Science Notes Part 46 to 50

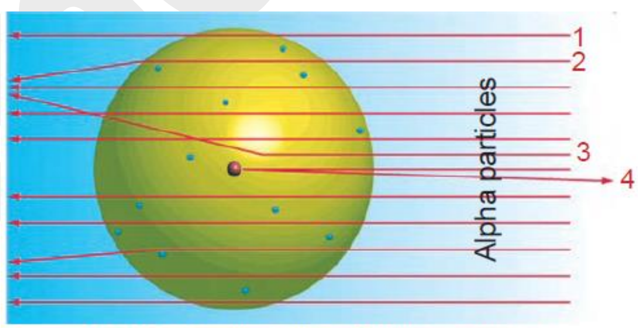
46] Atomic Structure

John Dalton proposed the idea of the atom as the smallest possible particle of any substance. He never worked with small particles of solids but actually he worked with gases. He analysed how they mixed with each other, how they formed compounds and how they dissolved in water etc.

While working with all these, he discovered that whenever elements combine to form more than one compound, the ratio of the masses of elements in the compounds are small whole number ratios of each other. It led him to the idea that the smallest particle of one substance combined with the smallest part of another substance in fixed quantities.

The development of modern atomic theory is an excellent example of how science progresses. Many scientists contribute their knowledge for the development. New experiments lead to changes in the old theories and even new theories. Theories are useful in providing the basis for further research. Although J.J.Thomson's atomic theory explained the electrical neutrality of atoms, it could not reveal the presence of nucleus in an atom, which was later proposed by Ernest Rutherford in 1909.

Schematic diagram showing alpha particles bombarding one gold atom. The nucleus of the gold atom is found in the centre.



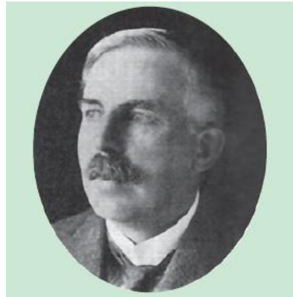
1. Not scattered at all 2. Slightly scattered
3. More scattered 4. Returned at 180º

DISCOVERY OF THE NUCLEUS

Rutherford's contribution

Rutherford observed what happens to the alpha particles projected at a thin metal foil.

Ernest Rutherford (1871-1937)



Ernest Rutherford, a British physicist probed atoms with alpha particles. He was known as the "father of nuclear physics". He was awarded the Nobel prize for his contribution to the structure of atom in 1908.

RUTHERFORD'S EXPERIMENT

A stream of alpha particles was made to pass through a thin gold foil of about $4x10^{-5}$ cm thickness. Most of the alpha particles did go through the foil in a straight line. Some alpha particles were deflected through an average angle of 90^o .Rarely the path of 1 in 20,000 alpha particles scored a direct hit on the nucleus and returned in an angle of 180^o.

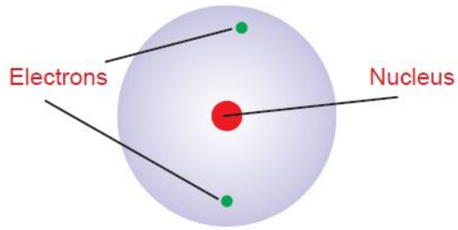
More to know

Alpha particles are helium ions He^{2+} (2 protons, 2 neutrons and no electrons). The mass of an alpha particle is about 8000 times the mass of an electron. Velocity of alpha particles is about 2×10^7 m/s.

From this experiment, he concluded that there is a heavy positive charge occupying small volume, at the centre of an atom.

RUTHERFORD'S MODEL OF ATOM

- Atom has a very small nucleus at the centre.
- There is a large empty space around the nucleus.
- Entire mass of an atom is due to the mass of nucleus.
- Electrons are distributed in the vacant space around the nucleus.
- The electrons are moving in circular paths around the nucleus.

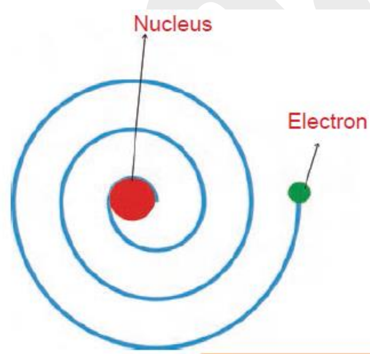


More to know

James Chadwick was one of Rutherford's students.

Limitations

According to the electromagnetic theory, a moving electron should accelerate and lose energy continuously. Due to the loss of energy, the path of electron may reduce and finally the electron might fall into nucleus. If it so happens, the atom becomes unstable, but atoms are stable. Hence, Rutherford's theory does not explain the stability of atom.



More to know

Imagine a small boy swinging a stone tied to the end of a string around him. The stone is able to occupy a larger volume because it is moving rapidly. Similarly, the electrons in an atom are able to occupy a larger volume because they are moving very fast.

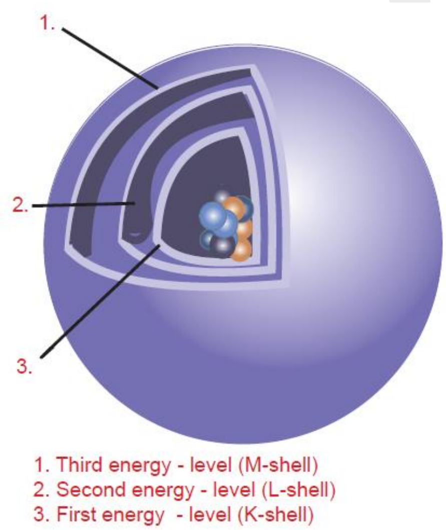
Niels Bohr (1885 - 1962)

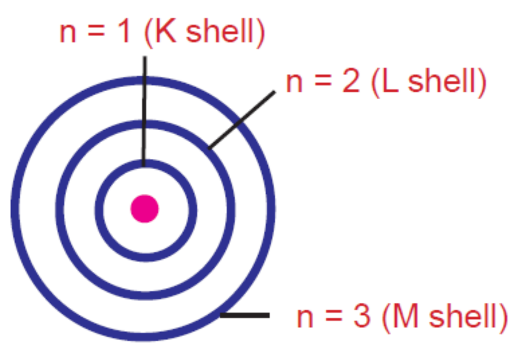
Niels Bohr was born on October 7, 1885 in Copenhagen, Denmark. He was also an outstanding soccer player. He worked with Rutherford at the University of Manchester. Bohr's theory became the basis for modern physics known as Quantum Mechanics. Bohr received the Nobel Prize for physics in 1922.

BOHR'S MODEL OF ATOM

Niels Bohr modified Rutherford's atom model and put forth the following postulates.

- ﬀ In atoms, electrons revolve around the nucleus in stationary circular paths. These paths are called orbits or shells or energy levels.
- As long as electrons revolve in the same orbit, it does not lose or gain energy.
- The circular orbits are numbered as 1, 2, 3, 4 or designated as K, L, M, N shells. These numbers are referred to as principal quantum numbers (n).
- As we move away from the nucleus, the energy of the orbit constantly increases.
- Maximum number of electrons that can be accommodated in an energy level (n) is given by 2n2 .
- When an electron absorbs energy, it jumps from lower energy level to higher energy level.
- When an electron returns from higher energy level to lower energy level, it gives off energy.

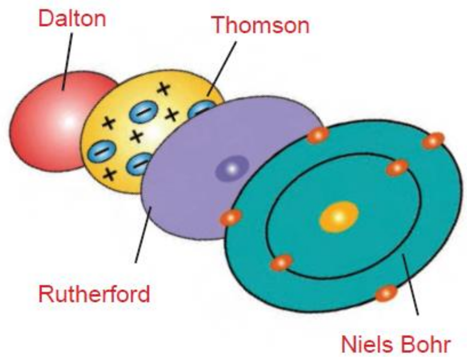




Orbit

Orbit is defined as the path, by which electrons revolve around the nucleus.

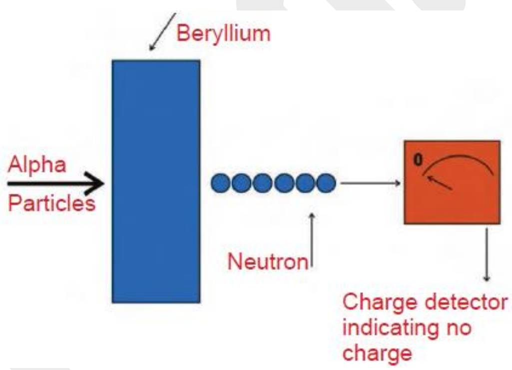
DALTON, THOMSON, RUTHERFORD AND NIELS BOHR - ATOM MODELS



DISCOVERY OF NEUTRONS

In 1932, James Chadwick observed that when beryllium was exposed to alpha particles, particles with about the same mass as protons were emitted. These emitted particles carried no electrical charge. Hence, they were called as neutrons.

Beryllium + alpha ray →carbon + neutron



More to know

Number of neutrons = Mass number - Atomic number (Number of protons or number of electrons)

Neutrons are particles with no charge i.e. neutral particles. Neutrons are present in the nuclei of all atoms except the hydrogen atom. The mass of a neutron is almost equal to the mass of a proton.

Atoms of the same element with different number of neutrons are called isotopes. Neutron is also regarded as a sub-atomic particle.

CHARACTERISTICS OF FUNDAMENTAL PARTICLES

The physical and chemical properties of elements and their compounds can be explained by the fundamental particles of an atom. The fundamental particles of an atom are:

Protons: They are positively charged particles. They are present inside the nucleus.

Electrons: They are negatively charged particles. They revolve around the nucleus in circular orbits.

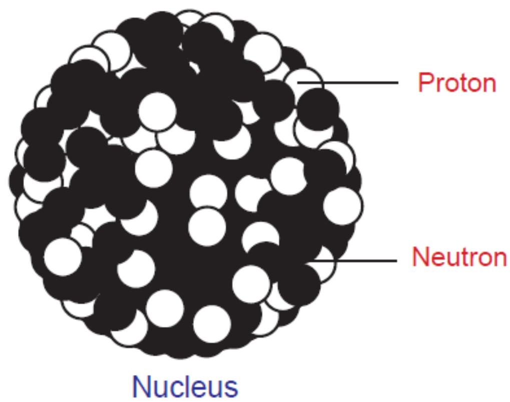
Neutrons: They are neutral particles. They are present inside the nucleus.

COMPOSITION OF NUCLEUS

Electrons have a negligible mass. Hence the mass of an atom mainly depends on the mass of the nucleus. Nucleus of an atom consists of two components. They are protons and neutrons.

Protons are positively charged. Protons repel each other because of their like charges. Hence, more than one proton cannot be packed in a small volume to form a stable nucleus, unless neutrons are present.

Neutrons reduce the repulsive force between the positively charged protons and contribute to the force that holds the particles in the nucleus together.



THE SUBATOMIC PARTICLES

Besides Electrons, Protons and Neutrons, there are many sub-atomic particles such as:

- Mesons
- Positrons
- Neutrinos
- Quarks
- Pions
- Gluons

Characteristics of sub-atomic particles

	Electron	**Proton**	**Neutron**
Discovered by	J.J. Thomson and H.A. Lorentz	E.Goldstein	James Chadwick

Mass	9.1×10^{-28} g	1.672×10^{-24} g	1.674×10^{-24} g
Charge in Units	-1	+1	0

Nucleons

The elementary particles such as protons and neutrons are collectively referred to as nucleons.

ATOMIC NUMBER AND MASS NUMBER

Atomic number (Z)

The Atomic number of an atom can be defined as the number of protons present in the nucleus of the atom or the number of electrons present outside the nucleus of the atom. Thus the atomic number of hydrogen would be one and that of helium would be two. The symbol of Atomic Number is Z. No two elements have the same atomic number; hence it is unique to each element. The atomic numbers of some elements are given in the table below:-

Element	H	He	Li	Be	B	C	N	O	F	Ne	Na
Atomic number	1	2	3	4	5	6	7	8	9	10	11

Mass number (A)

The mass number (A) is defined as the sum of the number of protons and neutrons present in the nucleus of an atom of an element. For example, the mass number of Sodium is 23, which implies that the total number of protons and neutrons in the sodium atom is 23.

The number of neutrons can be obtained by subtracting the atomic number from the mass number (12 for sodium). The mass numbers of some elements are given in the table below:-

Element	H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg
Atomic number	1	2	3	4	5	6	7	8	9	10	11	12

Mass number	1	4	7	9	11	12	14	16	19	20	23	24

More to know

In lighter atoms, one neutron per proton is enough. Heavier atoms with more protons in the nucleus need more neutrons in the nucleus, for the nucleus to be stable. Thus the stability of the nucleus is determined by the Neutron-Proton (n/p) ratio.

Representation of Atomic number and Mass number

$$_{Atomic\ number\ (Z)}^{Mass\ number\,(A)}X$$

For example,

Atomic number of nitrogen is 7.

Mass number of nitrogen is 14.

Representation: $^{14}_{7}X$

More to know

Chlorine has fractional atomic mass.

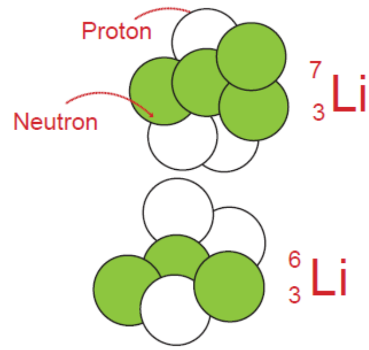
Chlorine-35 exists by 75%

Chlorine-37 exists by 25%

Average atomic mass of chlorine is,

$$\left\{\frac{75}{100} x35\right\} + \left\{\frac{25}{100} x37\right\} = 35.5$$

ISOTOPES



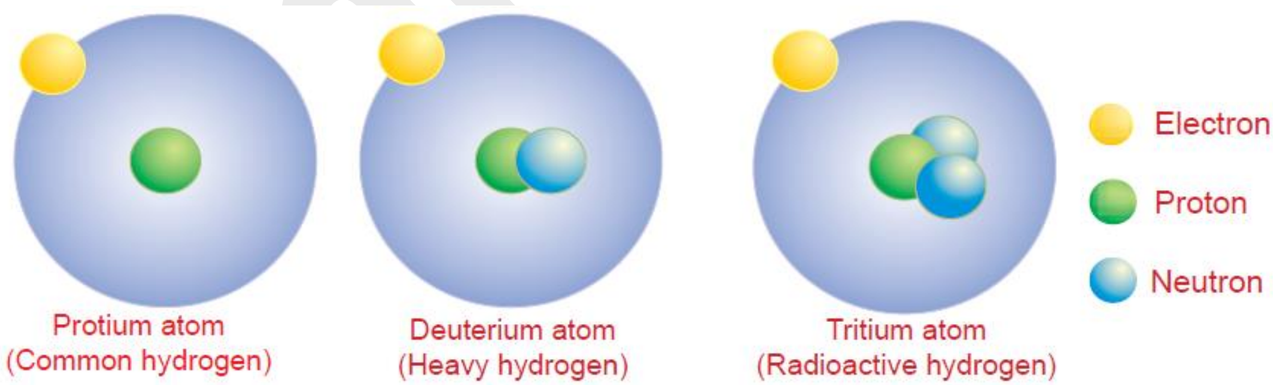
Isotopes of Lithium

American scientist, T.W.Richards observed to his amazement that Lead samples collected from different places differed in atomic mass. This suggested that all atoms of an element are not exactly alike. It is clear that the atoms of an element have the same chemical properties, but they may differ in their masses.

Isotopes are atoms of an element that differ in mass numbers, but have the same atomic number.

Characteristics of isotopes

- Isotopes of an element differ in mass numbers only.
- Difference in mass number is due to the difference in number of neutrons.
- Isotopes of an element have the same chemical properties.
- However, variation in physical properties are noted in isotopes.
- Elements having isotopes exhibit fractional atomic mass.



Isotopes of Hydrogen

Element	Isotope	Representation
Hydrogen	Protium	$^{1}_{0}H$

	Deuterium	${}^{2}_{1}H$ (or) ${}^{2}_{1}D$
	Tritium	${}^{3}_{1}H$ (or) ${}^{3}_{1}T$
Chlorine	Chlorine – 35	${}^{35}_{17}Cl$
	Chlorine – 37	${}^{37}_{17}Cl$
Carbon	Carbon – 12	${}^{12}_{6}C$
	Carbon – 14	${}^{14}_{6}C$
Uranium	Uranium – 235	${}^{235}_{92}U$
	Uranium – 238	${}^{238}_{92}U$

Uses of Isotopes

- Many isotopes find use in medical field.
- Iron-59 isotope is used in the treatment of anaemia.
- Iodine-131 isotope is used in the treatment of goitre.
- Cobalt-60 isotope is used in the treatment of cancer.
- Phosphorous-32 isotope is used in eye treatment.
- Carbon-11 isotope is used in brain scan.

ELECTRONIC CONFIGURATION OF ATOMS

It is known that atoms consist of a positively charged nucleus with protons and neutrons in it. Negatively charged electrons constantly revolve around the nucleus in a set of orbits. The electron orbits are numbered as 1, 2, 3, etc. Starting from the orbit closest to the nucleus. These orbits are also called **K, L, M, N** shells, as mentioned in the atom model proposed by Niels Bohr.

The maximum number of electrons in an orbit is given by **2n2**, where **n** is the orbit number.

Shell number or energy level	Maximum number of electrons ($2n^2$)

First shell (K)	$2(1^2) = 2$
Second shell (L)	$2(2^2) = 8$
Third shell (M)	$2(3^2) = 18$
Fourth shell (N)	$2(4^2) = 32$

It must be understood that the second orbit begins to fill with electrons only after the first orbit is filled. The third orbit begins to fill only after the second orbit is filled. But the fourth orbit commences even before the third orbit is completely filled. The reason for this lies in the concept of quantum numbers.

Thus the term electronic configuration or electronic structure refers to the way, the electrons are arranged around the nucleus. Most of the properties of elements and their compounds depend on their electronic configurations.

To write electronic configuration, the principal quantum number of the shells must be known. This number describes the number of orbits present in the atom.

Let us consider sodium atom.

Atomic number of **sodium** = Total number of electrons in sodium = **11**

Orbit wise distribution of electrons

Orbit Number of electrons

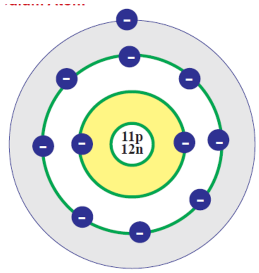
1. **(K-Shell)** $2n^2 = 2\times1^2 = 2$ *electrons*

2. **(L-Shell)** $2n^2 = 2\times2^2 = 8$ *electrons*

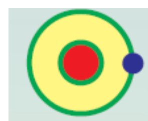
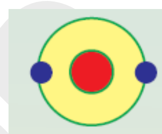
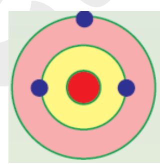
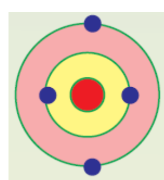
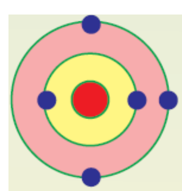
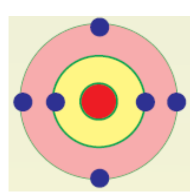
3. **(M-Shell)** *Remaining=1 electron*

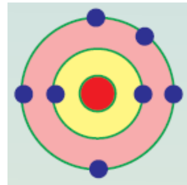
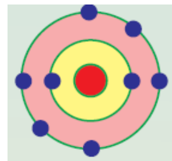
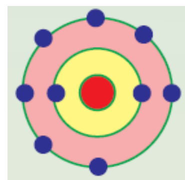
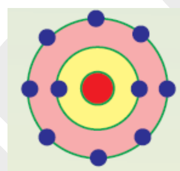
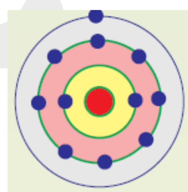
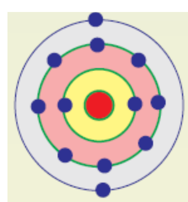
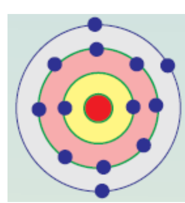
The electronic distribution in sodium is **2, 8, 1.**

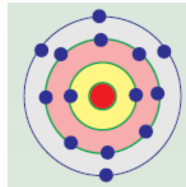
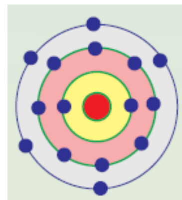
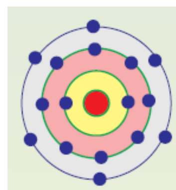
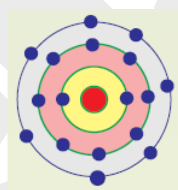
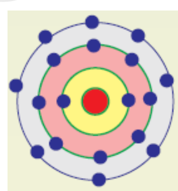
Sodium Atom



Some elements and their electronic configurations:

Element	Atomic Number	Electron dot structure	Electron distribution
Hydrogen (H)	1		1
Helium (He)	2		2
Lithium (Li)	3		2, 1
Beryllium (Be)	4		2, 2
Boron (B)	5		2, 3
Carbon (C)	6		2, 4

Nitrogen (N)	7		2, 5
Oxygen (O)	8		2, 6
Fluorine (F)	9		2, 7
Neon(Ne)	10		2, 8
Sodium (Na)	11		2, 8, 1
Magnesium (Mg)	12		2, 8, 2
Aluminium (Al)	13		2, 8, 3

Silicon (Si)	14		2, 8, 4
Phosphorus (P)	15		2, 8, 5
Sulpur (S)	16		2, 8, 6
Chlorine (Cl)	17		2, 8, 7
Argon (Ar)	18		2, 8, 8

Valence Electrons and valency

The number of electrons in the outer energy level (orbit) of an atom are the ones that can take part in chemical bonding. These electrons are referred to as the valence electrons.

The outermost shell or orbit of an atom is known as valence shell or valence orbit. The electrons present in the outer shell are called valence electrons.

The number representing the valence electrons is used to calculate the valency of the element. This valency is regarded as the combining capacity of elements.

Illustration

Lithium (Atomic number:3) has the electronic distribution,

(n=1) K Shell (2 electrons)

(n=2) L Shell (1electron)

Outermost shell is ‘L’.

The valence electron = 1

The valency of Lithium = 1

When the number of electrons in the outermost shell is close to its full capacity, (such as 8 for L shell) valency is then determined by subtracting the valence electron number from the full capacity of 8.

Valency = 8-valence electrons

For example, fluorine (atomic number: 9) has the electron distribution,

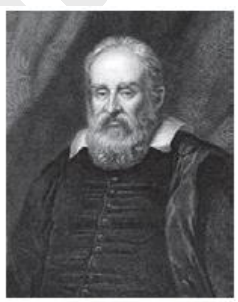
N	Shell	Electrons
1	K	2
2	L	7

Outer shell (L) has 7 electrons which is close to the full capacity of 8.

Hence valency = (8 -7) = 1

47] Measurement and Measuring Instruments


Nicolaus Copernicus


Galileo Galilei


Tycho Brahe


Johannes Kepler

Claudius Ptolemy (AD 90 – AD 168) was one of the most influential Greek writers of his times. He wrote that the moon, the sun and all the planets revolved around the Earth in an almost circular path. This remained the belief among people of Europe for almost thousand four hundred years. It was based on the observation that the sun, the stars and the moon rose in the east and set in the west.

Four sixteenth century astronomers Nicolaus Copernicus (1473-1543), Tycho Brahe (1546 – 1601), Galileo (1564 – 1642) and Johannes Kepler (1571-1630) changed that view completely. They dared to question the age-old belief. Based on keen observations and accurate measurements, they realized that it was the earth that was going around the sun; not the other way around.

Copernicus was the first to point out that Mercury, Venus, Saturn, Jupiter and Mars moved in a path that seemed to be centred around the sun and not the Earth.

Tycho Brahe, one of the greatest observing astronomers of any age, devised the most precise instrument available for observing the heavens. Observations of angular measurement in his times were correct to ¼ of a degree; but Tycho's were accurate to 1/30th of a degree. He produced the most detailed study of planets and stars of his time – an almanac of 777 stars.

Galileo built his own telescope, an instrument to observe the skies. The instrument gave a view of the heavens that was never before possible, affording close-up scrutiny of stars and planets. He discovered the three moons of the Jupiter, the rings of the Saturn and many other things in the skies. Based on his own observations, he supported Copernicus' view that the sun was at the centre of the orbits of the planets.

Kepler used the detailed record of observations made by Tycho particularly that of the planet Mars. Kepler proved beyond doubt using mathematical calculations that the planets followed an elliptical path around the sun rather than a circular one around the Earth. He was the first to introduce mathematically precise calculations.

Finally, the thousand four hundred year old belief was put to rest. It was made possible because of careful observations, accurate measurements using scientific instruments and detailed calculations.

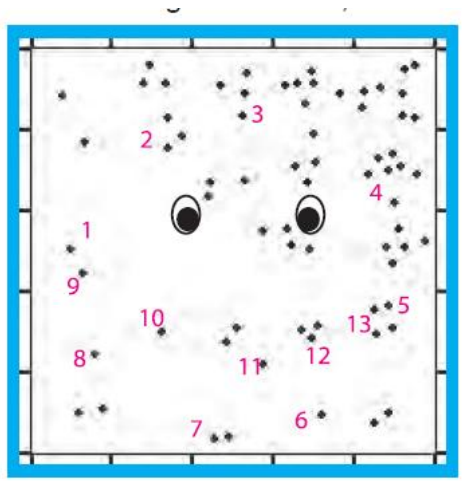
IMPORTANCE OF ACCURATE MEASUREMENTS

Have you read any detective stories or novels? The detective looks at the scene of crime, observes carefully, notices the position of things and is able to tell how the thief came into the room, what the thief looked for, what was stolen and finally, how the thief escaped from the scene of the crime with the booty.

Great scientists are a bit like the detectives, we come across in detective novels. They observe carefully, notice things, make the necessary measurements and are able to guess what must be actually happening in nature.

Look at the diagram given below. You can observe a set of dots in it.

Using a pencil, you can draw whatever pictures you want by joining the dots, in as many ways as possible. It is not necessary to use all the dots. Thereafter, erase all the lines and join the dots in the sequence as indicated by the numbers and see what the artist had in mind.



Imagine that each dot is a fact or a piece of data. The lines that join them are our interpretations of the data. We could give greater importance to some data by using that dot more than once. We could also avoid using some dots, if we thinkthose pieces of data are less important or less reliable. Such a construction is called a Hypothesis in science. Thus many interpretations or hypotheses are possible with the given one set of data, but which one is the right one? It is possible to decide on that, only after we verify the hypotheses in a number of different ways or by obtaining additional data to see if they coincide with the lines that we have drawn.

Quite often it happens that several years later, fresh data comes up and in the light of the fresh data our understanding of what is actually happening changes. Very often fresh data comes up with technological advancements and subsequently human beings are able to make more accurate measurements than what their forefathers did. A lot therefore depends on the instruments that are used to make the measurements. Are they accurate? Are they reliable? Let us learn more about measurements and measuring instruments!!

THREE CHARACTERISTICS OF MEASURING INSTRUMENTS

There are three important characteristics of measuring instruments that one must be familiar with. They are:

- Least Count

- Range
- Zero Error

The smallest value that any instrument can measure is called the least count of the instrument. For example, if you use a scale then the smallest division is one millimeter. It is the smallest value that the scale can measure and is called the least count of the scale. Some scales used for engineering drawing have half millimetre markings and therefore the least count of such scales is 0.5mm.

When we say that the length can be measured correct to a millimeter, then we mean that the least count of the scale is one millimeter. Can you find the least count of the spring balance shown in the picture on the right?

The values between the minimum measurable value and the maximum value that can be measured is called the range of the instrument. For example, the range of the scale is zero centimeter to thirty centimeters. Usually, we state the maximum value as the range since the minimum value is generally zero.

When we say, the range of the metre scale is 100cm, we mean that the range is from zero to 100cm. There are, however, special instruments that are designed to measure from a specific minimum value to a maximum value. In such cases we say the range of the instrument is from such and such value to such and such value.

For example, if you had a Voltmeter that reads from 150V to 250V, then we say that the range of the Voltmeter is from 150V to 250V. Usually such instruments are built for a specific purpose and optimized to give accurate readings within the design range and the designer expects that the value will not go outside the design range.

Often instruments do not read zero at the minimum position. For example, the needle of an Ammeter may read 0.02 amperes when it is not connected to the circuit. Such an error is called zero error, since the needle at the minimum position is not reading zero. While using the instrument, one has to apply a correction to the reading to obtain the real value. The value that is read off the instrument is called the observed value to which we apply the zero error correction and obtain the measured value. We will learn more about zero error and zero error correction later when we read about the Vernier Caliper.

SI PREFIXES

Dimension	SI unit
Length	Metre
Mass	Kilogram
Time	Second
Electric current	Ampere

The metre, the gram, the second and the ampere are known as the base units, to which we can add some prefixes. The international committee on weights and measures also agreed on standard prefixes to base units to express smaller and larger quantities in terms of the base units. As far as possible, the SI unit was kept as the base unit. The SI unit of mass, the kilogram, however was an exception –

Thus one-tenth of a metre or 0.1 of a metre can be referred to as a decimeter. Similarly 10-6 seconds of time can be referred to as a microsecond. These prefixes can be used along with derived SI units as well. 1000000(10^6) joules of energy can be referred to as a megajoule. You may be aware of some of these prefixes.

Smaller Quantities

Factor	Prefix	Symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	Nano	N

Larger Quantities

Factor	Prefix	Symbol

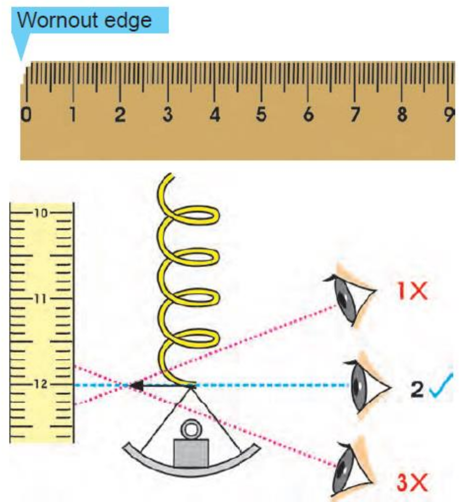
10^1	deca	Da
10^2	Hector	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G

The kilogram is an exception. The base unit for mass is the gram, however the SI unit of mass is the kilogram and it already uses a prefix "kilo" which means 1000 grams. The prefixes are added to the base unit 'gram' e.g.– milligram, decagram etc. A thousand kilograms would make a megagram; it is also referred to as a tonne or a metric ton.

Tips for making accurate measurements

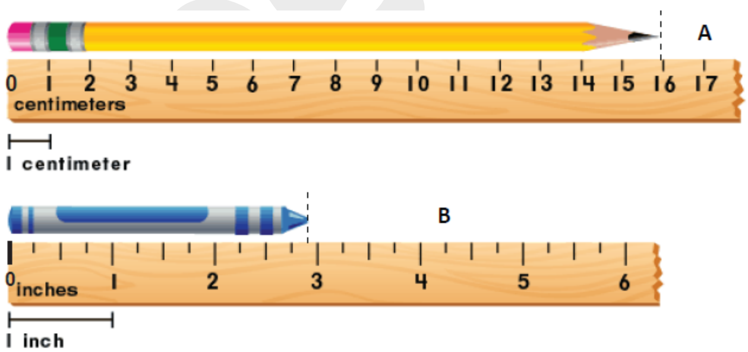
1. Never use the edge of the metre scale to measure the length of an object as it is invariably worn out and introduces an unspecified amount of zero error. Instead, align any centimeter mark to the left end of the object. Now take the reading of the left edge and that of the right edge. The difference between the two readings will give the length of the object.
2. Readings must be taken with one eye closed. The line joining the eye, the edge of the object and the scale marking must be perpendicular to the scale to avoid what is called parallax error. Eye position 1 in the given figure is incorrect as pointer would appear to read 12.2. Eye position 3 is incorrect as the pointer would appear to read 11.8. Eye position 2 is the correct one, where the observed reading is the same as the actual reading.
3. Readings must be exact multiples of the least count. For example, if the length of the object lies between two markings on the scale, the length must be read off to the nearest marking on the scale. Never estimate the value by interpolating. In the figure given, pencil A is exactly 16 cm since the tip of the pencil coincides with the 16cm mark. In case B, however, the crayon's length lies between 2.75 inches and 3 inches and is closer to 3 inches than to 2.75 inches. The length should

therefore be recorded as 3 inches. This "error" is actually a limitation of the instrument being used for measurement and not the fault of the person making the measurement. It is called the uncertainty in measurement and you will learn more about it in higher classes.



Tips for recording measurements

1. Recorded values of measurements must always be accompanied by the appropriate units.
2. As far as possible, measurements must be tabulated.



3. Values must be recorded to the appropriate decimal place. For example, if the length is measured correct to a millimeter, say 40mm, but is recorded in centimeters then it must be recorded as 4.0cm and not as 4cm. The '0' after the decimal indicates that the measurement has been made correct to the millimeter. On the other hand, if it is recorded in meters then it must be recorded as 0.040m and not as .04m. Once again the '0' after the digit '4' indicates that the measurement has been made correct to the millimeter. The recording 0.04 indicates that the value has been measured correct to the centimeter. The last digit '0' therefore signifies the least count to which the measurement has been made.

MEASURING LENGTH

Vernier caliper

The vernier caliper is a device that is used a great deal in engineering work and in workshops which manufacture things. It is an ingenious device where two scales with fairly large least counts are used in conjunction with one another to measure very small values of length. The auxiliary scale, now called the Vernier scale after the inventor, is used nowadays in almost every instrument meant for accurate measurement such as the barometer, the microscope, the sextant (for measuring small angles), etc.

The principle of the vernier

The principle of the Vernier is delightfully simple. Let us say, you have two scales, one with a least count of 1.0mm(main scale) and the other with a least count of 0.9mm (auxiliary or Vernier scale) you can then measure an object whose length is 0.1mm quite easily. Refer to the diagram alongside; by aligning the left edge of the object with the zero of the main scale and butting the edge of the auxiliary scale to the edge of the object, you would find that the first marking of the auxiliary scale would exactly coincide with the first marking of the main scale (object length, 0.1mm + vernier division, 0.9mm = 1.0mm, the first main scale division).

Going the other way around, if we did not know the size of the object and we found that the first vernier division coincided with the first main scale division, we could state that the size of the object must be 0.1mm, since:-

object length, 0.1mm = 1.0mm, the first main scale division - vernier division, 0.9mm

You could now say that the least count of the combination of scales is 0.1 mm, which is the difference between the two least counts. Popularly it is written as follows:-

Pierre Vernier *(1580 - 1637) was a French government official. Vernier was taught Mathematics and science by his father who was a lawyer and engineer. His father introduced Pierre to the works of Tycho Brahe. He worked for 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. He collaborated with his father in making a map of the Franche-Comté area. His interest in surveying led him to develop instruments for surveying and this prompted the invention for which he is remembered by all scientists. In his publication La Construction, l'usage, et les propriétés du quadrant* *nouveau de Mathématiques, he explains the use of the auxiliary scale in making measurements – now called the Vernier scale. He also compiled a huge table of natural sines – a table from which the angle of a triangle can be obtained if the length of the sides of the triangle is known, about which you will learn in your maths class.*

L.C. (of the instrument) = 1 MSD – 1 VSD

If on the other hand, the size of the object being measured is 0.2mm long and the auxiliary scale is butted against the object the second vernier marking will coincide with the second main scale division (object length, 0.2mm + two vernier divisions, 1.8mm = 2.0mm). Going the other way around, if we did not know the size of the object and we observed that the second vernier division coincided with the second main scale division we could say that the size of the object is 0.2mm.

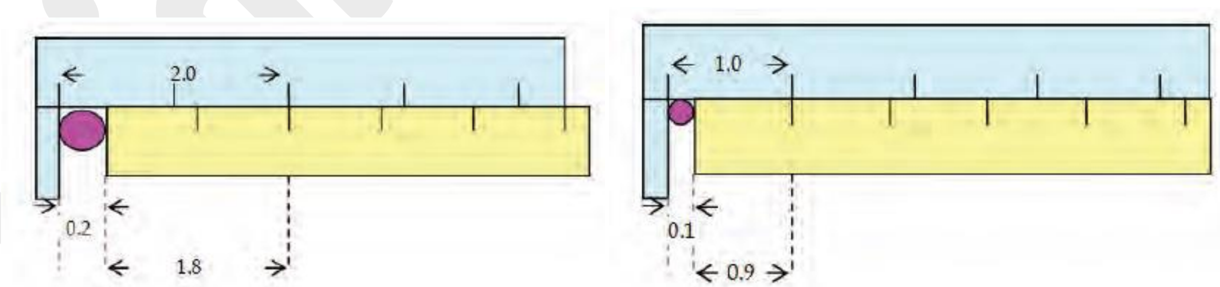
object length, 0.2mm = 2.0mm, the second main scale division – two x vernier divisions, 1.8mm

There is a pattern here and we could try extending by using the same logic and saying that if the object was 0.4mm long then the fourth vernier division would coincide with the fourth main scale division. Further if it was 0.9mm long, then the ninth vernier division would coincide with the ninth main scale division. I could write this as:

Object length, 0.9mm = 9.0mm, the ninth main scale division – nine x vernier divisions, 8.1mm

0.9mm = 9*Main scale division – 9*Vernier scale division

Isn't this quite an ingenious way of measuring correct to 0.1mm, when you have two scales with much larger least count?



We have discovered a pattern and we know how to extend the pattern using the same logic. Now let us try to generalise. To generalise means to write the same thing in terms of an unknown variable(X) which we call a formula - a formula which will be valid for all real values of X. So let us say that the Xth vernier division coincides with a main scale division. Then :-

object length, 0.X mm = X*Main scale division – X* Vernier scale divisions

object length, 0.X mm = X(Main scale division – Vernier scale division)

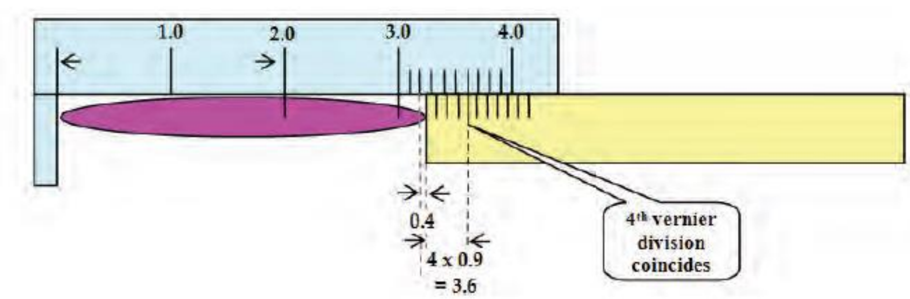
object length, 0.X mm = X(Least Count)…….[remember? Least count = 1 MSD – 1 VSD]

Let us consider a case where the size of the object is something like 3.24 cm (32.4mm). On the main scale, the edge of the object would lie between 3.2cm and 3.3cm. This could be written as 32mm+ X mm.

The 0.4mm of length extending beyond the 3.2cm (32mm) mark would be the extent of uncertainty as read on the main scale. When the auxiliary scale is slid in place, the fourth vernier division would coincide with some main scale division (we don't really care which). Using the formula given above, we know that the extra length can be obtained by multiplying the vernier coincident 4, by the least count which in the example happens to be 0.1mm. Therefore,

Object length, 32.X mm = 32+X*(Least Count)

We finally arrive at the most useful form of the formula which is:



Object length = Main scale reading + (Vernier coincident*least count)

Description of vernier caliper

The Vernier Caliper used in the laboratory is a modern version of the age-old one. A picture of a Vernier Caliper is shown below.

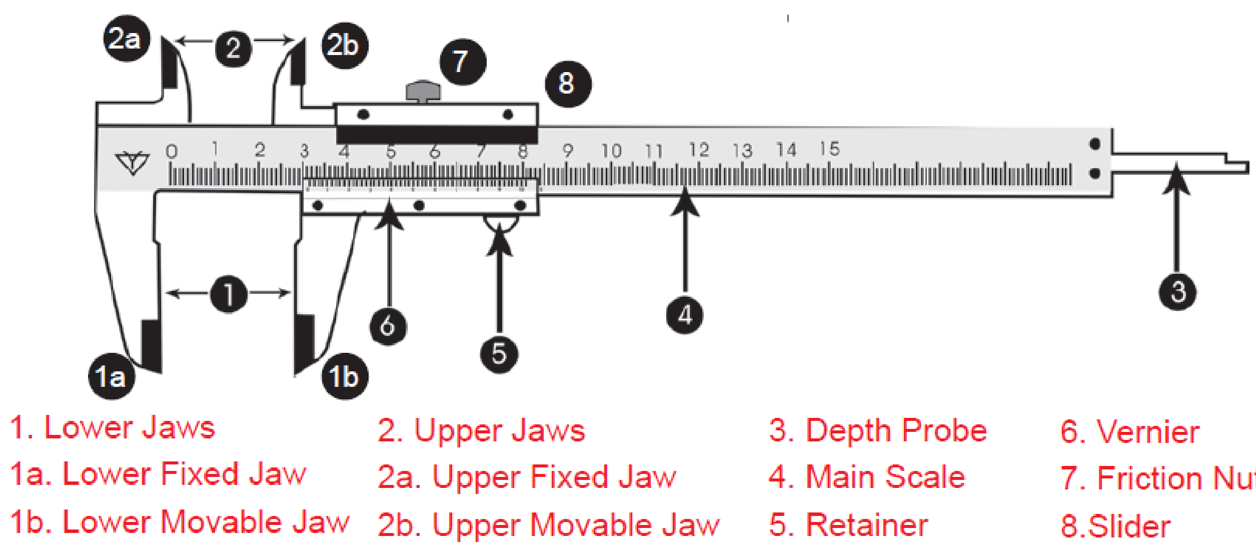
The Vernier Caliper consists of :-

- A thin long steel bar graduated in cm and mm (4). This is the Main scale.
- Fixed perpendicular to the bar at the left end of the steel bar carrying the main scale is an upper fixed jaw and a lower fixed jaw.

- To the right of the fixed jaws mounted on the steel bar is a slider with a upper movable jaw and a lower movable jaw.
- The slider can be fixed to any position using the tightening screw or friction nut.
- The Vernier scale (6) is marked on the slider and moves along with the movable jaws and the slider.
- The lower jaws (1) are used to measure the external dimensions and the upper jaws (2) are used to measure the internal dimensions of objects.
- The thin bar attached to the Vernier scale at the right side (3) is called the depth probe and is used to measure the depth of hollow objects.

Using the vernier caliper

The first step in using the vernier Caliper is to find out its characteristics Least count, Range and Zero error.



Least Count:

The least count is ascertained using the formula we obtained earlier in para 5.5.2. L.C (of the instrument) = 1 MSD – 1 VSD

The main scale division is easily obtained by inspecting the main scale. Invariably it will be in centimeters, further divided into millimeters. The least count of the main scale or main scale division is therefore usually one millimeter. The vernier scale division is obtained by measuring the vernier scale against the main scale. In the vernier Caliper, nine main scale divisions would be divided into ten equal parts (9mm/10 = 0.9mm). The least count would therefore be 1 MSD – 1VSD, 0.1mm (1mm – 0.9mm).

Zero Error:

Loosen the friction nut and close the jaws of the Caliper by moving the slider to the extreme left position. Check whether the zero markings of the main scale and the vernier scales coincide. Suppose the zero mark of the vernier is shifted slightly to the right, then we need to remember to subtract that amount from the observed value to get the measured value. The error is therefore considered positive and the correction you need to apply is negative (subtract). On the other hand, if the vernier zero is shifted to the left of the main scale zero marking then it is considered negative zero error and the correction for it is to add (+) the error value to the observed value. Rarely will the zero error exceed a mm, since the Vernier Caliper is an accurate instrument.

Positive zero error:

To obtain the value of the zero error simply count the number of the vernier scale division that coincides with any one of the main scale division and multiply it with the LC of the instrument. Suppose the fifth vernier division coincides with a main scale division, then multiply five with the least count (0.1mm) to get + 0.5mm.

Negative zero error:

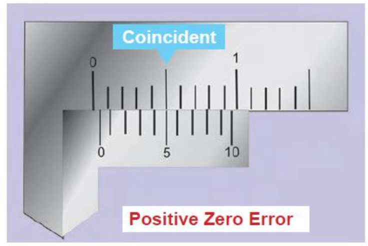
If the zero error is negative, then you need to imagine the main scale extending backwards by one division which we shall call negative 1(-1.0 mm). Therefore, we would need to add the vernier reading to -1.0mm. Let us say we find the 8th vernier division which coincides with any main scale division. Using the formula we evolved earlier:

Object length = Main scale reading + (Vernier coincidence*least count)

We get zero error = (-)1.0+8*0.1 = (-)1.0+0.8 =(-) 0.2mm

Range: Now move the slider to the extreme right position without slipping off the bar. Note the maximum value that can be read off the main scale. The range of the instrument decides the maximum size object that can be measured using Vernier Caliper.

Measure the dimensions of familiar objects using the Vernier Caliper. You could try measuring length, width and height of objects and calculate their volume. For example, you could measure the inner diameter of a beaker (use the appropriate jaws) as well as its depth (use the depth probe) and calculate the inner volume of the beaker.



Tabulate the values as shown in the sample table below.

Least Count ………..cm Zero Error …(+ or-)…….cm Zero Error Correction … (- or +)……cm

Digital vernier caliper

Digital Vernier Caliper has a digital display on the slider. The slider also houses the electronic calculator which calculates the measured value that is then displayed. The user need not manually calculate the least count, the zero error etc. or take the trouble of finding the vernier coincident manually.

MEASURING MASS

When we go to a shop to buy something, say a kg of rice, we often buy it in terms of the 'weight'. In layman's parlance what is called 'weight' is actually mass in science parlance. Many things are measured in terms of the mass in the commercial world. We buy gold which is measured in grams or milligrams, medicines in 500mg or 250mg values, load trucks in terms of tons etc. Can we use the same instrument for measuring milligrams of medicine or gold and the tens of tons of cargo that is loaded on an aeroplane? What kinds of instruments are used in measuring such quantities? In this section, we will go over some of the instruments that are used for measuring mass. Common (beam) balance

A beam balance compares the sample mass with a standard reference mass (known masses such as 100g, 200g etc.). Least counts of 20g to 50 mg are possible.

Two pan balance

This type of balance is commonly used for measuring mass in shops. This balance too compares the sample mass with a standard reference mass. The pans rest on top of the beam and can be conveniently placed on a table top. Least counts are generally in the region of 10g to 50g.

Physical balance

It is used in laboratories. It is similar to the beam balance but is a lot more sensitive and can measure mass of an object correct to a milligram.

MEASURING TIME

The pendulum as a reliable measure of time was first articulated by Galileo in 1602. In those days many lamps would be mounted on a large glass arrangement suspended from the ceiling. Such an elaborate arrangement was called a "chandelier". Watching the glass chandelier of the church move to and fro in the wind, Galileo realized that a simplified form of the pendulum could be used to keep time.

The pendulum

A pendulum is a heavy bob suspended by a light thread. The length [L] of the pendulum is measured from the point of suspension or pivot to the centre of gravity of the bob. When the pendulum is displaced from the centre position and released, it begins to swing to and fro. One complete to and fro motion is called an oscillation. The maximum displacement of the bob from the mean position is called the amplitude of the oscillation. The time taken for one oscillation (one complete to and fro movement) is called the time period of the pendulum (T). The time period of the pendulum:

- does not depend on the amplitude and this can be verified experimentally.
- is proportional to the square root of the length of the pendulum. [$T \alpha \sqrt{L}$].
- is inversely proportional to the square root of the acceleration due to gravity.

$$[\, T \alpha \frac{1}{\sqrt{g}} \,]$$

Putting both together along with the constant of proportionality, 2π, we get the final form of the formula:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

You will be doing an experiment related to this formula in your practical class, giving the time period of the pendulum. Alternatively, knowing the length, L; the time period, T; we can determine the acceleration due to gravity, g.

Clocks

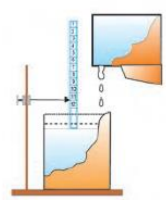
Sundial

The sundial has a stick or object to cast a shadow on the horizontal surface. As the sun moves across the sky, the position of the shadow moves on the dial face to indicate time. The least count of such sundials again varied a great deal and improved from about one hour to about 15 minutes in the later years.

More to know

The prehistoric man, by simple observation of the stars, change of seasons, and the day-night cycle came up with very primitive methods of measuring time. This was necessary for planning nomadic activity, farming, sacred feasts, etc. The earliest time measurement devices before clocks and watches were the sundial, the hourglass and the water clock. The Egyptians, in about 3500 B.C. built tall pillars to use the shadow as a way of telling time. Over time, these grew into more sophisticated instruments such as the sundial, yet they could not read the time at night or in cloudy weather or when the length of the days changed with the seasons.

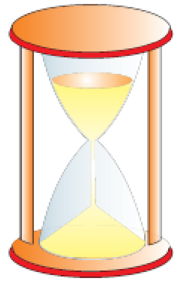
The Greeks invented the water clock and the sand hourglass. Both these were great improvements over the sundial. They could give the time during the day as well as the night and had a much better least count.



Water Clock

It was an evenly marked container with a float and pointer into which water dripped in at a fixed rate. As the water dripped into the container, the level of water increased. The time was read off on the level markings on the wall of the container. Since the rate of flow of water depended on the level of water in the upper container it was improved to provide a constant rate of flow as shown in the diagram alongside. The least count of such instruments varied a great deal but people were happy to have a least count of about a quarter of an hour.

Sand Clock



It was made up of two rounded glass bulbs connected by a narrow neck of glass, between them. When the hourglass is turned upside down, a measured amount of sand particles stream through from the top bulb to the bottom bulb of the glass. These were more like timers which measured one hour typically and were therefore also called “hourglass” and had to be inverted every hour. They can also be built to measure smaller units of time for special purposes.

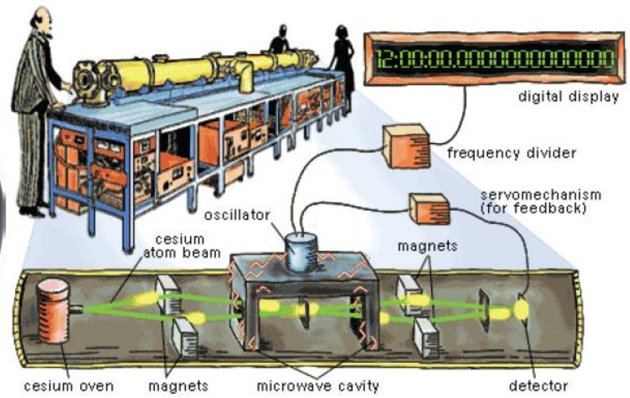
Another characteristic of instruments - accuracy

You would have observed that some watches keep correct time, while some lose or gain time. Some watches lose or gain as much as five minutes in a day (24 hrs.). Some watches, on the other hand, lose or gain about five minutes in a whole month. The latter are said to be more accurate than the former.

Do not confuse accuracy with least count. If we take two clocks with the same least count of 1 second but one loses 5 minutes every day and the other loses five minutes in 30 days; the second clock is said to be more accurate since the time measured by the second clock is closer to the actual value.

Atomic clock

Atomic clocks are the most accurate timekeepers ever known. The best ones lose or gain 1 second in 109 days (approximately 2739726 years). This means that once synchronized, for generations your family members need not reset the clock. Therefore, these clocks are used as primary standards for international time. Atomic clocks can be made to look like any other clock with a least count of one second or with a least count of one millisecond for scientific purposes.



More to know

In India, the time standard is provided by the atomic clock kept at the National Physical laboratory, New Delhi.

48] Motion

REST AND MOTION

How do we know whether an object is stationary or is moving? Sitting in a train, it seems as if the trees are moving in the opposite direction. Looking at another train overtaking ours it appears as if our own train is moving in the opposite direction (i.e. backwards). Let us look deeper into this question. Some scientists who went quite deep into this question were Newton and Einstein.

perhaps you arrived at the conclusion that if the position of an object does not change over time, then we know that it is not moving. But position itself is measured relative to another object. Therefore, to know if an object is moving or not, we need another object that we are sure is not moving. To check if the second object is not moving, we need a third object that we are sure is not moving…. Now this is proving to be more difficult than what we thought. So where do we start? We shall start with the understanding that, the idea of rest and movement are very relative.

On the earth, we take a point on the ground and we measure all distances with respect to this point which we call the datum. Of course we know that the earth itself is moving around the sun and the sun in turn is moving through space. But then, we sort of ignore all that, since we are only going to discuss movement of objects on the earth. You can select any point on the earth and call it your own datum. You make all measurements relative to your datum. You could then draw imaginary lines horizontally to represent the x and y axes and a third line vertically through the point to represent the z axis. The three imaginary lines representing the three axes together with the datum is called the frame of reference. It is helpful to take a prominent point or object that is easily recognisable as the datum.

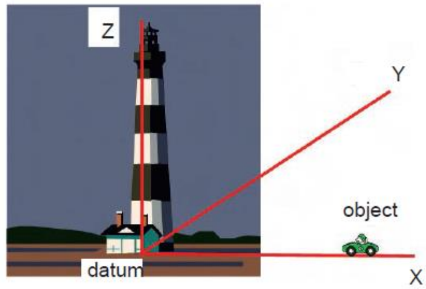


Fig 6.1

Position of object
X = 500m
Y = 10m
Z = 0m

Secondly, you have to determine the position of the object under observation in relation to the datum. This is easy and can be done by representing the position of the object in terms of its x distance, y distance and z distance exactly, as you would on a graph paper, if only this is in three dimensions.

Thirdly, you have to observe the object over a period of time say an hour or so. If the position of the object does not change during this time, then we could conclude that the object has been at rest with respect to the datum or frame of reference during the period of observation. If the position of the object changes with respect to the datum or frame of reference during this period, then we say that the object has moved during the period of observation.

A body is said to be in the state of rest when it remains in the same position relative to a datum over time.

More to know

One of the real mysteries of life is to find an object that is truly and absolutely at rest. Objects on the earth seem stationary but we know the earth itself is moving and is a part of the solar system. The solar system itself is moving around and is part of a larger galaxy. The galaxy itself is moving around amidst many other galaxies. Is there any object in this universe, which we could say with certainty that it is at rest?.....`

A body is said to be in the state of motion, when it changes its position with respect to a datum over time.

To summarise, therefore, to determine whether an object is 'at rest' or 'in motion' three parameters are required. They are:

- A datum and a frame of reference
- The position of the object in relation to the datum or frame of reference
- Time

TYPES OF MOTION

Movement can be classified under the following heads for convenience sake:

- 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 in the opposite direction.
- Random motion – where the motion of the object does not fall in any of the above categories.

DISTANCE AND DISPLACEMENT

Distance : It is the length of the actual path followed by an object or body while moving from one point to another. In the example shown alongside, the length of the left side path is 1.5km and we say that the distance between the two points following the left hand path is 1.5km, while the distance is 2.5km following the right hand path. Distance is a scalar quantity and the direction is not important. It always increases with time.

Displacement : It is the shortest distance between two points and is a vector quantity where direction is an essential feature. It is not merely sufficient to state the shortest distance between the two points but it is also necessary to state the direction. In the example above, the displacement of the destination is one km in the north easterly direction from the originating point.

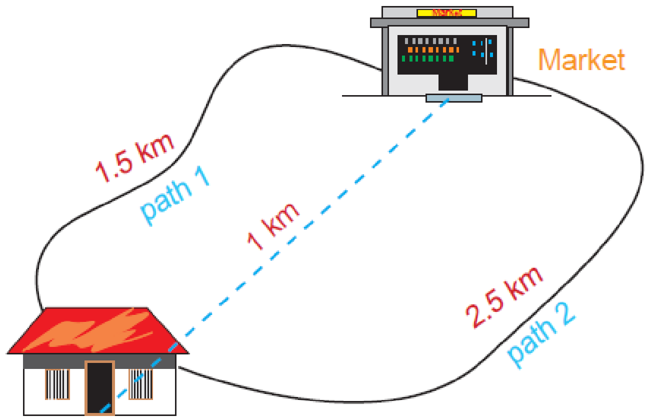


Fig 6.2

Let us compare the two terms, distance and displacement to understand the similarities and differences:-

Distance	Displacement
It is the length of the actual path followed by an object or body, while moving from one point to another.	It is the shortest distance between two points.
It is a scalar quantity (having only magnitude).	It is a vector quantity (having magnitude and direction)
It is measured in metres in the SI system.	It is measured in metres in a particular direction in the SI system.
It is not a unique quantity and is always path dependent.	It is only dependent on the starting point and the ending point and is independent of the path followed. It is unique to a given pair of points.

It can either be equal to or greater than displacement.	It is either equal to or lesser than the distance.
Distance in any direction would be a positive quantity, since direction is inconsequential.	It can be a negative quantity. If displacement in one direction is assumed to be positive then the displacement in the opposite direction would be a negative quantity.

SPEED, VELOCITY AND ACCELERATION

Speed is the rate of change of distance with respect to time or the distance travelled per unit time. The SI unit of speed is metres per second. It is a scalar quantity.

Velocity is the rate of change of displacement with respect to time. It is the displacementper unit time. The SI unit of velocity is metres per second. It is a vector quantity and therefore, the direction must always be specified along with the magnitude and the units.

Let us compare the two terms speed and velocity to understand the similarities and differences:-

Speed	**Velocity**
It is the rate of change of distance with respect to time.	It is the rate of change of displacement with respect to time.
It is a scalar quantity (having only magnitude)	It is a vector quantity (having magnitude and direction).
Speed is velocity without a particular direction.	Velocity is speed in a particular direction.

It is measured in metres per second in the SI system.	It is measured in metres per second in a particular direction in the SI system.
Distance can either be equal to or greater than displacement.	Displacement is either equal to or lesser than the distance.
Speed in any direction would be a positive quantity, since distance in any direction is a positive quantity.	Velocity can be a negative quantity. If velocity in one direction is assumed to be positive, then the velocity in the opposite direction would be a negative quantity.

Acceleration:

Acceleration is the rate of change of velocity with respect to time or it is the rate of change of velocity in unit time. It is a vector quantity. The SI unit of acceleration is m/s per second, also written as m/s^2 or ms^{-2}.

The velocity of a car moving in a particular direction changes from 10 m/s to 50 m/s in 10 seconds. What will be its acceleration? Look at the box on the right to find it out. The acceleration is $4m/s^2$, which means that every second the velocity increases by 4m/s. If the velocity is reduced from 50m/s to 10m/s, then we would get an acceleration value that is negative, indicating that the velocity is reducing. Try and work this out by yourself and ask your teacher for a feedback.

$$\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{time}}$$

$$= \frac{\text{Final velocity - initial velocity}}{\text{time taken}}$$

$$= \frac{50m/s - 10m/s}{10s} = \frac{40m/s}{10s}$$

GRAPHICAL REPRESENTATION OF MOTION ALONG A STRAIGHT LINE

The distance/displacement –time graph

Plotting a graph of distance/ displacement or speed/velocity on a graph helps us visually understand certain things about time and motion. The following table shows the distance walked by Murugan 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 the x-axis and 'distance' along the y axis.

The graph is known as distance – time graph.

When we look at the distance-time graph of Murugan's walk, we notice certain things. Firstly, it looks like a straight line.

We also notice that Murugan covers equal distances in equal intervals of time. We could therefore conclude that Murugan walked at a constant speed. Can you find the speed at which Murugan walked? Think about this for some time before you read on. See if you can find that out by yourself.

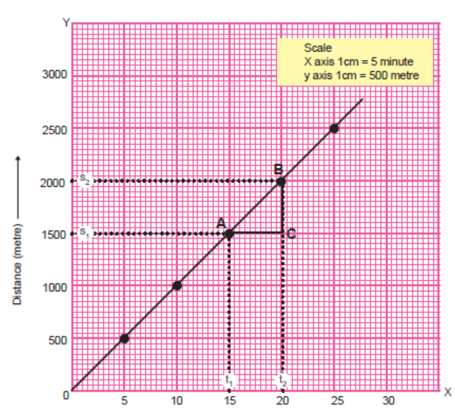


Fig 6.3

The speed at which Murugan walks can be found from the distance-time graph as shown in Fig 6.3. Consider a small part AB. From B, draw a line perpendicular to x axis. From A, draw a line parallel to x axis. These two lines meet each other at C to form a triangle ABC. Now on the graph, BC corresponds to the distance covered (s_2-s_1), and AC denotes the time interval (t_2-t_1). The speed at which Murugan walks can be calculated as follows:-

The parameter is referred to as the slope of the line. The steeper the slope (in other words the larger the value) the greater is the speed.

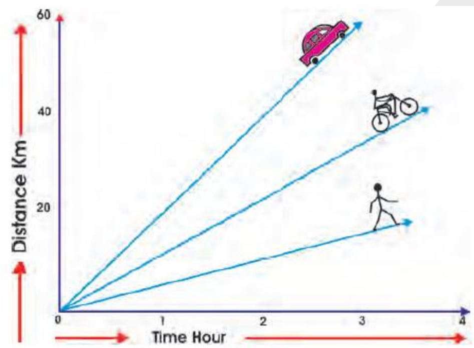


Fig 6.4

Let us take a look at the distance time graphs of three different people – Murugan walking, Kavitha cycling and Swamikannu 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 graphs of the three would look something like that given in fig. 6.4. The slope of the line on the distance – time graph becomes steeper as the speed increases.

If we plotted displacement in the graph instead of distance, then we would be able to calculate the velocity of the object. We need to note that the direction is not indicated on the graph and needs to be stated in words separately. If it is not stated then it is assumed that the displacement is in a single direction.

Uniform and non-uniform speed/ velocity

In the case that we discussed in the previous section, the speed/velocity of all objects were uniform. Uniform speed/ velocity means that the speed/velocity remains constant over time. In the world around us, we notice that the speed of objects keeps changing from time to time. In such a case the distance/displacement - time graphs would not be a straight line.

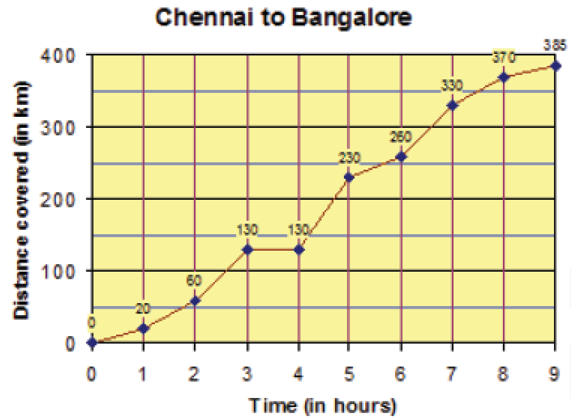


Fig 6.5

The velocity-time graph

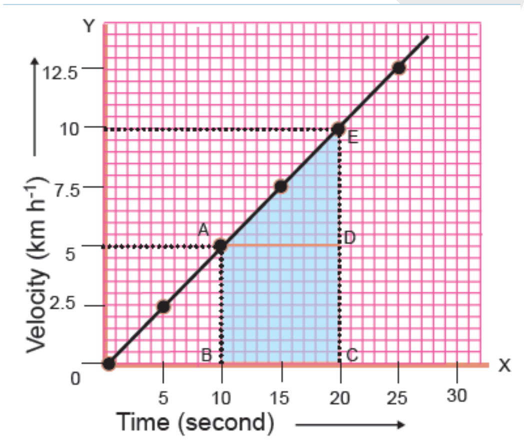


Fig 6.6.

The magnitude of the velocity of an object moving in a straight line can be plotted against time to give a velocity-time graph. What can we learn from a velocity time graph? The following table shows the velocity of a car at regular intervals during a test drive. The velocity-time graph for the motion of the car is shown as in Fig 6.6. When we look at the velocity-time graph of the car, we notice certain things.

Firstly, it looks like a straight line. We also notice that the car velocity is increasing steadily by equal amounts in equal intervals of time. We could therefore conclude that the car is moving with uniform acceleration. Can you find the rate of acceleration of the car? It would be possible to do that and the method is quite similar to finding the speed from a distance-time graph.

The value DE/AD is called the slope of the line. The steeper the slope of the velocity-time graph, the greater is the acceleration. Sometimes the acceleration need not be uniform and may vary over time. Fig 6.6 shows the velocity-time graph of a moving car.

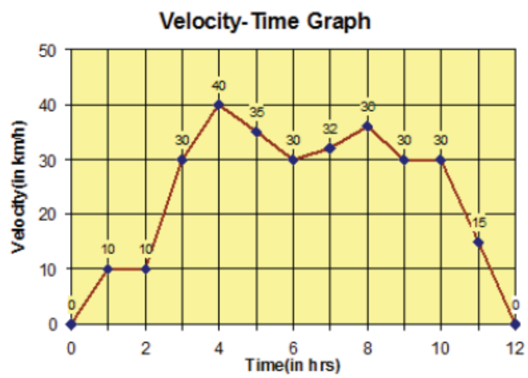


Fig 6.7

Finding displacement from the velocity-time graph

Let us see how we can find the displacement from a velocity-time graph (or distance from a speed-time graph). The following graph shows the velocity-time graph for a car moving with uniform velocity of 40km/h. In this graph, time is taken along the x axis and velocity is taken along the y axis. We notice that the velocity time graph is a straight line that is horizontal (parallel to the x –axis) indicating that the value of velocity remains unchanged.

If we take a time interval of say two hours from t1=1h to t2=3h (shown in blue on the graph), we would notice that AC or BD represents the velocity and AB or CD represents the duration. Since the velocity is constant, if we multiply the velocity by time we would get the distance covered in the two hour duration, which is represented by the area of the rectangle (width x length). We could conclude that the area under a velocity time graph represents the displacement. This would be true even if the velocity is not constant. Let us take a look at the graph given if fig. 6.8, which is reproduced alongside. To find the area under the graph from t=4h to t=8h, we split it up into a rectangle and a triangle. The area would therefore be:

$(40\times4)+(½\times4\times40)=160+80=240$KM

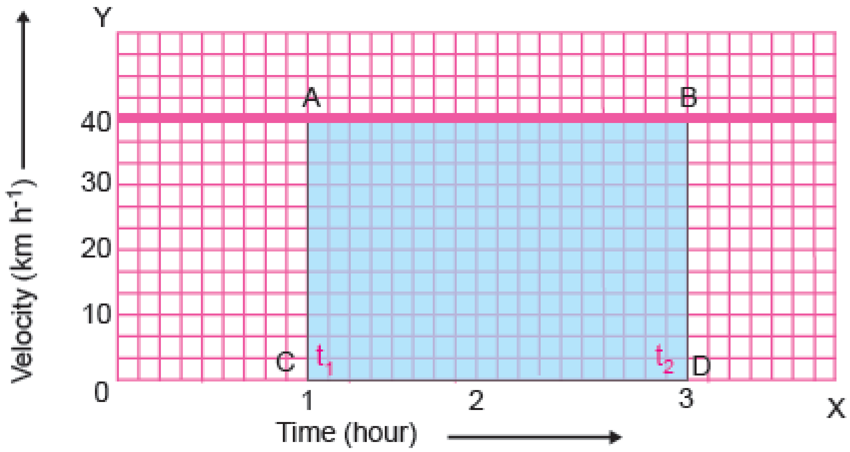


Fig 6.8

EQUATIONS OF MOTION

Instead of plotting a graph and calculating the area, slope etc. in order to find the displacement or acceleration, it is possible to evolve some formulae which can enable us to calculate these values. The three standard equations of motion are:

$v = u + at$

$s = ut + ½ at^2$

$v^2 – u^2 = 2as$

Where u is the initial velocity, v is the final velocity, a is the acceleration and s is the displacement.

These equations can be derived from the graphs. Consider the velocity- time graph in fig 6.9 where the velocity changes from u at point A to v at point B. From A, draw two perpendiculars, one to the x axis (AC) and another to the y axis (AD). Similarly, perpendicular lines are drawn from B (BE & BF). AG is the perpendicular drawn from A to BE.

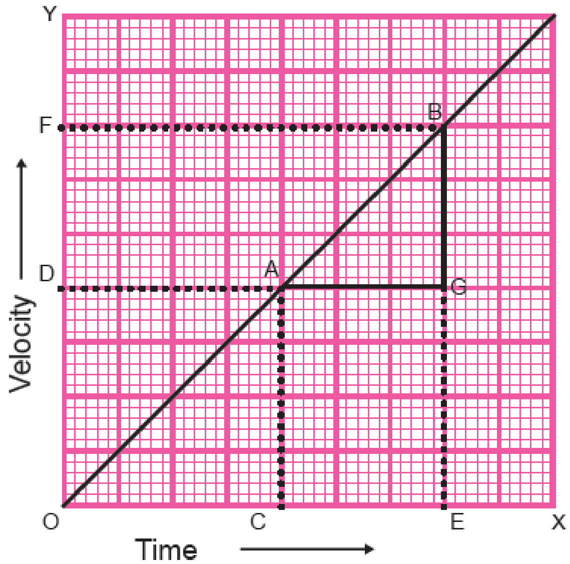


Fig 6.9.

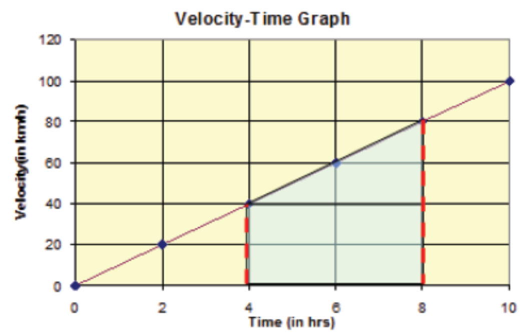


Fig 6.10

Equation for velocity at a time By definition, using the symbols we could say Rearranging we get,

Acceleration = slope = $\frac{BG}{AG}$

$= \frac{change\ in\ velocity}{time}$

$= \frac{final\ velocity - initial\ velocity}{time\ elapsed}$

a = (v-u)/t

This can be rearranged to become,

v = u + at

Equation for displacement after a given time

To obtain the second equation we need to find 's' the displacement, which is nothing but the area under the line AB. This as we know can be obtained by adding the areas of the rectangle ACEG and the triangle AGB. The area of rectangle ACEG is given by multiplying AC(initial velocity, u) with AG(time elapsed, t) which is equal to ut. To this, we add the area of the triangle AGB which is half the base multiplied by the height. The base is AG which is nothing but the elapsed time, t. The height of the triangle is BG which is nothing but the change in velocity, v-u which in turn is equal to 'at'. Thus, Equation for velocity at a given position In the graph,

Displacement = Area of the trapezium CABE

Total area of ABEC = area of ACEG + area of AGB

$s = ut + ½ \times t \times at = ut + 1/2\ at^2$

Equation for velocity at a given position In the graph, Displacement = Area of the trapezium CABE

$$s = \frac{1}{2} \times (u + v) \times t$$

$$\Rightarrow 2s = (u + v) \times \frac{(v-u)}{a}$$ (Substituting the value of **t** from the equation $v = u + at$)

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

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

Acceleration due to gravity

What do we observe when a body is thrown vertically upwards?

The velocity of the body gradually decreases and becomes zero at which stage, it reaches its maximum height. The velocity then gradually increases in the downward direction till the body reaches the ground. There is a constant acceleration in the downward direction due to gravity, which is responsible for the decrease in velocity followed by an increase in velocity in the downward direction. This constant downward acceleration is referred to as the acceleration due to gravity denoted by the letter 'g'. The average value of 'g' is 9.8 m/s^{-2}. The velocity of the body thrown vertically upwards will decrease by 9.8m/s every second and the velocity of a body falling down increases by 9.8m/s every second. Since the acceleration due to gravity is a constant value, the equations of motion can be applied to any object that falls vertically or is thrown up vertically.

CIRCULAR MOTION

Uniform circular motion

The movement of an object in a circular path is called circular motion. Some examples of circular motion are :-

- A person sitting on a merry-go-round goes around in a circular path.
- A car moving on a circular road or a curved racing track follows a circular path.
- An electron having a circular orbit around the nucleus.
- A stone tied to a string and whirled around – in athletics, such a sport is

called the hammer throw.

In real life, some of the objects may not follow an exactly circular path but may follow a near circular path as for example, the electrons or the planets that orbit around the sun. If the object moves at uniform speed on a perfectly circular path then we call it uniform circular motion. In this section, we will discuss the ideal case of a perfectly uniform circular motion.

Centripetal Acceleration

Uniform circular motion is a special case, where the speed of an object remains constant but the direction keeps on changing. We could therefore say that the velocity changes when the direction of motion changes. Since the velocity is changing then there must be acceleration, since the change in velocity must be happening over a period of time. Further, since the speed is uniform, the object is changing direction at a uniform rate and therefore we could conclude that the acceleration is uniform.

You will later learn how to derive an expression for this acceleration and also prove mathematically that it is a constant acceleration. This uniform acceleration that causes uniform circular motion is called Centripetal acceleration. Centripetal acceleration always acts perpendicular to the direction of the velocity and always acts radially towards the centre. Can you give reasons why the centripetal acceleration should be perpendicular to the velocity and always act radially towards the centre? Think about it for some time and check your reasoning with that given in the text box.

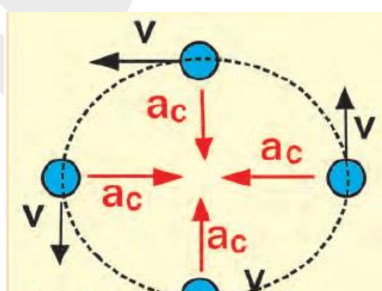


Fig 6.11

Two reasons

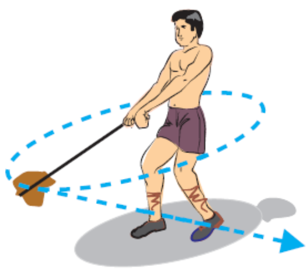
1. *If the acceleration were to act in the direction of the velocity, then the magnitude of the velocity (speed) would change. We however see that the speed does not change; therefore, we could conclude that it must be perpendicular to the velocity.*
2. *The arrow representing the velocity is a tangent to the circle. The line perpendicular to it must be radial (passing through the centre of the circle) as we know, the property of a circle is that the tangent is perpendicular to the radius.*

Centripetal force

Tie a stone to a piece of rope and rotate it in a circle. You will find that you have to exert a force (in the direction shown by the arrow in the diagram) to keep the stone going around in a circle. If you let go of the rope, the stone along with the rope, will fly off in a straight line as shown in the diagram (tangent to the circle). This force that keeps the body going around in circular motion is called the Centripetal force. The Centripetal force acts perpendicular to the velocity and is always directed radially inwards towards the centre of the circle.

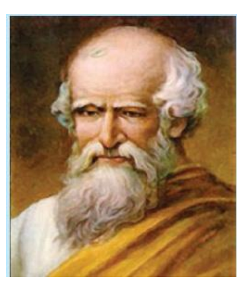
E.g.:

1. In the case of the stone tied to the end of a string and rotated in a circular path, the centripetal force is provided by the tension in the string.



2. When a car takes a turn on the road, the frictional force between the tyres and the road provides the centripetal force.
3. In the case of electrons revolving round the nucleus, the centripetal force is provided by the electrostatic force of attraction between the nucleus and the electron.

49] Liquids



Archimedes (BC 287 – BC 212) was one of the greatest Greek thinkers, mathematician, physicist, engineer, inventor, and astronomer of his times. He discovered many important principles of statics (physics relating to stationary objects) and hydrostatics (science relating to liquids at rest) and put them *into practice. He was the son of an astronomer and a friend and relative of Hiero, king of Syracuse. He received his training and education in Alexandria, in Egypt which was the centre of learning in those days.*

He invented the water screw for lifting water from a lower level to a higher level to irrigate the fields of Egypt. He discovered the principle of lever and is reported to have said to the king: "Give me a long enough rod and a place where I may rest it and I will move the world". He invented many mechanical devices.

One of his greatest discoveries later named after him – the Archimedes' Principle has remained one of the most important principles of hydrostatics. There is a popular story that is linked to the discovery of the principle that would be interesting to read about.

The story goes that the king had ordered a jeweller to make a crown of gold which he wanted as an offering to God. When the crown was delivered, the king suspected it might be mixed with silver which in those days was considered a less valuable and cheaper metal than gold. So the king asked Archimedes to look into the matter. The challenge before Archimedes was to find out whether the gold crown had any silver mixed in it without actually destroying or damaging the crown in any way.

The intense man that he was, Archimedes pondered over the question a great deal but the real breakthrough came when he was having a bath. He noticed that the level of water rose in the tub and overflowed. His quick mind immediately recognized that objects with identical weights but made of different materials, when immersed in water, would displace different quantities of water. It is said that he was so excited by the discovery that he jumped out of the bath and ran to the palace shouting 'Eureka' 'Eureka' not realising that he still hadn't got his clothes on !! Eureka in ancient Greek means 'I found it'. It is said that he obtained an equal weight of pure gold from the royal treasury and immersed the crown and the pure gold piece into a tub filled with water to the brim. If the crown displaced a different quantity of water compared to the pure gold piece, it would clearly indicate that the crown was not made of pure gold.

Quite ingenious! What the outcome of the test was is not known but the story of the discovery and the principle itself has outlived the result of the test!!!

PRESSURE IN A LIQUID

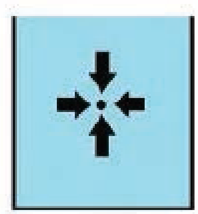
Pressure and Depth

The pressure at a point inside a liquid increases as the depth increases. The pressure depends only on the vertical distance from the surface of the liquid. In scientific language we say that the pressure is proportional to the depth. This is written in mathematical language as follows:-

$p \propto d$

where p is the pressure and d is the depth.

Direction of Pressure at a point inside the liquid



Experiments reveal that the pressure at a point acts in all directions. The pressure does not depend on the shape, size or area of the container.

Pressure and Density of liquids

At a point at the same depth in two different liquids, the pressure depends on the density of the liquid. Stated in scientific language, the pressure is proportional to the density of the liquid and can be written as follows:-

$p \propto \rho$

where p is the pressure and the greek letter ρ (pronounced 'roh') stands for the density of the liquid.

Pressure and Acceleration due to gravity

At a point in the same liquid at the same depth, the pressure is proportional to the acceleration due to gravity and can be written as follows:-

$p \propto g$

Thus, if the pressure at a point in a beaker of liquid is $10N/m^2$, it would be about 1/6th on the surface of the moon since the acceleration due to gravity on the moon is about 1/6th than that on the earth.

Pressure at a point in a liquid

We usually combine the three and write a simple formula to calculate the pressure at a point in a liquid.

p = dρg

RELATIVE DENSITY

You have already learnt what density of a substance is; it is the mass per unit volume of a substance.

$Density = \frac{mass}{volume}$

Relative Density of a substance is the ratio of the density of the substance to the density of water.

$RD = \frac{density\ of\ subtance}{density\ of\ water}$

BUOYANT FORCE OR UPTHRUST

Buoyant Force on an Object Immersed in a Liquid

If you have stood inside water in a pond or a swimming pool, you would have noticed that the body feels much lighter inside the water than outside it. It is very easy to stand on the tip of the toes while you are inside the water but it is difficult when you stand outside the water. This force that opposes the weight of the body is referred to as the buoyant force or upthrust. The buoyant force comes into existence whenever a body is immersed in any fluid (liquid or gas).

Let us consider a cylindrical body immersed in a liquid of density ρ. There is force F_1 acting on the top of the cylinder perpendicular to it, as shown in the diagram alongside. At the same time, there is a force F_2 acting on the bottom surface of the cylinder as shown in the diagram. Both these forces F_1 and F_2 are in opposite directions. Hence the net force acting on the cylinder due to the fluid would be (F_1 - F_2). Remember, however, that the force F_2 would always be greater than the force F_1.

Pause on that statement for a few minutes and think why. Do not read further till you have thought for sometime.

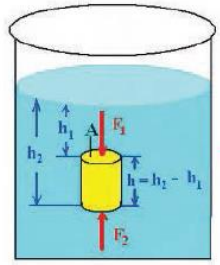


Fig. 7.1.

The force acting on the top surface of the cylinder F1 would be equal to the product of the pressure, P1 on the top surface and area, A . Remember that the pressure is proportional to the depth. Since h2 is deeper than h1, the pressure at P2 would be greater than pressure P1. Thus the force F2 would be greater than F1 and the net force acting on the cylinder would be the difference between the two forces ($F_2 – F_1$).

$F_2-F_1 = h_2\rho gA-h_1\rho gA$

$= A\rho g(h_2-h_1) = A\rho gh,$

where h is the height of the cylinder,

$= V\rho g,$

since the area of the base X height would be equal, the volume of the cylinder,

$= Mg$

since the volume of the cylinder multiplied by the density of the liquid equals the mass of the liquid displaced.

= Weight of the liquid displaced by the cylinder

More to know

Can we really measure our true weight on the earth….?

Imagine the earth's atmosphere tocbe a giant ocean of gas. Our bodies are immersed in this ocean of air and therefore experience a buoyant force that acts opposite to the direction of weight. The buoyant force would be equal to the weight of air displaced by the body. So can you really measure the true weight of any body?

Equal Volumes Feel Equal Buoyant Forces

You have equal sized spheres of cork, aluminium and lead, which have respective relative densities of 0.2, 2.7 and 11.3. If the volume of each is say 10 cubic centi meters, then their masses are 2, 27 and 113g respectively. When wholly immersed in water, each would displace 10cc of water thus suffering a 10gf loss of weight. The aluminium ball would weigh 17gf (27gf – 10gf) and the lead ball would weigh

103gf (113gf – 10gf). The cork however weighs only 2gf in air. Therefore, when an upthrust equivalent to 10gf acts on it; it would 'weigh' (-)8gf (2gf - 10gf). The cork sphere would accelerate upwards towards the surface, since the net force acting on it is equivalent to 8gf in the upward direction (The force of gravity acting on a body is called weight. The weight of a mass equivalent to 8g is referred to as 8 grams force and represented by the symbol 8gf).

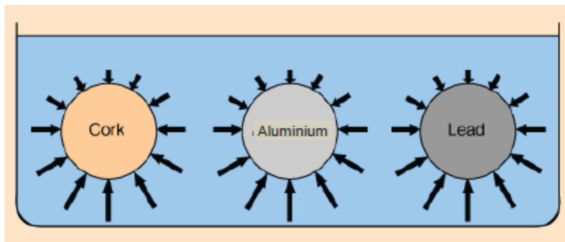


Fig. 7.2.

ARCHIMEDES' PRINCIPLE

The Statement of the Principle

Archimedes' principle states that:

When a body is immersed in a fluid, (liquid or gas) it experiences an apparent loss of weight which is equal to the weight of the fluid displaced.

The reason for the apparent loss of weight we know is the buoyant force.

Verification of Archimedes' Principle

- Suspend a piece of stone from the hook of a spring balance.
- Note the weight of the stone in air (w_1)
- Gently lower the stone into an overflowing jar filled with water as shown in the figure.
- Now note the weight of the stone (w_2).
- Collect the overflowing water in the beaker whose weight is known (w_3).
- Weigh the beaker with water (w_4).
- Find the weight of the displaced water ($w_4 – w_3$).
- Find the loss of weight of the stone ($w_1 – w_2$).

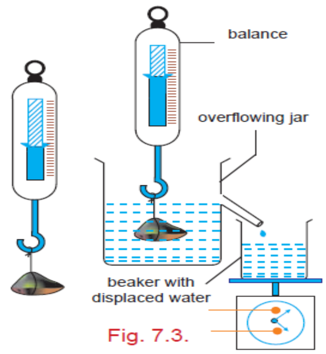


Fig. 7.3.

We find that $(w_1 - w_2) = (w_4 - w_3)$.

Thus the Archimedes' Principle is verified.

SOME APPLICATIONS OF ARCHIMEDES' PRINCIPLE

Some of the applications to which Archimedes Principle is put to use are as follows:-

- Finding the volume of irregular shaped solids (knowing the density of water).
- Finding the density of irregularly shaped solids (knowing the density of water).
- Finding the relative density of a liquid.
- Finding the density of liquids (knowing the density of water).

Finding the Volume of Irregularly Shaped Solids

To find the volume of an irregularly shaped object, such as a stone for example, suspend the stone from the hook of the spring balance as you did earlier and note its weight in air (W_1). Now immerse it in WATER and weigh the stone once again (W_2). According to the Archimedes' principle the loss of weight (W_1grams – W_2grams) would be equal to the weight of water displaced. Since the weight of 1cc of water is 1g we can calculate the volume of the liquid displaced ($W_1 - W_2$) cc. This in turn would be the volume of the stone. Thus if the loss of weight of an object immersed in water is W grams then, its volume would be W cc. By Archimedes principle,

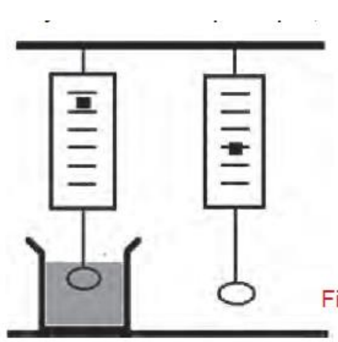


Fig. 7.4.

Loss of weight = weight of water displaced

weight in air – weight in water = density of water x volume of solid

Volume of solid

$$= \frac{weight\ in\ air - weight\ \ in\ water}{density\ of\ water}$$

Note that the density of a solid is mass per volume which is numerically the same as the weight (in gravitational units) per unit volume. To give an example, the weight of 1000 cc of water is 1000gf. The mass of 1000cc of water is 1000g, which is numerically the same as the weight.

Note:

In this method, you do not need a measuring jar to find the volume of an irregular object. Using the spring balance you could dip the stone in a basin of water, in pond or any water body which has fresh water and not salt water.

Finding the Density of Irregularly Shaped Solids

In the previous section, we found the volume by first weighing the stone in air (W_1) and then weighing it when immersed in water (W_2). Having found the volume using the procedure outlined above, we could find the density using the following :-

Density of solid(Numerically) = $\frac{W_1}{W_1 - W_2} \times$ Density of Water

Finding the Relative Density of a Liquid

First weigh any solid in air (W_1), then weigh the same solid in water (W_2) and in any other liquid (W_3). To find the relative density of a liquid, find the loss of weight in water ($W_1 – W_2$) and the loss of weight in the liquid ($W_1 – W_3$).

By Archimedes' principle,

Loss of weight in water = weight of water displaced

W_1 - W_2 = weight of water displaced = Mass of water x acceleration due to gravity

= Volume of solid x density of water x acceleration due to gravity

Therefore W1 - W2 = V x density of water x g ……..(1)

By Archimedes' principle,

Loss of weight in liquid = weight of liquid displaced

$W_1 – W_3$ = weight of liquid displaced

= Mass of liquid x acceleration due to gravity

= Volume of solid x density of liquid x acceleration due to gravity

Therefore, W1 - W2 = V x density of liquid x g ………(2)

Dividing equation (2) by equation (1)

Relative Density of the liquid = $\frac{W_1 - w_3}{W_1 - W_2}$

Finding the Density of Liquid

In the previous section, we learnt how to find the relative density of a liquid. Having found the relative density of the liquid, the density can be obtained by multiplying it by the density of water.

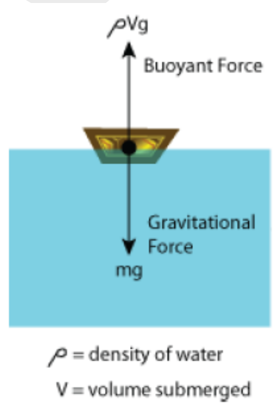
RD =$\frac{density\ of\ substance}{cedensity\ of\ water}$

Density of substance = RD x density of water

BUOYANCY AND FLOATATION

When solids are immersed in liquids we find that some solids float and some sink. This phenomenon can be explained using the Archimedes' Principle. Any solid immersed in a liquid will experience an apparent loss of weight due to the buoyant force acting on the object. The buoyant force acts vertically upward and is equal to the weight of the liquid displaced (in section 7.3, we calculated that the Buoyant force = Vρg [Volume x density x acceleration due to gravity]

Fig. 7.5.



The second force that acts on the solid is its weight (or the force of gravity which acts vertically down). Thus the object immersed in a liquid is under the influence of two opposite forces. When one of the two forces is larger than the other, then the object will move in the direction of the resultant force, that is upwards if the buoyant force is larger or downwards if the weight is larger. The object can be at rest only if these two forces are equal. Note that in the diagram shown alongside, the hull shaped object is not fully immersed in the liquid but the volume of water displaced is such that its weight is equal to the weight of the object. We could represent this by an equation as follows:-

V pg = mg

⇒ V p= mg

Therefore, the object will 'float' if the mass of the object is equal to the mass of the liquid displaced.

An interesting oft-quoted example is that, an iron ball will sink if immersed in water but a huge ship weighing several thousand tons will float. This can happen only if the shape of the iron is changed in such a way that the weight of the liquid displaced is made equal to the weight of the ship.

Ball : Displaced water weight is much lesser than the ball

Hull : Displaced water

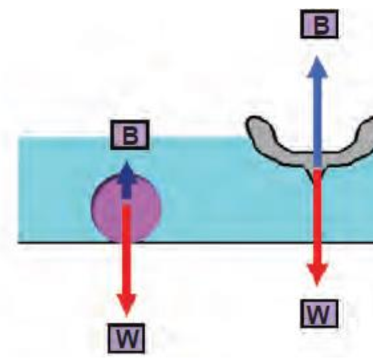
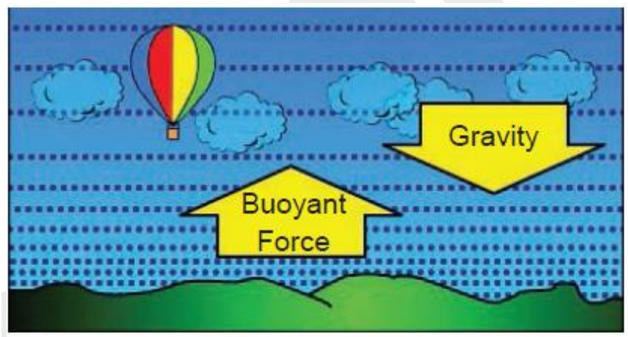


Fig. 7.6.



The density of air is 14 times greater than that of hydrogen. The weight of a hydrogen filled balloon is much lesser than the weight of the air it displaces. The difference between the two weights gives the lifting capability of the balloon. Thus hydrogen filled balloon flies high in the air.

HYDROMETER

The common hydrometer, based on the Archimedes' principle, is an instrument that can be used to find the relative density (specific gravity) of a liquid. To find the specific gravity of the liquid, float the hydrometer in the liquid. The reading on the stem at the level of the liquid indicates the specific gravity of the liquid. It consists of a narrow uniform stem of glass, closed at the top and provided with a glass bulb at the bottom. The bulb is weighed with mercury or lead shots to make the hydrometer float vertically in liquids. Usually, two different hydrometers are provided-one for liquids denser than water, and the other, for liquids lighter than water.

The hydrometer has a fixed weight. It can float in a liquid only if the weight of the liquid displaced is equal to its weight. If the liquid has a lower density, the hydrometer has to sink deeper in the liquid to displace sufficient liquid to equal the weight of the hydrometer. If the density of the liquid is higher, then it has to sink less into water to displace sufficient liquid to equal the weight of the hydrometer. A hydrometer used to check the purity of milk by floatation is called a lactometer. Similarly, a special hydrometer is also used to check the density of the acid in a car battery.

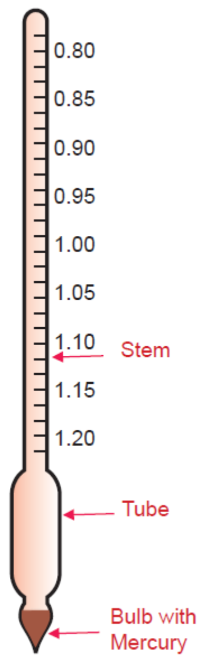
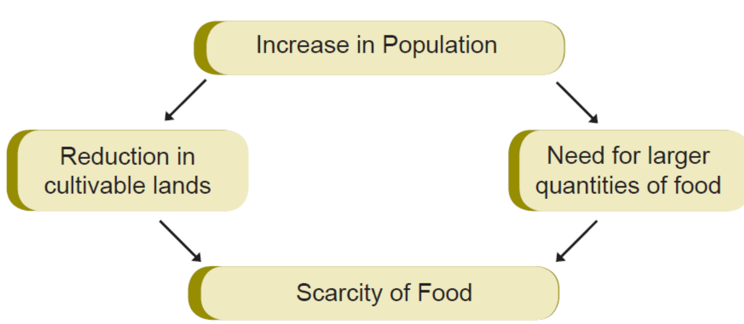


Fig. 7.7. Common Hydrometer

50] Improvement in Food Resources

The population on this planet is constantly growing. The world population, according to the United States Census Bureau, was 6 billion in 1999 and has grown alarmingly to 7 billion in 2012. This would put pressure on the supply of food to mankind. The area available for plant cultivation is shrinking but the amount of food required is increasing. We must meet the demand for food by increasing the food produce from agriculture and animal farming.



Thus, we clearly understand the reasons for the scarcity of food.

The problem of food scarcity can be overcome by:

i) increasing the yield of crops.

ii) preventing cultivable lands from being used for other purposes.

iii) optimizing water resources for cultivation.

iv) improving the system of preservation and distribution of food materials.

1.1 IMPROVEMENT IN CROP YIELDS

Majority of the world's population depends on agriculture. We have to think of smart ways to increase food production. Agricultural scientists are working to increase the quality and quantity of food that we produce from plants.

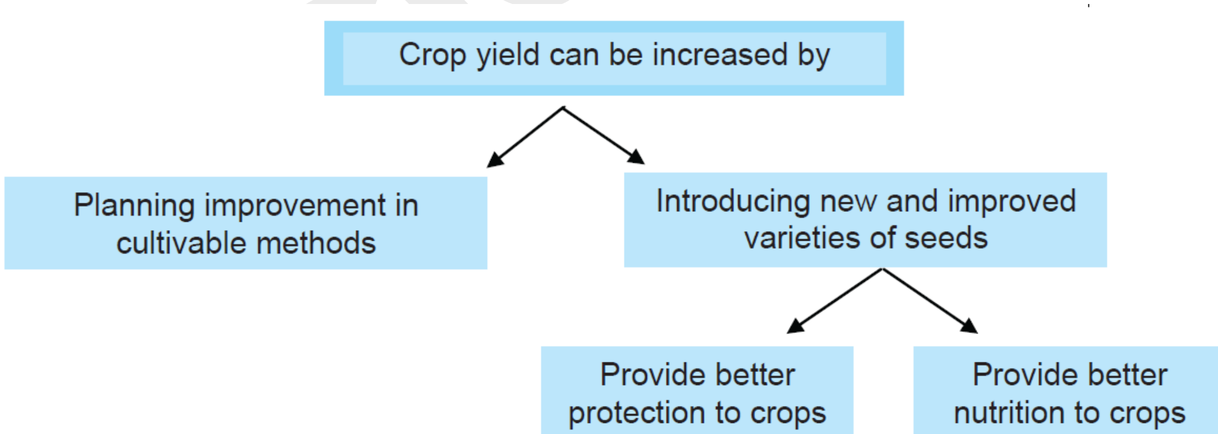
Plants that are cultivated in farms and harvested for food are called crops. There are a large variety of crops. Here are some examples:

Crops grown for cereals: Rice, Wheat, Maize, Millet

Crops grown for pulses : Pea, Greengram, Blackgram

Crops grown for oilseeds: Groundnut, Sunflower, Mustard, Sesame

Crops grown for animal fodder: Oats, Sudan grass, Elephant grass, Alfalfa.



Introduction of new and improved varieties

Improved varieties or strains of crops are produced by selective breeding for various important characteristics such as disease resistance, response to fertilizers, product quality and higher yield.

Common factors for crop improvement

Higher Yield	To increase the productivity of the crop per acre
Improved Quality	Quality of crop products vary from crop to crop. e.g. baking quality in wheat, protein quality in pulses, oil quality in oil seeds.
Biotic and abiotic resistance	Crop production is decreased due to biotic (diseases, insects and pests) and abiotic factors (heat, cold, salinity and drought). Resistance to these stress factors can improve crop production.
Change in maturity pattern	Shorter maturity period; Uniform maturity makes the harvesting process easy and reduces losses during harvesting.
Wider Adaptability	One variety can be grown under different climatic conditions in different areas. Developing varieties of wider adaptability helps in stabilizing crop production.
Desirable agronomic characters	Tallness and profuse branching are desirable characters for fodder crops. Dwarfness is desired in cereals. Developing varieties of desired agronomic characters give higher productivity.

Selecting good varieties of crops, planning improvement in crop production and ensuring crop protection will result in increased crop yield.

Some improved varieties of crops and fruits

Fodder crop, Paddy, Wheat, Baby corn, Maize, Sunflower, Mango, Grapes

1.2 NUTRIENT MANAGEMENT

Plants take in carbon, hydrogen and oxygen from air or water, and absorb many other nutrients from the soil. Scientists have identified sixteen elements that are important for the growth and reproduction of plants.

Nitrogen is needed for plants to prepare proteins, nucleic acids, chlorophyll and other important organic molecules. Deficiency of nitorgen causes chlorosis in plants. Phosphorus is needed for the process of converting light energy from the sun into chemical energy. Similarly, different elements are needed for important activities in the life cycle of a plant.

MACRO-NUTRIENTS

Elements which are essential in large quantities for the growth of plants are called Macro-nutrients. They are carbon, hydrogen, oxygen, nitrogen, phosphorous, sulphur, potassium, calcium, magnesium and iron.

MICRO-NUTRIENTS

Elements that are needed for the growth of plants in very small quantities are called Micro-nutrients. They are manganese, copper, molybdenum, zinc, boron and chlorine.

Just as in humans, plants too are affected by nutrition deficiencies. It can affect the process of growth and reproduction resulting in low yield or no yield.

1.3 USES OF MANURE AND FERTILIZERS

During farming and harvesting of crops, a large amount of nutrients are extracted by plants from the soil. This deficiency is compensated with the addition of chemicals in the form of fertilizers and manure.

Manure is an organic substance prepared by the decomposition of plant and animal waste.

Based on the kind of biological material used, manure can be classified as follows:

i) Compost & Vermi Compost:

Vermicompost is manure prepared by using earthworms to speed up the process of decomposition of plant and animal waste.

ii) Green Manure :

Green manure is prepared by using leguminous plants like sunhemp and soyabean. These are grown for a specific period of time and then ploughed back into the soil. Green plants add nutrients and organic matters like nitrogen and phosphorous to the soil.

USES OF MANURE

- ƒ Manure enhances the water holding capacity of the soil.
- ƒ It increases the number of friendly microbes.

- ƒ It improves the soil texture.

FERTILIZERS

Fertilizers are chemicals like nitrogen, phosphorous and potassium that are commercially produced in factories and used as plant nutrients.

When there is a specific nutrient missing in a plant, it is recommended to use a fertilizer. Small or micro doses of fertilizers can result in dramatic improvements in the health of a plant.

Types of Fertilizers	Examples
Nitrogenous Fertilizers	Urea, Ammonium Sulphate, Ammonium Nitrate
Phosphatic Fertilizers	Single Super Phosphate, Triple Super Phosphate
Potassic Fertilizers	Potassium Nitrate, Pottassium Chloride
Complex Fertilizers	Nitrophosphate, Ammonium Phosphate, Diammonium Phosphate (DAP)

Usage of fertilizers has its own disadvantages. Fertilizers account for additional expenses for farmers. Moreover, these chemicals being water-soluble can get washed away and contaminate the natural water-supply. Farmers also have to take meticulous care with the dosage, as excess chemicals can destroy soil fertility. Excess fertilizers that are washed away into the ponds, lakes, canals and rivers can also result in the growth of unwanted plants like Water Hyacinth and Algae.

These plants grow in excess amounts. They deprive the water-body of oxygen and stop the flow of water. As a result, fishes and other living organisms do not get sufficient sunlight and oxygen and they die. The excessive richness of nutrients in water that causes dense growth of algae on the surface and causes death of other organisms living in the water is called eutrophication.

Differences between Manure and Fertilizers

Manure	Fertilizers
1. Manure is a natural substance obtained from the decomposition of cattle dung, human waste and plant waste.	1. Fertilizer is a mineral or chemical compound containing nutrients like sulphur, phosphorous and nitrogen.
2. Manure contains organic substances.	2. Fertilizers are inorganic compounds.
3. Manure can be prepared in fields.	3. Fertilizers are manufactured in factories.
4. Manure contains all nutrients but in small quantities.	4. Fertilizers contain more quantities of one specific nutrient or more.
5. Manure adds plenty of humus to soil and improves the texture of the soil.	5. Fertilizers do not contribute to the addition of humus to the soil.
6. Manure is not easily absorbed because it is less soluble in nature.	6. Fertilizers are soluble in water and it is easily absorbed.
7. Manure is less soluble; it is not easily washed away from the soil and hence its effect is long lasting.	7. Fertilizers are easily washed away by water and hence their effect is of shorter duration and require repeated application.

Farmers must efficiently balance the use of fertilizers and manure.

Some agriculturists practice organic farming. This method makes use of manure like recycled farm waste to nourish the crops. This avoids the use of insecticides and fertilizers.

Fertilizers which are produced from living organisms are called Bio-fertilizers. The main source of bio-fertilizers are bacteria, cyanobacteria and fungi. Bio-fertilizers are renewable and non-polluting sources of plant nutrients. They also improve the soil nutrients. Rhizobium and Cyanobacteria such as Anabaena and Nostoc are some common bio-fertilizers.

1.4 PROTECTION FROM PESTS AND DISEASES

Organisms that attack or destroy crops, food or farm animals are called pests. They damage cultivated crops and plant products in storage. Crop yield is affected due to pests during the process of sowing, harvesting, storing and consumption. This causes a great loss to the national economy.

1.4.1 INSECT PESTS

Insects attack plants in all stages of their growth. Based on the mode of attack, insect pests are classified into three types:

i) Chewing Insects: They cut and chew the root, stem and leaves of the plants.

e.g. grasshoppers and caterpillars.

ii) Sucking Insects: They suck the cell sap from different parts of the plants.

e.g. leaf hoppers and aphids.

iii) Borer Insects: They make holes and enter different parts and feed on plant tissues.

e.g. sugarcane borer.

Some common Indian Insects and Pests of Crop Plants

Sugarcane Top-borer, Gundhi Bug, Sugarcane Stem-borer, Pyrilla (Sugarcane Leaf Hopper), Mustard Aphid, Painted Bug

1.4.2 DISEASES OF CROP PLANTS

A wide variety of plant pathogens such as bacteria, virus and fungi exist in our environment. When conditions become favourable, they spread and infect crop plants causing diseases. Based on the mode of transmission, plant diseases are classified into four types.

1	Seed borne diseases	They spread through seeds. e.g. Leaf spot of rice, Loose smut of wheat.
2	Soil borne diseases	They spread through the soil. They affect roots and stems in plants. e.g. Tikka disease of groundnut.
3	Air borne diseases	These diseases are transmitted through air. They attack all aerial parts of plants like leaves, flowers and

		fruits. e.g. Blast of rice, Rust of wheat .
4	Water borne diseases	The diseases which are transmitted through water are called water-borne diseases. e.g. Bacterial blight of rice.

Pesticides are toxic chemicals that destroy pests.

i) Insecticides: Chemical substances which are used to kill insects are called insecticides. e.g. DDT (Dichloro diphenyl trichloro ethane), Malathion.

ii) Fungicides: Chemicals used to kill fungi are called fungicides.

e.g. Bordeaux mixture.

iii) Weedicides: Chemical substances which are used to kill weeds are called weedicides. e.g. 2, 4-D. (2, 4 - Dichloro phenoxy acetic acid)

iv) Rodenticides: Chemicals used to kill rodents like rats, mice and squirrels are called rodenticides,

e.g. Zinc Phosphate, Arsenic.

1.4.3 METHODS OF INSECT PEST CONTROL

The infestation of different types of insect pests can be controlled by the following methods:

- Root-cutting insects are controlled by mixing insecticides in soil.
  e.g. Chloropyriphos.
- Stem and leaf cutting insects and boring insects are controlled by dusting or spraying insecticides.
  e.g. Malathion, Lindane and Thiodan.
- The sap-sucking insects can be controlled by spraying insecticides.
  e.g. Dimethoate and Metasystox.

1.4.4 PRECAUTIONS FOR APPLYING PESTICIDES

- Do not touch the pesticide with bare hands; use rubber gloves while handling it.
- Do not blow, suck or apply mouth to any sprinkler, nozzle or other parts of the spraying equipment.
- Do not spray pesticides against the direction of wind in the open field.
- Use only the prescribed dose of pesticides for spraying.

1.4.5 STORAGE OF GRAINS

- Most crops are harvested once a year. In order to get a supply of food items regularly throughout the year, they are stored in safe storage.
- Cereals or food grains are stored by the farmers, traders and the Food Corporation of India (FCI).
- During storage, grains and seeds are subjected to spoilage by various agencies. Factors responsible for such damages are:

i) Biotic factors (insects, rodents like squirrel and rat, birds, fungi, mites and bacteria)

ii) Abiotic factors (moisture and temperature)

These factors cause,

- infestation of insects
- degradation in quality
- loss in weight
- poor germinability
- discolouration of product
- poor marketability.

Therefore, it is essential to protect the produce from any kind of loss during storage.

Preventive and Control Measures are used when the produce is stored for future use. They include strict cleaning of the produce before storage, proper drying of the produce in sunlight and then in shade and fumigation using chemicals that kill pests.

1.5 HYBRIDIZATION IN PLANTS AND ANIMALS

1.5.1 HYBRIDIZATION IN PLANTS

Improved varieties of seeds and plants can be introduced by the process of hybridization.

Hybridization is the method of producing improved varieties by crossing the genes of two or more dissimilar and specially selected parent animals or plants. The parents with desirable qualities are selected and the best characters are brought together in a single variety.

Hybridization can be:

i) Intervarietal (cross between two different varieties)

ii) Interspecific (cross between two species of the same genus)

iii) Intergeneric (cross between different genera)

Of the above three types, intervarietal hybridization is widely adopted in plant breeding.

In maize, hybrids are grown because they produce good yield. Modern varieties of maize, wheat and rice that we consume are all products of hybridization.

1.5.2 HYBRIDISATION IN ANIMALS

Hybridisation is a method of breeding, where the offspring is formed by the union of two genetically dissimilar parents. It involves the application of the principles of genetics and physiology of reproduction.

Hybridization has long been used for commercial production of cattle, sheep and poultry. Black Rock chicken is a hybrid of Rhode Island Red and Barred Plymouth Rock chicken. These are examples of two normal breeds that are combined to form an extraordinary breed. Scientists however, proceed with much caution in their efforts to identify better breeds and hybrids.

Some of the characteristics that farmers look for when selecting parent crops or farm animals for hybridization are:

1. Resistance to diseases
2. Tolerance to climatic conditions
3. General appearance
4. Size and configuration
5. Productivity
6. Good health
7. Proper age of reproduction

The different methods of animal hybridisation are as follows :

Inbreeding

Breeding between closely related individuals within the same breed is known as inbreeding.

The importance of inbreeding are:

1. It is used as a tool primarily to build desirable genotype and to promote pure breeds with desirable characteristics.
2. To identify undesirable recessive genes. This enables the breeder to separate them from the stock.
3. Inbreeding promotes uniformity.
4. Inbreeding associated with selection can produce improved stocks.

Selection

It is a process of selecting productive individuals for further breeding. Modern approach of selection is based on records of performance.

Outbreeding

It involves breeding of animals that are not closely related.

a) Outcrossing: It involves breeding from the crossing of animals of the same breed (without a common ancestor).

b) Cross breeding: In this method, superior males of one breed are mated with superior females of another breed. It involves the fusion of two different breeds in order to combine the desirable qualities of both.

c) Interspecific Hybridisation: In this method, male and female animals of two different species are mated. In some cases, the progeny may combine desirable features of both the parents.
For example, mule is produced from a cross between female horse (mare) and male donkey. Mules are sturdier and harder than their parental species and are well suited for hard work in different terrains like mountainous regions.There are two methods of interspecific hybridisation.

i) Natural Method: In this method crossing of indigenous and exotic breeds takes place in order to improve the yield significantly.

ii) Artificial insemination: It is a method used in hybridization in which stored semen of a desired male animal is introduced into the genital tract of a selected female animal using suitable instruments in order to obtain a better breed of the animal.

Advantages of artificial insemination

1. Ensures progeny with desirable qualities.
2. It is an economical method wherein semen from one animal is used to impregnate many females.
3. It provides high yielding animals with increased production of milk, eggs and meat.
4. Frozen semen can be stored for a long period and it can be transported even to remote areas.

1.6. ANIMAL HUSBANDRY

The branch of agriculture which deals with the feeding, sheltering, nurturing and breeding of domestic animals such as cattle, pigs, horses and fowls is called animal husbandry.

The various elements of animal husbandry are :

1. Proper feeding of animals.
2. Provision of clean drinking water for animals.
3. Proper shelter for animals.
4. Prevention and cure of animal diseases.
5. Proper breeding of animals.

Different animals are bred for different purposes.

Some examples are:

Dairy animals: Those that are used as

Farm animals	**Purpose**
Cow	Meat and Milk
Buffalo	Meat and Milk
Duck	Egg and Meat
Chicken	Egg and Meat
Sheep	Wool, Meat and Milk
Silkworm	Silk
Bees	Honey and Wax

Meat producing animals: Animals that are reared for their meat, **e.g.** Cow, Pig.

Poultry animals: Birds that are source of egg and meat, **e.g.** Chicken, Turkey.

Animal Product	Fat %	Protein %	Sugar %	Minerals %	Water %

Milk	3.60	4.00	4.50	0.70	87.20
Egg	12.00	13.00	Trace	1.00	74.00
Meat	3.60	21.10	Trace	1.10	74.20
Fish	2.50	19.00	Trace	1.30	77.20

Cattle: Cows, bulls and oxen are together called cattle. They are raised for milk, meat or labour (draught / draft animals).

Shahiwal, Red Sindhi, Gir and Deoni are examples of Indian cattle breed that are used for their milk. Holstein Freisian is an exotic breed from Holland and Friesland in the Netherlands. It is distinctive with large black and white colour markings. These cattle have been in use as dairy animals for more than 2,000 years. They are known as a breed that gives very high yield of milk. Murrah and Jersey are examples of cattle that are selected for milk-yielding purposes.

Strong animals that are used for pulling heavy loads for transportation or ploughing fields are called draught (draft) animals. Kangayam, Umblacherry, Amritmahal and Hallikar are popular breeds of draught cattle. These animals can walk long distances carrying heavy loads.

Some breeds like Ongole, Khankrej and Tharparkar are used for both milk and work.

Cattle feed or fodder:

Cattle feed or dry fodder is made of roughage and concentrates. Roughage is a coarse and fibrous substance having low nutrient content. A variety of raw material such as sorghum (jowar or Cholam), cumbu (pearl millet or bajra), tamarind seed, rice bran, tapioca residue, ragi (finger millet) husk, sunflower meal, groundnut oilcake, gingelly oilcake, cotton seedcake and neem cake can be used to make concentrate feed.

On an average, a milch cow (a breed that is used for milk production) will consume concentrate feed equivalent to 2.5% - 3% of its bodyweight. About two-thirds of this dry feed should be in the form of crude fibres and the rest one-third should be concentrates. They should also feed on forage or grass varieties like Hybrid Napier, Sudan grass, Berseem and millets. These are also called as green fodder.

When there is a demand for more milk production or stronger draught animals, it directly reflects on an improvement on their feed. Silage is a feed that is highly nutritious. When green fodder is not available, cattle can be fed with silage. Silage can be defined as fermented highmoisture stored fodder, which can be fed to cows, sheep and goats. It is made from ordinary green grass, maize, sorghum or other cereals and other weeds using the entire green plant.

The crops are shredded into small pieces and packed inside bags and sealed to allow fermentation. After two weeks the silage is ready to be fed to cattle.

Cattle can suffer from diseases and parasitic infections. Vaccinations are given to protect them against bacterial and viral infections.

1.7. POULTRY FARMING

Poultry farming is defined as rearing and breeding of avian species for the purpose of egg and meat. Chicken occupy 90% of the total poultry.

The term poultry includes chicken, ducks, geese, turkeys, pigeons and guinea fowls. The poultry industry with its production in the form of eggs and meat is of particular importance in providing a balanced diet for the human population. Proper management of poultry includes methods of hatching, rearing, housing, sanitation, prevention of diseases and a sound marketing system.

Dr. V. Kurien is considered as the Father of White Revolution. White Revolution refers to a time when there was tremendous increase in milk production with the use of new improved breeds of cattle. Dr. V.Kurien is the founder chairman of National Dairy Development Board (NDDB). This board designed and implemented the world's largest dairy development programme called OPERATION FLOOD.

Silver revolution

The increase in egg production brought about the 'Silver Revolution' in the area of animal husbandry.

NUTRITIONAL VALUE OF MILK

Constituents	**Functions**
Calcium	Builds and maintains bone mass
Vitamin D	Promotes calcium metabolism

Protein	Builds and repairs Muscles
Potassium	Maintenance of bloodpressure.
Vitamin B2	Cellular metabolism
Vitamin B4	Functioning of enzymes
Vitamin B12	Maturation of red bloodcells.

There are more than hundred breeds of fowls. The fowls are classified on the basis of their utility to man. They are: 1. meat type 2. egg type 3. dual type.

Examples for cross breeds of Poultry are: HH-260, IBL-80, B-77, IIS-82

Advantages of Cross breeds

1. Cross breeds lay more number of eggs.
2. The eggs produced are larger in size.
3. They yield more meat.

Nutritional value

Eggs and meat are good sources of protein. Eggs also contain calcium, phosphorus, sodium, vitamins B1, B12 and D.

Housing of Birds

In free-range farming, the poultry are allowed to roam around freely during the day. They are confined in a cage only in the nights. This is a semi-intensive method.

- White leghorn is the most high egg yielding breed in the world.
- India ranks fifth in the world poultry production.

Vegetarian eggs: Fertile eggs rot more rapidly than infertile eggs. Hence the production of infertile eggs is desired. Hens are capable of laying eggs without the presence of cock and the eggs obtained are infertile. Such eggs are called vegetarian eggs.

Intensive farming involves growing birds in small cages that are just large enough for them to feed and lay eggs. Animal welfare activists discourage this method as this does not provide sufficient space for the bird to move or spread its wings.

Birds that are reared for meat are also grown in large coops or houses that protect them from predators.

Aseel, Chittagong and Karaknath are examples of Indian varieties of poultry. Broilers are young chicken that are grown only for their meat.

Poultry feed

Poultry diets are composed of a mixture of cereal grains, soya bean meal, fish meal, bone meal, wheat bran, groundnut cake, barley, oats, maize, animal by-product meals etc. Trace minerals such as zinc, iron, copper iodine, manganese and selenium must be included in the poultry feed.

Poultry disease and control

Poultry are often affected by diseases and attacked by predators like cats, dogs and foxes. Some of the common diseases found in Indian fowls are tick fever (Spirochaetosis), tuberculosis, fowl cholera, fowl pox and flu.

Disease control

Poultry diseases can be controlled by vaccination, isolation of affected birds, improving the sanitary conditions, removing dampness through exposure to sunlight. Feeding poultry with a wellbalanced diet will prevent them from developing deficiency diseases.

Poultry industry in Tamilnadu

The Tamilnadu Government is giving great importance to poultry industry. Namakkal, Palladam and Chennai are well-known for poultry industries. Every student studying in schools of Tamilnadu is served with an egg, as a part of nutritious meal on all working days.

1.8. PISCICULTURE

The process of rearing and breeding of fishes in rivers, streams, ponds, irrigation canals and paddy fields is known as pisciculture. Pisciculture plays an important role in Indian economy. It provides employment and income to millions of fishermen and farmers, particularly in the coastal areas. Factors to be considered for pisciculture:

1. Topography or location of pond.
2. Water resources and quality of water.
3. Quality of soil (Nutrients).
4. Temperature of water.

Types of pisciculture

a. Extensive pisciculture: growing fish on natural feed.

b. Intensive pisciculture: Growing fish on artificial feed to maximize production.

c. Monoculture: Growing a single type of fish in a water body.

d. Polyculture: Growing one type of fish or more types of fishes with different feeding habits together in a waterbody.

e. Integrated pisciculture: Growing fish along with agricultural crops or other animals.

Types of fishing ponds

Fish culture requires different types of ponds for the various stages of the growth of fish. The types of ponds are as follows:

1. Breeding ponds: Sexually mature males and females are collected and left in these ponds for breeding.
2. Hatchery ponds: The seeds collected from breeding ponds are delivered here in order to hatch young fishes called fish fries.
3. Nursery pond: 3 to 5 day old fish fries are retained here for about 20 days and fed well.

4. Rearing ponds: These are deeper ponds where fish fries from the nursery ponds are transferred and maintained for about three months. The fish fries grow to a size of about 125 mm in length and are now called fish fingerlings.

5. Stocking ponds: These are larger ponds and the fingerlings are fed with artificial feed. Organic and inorganic fertilizers are used to increase their size. Antibiotics are used to prevent infectious diseases. When the fishes attain the required growth, they are harvested.

1.9. AQUACULTURE

Aquaculture is a business that involves the production and marketing of aquatic organisms, both plants and animals, under controlled conditions. Aquaculture includes culture of prawn, lobsters, fish, pearl oysters, mussels and crabs.

Nutritional value of fishery products

Fishes are rich in animal protein, vitamins and minerals. The vitamin A content of fish liver helps for good vision. Vitamins such as B6, B12, D, Biotin, Niacin and minerals such as phosphorus, potassium and iron promote normal growth of the human body. Fish meal for cattle and poultry is prepared from the non-edible parts of fishes.

1.10. APICULTURE

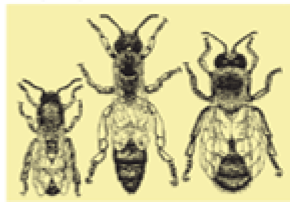
The scientific method of rearing honeybees for honey and wax is called 'Apiculture' or 'Bee keeping'. Honey bees are social insects. They live in colonies. They exhibit teamwork and division of labour.

They feed on the pollen and nectar of flowers. The honey bees collect nectar from various flowers. The nectar is swallowed by the bees. In the stomach, the nectar is converted into honey by enzymatic action and stored in the honeycombs. There are three types of bees in a colony.

a. Queen: It is the only fertile female in the hive. The work of the queen bee is to lay eggs.

b. Drones: These are fertile male bees and its function is to mate with the queen bee and fertilize eggs.

c. Workers: These are sterile females. They take care of the queen bee and the young bees, collect nectar, build honeycombs and protect the beehive.



Facts about Indian Fisheries (both capture and culture)

1. Total fish production– 2rd position in the world.
2. Marine fish production– 7th position in the world.
3. Aquaculture production– 2nd position in the world.
4. Fish industry contribution -Rs.53,000 crores as foreign exchange annually.

Honey bee varieties

a. Indigenous varieties

i. Apis indica (Common Indian honey bee)

ii. Apis dorsata (Rock bee)

iii. Apis florea (Little bee)

b. Exotic varieties

i. Apis mellifera (Italian bee)

ii. Apis adamsoni (South African bee)

Economic importance of honey bees

Honey bees are used in the production of honey and bee wax.

Uses of honey

1. Honey is an energy-rich food. For example, 1 Kg of honey contains 3,200 calories of energy.
2. Honey contains sugar, minerals, vitamins, enzymes and pollen.
3. Honey is an antiseptic and contains formic acid as the preservative.
4. Honey is a blood purifier, a cure against cough, cold, sore throat, ulcers of tongue, stomach and intestine.
5. Honey is helpful in building up the haemoglobin content of the blood.
6. Honey is used in the preparation of bread, cakes and biscuits.

Bee wax

It is utilized in the manufacture of cosmetics, lubricants, cold creams, shaving creams, polishes, candles, ointments and in medical preparations.

HONEY BEE COMMUNICATION (Dance forms)

Round dance indicates that the source of nectar is within 100 mts. Waggle dance signifies a long distance. The dance patterns specify the direction of nectar with respect to the sun. In 1973, KARL VON FRISCH received the Nobel Prize for deciphering this dance language.

Round dance Waggle dance