Chapter-2
PHYSICAL QUANTITIES AND MEASUREMENT

STUDY NOTES

Definition of Measurement

A measurement is the action of measuring something, or some amount of stuff. So it is important to measure certain things right. Distance, time, and accuracy are all great things to measure. By measuring these things or in other words, by taking these measurements we can better understand the world around us.

Measurement is a comparison of an unknown quantity with a known fixed quantity of the same kind.

PURPOSE OF MEASUREMENT

The purposes of measurement can be categorized as measurement being in the service of quality, monitoring, safety, making something fit (design, assembly), and problem solving.

Why is measurement important in our lives?

Time, size, distance, speed, direction, weight, volume, temperature, pressure, force, sound, light, energy—these are among the physical properties for which humans have developed accurate measures, without which we could not live our normal daily lives

We use measurements for just about everything in life. For example,

- Your mother may correctly measure items that are required to bake a cake.
- In a grocery store, you will buy different groceries, juices, milk, and oil in litres, cereals in kilograms, spices in grams, etc.
- Distance is measured in kilometers and miles
- The land is measured in acres, hectares, square kilometers, feet, yards etc.
- Time is measured in hours, minutes, seconds etc.

Measurement of weight, volume, length, and time has now become a part of our daily life.

A measurement needs to things the unit 'u' and the number 'n' which tells us how many times that the unit is contained in that quantity. Thus the measurement is expressed as

Measurement =n x u =nu

TWO CHARACTERISTICS OF UNIT

Two characteristics of a unit are

- It should be of convenient size.
- It must be universally accepted, i. e. its value must remain same at all places and at all times.

In the past, different units were used to measure the length, mass and time in different countries. The following three systems of units were used :

1. Centimetre-gram-second (C.G.S.) system
2. Foot-pound-second (F.P.S.) system, and
3. Metre-kilogram-second (M.K.S.) system or metric system.

The units of length, mass and time in these systems are listed below:

System	Unit and symbol of length	Unit and symbol of mass	Unit and symbol of time
1. C.G.S.	centimetre (cm)	gram (g)	second (s)
2. F.P.S.	foot (ft)	pound (lb)	second (s)
3. M.KS.	metre (m)	kilogram (kg)	second (s)

BASIC PHYSICAL QUANTITIES

A quantity that can be measured is called a physical quantity.

In our daily life the measure the following four basic physical quantities

1. length
2. mass
3. time
4. temperature

In 1960 the scientist all over the world accepted a set of unit of measuring the basic physical quantities length mass time and temperature this set of units is called as standard International unit which in short form is written as SI unit.

SI unit of basic physical quantities and their symbols are given in the following table

	Quantity	S.I. unit	Symbol of S.I. unit
(i)	Length	metre	m
(ii)	Mass	kilogram	kg
(iii)	Time	second	s.
(iv)	Temperature	kelvin	k

NOTE-

In earlier times people across the world were using different systems of units for measurement. Without a widely accepted system of units of measurement, economies all over the world would collapse. Imagine the chaos if there were no standards for the measurement of mass, length and time.

There was a need, therefore, to end the confusion and bring in uniformity.

The International System of Units (abbreviated as SI Units from its French name, Système International d'unités) is an internationally agreed metric system of units of measurement that has been in existence since 1960.s. It is the modern form of the metric system and is the most widely used system of measurement.

we use different units of measurement for length, weight, time, area, and volume.

Distances are measured in miles and kilometres. Length is measured in inches, millimetres, centimetres, metres.

Land is measured in feet, yard, acres, hectares, square yards, etc.

Weight is measured in grams, kilograms, pounds, ounces etc.

Time is measured in seconds, minutes and hours.

Length:

- The length and type of an object determine the kind of measuring tool that can be used.
- Large distances, e.g. distances between cities, are measured in kilometres.
- Astronomical distances, e.g. distances between stars, are expressed in a unit called the light year.
- A light year is equal to the distance travelled by light in one year. 1 light year = 9.46 x 1015 m.
- The units used for expressing extremely small distances, e.g. the diameter of a molecule or atom, are the micron and the angstrom. Nuclear distances are measured in fermi (fm).

Unit of Length: The SI unit of length is the metre (m). The multiples and submultiples of metre are given below.

Multiples of Metre

1 decametre (dam) = 10 m
1 hectometre (hm) = 100 m
1 kilometre (km) = 1000 m

Submultiples of Metre

1 m = 10 decimetre (dm)
1 m =100 centimetre (cm)
1 m = 1000 millimetre (mm)
1 m = 106 micron (μm)
1 m = 109 nanometre (nm)
1 m = 1010 angstrom (A o)
1 m = 1015 femtometre or fermi (fm)

Measurement of Length of an Object (or) a Straight Line Segment

First place the ruler along the edge of the object whose length is to be measured, with the zero mark of the ruler placed at one end of the object.

On the ruler, note the reading at the other end of the object. This gives the length of the object. The same procedure can be followed to measure the length of a straight line segment.

Measurement of Length of a Curved Line

- Take a non-stretchable string or a thread and tie a knot at one of its ends.
- Place the knotted end of the thread at one end of the curved line.
- Holding the thread steadily with your fingers, stretch it along the curved line until you reach the other end.
- Now make a mark on the thread where it reaches the other end.
- Finally, place the thread along with a metre scale and measure the length between the knot and the marked point. This gives the length of the curved line.

Measurement of Diameter of a Sphere

Place the sphere whose diameter is to be measured on a table, between two rectangular blocks of wood. Adjust the lower edges of the blocks along a ruler.

Take readings for each face of the block touching the spherical object.

The difference between the two readings gives the diameter of the sphere.

Measurement of Thickness of a Coin

To find the thickness of a coin, arrange 20 such coins one above the other and measure the height of the pile of coins using a ruler.

Divide this height by 20. This will give you the thickness of a single coin.

Measurement of Diameter of a Wire

To find the diameter of a wire, wind the wire over a pencil tightly in the form of a coil, without overlapping, such that there are 50 turns in the coil.

Measure the length of the coil using a ruler and divide it by the number of turns in the coil. This gives the diameter of the wire.

Avoiding Parallax Error

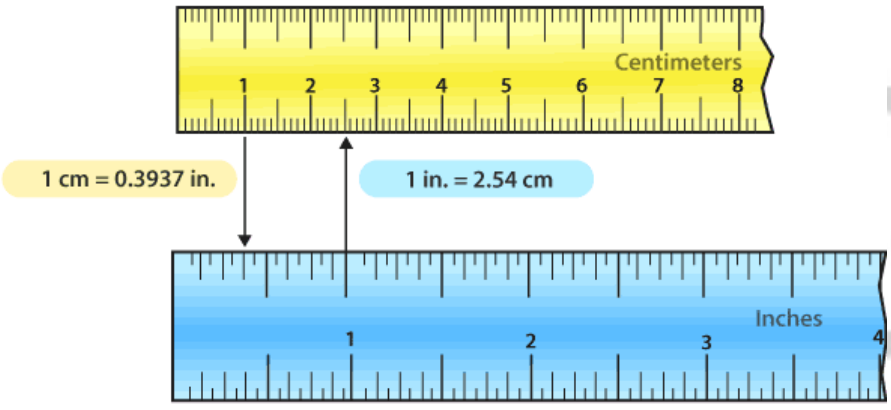
- When noting the reading on a ruler, you should look at it with the eyes directly above the reading, and not in an oblique way.
- Otherwise, you will not be able to note the reading accurately.
- In case the ruler has a damaged edge, place the broken or damaged ruler along the edge of the object whose length is to be measured in such a way that any visible mark coincides with one end of the object.

- Now note the reading on the ruler at the other end of the object. The difference between the two readings gives the length of the object.

Converting from Standard to Metric

Convert from:	To:	Multiply by:
mile	kilometer (km)	1.609347
inch	millimeter (mm)	25.4
inch	centimeter (cm)	2.54
foot	meter (m)	0.3048
yard	meter (m)	0.9144

RELATION BETWEEN INCH AND CENTIMETERS



MASS-

The mass of a body is the quantity of matter contained in it.

UNIT OF MASS-

SI unit of mass is kilogram in short form it is written as kg.

NOTE-

In 1889, 1 kilogram was defined as the mass of a cylinder of platinum- iridium alloy kept at the International Bureau of weights and measures at service near Paris

However at present the mass of one litre is equal to 1000 ml of water at 4 degree celsius is taken as one kilogram.

Multiple and Sub multiple unit of mass

A bigger unit of mass is **quintal**

100 kilogram make one quintal

1 quintal = 100 kg

A still bigger unit of mass is **metric ton**

10 quintal make one metric ton that is

1 metric ton = 10 quintal = 1000 kg

The mass of a light body is expressed in a smaller unit of mass called **gram** the short form of it is 'g'

1 gram is the 1000 part of kilogram or 1000 gram make 1 kilo gram that is

1 Kg = 1000 gm or

1 gm= 1 / 1000 kg

A still smaller unit of mass is milligram in short form it is written as 'mg'

1 milligram is the 1000 part of a gram or 1000 milligrams make one gram that is

1 gm = 1000 mg

1 mg = 1 / 1000 g

In F.P.S. system, the unit of mass is pound (*lb*)

In C.G.S. system, the unit of mass is gram (g)

Relationship between gram, kilogram and pound

1 g = 1/1000 kg

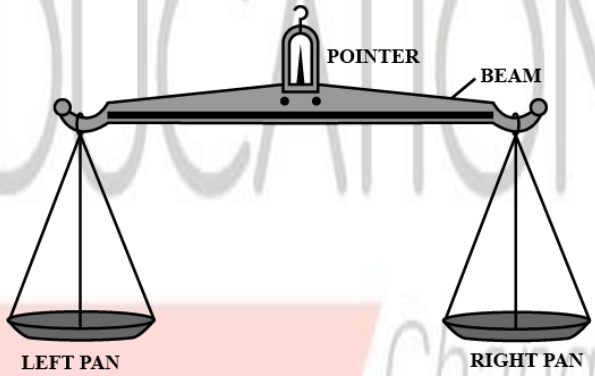
1 *lb* = 453.59 g

DEVICES FOR MEASURING MASS

For measuring the mass of a body which generally use the following two balances

1. The Beam balance and
2. Electronic balance

1. Use of a beam balance to measure the mass of a body



- It consists of a straight beam of Wood or metal of length about 50 cm.
- The Beam has a support just at its middle having a pointer.
- 2 identical pans are suspended at the ends of the beam by means of Strings of equal length.
- Each Pan is at the same horizontal distance from the support that is the length of the beam balance of each Pan from the support is equal.
- The balance can be held up by the support.

To measure the mass of an object standard weights are used.

To measure the mass of an object standard weights are used. Standard weights are of 20 kg, 10 kg ,5 kg ,2 kg and 1kg however smaller weights of 500 gram 200 gram 150 gram 20 gram 10 gram and 5 gram are also available.

HOW TO MEASURE?

- For measuring the beam balance is first held up.
- On holding up the balance it is ensured that when there is nothing on either pan, the beam is horizontal.
- The body whose mass is to be measured is placed on the left pan and the standard weights are placed on the right pan.

- They are so adjusted that the beam is again horizontal on holding the balance up.
- The total of the standard weights give the mass of the given body.

2. Use of an electronic balance to measure the mass of an object

- Precise and accurate measurement of mass of an object in electronic balance is used.
- They are available to measure a small mass of 1 mg, as well as a large mass of the order of a quintal.
- Small electronic balance is a portable while big electronic balances are fixed at a place.

An electronic balance has the following three parts

1. **The structure** - It is the load-bearing part which transfers the load of the object to the load cell.
2. **The load cell** -It converts the load into electrical signals.
3. **The signal conditioner-** It is the electronic part which processes the electrical signal and displays the mass.

Electronic balance is measured the mass automatically without any prior to setting or using a separate weight box directly measure the mass of the object and display it in digital form on the screen.

TEMPERATURE-

Temperature is how hot or how cold an object is. What the thermometer reads is the temperature. Temperature can, therefore, be defined as the reading on a thermometer. There are a variety of thermometers about which we will learn in this chapter and also about approximation.

Thermometer

A thermometer is used to measure the temperature of an object.

Galileo invented the basic water thermometer in 1593 and called it a thermo scope. This device did not work well as water froze at low temperatures.

In 1714, Gabriel Fahrenheit invented the modern mercury thermometer.

A thermometer consists of a long, narrow, uniform glass tube called the stem. The scales in which the temperature is measured are marked on the stem. At the end of the stem, there is a small bulb which contains mercury in it. A capillary tube is inside the glass stem in which mercury expands when the bulb is kept in contact with a hot body.

Mercury is toxic, and it is very difficult to dispose of it when the thermometer breaks. So, nowadays digital thermometers are used to measure the temperature, as they do not contain mercury.

Advantage of Using Mercury in Thermometers

- Mercury is a good conductor of heat. It quickly absorbs heat to attain the temperature of the object.
- It has a low freezing point (-39°C) and a high boiling point (357°C). Hence it can be used over a wide range of temperatures.
- It is opaque and shiny which makes it visible through the glass.
- It does not wet the glass.

Scales of Temperature:

- The different units to measure temperature are represented by different scales of temperature.
- A temperature scale is defined by choosing two reference temperatures and dividing the difference between these two temperatures into a certain number of divisions.

- Each division is called one degree.
- The reference temperatures usually used are the melting point of pure ice, called the lower fixed point, and the boiling point of water called the upper fixed point.
- The two commonly used temperature scales are the Celsius and the Fahrenheit scales. In scientific calculations, Kelvin scale is used.

Celsius scale and Fahrenheit scale:

In Celsius scale, the melting point of ice is taken as 0 °C and the boiling point of water as 100 °C. The difference between the two points is divided into 100 degrees.

In Fahrenheit scale, the lower fixed point or the melting point of ice is 32 °F and the upper fixed point or the boiling point of water is 212 °F. The difference between these two points is divided into 180 degrees.

In Kelvin scale, 0 °C corresponds to 273 K and 100 °C corresponds to 373 K.

Conversion between Celsius and Fahrenheit Temperatures

The Celsius and Fahrenheit scales are related as follows, where C and F are the temperatures measured in Celsius and Fahrenheit scales, respectively.

If K is the Kelvin temperature, then K = C + 273.

Types of Thermometers

There are different types of thermometers for measuring the temperatures of different things like air, our bodies, food, and many other things.

There **are clinical thermometers, laboratory thermometers, Galileo thermometers, maximum-minimum thermometers and digital remote thermometers.**

Among these, the commonly used thermometers are clinical thermometers and laboratory thermometers.

Clinical Thermometer

- Clinical thermometers are used to measure the temperature of a human body, at home and at clinics, and hospitals.

- All clinical thermometers have a kink that prevents the mercury from flowing back into the bulb when the thermometer is taken out of the patient's mouth. This helps the mercury to stay at the measured temperature and it can be noted easily.
- There are temperature scales on either side of the mercury thread, one in Celsius scale and the other in Fahrenheit scale.
- Since the Fahrenheit scale is more sensitive than the Celsius scale, body temperature is measured in °F only.
- A clinical thermometer indicates temperatures from a minimum of 35 °C or 94 °F to a maximum of 42 °C or 108 °F.

Precautions to be Followed While Using a Clinical Thermometer

- The thermometer should be washed before and after use, preferably with an antiseptic solution.
- Shake the thermometer a few times to bring the level of the mercury down.
- Before use, the mercury level should be below 35 °C or 94 °F.
- Do not hold the thermometer by its bulb.
- Keep the mercury level along with your line of sight and then take the reading.
- Handle the thermometer with care. If it hits against some hard object, it may break.
- Do not place the thermometer in a hot flame or in the hot sun.

Laboratory Thermometers

- Lab thermometers are used to measure the temperature in school and other laboratories for scientific research.
- They are also used in the industry as they can measure temperatures higher than what clinical thermometers can record.
- The stem and the bulb of a lab thermometer are longer when compared to that of a clinical thermometer and there is no kink in the lab thermometer.
- A laboratory thermometer has only the Celsius scale ranging from −10 °C to 110 °C.

Precautions to be Followed While Using a Laboratory Thermometer

- Do not tilt the thermometer while measuring the temperature. Place it upright.
- Note the reading only when the bulb has been surrounded by the substance from all sides.
- Six's Maximum and Minimum Thermometer
- Six's maximum and the minimum thermometer is used for measuring the day's maximum and minimum temperature.
- It was invented by Englishman James Six in 1782.

- It consists of a U-shaped capillary tube with bulbs at both ends. The bend of the U-tube is filled with mercury.
- One of the bulbs is completely filled with alcohol and the other bulb is partly filled with alcohol. The space in the bulb partly filled with alcohol is initially a vacuum.
- The thermometric liquid is alcohol, whose expansion and contraction allow the change in temperature to be recorded. Just above the mercury are two dumbbell-shaped steel indices, which are kept in place by tiny steel springs.
- The two dumbbell-shaped steel indices are reset to their initial positions just above the mercury by means of a horse-shoe magnet.

Maximum Temperature:

- Due to a rise in the temperature during the day, the alcohol in the completely-filled bulb expands and exerts a pressure on the mercury.
- The Mercury moves toward the partly-filled bulb and pushes up the index in the capillary closer to the partly-filled bulb.
- Thus, the index closer to the partly-filled bulb records the maximum temperature.
- Minimum Temperature:
- Due to a fall in the temperature during the night, the alcohol in the completely-filled bulb contracts.
- The Mercury moves toward the completely-filled bulb and pushes up the index in the capillary closer to the completely-filled bulb.
- Thus, the index closer to the completely-filled bulb records the minimum temperature.

AREA

The total surface occupied by an object is called its surface area or simply the area.

Multiple and Sub-multiple Units of Area

1 hectare = 100 m x 100 m = 10,000 m2

1 m2 = (1/10,000) hectare = 10−4 hectare

1 km2 = 1000 m x 1000 m = 1,000,000 m2

1 km2 = 100 hectares

Measurement of Area of a Regular Surface

We can find the area of regular surfaces by measuring their linear dimensions like length, breadth, etc. and calculating the area using appropriate formulae. The formulae used to find the area of some regular shapes are given below:

Area of a square = side x side

Area of a rectangle = length x breadth

Area of a triangle = ½ x base x height

Area of a circle = π x radius x radius

We can find the area of a small regular surface using a centimetre graph sheet also.

Measurement of Area of an Irregular Flat Surface

- We can find the area of an irregular flat surface, for example, a leaf, using a graph sheet.
- For doing this, the leaf is placed on a centimeter graph sheet and its outline is drawn.
- Then the number of complete and incomplete squares is counted separately.
- Assuming the area of an incomplete square to be equal to half the area of a complete square, the approximate area of the leaf is the sum of the number of complete squares and half of the number of incomplete squares. This area is in cm square.

TIME-

The interval between two instances or events is called time.

We measure time in terms of the mean solar day. A solar day is the time taken by the earth to complete one rotation about its own axis. The mean of 365 days in a year is called the mean solar day.

Units of time

The SI unit of time is second (s).

1 second is defined as 1/ 86400 part of a mean solar day that is

1 s = 1 / 86400 x one mean solar day.

1 second is the time interval between two consecutive ticks that we hear from a Pendulum wall clock.

Note-

In case of metric system F.P.S. system as well as in C.G.S. system , the unit of time is second (s) Second is a smaller unit of time.

Bigger unit of time is **minute**.

1 minute = 60 second or 1 min = 60 s

Still a bigger unit of time is **hour**

1 hour = 60 minutes

1 hour = 60 x 60 seconds = 3600 s

Another big unit of the time is day.

24-hour makes 1 day. 1 day is the time taken by the earth to rotate once on its own axis.

Thus 1 day = 24 hour = 24 X 60 minutes = 1440 minutes = 24 X 60 X60 = 86400 seconds.

A year is another bigger unit of time.

365 days makes one year. 1 year is the time taken by the earth to complete one Revolution around the sun.

1 year = 365 days = 365 x 86400 s = 3.15x 10 to the power 7.

1 min= 60s

1 hr= 60 min= 3600 s

1 day= 24 hr= 86400 s

1 year= 365 days= 3.15 x 10 to the power 7 s

Devices for measuring time

We use

1. pendulum clock and
2. a watch to find the time in our daily life

1. **PENDULUM CLOCK-**
   - In pendulum time is measured by making the use of the time taken by a pendulum to complete one oscillation.
   - The pendulum complete 1 to and fro oscillation in 2 s , that is it moves from one extreme to the other extreme in one second and then returns from the other extreme to the first extreme in the next one second .
   - The circular dial has 12 marking divided in 4 quadrants.
   - Each marking is for the divided into five small divisions so there are in all 60 small division there are three leaders joined to the axle of the gear wheels at the centre of the dial.
   - These needles are named as seconds arm, minute arm and hours arm.
   - The second arm moves by one small division in the time interval when the pendulum moves from one extreme to the other extreme.
   - The minutes are moved by a small division when the second arm completes one round and the hours arm moves by 5 small divisions when the minutes arm completes one round.
2. **A WATCH**- A watch makes use of gear wheels. These wheels set up the speed of rotation of the second minutes and hours arms.
   The second arm is driven by a wound up spring. The dial of a watch is graduated similarly as that of the pendulum clock.

Measuring devices for a short time interval

The short time interval of an event is measured with the help of a stop clock or a stopwatch.

Stopwatch has arrangements **to start**, **to stop** and to **reset** at 0.

An electronic stop watch is more accurate than a mechanical stopwatch.

It can measure time intervals accurately up to 0.01 second

It does not have a minute or a second arm.

On the other hand it has the digital display screen.

Such watches are used for measuring the timings of Athletic activities such as the time taken by the athletes to complete a hundred metre race.