleum and the atmosphere has only 0.03% of carbon dioxide (i.e.300 parts per million by weight). Even though available in small amount in nature, carbon compounds have an immense importance in everyday life.

Carbon is present in our muscles, bones, organs, blood and other components of living matter. A large number of things which we use in our daily life are made up of carbon compounds. So, without carbon there is no possibility for the existence of plants and animals including human. Thus, Carbon Chemistry is also called as Living Chemistry. In this lesson we will study about the special features of carbon, its properties and also about plastic which are the catenated long chain compounds.

Discovery of Carbon- Milestones

Carbon has been known since ancient times in the form of soot, charcoal, graphite and diamonds. Ancient cultures did not realize, of course, that these substances were different forms of the same element.

In 1772, French scientist Antoine Lavoisier pooled resources with other chemists to buy a diamond, which they placed in a closed glass jar.

They focused the Sun's rays on the diamond with a remarkable giant magnifying glass and saw the diamond burn and disappear. Lavoisier noted that the overall weight of the jar was unchanged and that when it burned, the diamond had combined with oxygen to form carbon dioxide. He concluded that diamond and charcoal were made of the same element – carbon.

In 1779, Swedish scientist Carl Scheele showed that graphite also burned to form carbon dioxide. In 1796, English chemist Smithson Tennant established that diamond is pure carbon and not a compound of carbon and it burned to form only carbon dioxide. Tennant also proved that when equal weights of charcoal and diamonds were burned, they produced the same amount of carbon dioxide.

In 1855, English chemist Benjamin Brodie produced pure graphite from carbon, proving graphite is a form of carbon. Although it had been previously attempted without success, in 1955 American scientist Francis Bundy and his co-workers at 'General Electric' company finally demonstrated that graphite could be transformed into diamond at high temperature and pressure.

In 1985, Robert Curl, Harry Kroto and Richard Smalley discovered fullerenes, a new form of carbon in which the atoms are arranged in soccer-ball shapes. Graphene, consists of a single layer of carbon atoms arranged in hexagons. Graphene's discovery was announced in 2004 by Kostya Novoselov and Andre Geim, who used adhesive tape to detach a single layer of atoms from graphite to produce the new allotrope. If these layers were stacked upon one other, graphite would be the result. Graphene has a thickness of just one atom.

Compounds of Carbon – Classification

Carbon is found both in free state as well as combined state in nature. In the pre-historic period, ancients used to manufacture charcoal by burning organic materials. They used to obtain carbon compounds both from living things as well as non-living matter. Thus, in the early 19th century, Berzelius classified carbon compounds based on their source as follows:

Organic Carbon Compounds: These are the compounds of carbon obtained from living organisms such as plants and animals. e.g. Ethanol, cellulose, Starch.

Inorganic Carbon Compounds: These are the compounds containing carbon but obtained from non-living matter. e.g. Calcium Carbonate, Carbon Monoxide, Carbon dioxide.

Organic Compounds of Carbon

There are millions of organic carbon compounds available in nature and also synthesized manually. Organic carbon compounds contain carbon connected with other elements like hydrogen, oxygen, nitrogen, sulphur etc. Thus, depending on the nature of other elements and the way in which they are connected with carbon, there are various classes of organic carbon compounds such as hydrocarbons, alcohols, aldehydes and ketones, carboxylic acids, amino acids, etc. You will study about organic carbon compounds in your higher classes.

Inorganic Compounds of Carbon

As compared to organic compounds, the number of inorganic carbon compounds are limited. Among them oxides, carbides, sulphides, cyanides, carbonates and bicarbonates are the major classes of inorganic carbon compounds. Formation, properties and uses of some of these compounds are given in Table 15.1.

Special Features of Carbon

The number of carbon compounds known at present is more than 5 million. Many newer carbon compounds are being isolated or prepared every day. Even though the abundance

Inorganic carbon compounds

Compounds	Formation	Properties	Uses
Carbon monoxide (CO)	Not a natural componentof air. Mainly added to atmosphere due to incomplete combustion of fuels.	Colourless, odourless, highly toxic, sparingly soluble in water.	Main component of water gas (CO+H2). Reducing agent.
Carbon dioxide (CO_2)	Occurs in nature as free and combined forms. Combined form is found in minerals like limestone, magnesite. Formed by complete combustion of carbon or coke.	Colourless, odourless, Tasteless Stable, highly soluble in water, takes part in photosynthesis.	Fire extinguisher, preservative for fruits, making bread, to manufacture urea, carbonated water, nitrogenous fertilizers, dry ice in refrigerator
Calcium Carbide (CaC_2)	Prepared by heatingcalcium oxide and coke.	Greyish black solid.	To manufacture graphite and hydrogen. To prepare acetylene gas for welding.
Carbon disulphide (CS_2)	Directly prepared from Carbon and Sulphur	Colourless, inflammable, highly poisonous gas.	Solvent for sulphur. To manufacture rayon, fungicide, insecticide
Calcium Carbonate ($CaCO_3$)	Prepared by passing Carbondioxide into the solution of slaked lime	Crystalline solid, insoluble in water.	Antacid
Sodium bicarbonate ($NaHCO_3$)	Formed by treating sodium hidroxide with carbonic acid (H2CO3)	White crystalline substance, sparingly soluble in water	Preparation of sodium carbonate, baking powder, antacid

of carbon is less, the number of carbon compounds alone is more than the number of compounds of all the elements taken together. Why is it that this property is seen in carbon and in no other elements? Because, carbon has the following unique features.

Catenation

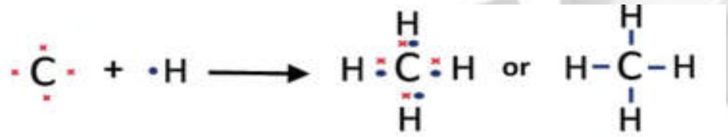
Catenation is **binding of an element to itself or with other elements through covalent bonds** to form open chain or closed chain compounds. Carbon is the most common

element which undergoes catenation and forms long chain compounds. Carbon atom links repeatedly to itself through covalent bond
to form linear chain, branched chain or ring structure.

This property of carbon itself is the reason for the presence of large number of organic carbon compounds. So organic chemistry essentially deals with catenated carbon compounds. For example, starch and cellulose contain chains of hundreds of carbon atoms. Even plastics we use in our daily life are macro molecules of catenated carbon compounds.

Tetravalency

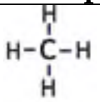
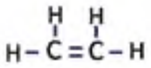
Another versatile nature of carbon is its tetravalency. The shell electronic configuration of carbon is 2,4 (Atomic no: 6). It has four electrons in its outermost orbit. According to Octet Rule, carbon requires four electrons to attain nearest noble gas (Neon) electronic configuration. So carbon has the tendency to share its four electrons with other atoms to complete its octet. This is called its tetravalency. Thus, carbon can form four covalent bond with other elements. For example, in methane, carbon atom shares its four valence electrons with four hydrogen atoms to form four covalent bonds and hence tetravalent.



Multiple Bonds

As seen above, the tetravalent carbon can form four covalent bonds. With this tetravalency, carbon is able to combine with other elements or with itself through single bond, double bond and triple bond. As weknow, the nature of bonding in a compound is the primary factor which determines the physical and chemical characteristics of a compound. So, the ability of carbon to form multiple bonds is the main reason for the existance of various classes of carbon compounds. Table 15.2 shows one of such classes of compounds called ‘hydrocarbons’ and the type of bonding in them.

Hydrocarbon

Type of bond	Example	Class of the Compound
Single Bond	 Methane	Alkane
Double Bond	 Ethene	Alkane
Triple Bond	H-C ≡ C-H Ethene	Alkane

When one or more hydrogen in hydrocarbons is replaced by other elements like O, N, S, halogens, etc., a variety of compounds having different functional groups are produced. You will study about them in your higher class.

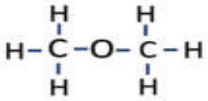
Isomerism

Isomerism is another special feature of carbon compounds especially found in catenated organic compounds. Let us consider the molecular formula of an organic compound C2H6O. Can you name the compound? You can't. Because the molecular formula of an organic compound represents only the number of different atoms present in that compound. It does not tell about the way in which the atoms are arranged and hence its structure. Without knowing the structure, we can't name it.

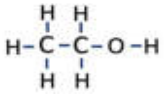
A given molecular formula may lead to more than one arrangement of atoms. Such compounds are having different physicaland chemical properties. _ is phenomenon in which the **same molecular formula may exhibit different structural arrangement** is called isomerism. Compounds that have the same molecular formula but different structural formula are called isomers (Greek, isos = equal, meros = parts).

The given formula C_2H_6O is having two kinds of arrangement of atoms as shown below.

(a) CH_3-CH_2-OH (b)CH_3-O-CH_3



$$\begin{array}{ccccc} & H & & H & \\ H- & C & -O- & C & -H \\ & H & & H & \end{array}$$



$$\begin{array}{cccccc} & H & H & & \\ H- & C & -C & -O & -H \\ & H & H & & \end{array}$$

Both the compounds have same molecular formula but different kind of arrangements. In compound 'a', the oxygen atom is attached to a hydrogen and a carbon. It is an alcohol. Whereas in compound 'b', the oxygen atom is attached to two carbon atoms and it is an ether. These compounds have different physical and chemical properties. You will study about isomerism in detail in higher classes.

Allotropy

Allotropy is a property by which an element can exist in more than one form that are physically different and chemically similar. The different forms of that element are called its allotropes. The main reason for the existence of allotropes of an element is its method of formation or preparation. Carbon exists in different allotropic forms and based on their physical nature they are classified as below.

(a) Crystalline forms of Carbon

Diamond:

- In diamond, each carbon atom shares its four valence electrons with four other carbon atoms forming four covalent bonds.

Here the atoms are arranged in repeated tetrahedral fashion which leads to a three dimensional structure accounting for its hardness and rigidity.

Graphite:

- In graphite, each carbon atom is bonded to three other carbon atoms through covalent bonds in the same plane.
- This arrangement forms hexagonal layers which are held together one over other by weak Vander Waals forces.
- Since the layers are held by weak forces, graphite is softer than diamond.

Fullerene:

- The third crystalline allotrope of carbon is fullerene. The best known fullerene is Buckminster fullerene, which consists of 60 carbon atoms joined together in a series of 5- and 6- membered to form spherical molecule resembling a soccer ball. So its formula is C60.
- This allotrope was named as Buckminster fullerene after the American architect

Difference between Diamond and Graphite

Diamond	Graphite
Each carbon has four covalent bonds.	Each carbon has three covalent bonds.
Hard, heavy and transparent	So , slippery to touch and opaque.
It has tetrahedral units linked in three dimension.	It has planar layers of hexagon units.
It is a non-conductor of heat and electricity.	It is a conductor of heat and electricity.

Buckminster **fuller**. Because its structure reminded the framework of **dome shaped halls** designed by Fuller for large international exhibitions, it is called by the pet name **Bucky Ball**. A large family of fullerenes exists, starting at C20 and reaching up to C540.

(b) Amorphous forms of carbon

In amorphous form of carbon, carbon atoms are arranged in random manner. These form of carbon are obtained when wood is heated in the absence of air. E.g., charcoal

Physical properties of Carbon and its compounds

- Carbon is a non-metal found in various allotropic forms from soft powder to hard solid.
- All the allotropic forms of carbon are solids whereas its compounds exist in solid, liquid and gaseous state.

- Amorphous forms of carbon and graphite are almost black in colour and opaque. Diamond is transparent and shiny.
- Its amorphous forms have low melting and boiling point compared to crystalline forms.
- Carbon is insoluble in water and other common solvents. But some of its compounds are soluble in water and other solvents. e.g., Ethanol, CO_2 are soluble in water.

Chemical properties of Carbon and its compounds

Elemental carbon undergoes no reaction at room temperature and limited number of reactions at elevated temperatures. But its compounds undergo large number of reactions even at room temperature.

Oxidation – (Reaction with oxygen)

Carbon combines with oxygen to form its oxides like carbon monoxide (CO) and carbon dioxide (CO_2) with evolution of heat. Organic carbon compounds like hydrocarbon also undergo oxidation to form oxides and steam with evolution of heat and flame. This is otherwise called combustion.

$2C(s) + O_2(g) \rightarrow 2CO(g) + \text{heat}$
$C(s) + O_2(g) \rightarrow CO_2(g) + \text{heat}$
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{heat}$

Reaction with steam

Carbon reacts with steam to form carbon monoxide and hydrogen. This mixture is called water gas.

$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$

Reaction with sulphur

With sulphur, carbon forms its disulphide at high temperature.
$C(s) + S(g) \rightarrow CS_2(g)$

Reaction with metals

At elevated temperatures, carbon reacts with some metals like iron, tungsten, titanium, etc. to form their carbides.

Tungesten + Carbon → Tungesten carbide

Carbon compounds in everyday life

It is impossible to think of our daily life without carbon compounds. Over time, a large number of carbon compounds have been developed for the improvement of our lifestyle and comfort. They include carbon-based fuels, carbon nanomaterials, plastics, carbon filters, carbon steel, etc.

Even though carbon and its compounds are vital for modern life, some of its compounds like CO, cyanide and certain types of plastics are harmful to humans. In the following segment, let us discuss the role of plastics in our daily life and how we can become aware of the toxic chemicals that some plastics contain.

Plastics – Catenated long chain carbon compounds

Plastics are a major class of catenated organic carbon compounds. They are made from long chain organic compounds called 'polymer resins' with chemical additives that give them different properties. Different kinds of polymers are used to make different types of plastics. Plastics are everywhere. They are convenient, cheap and are used in our everyday life. Plastics have changed the way we live. They have helped improve health care, transport and food safety. Plastics have allowed many breakthroughs in technologies such as smartphones, computers and the internet. It is clear that plastic has given our society many benefits. But these benefits have come at a cost.

Drawbacks of plastics

- Plastics take a very long time to fully break down in nature.
- The microbes that break down plastic are too few in nature to deal with the quantity of plastics we produce.
- A lot of plastic does not get recycled and ends up polluting the environment.
- Some types of plastics contain harmful chemical additives that are not good for human health.
- Burning of plastics releases toxic gases that are harmful to our health and contribute to climate change.
- One-time use and throwaway plastics end up littering and polluting the environment.
- In order to know which plastics are harmful, you will need to learn the secret 'language' of plastics (resin codes).

Identifying different types of plastics
(a) The resin codes

Look at the following pictures. One is a plastic sachet in which milk is distributedto consumers and the other is a plastic food container. Observe the code shown on it (circled). Do you know what this code means? It is called a '**resin code**'. The resin code represents the type of polymer used to make the plastic.

(b) Need for resin codes

Plastics should be recycled or disposed of safely. Certain types of plastics should be avoided so that they do not end up polluting the environment or harming our health. Each plastic is composed of a different polymer or set of molecules. Different molecules do not mix when plastics are recycled, it is like trying to recycle paper and glass together. For this reason, they need to be separated. The resin codes of plastics were designed in 1988 and are a uniform way of classifying the different types of plastic which help recyclers in the sorting process.

(c) Find in the resin code on plastic items

The secret resin codes are shown as **three chasing arrows in a triangle**. There is a **number in the middle or letters under the triangle** (an acronym of that plastic type). This is usually difficult to find. It can be found on the label or bottom of a plastic item.

The resin codes are numbered from 1 to 7. Resin codes #1 to #6 each identify a certain type of plastic that is often used in products. Resin code #7 is a category which is used for every other plastic (since 1988) that does not fit into the categories #1 to #6. The resin codes look very similar to the recycling symbol, but this does not mean that all plastics with a code can be recycled.

(d) Where will the resin code be shown on plastic items?

- Flip a plastic item to find the resin code on the bottom.
- Sometimes the bottom of plastic item will only have an acronym or the full name of that plastic type.
- If you do not find it on the bottom, search for the code on the label.
- Some plastics do not have a code. The company did not follow the rules and you do not know if it is safe to use.

Harmful effects of plastics

Plastics in our everyday life can be harmful for two reasons. The first reason is that some types of plastic contain chemicals that are harmful to our health. The second reason is that a lot of plastics are designed to be used just for one time. This use and throwaway plastic causes pollution to our environment.

(a) Harmful plastics

There are three types of plastic that use toxic and harmful chemicals. These chemicals are added to plastics to give them certain qualities such as flexibility, strength, colour and fire or UV resistance. The three unsafe plastics are: PVC (resin code #3), PS (resin code #6 also commonly called Thermocol) and PC/ABS (resin code #7).

PVC – Polyvinyl Chloride plastics

- Heavy metals (cadmium & lead) are added to PVC.

- Phthalates (chemical additive) copy our hormones.
- Burning PVC releases dioxins (one of the most toxic chemicals known to humans). PS – Polystyrene plastics
- Styrene is a building block of this plastic and may cause cancer.
- It takes very long time to break-down (100- 1 million years).
- Higher amounts of toxic styrene leak into our food and drinks when they are hot or oily.

PC – Polycarbonate plastics

- PC plastic contains Bisphenol A (BPA).
- BPA leaks out of PC products used for food and drinks.
- BPA increases or decreases certain hormones and changes the way our bodies work.

ABS – Acrylonitrile Butadiene Styrene

- Styrene causes problems for our eyes, skin, digestive system and lungs.
- Brominated Flame Retardants (BFRs) are often added.
- Studies show that toxic chemicals leak from this plastic.

(b) One-time use plastic

Use and throwaway plastics cause short and long-term environmental damage. Half of all the plastic made today is used for throwaway plastic items. These block drains and pollute water bodies. One-time use plastic causes health problems for humans, plants and animals. Some examples are plastic carry bags, cups, plates, straws, water pouches, cutlery and plastic sheets used for food wrapping. **Figure 15.5** One-time use plastic items These items take a few seconds to be made in a factory. You will use them for a very short time. Once you throw them away, they can stay in our environment for over a 1,000 years causing plastic pollution for future generations. We need rules and laws to protect people and the environment from plastic pollution.

New rules to make Tamil Nadu plastic free

As we know, the Government of India is progressively taking various legal initiatives to stop plastic pollution by making some provisions and amendments in the Environment (Protection) Act, 1988. With reference to this act, Government of Tamil Nadu has taken a step forward to ban the usage of some kind of plastic items (Environment and Forests Department, T.N. G.O. No: 84, dated 25/06/2018).

As per the government order cited above, the Tamil Nadu Government has banned the usage of one-time use and throwaway plastics from 1st January 2019. This excellent legislation is designed to protect Tamil Nadu from plastic pollution.

Rules which ban the production, storage, supply, transport, sale and distribution of one-time use plastics are extremely effective. They are successful because they target all sections of society–manufacturer, supplier, shopkeeper and customer. This progressive initiative taken by the State of Tamil Nadu leads by example for the rest of the nation.

You can find below some key aspects of the new rules along with science-based facts why these items have been banned in Tamil Nadu.

Banned items

Plastic carry bags

- Globally we use 2 million plastic bags each minute.
- 97% of plastic bags do not get recycled.
- Animals eat plastic bags by accident as they contain food. A cow was found with over 70 kilos of plastic in its stomach.

Plastic plates

- Dirty plastics (like a used plate) are difficult to recycle.
- Most of the one-time use plates are made from Polystyrene (resin code # 6) which is harmful to our health.
- Plates will be used for just 20 minutes but stay in the environment for over a 1,000 years.

Water pouches

- Water pouches are often littered, increasing plastic pollution.
- The blue print (ink) on the clear plastic pouch decreases the recycling value.
- Once a water pouch is used, it is difficult to recycle as it contains leftover water and gets covered in dirt.

Plastic straws

- Plastic straws are too light and small to be recycled.
- Straws are one of the top 10 items which are found in the plastic pollution in oceans.
- 90% of seabirds have ingested plastics such as straws.

Plastic sheets

- Plastic sheets used on top of plates get dirty and cannot be recycled.
- More chemicals leak from plastic into food when it is hot, spicy or oily.
- Animals such as cows, goats, and dogs eat plastic by accident because it smells like food.

Role of students in the prevention of plastic pollution

You play a very important role and have the power to minimise plastic pollution. Ask yourself, is this plastic safe or harmful plastic? If it is not a harmful plastic type, is it a one-time use plastic item? These questions and the science-based knowledge will help you to reduce unnecessary plastic pollution.

What can you do to prevent plastic pollution?

- As a student, you can share your scientific knowledge on plastics and their effects with your parents, relatives and friends to make them aware of plastic pollution.
- You can help by teaching them how to avoid harmful plastics by searching for the resin codes.
- You can educate them about the new rules and how important it is to stop one-time use plastics.

Practice in your daily life

- Do not litter the environment by throwing plastic items.
- Do not use Thermocol (resin code #6 PS) for your school projects.
- Do not use one-time use or throwaway plastics like plastics bags, tea cups, Thermocol plates and cups, and plastic straws.
- Do not burn plastics since they release toxic gases that are harmful to our health and contribute to climate change.
- Burning PVC plastic releases dioxins which are one of the most dangerous chemicals known to humans.
- Do not eat hot or spicy food items in plastic containers.
- Segregate your plastic waste and hand this over to the municipal authorities so that it can be recycled.
- Educate at least one person per day about how to identify the resin codes and avoid unsafe plastics (resin code #3 PVC, #6 PS and #7 ABS/PC).