Why do we study physics? Which device will you choose to measure the length of a small cylinder? How will you determine the thickness of a piece of wire? How will you find the volume of small stone? why ice floats while a coin sinks in the water? After learning this unit you will be answer these and other similar questions.

Quote

"No one undertakes research in physics with the intention of winning a prize. It is the joy of discovering something no one knew before."
Stephen Hawking

1.1 INTRODUCTION TO PHYSICS

One of the most basic and ancient science is the Physics. The word science refers to the study of a fact by collecting information through observation, presenting it in a mathematical way, justifying the idea with experiment and finally making a conclusion about the fact. Thus physics can be defined as:

Physics is the branch of science which observes the nature represents it mathematically and conclude with the experiment.

Do You Know!

Physics Derived from Ancient Greek 'physicos' meaning 'knowledge of nature'.

It basically deals with the behavior and structure of matter and the energy that derives the matter. Physics is the branch of natural science that studies matter, its motion, its behavior through space and time and the related entities of energy and force. Physics is one of the most fundamental scientific disciplines, and its main goal is to understand how the universe behaves.

It is a matter of fact that Physics can be considered as the mother of all sciences. The beauty of physics lies in its Laws that govern this whole universe from an atom to large scale galaxies and in its experiments from home to large scale experiment labs. Physicist are categorized into two categories: those who observe the nature solve its mysteries with available and missing information, present their theories with mathematical approach. They are known as theoretical physicist and other are more interested to test those theories with experiments are known as experimental physicists.

Since from the beginning of the universe, the structure of universe is very straight forward, the classification of physics was not that much easy but as the physicist explained the universe, they classified Physics into many branches. These branches show the spectrum and scope of Physics around us and help scientist to describe ideas in a well-organized way.

The main branches of Physics are as follows.

Mechanics

This branch of physics is mainly concerned with the laws of motion and gravitation.

Thermodynamics

Thermodynamics deals with heat and temperature and their relation to energy and work.

Electricity

Electricity is the study of properties of charges in rest and motion

Magnetism

Magnetism is the study of magnetic properties of materials

Atomic Physics

Atomic physics deals with the composition structure and properties of the atom

Fig. 1.1Mechanics

Fig 1.2 Thermodynamics

Fig 1.3Electricity

Fig 1.4 Magnetism

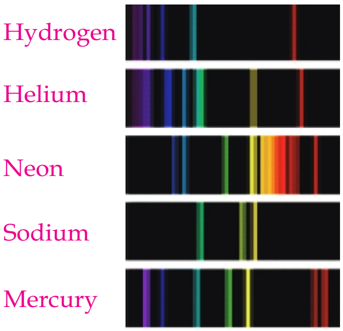


Fig. 1.5 Atomic Physics

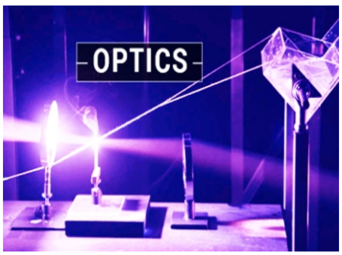


Fig. 1.6 Optics

Fig. 1.7 Sound

Fig. 1.8 Nuclear Physics

Optics

Optics studies physical aspects of light and its properties with the help of optical instruments.

Sound

Sound is the study of production, properties and applications of sound waves.

Nuclear physics

Nuclear physics deals with the constituents, structure, behavior and interactions of atomic nuclei.

Particle physics

Particle Physics studies the elementary constituents of matter and radiation, and the interactions between them.

Astrophysics

The study of celestial objects with the help of laws of physics is known as **Astrophysics**.

Plasma physics

The study of ionized state of mater and its properties is known as **Plasma Physics**.

Geo physics

The study of internal structure of earth is known as **Geo physics**.

Importance of Physics in Science Technology and Society

Society's reliance on technology represents the importance of physics in daily life. Many aspects of modern society would not have been possible without the important scientific discoveries made in the past. These discoveries became the foundation on which current technologies were developed.

Discoveries such as magnetism, electricity, conductors and others made modern conveniences, such as television, computers, smart phones, medical instruments, other business and home technologies possible. Moreover, modern means of transportation, such as aircraft and telecommunications, have drawn people across the world closer together all rely on concepts of physics.

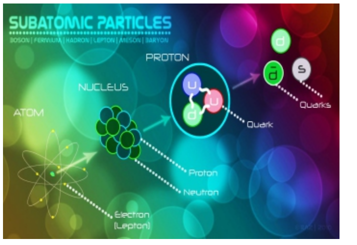


Fig. 1.9 Particle Physics

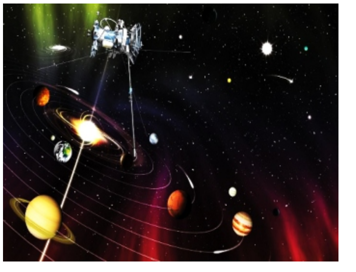


Fig. 1.10 Astro Physics

1.2 MEASURING INSTRUMENTS

Physics is much concerned with matter and energy and the interaction between them which is explained with the help of describing the mathematical relations between various physical quantities. All **physical quantities** are important for describing the nature around us. A physical quantity is a physical property of a phenomenon, body, or substance that can be quantified by measurement.

A physical quantity can be expressed as the combination of a magnitude expressed by a number – usually a real number – and a unit. Physical quantities are classified into two categories:

- Fundamental quantities
- Derived physical quantities.

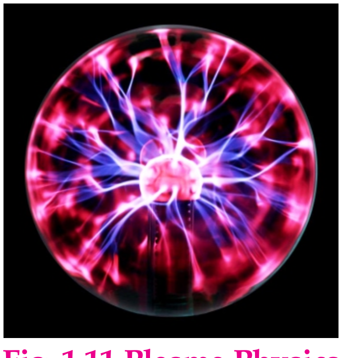


Fig. 1.11 Plasma Physics

Physical quantities which cannot be explained by other physical quantities are called fundamental physical quantities.

There are seven fundamental physical quantities and are listed in table 1.1 along with their units.


Fig. 1.12 Geo Physics

Table 1.1 Fundamental quantities and their S.I units

Fundamental quantities	S.I Unit	Symbol of Unit
Length	meter	m
Mass	Kilogram	kg
Time	second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Physical quantities which are explained on the basis of fundamental physical quantities are called derived physical quantities.

Table1.2 derived quantities and their units

Derived Quantities	S.I Unit	Symbol of Unit
Volume	cubic meter	m^3
Velocity	meter per second	$m^{-1}s$
Force	Newton	N
Density	kilogram per cubic meter	kg/m^3
Acceleration	meter per second square	m/s^2

All physical quantities are either calculated mathematically or measured through an instrument. Scientist, Engineers, Doctors and others like blacksmith, carpenter, and goldsmith even the workers and ordinary human's measure those physical quantities with the help of instruments. For instance, your doctor uses a thermometer to tell your body temperature, a carpenter uses the inch tape to measure the length of woods required for furniture.

Do You Know!

Some Physical quantities are unit-less. Such as Elastic modulus, Plane angle and solid angle

Do You Know!

The notion of physical dimension of a physical quantity was introduced by Joseph Fourier in 1822 by convention, physical quantities are organized in a dimensional system built upon base quantities, each of which is regarded as having its own dimension.

A puncture mender uses air gauges to check the air pressure in the tyre. Similarly, a chemical engineer uses hydrometer for describing the density of a liquid.

Measuring the physical quantity correctly with instrument is not an easy task for scientist and engineers. Scientist are seriously concerned with the accuracy of the instrument and its synchronization. Moreover, the instrument they design mostly for their own sake of research which readably goes on to commercial market. Many of the instruments we use today are inventions of pioneers of science. Usually, the basic physical quantities that we use in our daily life are measured with basic and simple instruments.

Do You Know!

Use of every instrument is restricted by smallest measurement that it can perform which is called least count.

The Standard of Length

If there is any measurement that has proven to be the most useful to humanity, it is length. For examples units of length include the inch, foot, yard, mile, meter etc.

The length is defined as the minimum distance between two points lying on same plane.

The **meter** (m) is the SI unit of **length** and is defined as:

The length of the path traveled by light in vacuum during the time interval of 1/299 792 458 of a second.

The basic measurement of length can be obtained with the help of a meter rod or an inch tape.

Do You Know!

1000m = 1km
100cm =1m
1cm = 10mm
1inch = 2.53cm
12 inch = 1 ft
1 yard = 3ft

Meter Rule

A **meter rule** is a device which is used to measure length of different objects. A meter rule of length 1m is equal to 100 centimeters (cm). On meter rule each cm is divided further in to 10 divisions which

Fig 1.13 Meter Rule

are called millimeters (mm). So, a meter rule can measure up to 1mm as smallest reading. It is made up of a long rigid piece of wood or steel(Fig 1.13).

The zero-end of the meter rule is first aligned with one end of the object and the reading is taken where the other end of the object meets the meter rule.

Fig 1.14 Vernier Calipers

Fig 1.15 Digital vernier calipers

Vernier Caliper

The **Vernier Caliper** is a precision instrument that can be used to measure internal and external distance extremely accurate. It has both an imperial and metric scale. A Vernier caliper has main jaws that are used for measuring external diameter, as well as smaller jaws that are used for measuring the internal diameter of objects. Some models also have a depth gauge. The main scale is fixed in place, while the Vernier scale is the name for the sliding scale that opens and closes the jaws (Fig1.14).

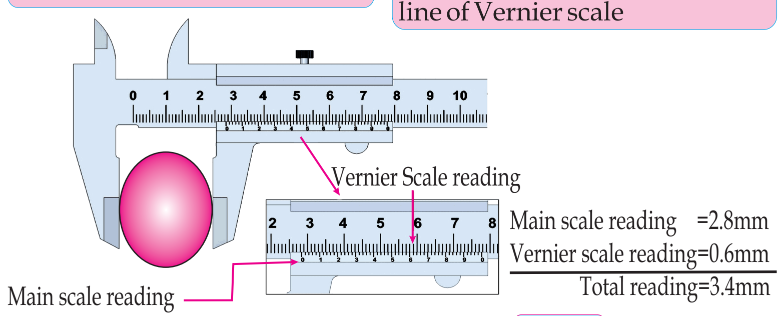
Reading a Vernier Caliper

Step 1

Place the object between the jaws of the Vernier caliper

Step 2

Note the main scale reading by counting lines before the zero line of Vernier scale

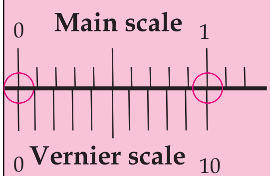
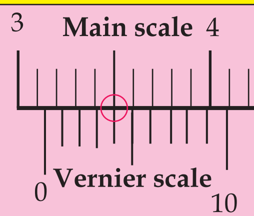
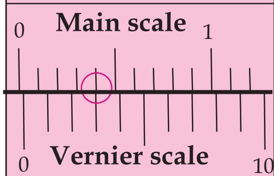
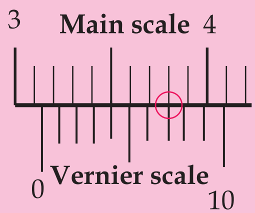
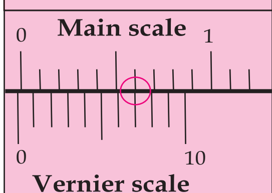
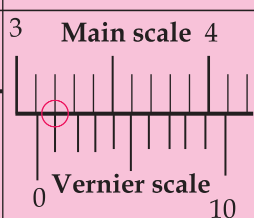


Step 3

Count the next line of Vernier scale after zero coinciding main scale

Step 4

Add the two reading for total

CHECKING FOR ZERO ERROR	OBSERVED READING	CORRECTED READING
 Two zero marks coincide No Zero error.	 Reading=3.14cm	3.14cm (No zero error No correction required)
 zero mark on vernier scale is slightly to the right Zero error is 0.03	 Reading=3.17cm	3.17cm-(+0.03)=3.14cm (The positive zero error is subtracted from reading)
 Zero mark on vernier scale is slightly to the left. zero error of -0.07	 Reading=3.11cm	3.11cm -(-0.07) =3.18cm (Negative zero error is added to the reading)

Micrometer Screw Gauge

Screw gauge in extensively used in engineering field for obtaining precision measurements. Micrometer screw gauge is used for measuring extremely small dimensions.

A screw gauge can even measure dimensions smaller than those measured by a Vernier Caliper. Micrometer Screw gauge works on the simple principle of converting small distances into larger ones by

Fig 1.16 Screw Gauge

measuring the rotation of the screw. This "screw" principle facilitates reading of smaller distances on a scale after amplifying them (Fig 1.16).

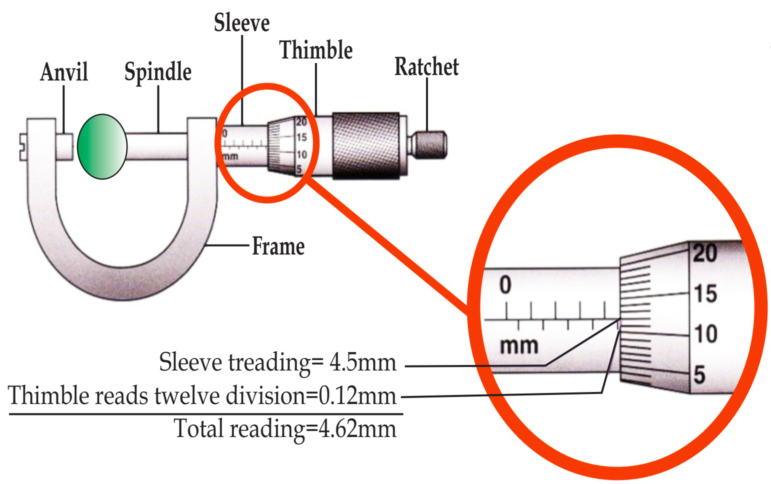
Reading A Micrometer Screw Gauge

Step 1

Turn the thimble until the anvil and the spindle gently grip the object. Then turn the ratchet until it starts to click.

Step 2

Take the main scale reading at the edge of the thimble.

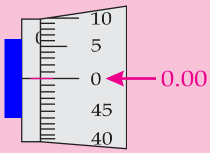
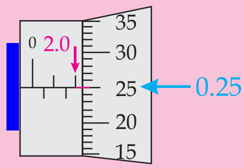
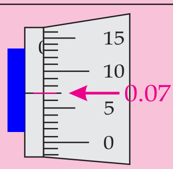
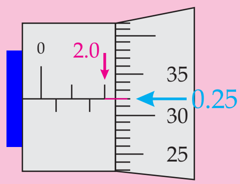
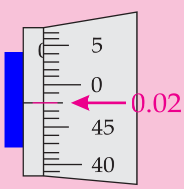
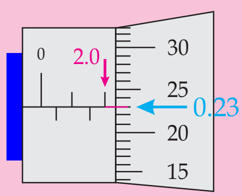


Step 3

Take the thimble scale reading opposite the datum line of the main scale. Multiply this reading with least count i.e., 0.01mm

Step 4

Now add main scale reading to thimble reading. This will be the diameter of the object.

Checking For Zero Error	Observed reading	Corrected Reading
 **Zero mark on thimble scale coincides with the datum line on the main scale and reading on the main scale is zero. No zero error**	 **Reading = 2.0+0.25 = 2.25mm**	2.25mm No zero error No Correction is required
 **Zero on** datum line can be seen. Positive Zero Error Reading =+0.07 mm **(Count from Zero.)**	 Reading=2.0+0.32 =2.32mm	2.32 - (+0.07) =2.25mm
 Zero mark on datum line cannot be seen negative zero error Reading= -0.02mm (count down from 0)	 Reading=2.0+0.23 =2.23mm	2.23 - (-0.02) =2.25mm

The Standard Of Mass

The **kilogram** is the SI unit of **mass** and is equal to the mass of the international prototype of the kilogram, a platinum-iridium standard that is kept at the International Bureau of Weights and Measures (Fig1.17).

Do You Know!

The kilogram, originally defined as: The mass of one cubic decimeter of water at the temperature of maximum density.It was replaced after the International Metric Convention in 1875 by the International Prototype Kilogram.

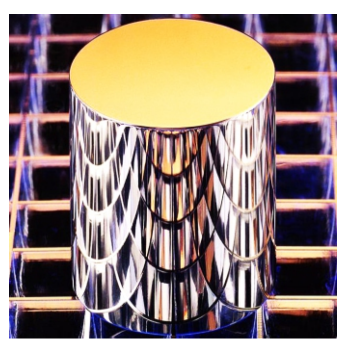


Fig 1.17 Kilo gram

Do You Know!

1000g = 1kg
1g = 1000mg
1g= 1000000µg
1g=1000000000ng
1g=0.002lb

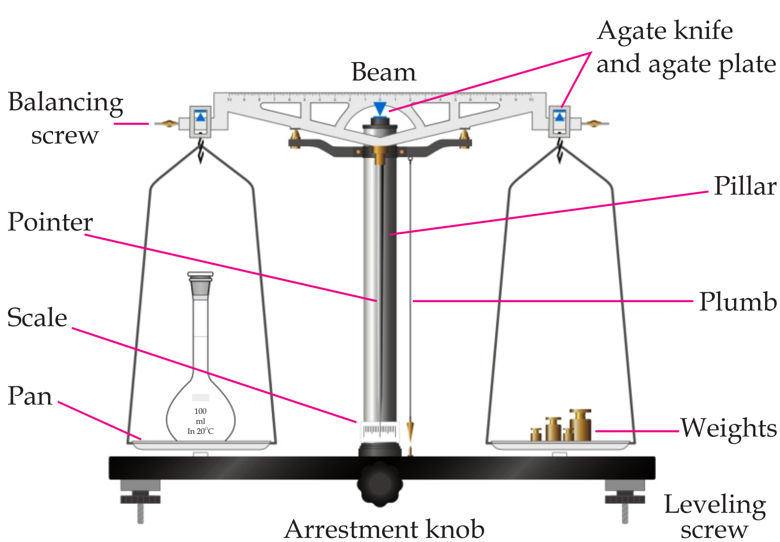
The kilogram is a cylinder of special metal about 39 millimeters wide by 39 millimeters tall that serves as the world's mass standard.

Each country that subscribed to the International Metric Convention was assigned one or more copies of the international standards; these are known as National Prototype Meter and Kilogram.

The Physical Balance

Fig 1.18 Physical Balance

The **Physical balance** is an instrument used for measurement of mass. It is mostly used in laboratory. It works on the principle of moments. It consists of a light and rigid beam of brass, a metallic pillar, a wooden base, two pans, a metallic pointer and an ivory scale (Fig 1.18). The plumb line indicates whether the balance is horizontal. In ideal condition the plumb line is aligned with the end of the knob fixed with the pillar. When the beam is horizontal the pointer remains on zero mark on the ivory scale. The whole box has leveling screws at the bottom to set it to horizontal. The device is enclosed in a glass box to avoid wind effects.



The Electronic Balance

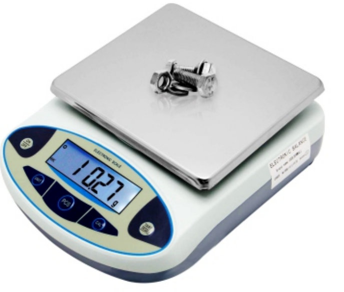


Fig 1.19 Electronic Balance

The digital mass meter is an electronic instrument configured with integrated circuits and it works on the principal of balancing the forces.

The device is turned on and set to zero then object is placed on the plate. The reading on the screen gives the mass of object. The electronic balance (Fig 1.19) is available in different ranges of measurement such as micro gram, milligram and kilogram etc.

The Standard of Time

Fig 1.20 Atomic Clock

Before 1960, the standard of time was defined in terms of the mean solar day for the year 1900. The rotation of the Earth is now known to vary slightly with time, this motion is not a good one to use for defining a time standard.

In 1967, the **second** was redefined to take advantage of the high precision attainable in a device known as an atomic clock(Fig 1.20), which uses the characteristic frequency of the cesium-133 atom as the "reference clock".

The second is now defined as 9 192 631 770 times the period of vibration of radiation from the cesium atom.

Stop Watch

A stopwatch is used to measure the time interval between two events. There are two types of stopwatch : Mechanical stopwatch and Digital stopwatch.

Fig. 1.21 Stop Watch

Mechanical/ Analogue Stopwatch

A **mechanical stop** watch can measure a time interval up to 0.1 second (Fig1.21). It has a knob that is used to wind the spring that powers the watch. It can also be used as a start stop and reset button. The watch starts when the knob is pressed once. When pressed second time, the watch stops While the third press brings the needle back to zero.

Digital Stopwatch

Fig. 1.22 Digital stop watch

A digital stop watch can measure a time interval up to 0.01 second (fig 1.22). It starts to indicate the time lapsed as the start/stop button is pressed. As soon as start/stop button is pressed again, it stops and indicates the time interval recorded by it between start and stop of an event. A reset button restores its initial zero setting. Now a days almost the mobile phones have a stopwatch function.

Human Reaction Time

As analogue or digital or watch is operated by human manually i.e., they have to be started or stopped by hand. This causes a random error in measurement of time i.e called human reaction time. For most people human reaction time is about 0.3- 0.5 s. Therefore for more accurate measurement of time intervals light gates (Fig1.23) can be used.

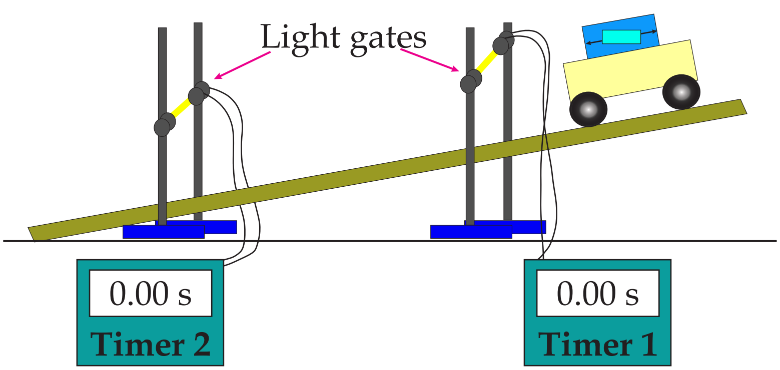


Fig 1.23 Light gates

SELF ASSESSMENT QUESTIONS:

Q1: What instrument will you choose to measure height of your friend?

Q2: Can you describe how many seconds are there in a year?

Q3: Which instrument will you choose to measure your mass?

Do You Know!

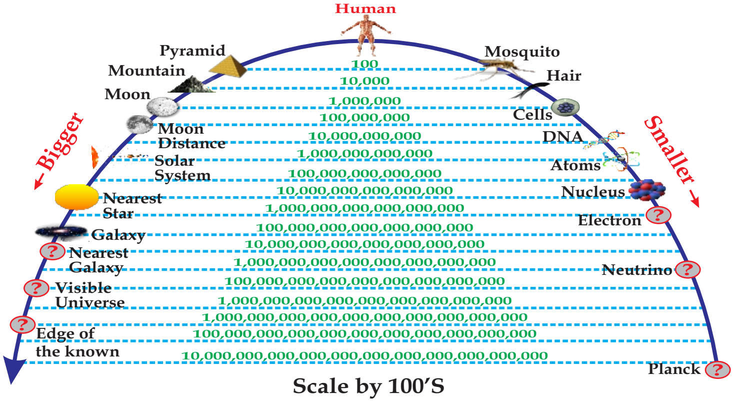
1 hour = 60 min
1 hour = 3600 sec
1min=60sec
1sec=1000ms
1sec=1000000µs

1.3 PREFIXES

The Physical quantities are described by the scientist in terms of magnitudes and units. Units play a vital role in expressing a quantity either base or derived. Prefixes are useful for expressing units of physical quantities that are either very big or very small.

A **unit prefix** is a specifier. It indicates multiples or fractions of the units.

Units of various sizes are commonly formed by the use of such prefixes. The prefixes of the **metric system**, such as kilo and milli , represent multiplication by powers of ten. Historically, many prefixes have been used or proposed by various sources, but only a narrow set has been recognized by standards organizations.



Scale by 100'S

Table 1.3 SI pre fixes

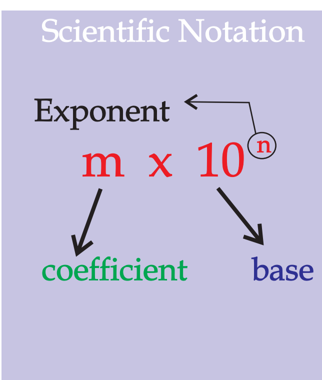
SI Prefixes

Prefix	Symbol	Meaning	Multiplier (Numerical)	Multiplier (Exponential)
		Greater than 1		
tera	T	trillion	1 000 000 000 000	10^{12}
giga	G	billion	1 000 000 000	10^{9}
mega	M	million	1 000 000	10^{6}
kilo	k	thousand	1 000	10^{3}
hecto	h	hundred	100	10^{2}
deka	da	ten	10	10^{1}
		Less than 1		
Unit	**1**			
*deci	d	tenth	0.1	10^{-1}
*centi	c	hundredth	0.01	10^{-2}
*milli	m	thousandth	0.001	10^{-3}
*micro	µ	millionth	0.000 001	10^{-6}
*nano	n	billionth	0.000 000 001	10^{-9}
pico	p	trillionth	0.000 000 000 001	10^{-12}
femto	f	quadrillionth	0.000 000 000 000 001	10^{-15}
atto	a	quintillionth	0.000 000 000 000 000 001	10^{-18}

SELF ASSESSMENT QUESTION:

Q4: Can you tell if the size of a nucleus is up to 10^{-15}m. What prefix shall we use to describe its size?

1.4 SCIENTIFIC NOTATION



Scientific notation or the standard form is a simple method of writing very large numbers or very small numbers. In this method numbers are written as powers of ten. Thus calculation of very large or very small numbers becomes easy.

Numbers in Scientific Notation are made up of three parts: The coefficient, the base and the exponent.

- The coefficient must be equal to or (Not zero) greater than one
- The base must be 10
- The exponent can be negative or positive.

Worked Example 1

Convert mass of Sun 2 000 000 000 000 000 000 000 000 000 000 000 kg. into Scientific Notation.

Solution

Step 1: Since, M_{Sun} = 2 000 000 000 000 000 000 000 000 000 000 000 kg

It's obvious that in this value decimal lies at the end.

Step 2: Converting into scientific notation

Move the decimal to left writing in terms of base of ten

$M_{sun} = 2.00 \times 10^{30}$ kg.

Note: power of exponent is taken as positive not to be confused as we have displaced decimals but not numbers.

Worked Example 2

Convert mass of an electron 9.11 x 10^{-31} kg into standard form.

Solution

Step 1: The decimal lies in the middle of the value.

Since, $m_{electron} = 9.11 \times 10^{-31}$ kg

Step 2: Move the decimal 31 steps towards left

$m_{electron}$ = 0.000 000 000 000 000 000 000 000 000 000 911 kg

1.5 DENSITY AND VOLUME

The three common **phases** or **states** of matter are **solid, liquid** and **gas**. A solid maintains a fixed shape and a fixed size, even if same force is applied it not readily change its volume. A liquid does not maintain a fixed shape it takes on the shape of its container. But, like a solid it is not readily compressible, and its volume can be changed significantly only by a large force.

Quick Lab

Fill a tub with water to certain level and mark.

Put some ice in it and observe the water level carefully as well as floating or sinking.

Remove the ice from the tub without being melt and put a balloon in it and then observe.

Likewise, put a spoon in that tub and observe.

Again put an empty can of coke and observe.

Can you tell which of all four has more density? And which has more volume?

Do You Know!

1 liter = 1000cm^3

1m^3 = 1000 litr

However, a gas has neither a fixed shape nor a fixed volume- it will expand to fill its container.
Often we find the large weight woods floating on the surface of water. However, an iron needle sinks into the water. We say iron is "heavier" than wood. This cannot really be true rather we should say like iron is "denser" than wood. Physicist are concerned with a physical quantity, a property of matter which may help to define the nature of matter in terms of its mass and space.

Measuring the Volume

For density to be measured or calculated we first need to find the volume of substances. Most of solid geometrical shapes have formulae for their volume which is obtained through different parameters such as radius, height, depth, width, base and length, but for irregular objects, liquids and gases this approach is unusual. The volume of liquids can be measured with the help of Cylinders, and Beakers.

Measuring Cylinder

Measuring cylinder is a glass or plastic cylinder with a scale-graduated in cubic centimeters or milliliters (ml)(fig1.24). It is used to find the volume of liquids. When a liquid is poured, it rises to a certain height in the cylinder. The level of liquid in the cylinder is noted and volume of the liquid is obtained.
In order to read the volume correctly we should keep the eye in level with the bottom of the meniscus of the liquid surface as you learned in previous grade.

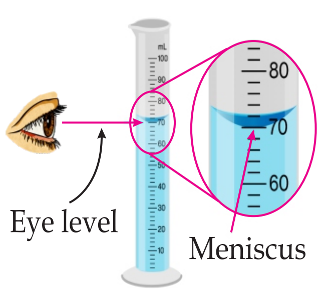


Fig. 1.24
Measuring Cylinder

1. Volume of Liquid

A volume of about a liter or so can be measured using a measuring cylinder. When the liquid is poured into the cylinder the level on scale gives the volume. Most measuring cylinders have scales marked in milliliters (ml) or cubic centimeters (cm^3). It should be noted that while recording the value from cylinder the eyes should maintain the level with the value. Angular observation may result a false reading of the volume.

2. Regular solid

If an object has a regular shape its volume can be calculated
For instance:
Volume of a rectangular block = length x width x height
Volume of a cylinder = $\pi \times \text{radius}^2 \times$ height

3. Irregular solid

For an irregular solid its volume is calculated by lowering the object in a partially filled measuring cylinder (fig 1.25). The rise in the level on the volume scale gives the volume of that object. Thus the volume of irregular solid is calculated by subtracting the original volume of liquid from the raised volume of liquid.

The total volume is found. The volume of the solid is measured in a separate experiment and then subtracted from the total volume.

Quick Lab

Take a measuring cylinder of 1 liter capacity at full place it in a beaker.

Fill cylinder full with water.

Pour a stone of irregular shape in it gradually.

As you pour the stone in the cylinder, the water from cylinder drops into the beaker.

Drop the stone in cylinder completely

Calculate the volume of water ejected out of cylinder.

Volume of water ejected is the volume of the stone.

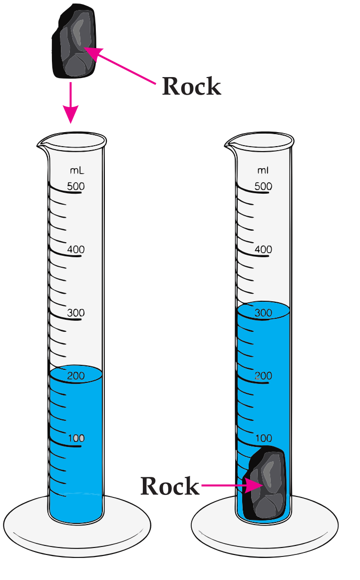


Fig 1.25. Volume Irregular shaped Solid

Density

The term **density** of a substance is defined as mass of substance (m) per unit volume (V). It is denoted by Greek letter **ρ (rho)**.

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

Density is characteristic property of any pure substance. Objects made of a particular pure substance such as pure Gold can have any size or mass but its density will be same for each.

In accordance with the above equation mass of a substance can be expressed as

$$m = \rho V$$

The S.I unit for density is kg/m^3 kgm^{-3}. Sometimes dens of substances is given in gm/cm^3. The density of Aluminum is 2.70 gm/cm^3 which is equal to 2700 Kg/m^3.

Do You Know!

During the Cold War between Russia and America. There was a race of Astrophysics. America was facing the period of racism. A Black lady mathematician named Katherine solved the problem of putting the first orbital satellite.
Recommended!
Watch movie "Hidden Figures"
Observe the importance of Reliable Numbers.

Measuring the Density

It is to be noted that there are two ways of finding the density of a substance either mathematically or experimentally by taking density of water at 4°C as a reference which is sometimes known as relative density or **'Specific gravity'**. It has no unit, it is a number whose value is the same as that of the density in g/cm^3.

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water}}$$

Do You Know!

In Jordan there is sea known as 'Dead Sea'
The humans in that sea while swimming does not sink!
This is because the water of sea is much more salty than normal, which raises the density of water.

Worked Example 4

What is the mass a solid iron wrecking ball of radius 18cm. if the density of iron is 7.8 gm/cm^3?

Solution:

Step 1: write known physical quantities with units and point out the quantity to be found.

Density of iron ball $\rho = 7.8\ gm/cm^3 = 7.8 \times 1000\ kg/m^3$

Radius of iron ball is $r = 18cm = 18 \times 10^{-2}\ m = 0.18m$

Volume of the iron ball is $V = (4/3) \times \pi \times r^3 = (1.33) \times 3.14 \times (0.18m)3\ V = 0.024m^3$

Step 2: write down the formula and rearrange if necessary

$m = \rho \times V$

Step 3: put the values in formula and calculate

Since mass of iron ball is $m = \rho \times V = (7.8 \times 10^3) \times (0.024)$

$m = 187.2\ kg$

SELF ASSESSMENT QUESTIONS:

Q5: How can you identify which gas is denser among the gases?

Q6: Can you tell how hot air balloon works?

1.6 SIGNIFICANT FIGURES

Engineers and scientist around the world work with numbers either representing a large or small magnitude of a physical quantity. The engineers are however interested in the accuracy of a value as they mostly work on estimation but scientist especially physicist are more concerned in the accuracy of these numbers. For instance, an engineer records the speed of wind and explains it on an average. On the other hand, for the physicist, the speed of earth on its course, the speed of light in vacuum the mass or charge on an electron is just not a matter of numbers but accurate numbers.

The numbers of reliably known digits in a value are known as significant figures.

Table 1.4 Rules for determining significant figures

Rule	Example
1. All non-zeroes are significant	2.25 (3 significant figures)
2. Leading zeroes are NOT significant	0.00000034 (2 significant figures)
3. Trailing zeroes are significant ONLY if an explicit decimal point is present	200 (1 significant figure) 200. (3 significant figures) 2.00 (3 significant figures)
4. Trapped zeroes are significant	0.00509 (3 significant figures) 2045 (4 significant figures)

Worked example 5

How many significant figures are there in the area of a cylinder whose diameter is 5 cm

Solution:

Step 1: write known physical quantities and point out the unknown quantity

Diameter of the cylinder is $d = 5cm = 5 \times 10^{-2}\,m = 0.05m$

Radius of cylinder is $r = d/2 = 2.5 \times 10^{-2}\,m = 0.025m$

Step 2: write down formula and rearrange if necessary

The area of the cylinder is $A = \pi \times r^2 = 3.14 \times (0.025m)^2 = 0.0019m^2$

Step 3: put value in formula and calculate

Thus area of cylinder can be written as $A = 1.9\ mm^2$

Thus, there are two significant numbers in the value 1 and 9.

SELF ASSESSMENT QUESTIONS:

Q7: Determine the number of significant figures in
00.6022009

SUMMARY

- Physics is the branch of science which deals with studies of matter its composition, properties, and interaction with energy.
- The branches of Physics are classified on the basis of different areas of study with different approaches.
- There are two types of physicist, theoretical and experimental physicist.
- Physics define mathematical relation between physical quantities. A physical quantity has magnitude and unit.
- Physical quantity are mainly classified into two categorize
  (i) Base or fundamental quantities
  (ii) Derived physical quantities.
- Base quantities are length, mass, time, temperature, current, luminous intensity, and amount of substance.
- The standard of length is meter can be measured by measuring tape , or meter rule.
- The standard of mass is kilogram can be measured by physical balance.
- The standard of time is second can be measured by stop watch.
- The measured or calculated values either macroscopic or microscopic can be expressed in Scientific Notations.
- The volume of liquid is calculated or measured with help of measuring cylinder

- The volume of irregular objects can be calculated through measuring cylinder with displacement of water.
- The density of a pure substance is its characteristic property it is the ratio of mass per unit volume.
- The density of objects can be calculated with the help of water as a reference known as specific gravity also known as relative density.
- Prefixes can be used to represent large or smaller values of a physical quantity.
- The most accurate or reliable numbers of a value are known as significant figures.

CONCEPT MAP

Physics Quantities

- Based on its types, is divided into
  - **Base Quantities** — There are
    1. Length
    2. Mass
    3. Time
    4. Temperature
    5. Electric current
    6. Luminous intensity
    7. Amount of substance
  - **Derived Quantities** — For examples
    - Area
    - Volume
    - Force
    - Energy
    - Density
- Based on existing or has not direction, divided into
  - **Scalar Quantity** — For examples
    - Distance
    - Speed
    - Energy
    - Volume, etc.
  - **Vector Quantity**
    - Displacement
    - Velocity
    - Work
    - Force

Physics Quantities

- **Length** → Meter → Ruler/ Measuring Tape
  - Multiple — Basic — Sub multiple
  - km ↔ m ↔ mm
- **Mass** → Kilogram → Spring Balance/ Electronic balance/ Beam balance
  - Multiple — Basic — Sub multiple
  - Metric Tone (t) ↔ kg ↔ mg
- **Time** → Seconds → Stopwatch/clock
  - Multiple — Basic — Sub multiple
  - Min, hour ↔ Second (s) ↔ ms
- **Volume** → Liter → Measuring cylinder/ flask/ beaker/pipette
  - Liter ↔ Milliliter
  - l ↔ ml

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

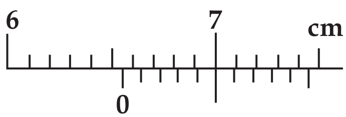


Fig 1.26

1. The Figure 1.26 shows part of a Vernier scale, what is the reading on the Vernier scale

a) 6.50 cm b) 6.55 cm
c) 7.00 cm d) 7.45 cm

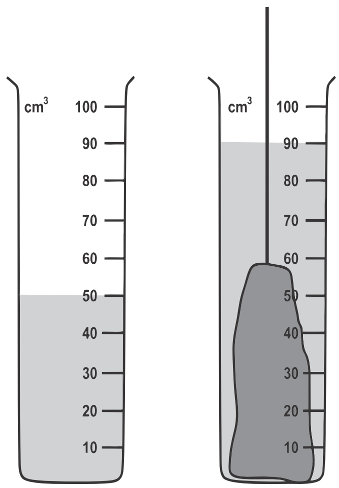


Fig 1.27

2. Ten identical steel balls each of mass 27g, are immersed in a measuring cylinder having 20cm^3 of water. The reading of water level rises to 50cm^3. What is the density of the steel?

a) 0.90 gm/cm^3 b) 8.1 gm/cm^3
c) 9.0 gm/cm^3 d) 13.5gm/cm^3

3. An object of mass 100g is immersed in water as shown in the figure 1.27, what is the density of the material from which object is made?

a) 0.4gcm^3 b) 0.9gcm^3
c) 1.1 gcm^3 d) 2.5gcm^3

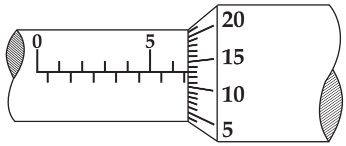


Fig 1.28

4. What is the reading of this micrometer in figure 1.28

a) 5.43mm b) 6.63mm
c) 7.30mm d) 8.13mm

5. A chips wrapper is 4.5 cm long and 5.9 cm wide. Its area upto significant figures will be

a) 30 cm^2 b) 28 cm^2
c) 26.55 cm^2 d) 32 cm^2

6. A worldwide system of measurements in which the units of base quantities were introduced is called
   a) prefixes
   b) international system of units
   c) hexadecimal system
   d) none of above
7. All accurately known digits and first doubtful digit in an expression are known as
   a) non-significant figures
   b) significant figures
   c) estimated figures
   d) crossed figures
8. If zero line of Vernier scale coincides with zero of main scale, then zero error is
   a) positive b) zero
   c) negative d) one
9. zero error of the instrument is
   a) systematic error b) human error
   c) random error d) classified error
10. Length, mass, electric current, time, intensity of light and amount of substance are examples of
   a) base quantities b) derived quantities
   c) prefixes d) quartile quantities

Section (B) Structured Questions

1.

Column A Action	Column B Branch
Cooking Bar B.Q	Thermodynamics
Turning the Bulb on	
Riding a bicycle	
Looking for Giant Galaxies	
Producing a loud sound	
Describing an atom	
Obtaining energy from Earth	

2.

Physical Quantity	S.I Unit	Type
Ampere		
	m^3	
	Sec	Base
Temperature		Base
	N	
Density	Kg per m^3	
Acceleration		

3. Convert the following values.

a) 230 cm = ______________m
b) 250 g = ______________kg
c) 0.5 s = _________________ms
d) 0.8 m = _____________mm
e) 350ms = _________________s
f) 1.2Kg = ______________g

4. An engineer measures the width of an aluminum sheet using Vernier caliper as shown in fig 1.29

   a) What is the measurement of the width of aluminum sheet

   b) Which gives more precise measurement Vernier caliper, Screw Gauge or meter rule?

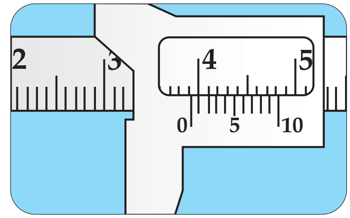


Fig 1.29

5. A pendulum swings as shown if figure 1.30 from X to Y and back to X again

   i) What would be the most accurate way of measuring time for one oscillation? with the help of a Stop Watch.

      a) Record time for 10 oscillations and multiply by 10

      b) Record time for 10 oscillation and divide by 10

      c) Record time for one oscillation

      d) Record time from X to Y and double it

   ii) Suggest an instrument for measuring time period more accurately.

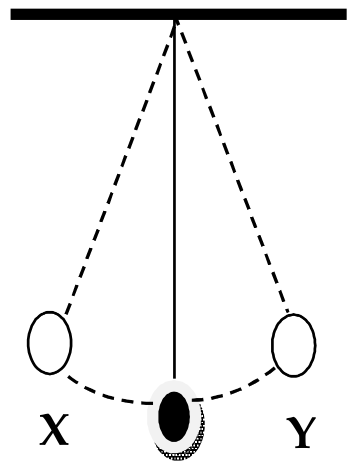


Fig. 1.30

Prefixes

6. write the correct prefix of notion

   a) 75000m = 750 __________

   b) 2/1000 sec = 1 __________

   c) 1/1000000 g = 1 __________

   d) 1000000000 m = 1__________

Scientific Notation

7. Write values in standard and scientific notation

   a) The radius of 1st orbit of Hydrogen atom is r = 0.53 A^0 = __________

   b) 1 light year is 2628000000000m = __________

   c) Vacuum pressure 2.7×10^{-4} torr = __________

Density and Volume

8. A wooden piece is made in different shapes take length (l) = radius (r) = 2m Calculate its volume as a:
   a) Sphere   b) Cube
   c) Cylinder   d) Pyramid
   e) Cylinder
9. Find the density of wood as sphere and cube if the mass of wood is 1kg. Is there any change in density due to shape?
10. A measuring cylinder (fig 1.31) is filled with 500cc water. A stone of mass 20g is immersed in to the cylinder such that ,water level rises up to 800cc. Which statement is correct?
    a) The difference between the readings gives the density of stone.
    b) The difference between the readings gives volume of the stone
    c) The final reading gives the density of stone
    d) The final reading gives the volume of stone

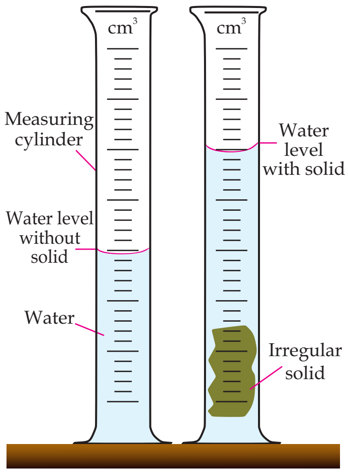


Fig 1.31

Significant Figures

11. Write significant numbers in the following values.
    a) 980 has ________ Significant numbers.
    b) 91.60 has ________ Significant numbers.
    c) 10010.100 has ________ Significant numbers.
    d) 0.0086 has ______ Significant numbers.

Unit - 2

KINEMATICS

The word Kinematics is derived from Greek Word kinema.
How an object changes its position in space in a certain time interval without considering the causes of motion it is the study of motion of bodies without any reference of force.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Describe using examples how objects can be at rest and in motion simultaneously.
- Identify different types of motion i.e., translatory, (linear, random, and circular); rotatory and vibratory motions and distinguish among them.
- Define with examples distance, displacement, speed, velocity and acceleration (with units)
- Differentiate with examples between distance and displacement, speed and velocity.
- Differentiate with examples between scalar and vector quantities.
- Represent vector quantities by drawing.
- Plot and interpret distance-time graph and speed-time graph
- Determine and interpret the slope of distance-time and speed-time graph
- Determine from the shape of the graph, the state of a body (i) at rest (ii)moving with constant speed (iii) moving with variable speed
- Calculate the area under speed-time graph to determine the distance traveled by the moving body.
- Solve problems related to uniformly accelerated motion using appropriate equations
- To rearrange the equation according to the requirement of the problem
- Solve problems related to freely falling bodies using $10\ m/s^2$ as the acceleration due to gravity.

When you throw a ball straight up in the air, how high does it go? When a glass slips from your hand, how much time do you have to catch it before it hits the ground? How will you describe the motion of a jet fighter being catapulted down the deck of an air craft carrier? These and some other similar questions you will learn to answer in this unit.


Fig 2.1, Car with respect to tree at rest position

The branch of physics which is related with the study of motion of objects is called Mechanics.

It is divided in two parts

(i) Kinematics **(ii) Dynamics**

The word kinematics is derived from Greek word "Kinema" which means motion.

Kinematics is the branch of Mechanics which deals with motion of objects without reference of force which causes motion.

2.1 REST AND MOTION

Have a look around in your classroom, You can observe various things like, table, chairs, books etc all are in state of rest. A car is in the state of rest with respect to trees and bushes around it Fig 2.1. Thus rest can be defined as:


Fig 2.2, Train at station

A body is said to be in rest if it does not change its position with respect to its surroundings.

A train is stationed at the platform. A person can notice that the train does not changes its position with respect to its surroundings, hence the train is in the state of rest Fig 2.2. But as soon as the train starts moving its position continuously changing with respect to its surroundings. Now we can say that the train is in motion. Thus motion can be defined as:

A body is said to be in motion if it changes its position with respect to its surroundings.

Rest and Motion are Relative State

No body in the universe is in the state of absolute rest or absolute motion. If a body is at rest with respect to some reference point at the same time, it can also be in the state of motion with respect to some other reference point.

For example, A Passenger sitting in a moving bus is at rest because passenger are not changing their position with respect to other passengers or objects in the bus as shown in fig 2.3. But for another observer outside the bus noticed that the passengers and objects inside the bus are in motion as they are changing their position with respect to observer standing at the road.

Fig 2.3, A moving bus

Similarly a passenger flying on aeroplane is in motion when observed from ground but at the same times he is at rest with reference to other passengers on board.

SELF ASSESSMENT QUESTIONS:

Q 1. Define Kinematics.

Q 2. When is a body said to be in state of rest?

Q 3. How are rest and motion related to each other?

2.2 TYPES OF MOTION

We observe around us that all objects in universe are in motion. However the nature of their motion is different, some objects move along circular path, other move in straight line while some objects move back and forth only. There are three types of motion.

(i) Translatory motion (linear, circular and random)

(ii) Rotatory motion

(iii) Vibratory motion.

(I) Translatory Motion


Fig 2.4 A train moving along a straight track

Different objects are moving around in different ways. You can observe how various objects are moving? Which objects move along a circular path? Which objects move along a linear path?

A train is moving along a straight track in Fig 2.4. you can observe that every part of the train is moving along that straight path.

This is called translatory motion. Translatory motion can be defined as:

When all points of a moving body move uniformly along the same straight line, such motion is called translatory motion.


Fig 2.5 Moving bus

(a) Linear Motion:

We observe many objects moving along straight line. The motion of a bus in a straight line on road is called linear motion Fig. 2.5. Thus the linear motion can be defined as:

Motion of a body along a straight line is called linear motion.


Fig 2.6
An artificial satellite

(b) Circular Motion:

An artificial satellite moving around the Earth along circular path is an example of circular motion Fig 2.6. Thus circular motion can be defined as:

Motion of a body along a circular path is called circular motion.

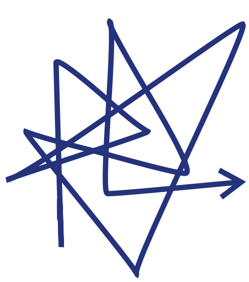


Fig 2.7 Random motion

(c) Random Motion

You must have observed the motion of flies, insects and birds? They suddenly change their direction. The path of their motion is always irregular. This type of motion is known as random motion . The random motion can be defined as :

Irregular motion of an object is called random motion.

The motion of butterfly, house fly, dust and smoke particles along zigzag paths are examples of random motion. The motion of the particles of a gas or a liquid known as the Brownian motion which is an example of random motion Fig2.7.

Fig 2.8 (a) Spinning top

(ii) Rotatory Motion

Have you noticed the type of motion of fan and spinning top? Every point of the top moves in a circle around a fixed axis. Thus every particle of the top possess circular motion Fig 2.8(a).

Fig 2.8 (b) A wheel

But the top as whole moves around an axis which passes through top itself so the motion of top is rotatory Thus rotatory motion can be defined as:

The motion of the body around a fixed axes which passes through body itself is called spin or rotatory motion.

Fig 2.8 (c) Ferris wheel

The motion of a wheel about the axle, the motion of a rider on the Ferris wheel are some examples of rotatory motion Fig 2.8 (a, b, c).

(iii) Vibratory Motion

Look at the motion of child in swing Fig 2.9(a). when swing is pulled away from its mean position and then released, the swing start moving back and forth about the mean position. This type of motion is called vibratory or oscillatory motion. Thus vibratory motion can be defined as:

Fig 2.9 (a) Motion of child in swing

Fig 2.9 (b)
Clock's pendulum

Back and forth motion of a body about its mean position is called vibratory or oscillatory motion.

There are many examples of vibratory or oscillatory motion in daily life. for example, motion of the clock's pendulum Fig 2.9 (b).

Distinguish between Translatory, Vibratory and Rotatory

Translatory Motion	Rotatory Motion	Vibratory Motion
A body moves along a straight line.	The spinning of a body about its axis.	The body move back and forth about mean position.
Movement of an object from one place to another.	The motion of an object about fixed point.	The body moves up and down.
All particles of the rigid body move with the same velocity at every instant of time.	The motion of a rigid body about a fixed axis. Every particle of body move in a circular path	An object repeat its motion itself.

SELF ASSESSMENT QUESTIONS:

Q 4. Define Translatory Motion?

Q 5. What is vibratory motion?

Q 6. Differentiate between translatory motion, rotatory motion and vibratory motion.

2.3 DESCRIBING MOTION

The motion of an object can be described by specifying its position, change in position. speed, velocity and acceleration.

(i) Distance and Displacement

A person can use three different paths to move from place A to an other place B. It can be used to illustrate meaning of distance and displacement Fig 2.10.

What if the person moves back from B to A along any of the three paths. The person covers the distance is either 16 km (purple path) or 24 km (red path).
While the person is back at A so, the net displacement becomes zero.

Thus distance and displacement can be differentiated as follows:

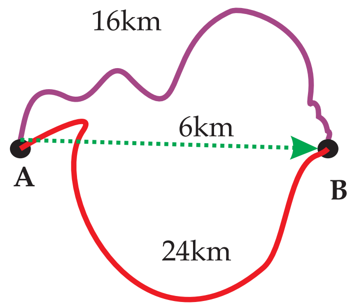


Fig 2.10
Distance and displacement

Distance	Displacement
➢ The total length covered by moving body without mentioning direction of motion.	➢ The distance measured in straight line in a particular line.
➢ It is an scalar quantity.	➢ It is a vector quantity.
➢ The S.I unit is **metre (m).**	➢ The S.I unit is **metre (m).**
➢ The distance traveled by the person from A to B is either 16 km (purple path) or 24 km (red path)	➢ The displacement of the person is 6 km from A to B due west of A.

(ii) Speed and Velocity

The speed of an object determines how fast an object is moving? It is rate of change of position of an object. There are many ways to determine speed of an object. These methods depend on measurement of two quantities.

- The distance traveled
- The time taken to travel that distance

Thus the average speed of an object can be calculated as:

$$\text{Speed} = \frac{\text{distance traveled}}{\text{time taken}}$$

$$V = \frac{S}{t}$$

The equation for average speed in symbols can be written as :

$$V = \frac{S}{t} \quad \text{..............(eq 2.1)}$$

Where, "V" is the speed of the object, "S" distance traveled by it and "t" time taken by it. Thus average speed can be defined as:

Distance covered by an object in a unit time is called speed.

The equation (2.1) gives only average speed of the body it can not be said that it was traveling with uniform speed or non uniform speed. For example, a racing car can be timed by using a stop watch over a fixed distance say, 500m Fig 2.11. Dividing distance by time gives the average speed, but it may speed up or slow down along the way. Speed is a scalar quantity and its S.I unit is ms^{-1}.

Do You Know!

Average speed of different animals and objects :

Animal /Object	Speed (kmh^{-1})
White-tailed deer	48
Ren deer	60-80
cheetah	100-120
Walking man	6
Grand prix car	360
Passenger jet	900
Sound	1200
Space shuttle	36000

Fig 2.11
A racing car

Uniform speed

An object covers an equal distance in equal interval of time its speed is known as uniform speed.

Velocity

Velocity means speed of an object in a certain direction. Velocity is a vector quantity. thus velocity of an object can be defined as:

Rate of change of displacement with respect to time is called velocity.

$$\text{Velocity} = \frac{\text{Change in displacement}}{\text{time taken}}$$

$$\mathbf{v} = \frac{\Delta \mathbf{d}}{\mathbf{t}} \quad \text{..............} \mathbf{(2.2)}$$

Here **d** is displacement of the moving object, **t** is time taken by object and **v** is velocity. SI unit of velocity is ms^{-1}.

The velocity of an object is constant when it moves with constant speed in one direction. The velocity of object does not remain constant when it changes direction with out changing its speed, or it changes speed with no change in direction. Thus average velocity of an object is given by

$$\text{Velocity} = \frac{\text{total displacement}}{\text{total time taken}}$$

Uniform velocity:

A body is said to have uniform velocity if it cover equal distance in equal interval of time in a particular direction .

Worked Example 1

A car travels 700m in 35 seconds what is the speed of car?

Solution

Step 1: Write the known quantities and point out quantities to be found.

$$d=700m$$
$$t=35s$$
$$v=?$$

Step 2: Write the formula and rearrange if necessary.

$$v=\frac{d}{t}$$

Step 3: Put the value in formula and calculate

$$v=\frac{700}{35}=20ms^{-1}$$

Thus the average speed of car is $20ms^{-1}$.

Worked Example 2

The speed of train is 108 kmh^{-1}. How much distance will be covered in 2 hours?

Solution

Step 1: Write the known quantities and point out quantities to be found.

$$v=\frac{108\ km}{h}=\frac{108\times 1000\ m}{3600\ s}=30ms^{-1}$$
$$t=2h=2\times 3600s=7200s$$
$$d=?$$

Step 2: Write the formula and rearrange if necessary

$$v=\frac{d}{t}$$
$$d=v\times t$$

Step 3: Put value in formula and calculate

$$d=30\times 7200=216000m$$

Thus distance traveled by train is 216000m.

Acceleration

An object accelerates when its velocity changes. Since velocity is a vector quantity so it has both magnitude and direction. Thus acceleration is produced when ever:

- Velocity of an object changes
- Direction of motion of the object changes,
- Speed and direction of motion of the object change.

Thus acceleration can be defined as:

Rate of change of velocity of an object with respect to time is called acceleration.

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

$$a = \frac{\Delta v}{t} \qquad \because \ \Delta v = v_f - v_i$$

$$\therefore \quad a = \frac{v_f - v_i}{t} \quad \text{...............(eq 2.3)}$$

Acceleration is a vector quantity. Its SI unit is metre per second per second (**ms**$^{-2}$).

When velocity of an object increases or decreases with passage of time, it causes acceleration. The increase in velocity gives rise to positive acceleration Fig 2.12(a). It means the acceleration is in the direction of velocity. Whereas acceleration due to decrease in velocity is negative and is called **deceleration** or *retardation* Fig 2.12(b).The direction of deceleration is opposite to that of change velocity.

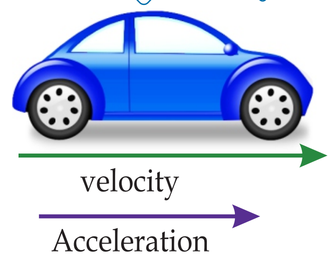


Fig 2.12 (a)
Velocity of this car is increasing

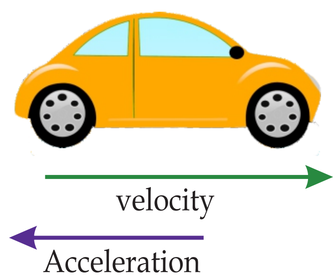


Fig 2.12 (b)
Velocity of this car is decreasing

Uniform Acceleration

A body has uniform acceleration, if the velocity of body changes by an equal amount in every equal time period.

When the change i.e., increase or decrease in the velocity of an object is same for every second then its acceleration is uniform. when velocity of an object is increasing by 10 ms^{-1} every second ,the acceleration is $10ms^{-2}$.When the velocity of the object is decreasing by $10ms^{-1}$ every second, the deceleration is 10 ms^{-2}. Thus, uniform acceleration can be defined as:

A constant rate of change of velocity is called uniform acceleration.

The uniform acceleration can be calculated by using following formula :

$$\vec{a} = \frac{\Delta\vec{V}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{t_2 - t_1}$$

Where $\mathbf{v}_f$ = initial velocity (in ms^{-1});
$\mathbf{v}_i$ = final velocity (in ms^{-1});
$\mathbf{t}_1$ = time at which an object is at initial velocity u (in s);
$\mathbf{t}_2$ = time at which an object is at final velocity v (in s);
$\Delta\mathbf{v}$ = change in velocity (in ms^{-1})
$\Delta\mathbf{t}$ = time interval between t_1 and t_2(in s)

Worked Example 3

A bus start from rest and travels along a straight path its velocity become $15ms^{-1}$ in 5 seconds. Calculate acceleration of the bus?

Solution:

Step 1. Write the known quantities and point out quantities to found.

v_i = 0 ms^{-1}
v_f = 15 ms^{-1}
t = 5 second
a = ?

Step 2: Write the formula and rearrange if necessary

$$a = \frac{v_f - v_i}{t}$$

Step 3: Put the value in formula and calculate.

$$a = \frac{15 - 0}{5} = \frac{15}{5} = 3ms^{-2}$$

Acceleration of bus is $3ms^{-2}$.

Worked Example 4

A motorcyclist moving along a straight path applies breakes to slow down from $10ms^{-1}$ to $3ms^{-1}$ in 5 seconds. Calculate its acceleration.

Solution

Step 1. Write the known quantities and point out quantities to be found.

$v_i = 10ms^{-1}$

$v_f = 3ms^{-1}$

$t = 5$ second

$a = ?$

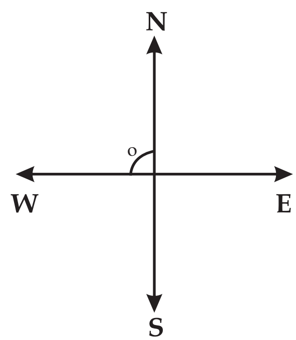
Step 2. Write the formula and rearrange if necessary.

$$a = \frac{v_f - v_i}{t}$$

Step 3: Put the value in formula and calculate.

$$a = \frac{3 - 10}{5} = \frac{-7}{5} = -1.4\ ms^{-2}$$

Deceleration of motorcycle is $-1.4\ ms^{-2}$.
The negative sign shows the retardation in opposite direction of velocity.



Self Assessment Questions:

Q 7. Define Speed.

Q 8. What is velocity?

Q 9. Define acceleration.

2.4 SCALARS AND VECTORS

All physical quantities are divided into two types on the bases of information required to describe them completely.

- Scalars
- Vectors

Scalars

There are certain physical quantities that can be described through their magnitude and a suitable unit. This information is enough to describe them, For example the mass of a watermelon is 3kg, where 3 is the magnitude and kg is a suitable unit such quantities are called scalar quantities. Thus we can define **scalar** quantities as:

The physical quantities that have magnitude and a suitable unit are called scalar quantities.

The other examples of scalar quantities are speed, temperature, mass, density etc.

Vectors

Some physical quantities need direction along with their magnitude and unit for their complete description. For example, a bus traveling with a velocity of $50ms^{-1}$ in the direction of North. The vector quantities can be defined as:

The physical quantities which are completely specified by magnitude with suitable unit and particular direction are called as "Vector" quantities.

Force ,acceleration , momentum, torque and magnetic field are the examples of vector quantities

SELF ASSESSMENT QUESTIONS:

Q10. Define Vector.

Q11. Differentiate between vector and scalar quantities.

Representation of vector:

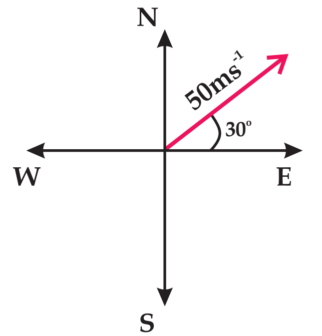


Fig. 2.14

Vector diagram is an easy way to represent a vector quantity. The directed line segment can be used to represent a vector. The length of the line segment gives the magnitude of the vector and arrow head gives its direction. For example, Fig 2.14 represents velocity of a car travailing at 50ms^{-1} in the direction of 30° North of East.

2.5 GRAPHICAL ANALYSIS OF MOTION

Graph gives the complete information about the motion of the object based on the measured physical quantities such as distance, speed, time etc.

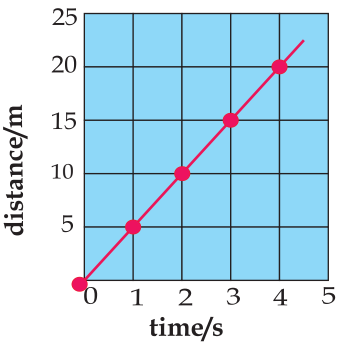


Fig. 2.15 (a)
Uniform speed

Distance - Time Graphs

A bus travels along a straight road from one bus stop to another bus stop. The distance of the bus from first bus stop is measured every second. The possible motion of the bus is shown by three examples.

The vertical axis gives rise of the graph while horizontal axis shows its run. The rise divided by run is called **gradient.**

The gradient on the distance time graph is numerically equal to the speed.

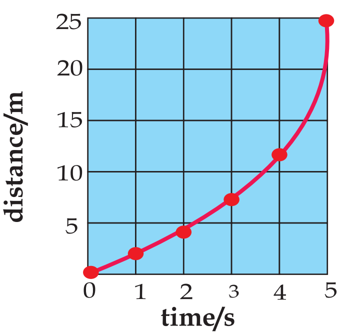


Fig.2.15 (b)
Non-uniform speed

When bus travels with uniform speed, the distance time graph is a straight line. Fig 2.15(a) shows graph of the motion of bus with steady speed, the line rises 5 m on the distance scale for every 1 seconds on the time scale.

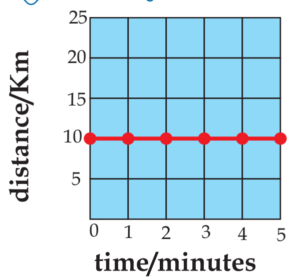


Fig.2.15 (c)
Objective at rest

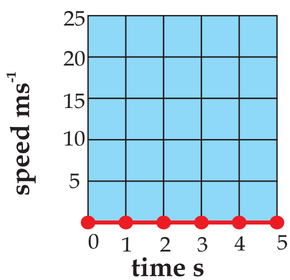


Fig. 2.16 (a)

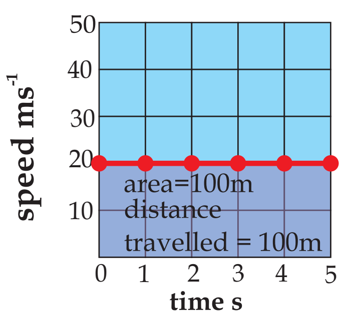


Fig.2.16 (b)

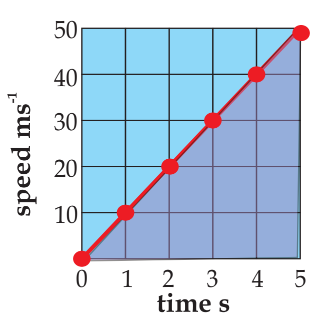


Fig 2.16 (c)

$$\text{Gradient}= \frac{20}{4} = 5$$

Thus speed = 5 ms^{-1}.

when bus travels with non-uniform speed, the distance time graph is a curve. Fig 2.15(b) shows motion of the bus, for this case the speed rises every second. So the bus covers more distance each second than the one before.

When the bus stops on the next bus stop to drop or pick the passengers the time continues running but the distance stays same. The graph line is now parallel to the time axis which shows the bus does not change its position Fig. 2.15(c).

Speed -Time Graph

Speed -time graph tells us that how much speed is increasing or decreasing in every second. Thus,

The gradient on speed - time graph gives the acceleration of the moving object.

If the gradient is positive then acceleration is also positive. On the other hand, if gradient is negative then acceleration will be negative which is known as deceleration or retardation.

In graph Fig.2.16(a), the bus is at rest for an interval of 5 seconds. Therefore, speed of bus remains zero for entire interval of time.

Fig.2.16(b), the bus moves at steady speed 20 ms^{-1} for 5 second, so the distance covered is 100 m. The distance is always product of speed and time, therefore two magnitudes on speed-time graph ($20 \times 5 = 100$) determine the distance represented through shaded rectangle on the graph Fig 2.16 (b).

Now suppose that once again bus is accelerated as the speed of bus increases at the rate of 5 m every second, the distance covered in next 5 seconds is determined by shaded triangle on the graph Fig 2.16 (c).

The area of shaded triangle, $\frac{1}{2}$ (base $\times$ height). So the distance travelled is 75 meters.

On a speed -time graph, the area under the line is numerically equal to the distance travelled.

2.6 EQUATIONS OF MOTION

There are three basic equations of motion for bodies moving with uniform acceleration. These equations are used to calculate the displacement (s), velocity, Time (t) and acceleration (a) of a moving body.

Suppose a body is moving with uniform acceleration "a" during some time interval "t" its initial velocity "v_i" changes and denoted as final velocity "v_f". The covers a distance "s" in this duration of time.

First Equation of Motion

In First equation determine the final velocity of a uniformly accelerated body.

where v_f = Final Velocity
v_i = Initial Velocity
a = acceleration
t = time

The average acceleration is the change in velocity over a time interval

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

$$a = \frac{v_f - v_i}{t}$$

$$at = v_f - v_i$$

$$\therefore \quad v_f = v_i + at \quad \cdots\cdots\cdots\cdots (2.5)$$

This is known as the first equation of motion.

Second Equation of Motion

The second equation of motion determines the distance covered during some time internal "t", while a body is accelerating from a known initial velocity.

As we know the average velocity $= \dfrac{v_f + v_i}{2}$

Putting value of v_f from equation 2.5 we get

$$\text{Average velocity} = \frac{(v_i + at) + v_i}{2}$$

$$= \frac{v_i + v_i + at}{2}$$

$$= \frac{2v_i + at}{2}$$

$$= \frac{2v_i}{2} + \frac{at}{2}$$

$$= v_i + \frac{1}{2}at$$

As the $s = vt$ or $v = \dfrac{s}{t}$

$$\frac{s}{t} = v_i + \frac{1}{2}at$$

$$\therefore s = v_i t + \frac{1}{2}at^2$$

This equation is known as second equation of motion

$$S = v_i t + \frac{1}{2}at^2 \text{ ....(2.6)}$$

Third Equation of Motion

Third equation of motion determines relationship among the velocity and the distance covered by a uniformly accelerated body, where time interval is not mentioned.

Let us take the first equation of motion.

$$v_f = v_i + at$$

By squaring the both sides of equation we get:

$$v_f^{\,2} = (v_i + at)^2$$

or $$v_f^{\,2} = v_i^{\,2} + 2v_i at + a^2t^2$$

or $$v_f^{\,2} = v_i^{\,2} + 2a(v_i t + \frac{1}{2}at^2)$$

According to second equation of motion $S = v_i t + \frac{1}{2}at^2$

Therefore $$v_f^{\,2} = v_i^{\,2} + 2a(S)$$

$$2aS = v_f^{\,2} - v_i^{\,2} \quad \text{..............(2.7)}$$

This is known as third equation of motion for bodies moving with uniform acceleration.

Worked Example 5

A car moving on a road with velocity 30 ms^{-1}, when brakes are applied its velocity decreases at a rate of 6 meter per second.

Find the distance it will cover before coming to rest.

Solution

Step 1: Write the known quantities and point out quantities to found.

$a = -6\ ms^{-2}$

$v_i = 30\ ms^{-1}$

$v_f = 0$

$S = ?$

Step 2: Write the formula and rearrange if necessary.

$$2aS = \frac{v_f^{\,2} - v_i^{\,2}}{2a}$$

$$S = \frac{v_f^{\,2} - v_i^{\,2}}{2a}$$

Step 3: Put value in formula and calculate

$$S = \frac{(0)^2 - (30)^2}{2 \times (-6)}$$

$$S = \frac{-900}{-12} = 75m$$

Thus the car will stop after covering 75m distance.

Worked Example 6

A motor cycle moving with velocity of 40 ms^{-1}. It gets accelerating at a rate of 8 ms^{-2}. How much distance will it cover in the next 10 seconds.

Solution

Step 1: Write the known quantities and point out quantities to found.

$v_i = 40\ ms^{-1}$

$a = 8\ ms^{-2}$

$t = 10s$

$S = ?$

Step 2: Write the formula and rearrange if necessary

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

Step 3: Put value in formula and calculate

$$S = 40 \times 10 + \frac{1}{2} \times 8 \times (10)^2$$

$$S = 400 + \frac{1}{2} \times 8 \times 100$$

$$S = 400 + \frac{800}{2}$$

$$S = 400 + 400m$$

$$S = 800m$$

Thus motor cycle covers 800 m in next 10 seconds.

2.7 MOTION DUE TO GRAVITY :

If two stones of different sizes are dropped from same height simultaneously, which of them will hit the ground first? You can observe that lighter and lighter stone catch the same accelerated and hit the ground at same time.

To discover this Galileo Galilei carried out a series of experiments from at leaning tower Pisa and carefully observed that all objects catch the same acceleration due to gravity of earth. The mass or size of object has no effect. It was against the widely accepted claim of Aristotile that heavier objects would fall faster than lighter one. A small feather and a stone are dropped in an air filled tube. Since air resistance greatly affects the feather, so the stone falls faster; Fig 2.18. On the other hand, when feather and stone are dropped in absence of air resistance, they acquire the same acceleration and reach the bottom at same time..

Acceleration due to gravity 'g' is a constant. Its value near the surface of earth is found to be 9.81 ms^{-2}. However for ease of calculation value of 'g' is approximated to 10 ms^{-2}.

Gravitational acceleration is taken negative for objects moving downward and positive for objects moving upward.

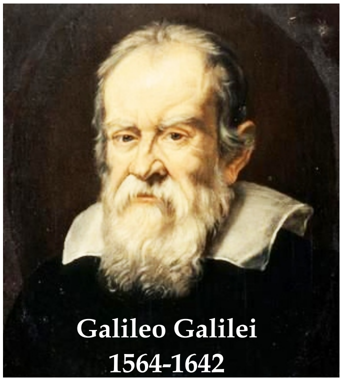


Fig 2.17

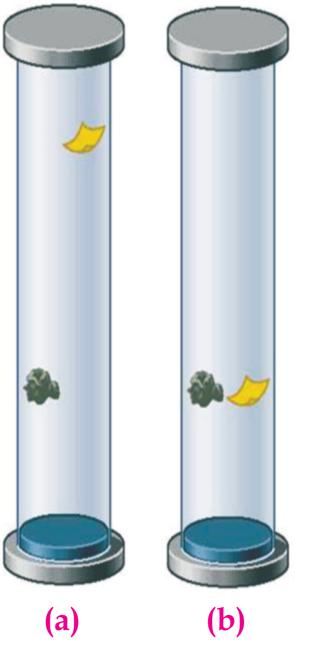


Fig 2.18

A piece of feather and a piece of stone dropped together in an air filled glass tube (a) and an evacuated air free glass tube (b)

For the motion of bodies under the influence of gravity the equation of motion are slightly modified. Where distance is taken as (S=h) and acceleration is taken as g (a=g).

There fore equation of motion are taken as.

(i) $v_f = v_i + gt$

(ii) $S = v_i t - \frac{1}{2} g t^2$

(iii) $2gh = v_f^2 - v_i^2$

Worked Example 7

A ball is thrown vertically upward with velocity of 12 ms^{-1}. The ball will be slowing down due to pull of Earth's gravity on it, and will return back to Earth.
Find out the time the ball will take to reach the maximum height.

Solution

Step 1: Write the known quantities and point out quantities to be found.

$v_i = 12\ ms^{-1}$

$v_f = 0\ ms^{-1}$

$g = -10\ ms^{-2}$

$t = ?$

Step 2: Write the formula and rearrange if necessary.

$$v_f = v_i + gt$$

$$t = \frac{v_f - v_i}{g}$$

Step 3: Put the value in formula and of calculate.

$$t = \frac{0 - 12}{-10}$$

$$t = 1.2\ s$$

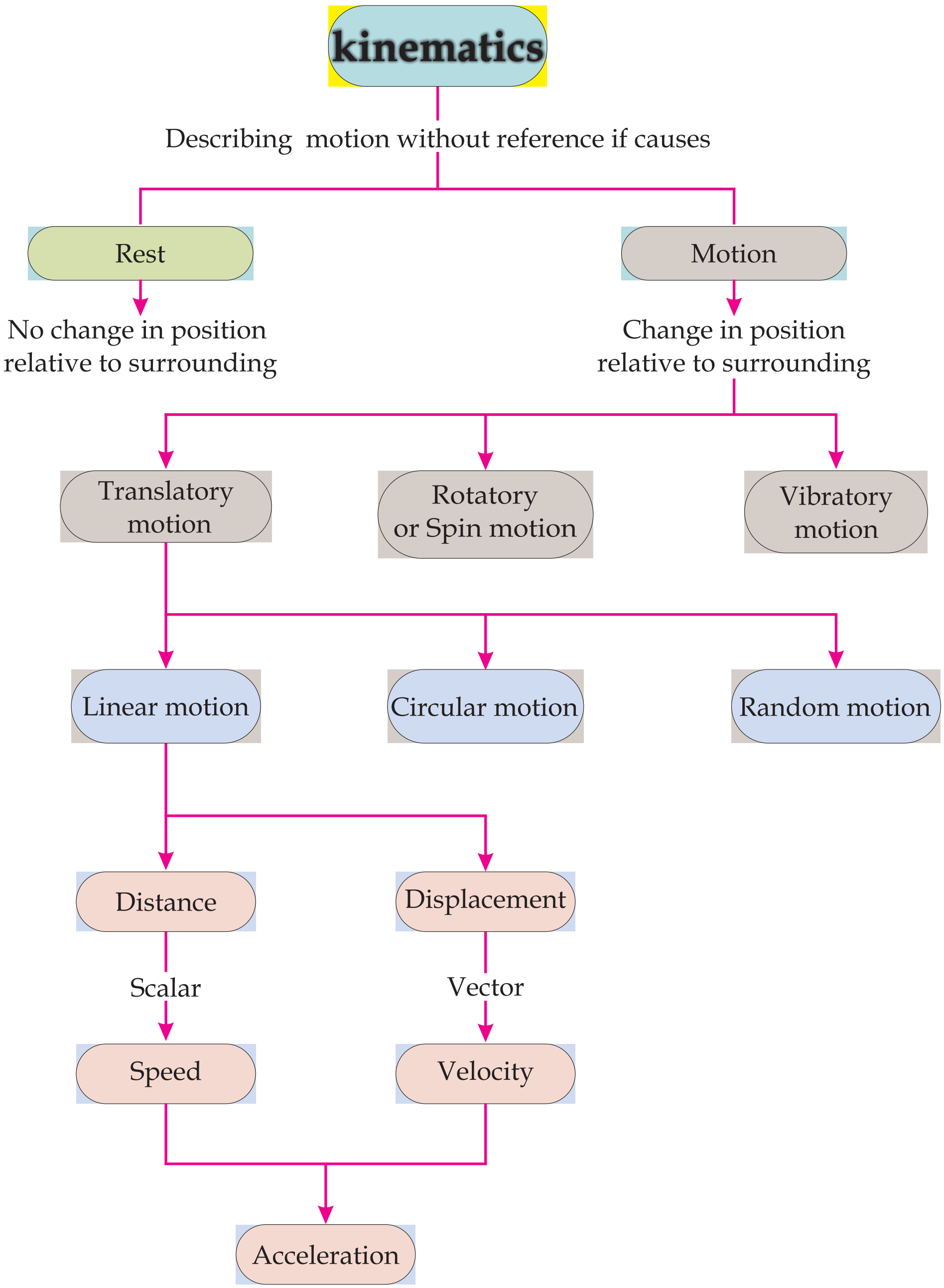
The ball will reach maximum height in 1.2 seconds.

SUMMARY

- A body is said to be at rest if it does not change its position with respect to its surroundings.
- A body is said to be in motion if it changes its position with respect to its surroundings.
- When all points of moving body move uniformly along the same straight line the motion is called translatory motion.
- Motion of a body along straight line is called linear motion.
- Motion of a body along a circular path is called circular motion.
- Irregular motion of an object is called random motion.
- The motion of the body around a fixed axis which passes through body itself is called spin motion.
- Back and forth motion of a body about its mean position is called vibratory of oscillatory motion.
- The total length covered by moving body without mentioning direction of motion is called distance.
- The distance measured in straight line in a particular direction is called displacement.
- Distance covered by an object in a unit time is called speed.
- An object covers an equal distance in equal interval of time is called uniform speed.
- Rate of change of displacement with respect to time is called velocity
- Rate of change of velocity of an object with respect to time is called acceleration.

- The gradient on the distance time graph is numerically equal to the speed.
- The physical quantities that have magnitude and suitable unit are called scalar quantities.
- The physical quantities completely specified by magnitude in suitable unit and particular direction are called vector.
- The motion under gravitational force of Earth is always directed towards Earth.
- The value of 'g' is taken as $10ms^{-2}$.

CONCEPT MAP


kinematics
Describing motion without reference if causes
Rest
No change in position relative to surrounding
Motion
Change in position relative to surrounding
Translatory motion
Rotatory or Spin motion
Vibratory motion
Linear motion
Circular motion
Random motion
Distance
Displacement
Scalar
Vector
Speed
Velocity
Acceleration

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. Scalar Quantities have .... and suitable unit.
   a) magnitude b) direction c) both a and b
2. Vector quantities have .... along with magnitude and unit.
   a) Magnitude b) direction c) both a and b
3. Which one is a vector quantity ....
   a) Mass b) Weight c) time
4. Which one is a scalar Quantity............
   a) time b) Force c) Velocity
5. Distance is a ....quantity.
   a) Vector b) Scalar c) both a and b
6. What is SI unit of acceleration
   a) ms^{-1} b) ms^{-2} c) nm
7. What is a SI Unit of Velocity.............
   a) Nm b) ms^{-1} c) ms^{-2}
8. Shortest distance between two points is called
   a) distance b) speed c) displacement

Section (B) Structured Questions

Rest and motion

a) Define rest and motion.
b) What is meant by relative motion.

Types of motion

a) Define speed and velocity
b) What is difference between distance and displacement.

c) Define acceleration

d) Calculate the acceleration of a bus that speed up from $20ms^{-1}$ to $40ms^{-1}$ in 8 seconds.

Scalars and vectors

a) Define scalar and vector quantities?

b) How represent vector quantities are represented graphically?

Equation of motion

a) A bus is moving on a road with $15ms^{-1}$ and it accelerates at $5ms^{-2}$. Find the final velocity of bus after 6 seconds.

b) A car starts moving from rest with an acceleration of $5ms^{-1}$. Find out the time to travel 50m distance.

Motion due to gravity

a) Define motion under gravity?

b) Why gravity is taken negative for an object moving in upward direction?

c) A ball is dropped from a height of 50m. What will be its velocity before touching ground?

d) If a body is thrown up ward with vertical velocity $50ms^{-1}$. Calculate maximum height which body can reach.

e) A ball falls down from top of height of 70m. How much time the ball will take to reach the ground.