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MEASUREMENT IN SCIENCE AND TECHNOLOGY

Measurement is a basic skill which forms an essential part of our day to day activities irrespective of what we do. You would definitely have observed that while cooking food, measured quantities of ingredients are cooked for a measured amount of time. When you go to buy fruits and vegetables, you take them in measured amounts. You can identify which one of your friends runs fastest. This is possible by making them run a known distance say from one end of a playground to the other and noting who is first to reach the destination. In other words, you measure the time. Can you tell by the above measurement how fast does your friend run? For this, you need to precisely measure the distance run and the time taken. Science and technology helps us in making precise measurements for our daily life activities such as stitching, cooking, sports, shopping, travelling etc.

In this lesson we would like to seek answers to several questions. What is the measurement and why do we need it? How do we measure? How do we quantify a measurement, so that it is understood by everyone in the same sense? What is the currently accepted International System of units? We would also learn about commonly used tools for measurement of the physical quantities like length, mass, time, area and volume.

OBJECTIVES

After completing this lesson, you will be able to:

- *define measurement and explain the need for measurement;*
- *give examples of the parts of human body that may be used to measure length of an object and state the limitations of such measurements;*
- *describe the Indian and various other measurement systems used in the ancient times;*
- *explain the need of a common system of units;*
- *define and differentiate base and derived SI units;*

- *derive the SI unit of a physical quantity;*
- *explain the need of SI prefixes;*
- *use SI prefixes for the units and*
- *correctly write the SI units using the rules for writing the same.*

1.1 WHAT IS A MEASUREMENT?

Suppose you are asked to measure the length of a play ground, what would you do? May be you would walk from one end of the field to the other and count the number of steps. The other possibility is that you may arrange for a measuring tape or some scale, say a meter scale. Then again go from one end and count how many times the meter scale was used to reach the other end. Let us take another example. Suppose you need to weigh a carton full of books; you would use a weighing scale and see how many kilogram weights you need to correctly weigh the carton- again a kind of counting. Thus we may define measurement to be **a counting of the number of times a chosen scale is used.**

"When you can measure what you are talking about, and express in numbers, you know what you are talking about; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of a Science"

Lord Kelvin (1824-1907)

1.1.1 Why do we need to make a measurement?

Suppose you go to the market to buy mangoes and they are priced at say Rs.50 per kilogram. What would you expect the shopkeeper to do? Would you be happy if he/she gives you 4 or 5 small mangoes, which are surely less than a kilogram, and asks for the price of one kilogram? Similarly, the shopkeeper will also not like to give you more than a kilogram of mangoes for the price of a kilogram. An accurate measurement is desirable for both buyer and the seller. The absence of a suitable measurement may lead to conflicts between them. Measurement is an essential activity in our everyday life. You may ask why it is essential. Can't we do without it?

Have you ever wondered how space scientists make sure that the space shuttle reaches the desired destination? Or when the shuttle comes back it comes at a predetermined time and place. This is made possible by accurate measurement of many parameters and extensive calculations. For measurement we require specific scale which is called unit.

1.1.2 What is a Unit?

Imagine a situation. Suppose you are blindfolded and handed a bunch of currency notes. On counting them you find that they are 46 in number. Can you tell how much money is in your hand? For knowing the exact amount of money, you need to know the denomination i.e., whether the notes are of Rs.10, Rs.50, Rs100 or of some other denomination?

Similarly, if you are told that two trees are 100 away from each other. How would you interpret it? Are the trees 100 cm, 100 ft or 100 m or….away? These examples suggest that the result of every measurement must be expressed in such a way that it makes a sense and has a unique meaning. For this we need to know two things. Firstly, what is the measuring standard used, say centimetre (cm), metre (m) or foot (ft) in the above example and the number of times it is used.

The result of measurement of a physical quantity is expressed in terms of a **value**. The value of the physical quantity is equal to the product of the number of times the standard is used for the measurement and the quantity (the standard) defined for making the measurement. This defined or standard quantity i.e., the scale used e.g., metre or the foot in above case, is called a unit.

Value of physical quantity = numerical quantity x unit

A unit is a measure, device or a scale in terms of which we make physical measurement. The value of a physical quantity consists of two parts; a numerical quantity and a unit and is equal to their product.

Thus, it is necessary to state the numerical quantity as well as the unit while expressing the result of a measurement. So by now we know that the measurements are essential in every sphere of human activity and also that we need a unit or a standard in terms of which we make the measurement and express the result of such a measurement. Let us learn about the characteristics of such a unit. What qualities should a unit have?

1.1.3 Characteristics of a Unit

Can we measure the distance in kilograms? Obviously not; it is ridiculous to measure distance in terms of kilogram. It has no relevance for measuring distances. So to be useful, a unit should be **relevant** for the quantity being measured. Further, the unit used should be **convenient** also. Would it be convenient to express the distance between two cities in inches? Don't you think that kilometre would be a better unit? In addition to being relevant and convenient a unit should also be **well defined** i.e. it should be well understood by other people. For example, we may express the distance between my house and a nearby shop as 200 steps. In order to make some sense, we need to define the step - whether it is my step or an adult and child. Is it while walking slowly or while running fast? How long is the step? Thus, to be useful, a unit must be:

- relevant
- convenient
- well defined

In today's world, an accurate measurement is a necessary. We have in numerable devices to make such measurement. You would be surprised to know that an atomic clock is so accurate that it may make an error of just one second in about 15 million years. Have you ever thought how our ancestors made measurements? What were the devices used and what the units of measurement? Let us try to learn about the interesting way measurements were made and also the way the system of measurement has evolved since then. However, why don't you assess your understanding of the meaning and need of measurement and about the units and their characteristics.

INTEXT QUESTIONS 1.1

1. Define the term measurement by giving two examples.
2. What is a unit?
3. List the essential characteristics of a unit.

1.2 HOW DID OUR ANCESTORS MAKE MEASUREMENTS?

The need for measurement and measuring devices dates back to antiquity. When the humans became civilised, started cultivating and living in communities they realised that one cannot do everything and they need to be interdependent. This paved the way for trade and then probably a need of a measure was felt. Various ways of measurements were adopted. The system of measurement has evolved a lot since then. Let us have a brief account of interesting means of measurement used by our forefathers.

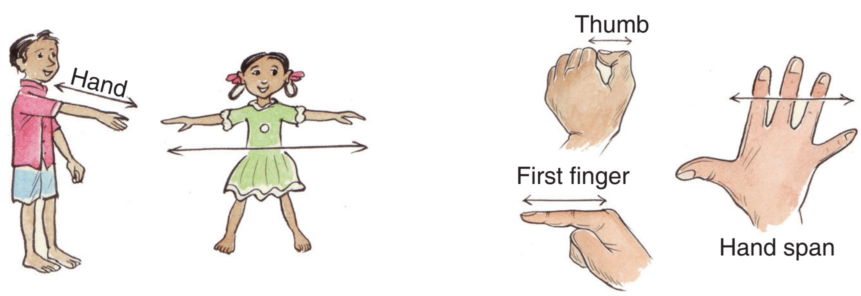

Fig. 1.1 *Use of body parts for measurements*

The recorded history shows ample evidence that the different parts of the human body were used as a point of reference while making measurements. Some of these were, digit : the width of a single finger; foot : the length of a foot; cubit: length of an arm; hand span : the distance between the tip of the thumb and the tip of the little finger when the hand is fully stretched out. similarly fathom meant the distance between the ends of the hands of a Anglo-Saxon farmer when his arms were fully out stretched. It is interesting to note that these are still used sometimes.

Certain historical units were based on the things around us, e. g., Romans used a unit called pace which was equal to the stride of their army contingent and they called the distance travelled by it in 1000 paces to be equal to a mile. Similarly, the grain was used as the unit of mass in sixteenth century and was equal to the weight of a wheat grain.

Based on the criteria given under section 1.1.3, evaluate the above units. What are the limitations you find in above ancient units of measurement? Write your response in the space given below.

....

....

....

....

The following activity may help you to respond to the above query. Perform the following activity and then revisit your response above.

ACTIVITY 1.1

Can you check the accuracy of the measurements using parts of your body as a unit? In your personal contact programme (PCP) you can perform this. Take a black board (or a table, a desk, a wall or any other suitable reasonably long object) with group of 4-5 learners.

This activity can be performed in the class or even at home. In the class a group of 4-5 students can participate in it. (At home the family members or friends can do the same).

First measure the length of the black board using hand span and digits as the units of measurement and record your observations in the table given below.

S. No.	Name of the learner	Length of the black board* in Hand span and digits e.g., 10 Hand spans and 3 digits
1		
2		
3		
4		
5		

* or any other object on which the measurement is made

Now ask your friends (or other learners of the group) to make the same measurement one by one and record their results in the table above. Thus you can record your body **can/cannot** be used for accurate measurements based on your observation. (Tick the right option and delete the incorrect one)

Would you like to revisit your response given above and revise?

1.2.1 Need for a standard unit

As you would have concluded from the activity given above, the units based on parts of human body are arbitrary and inaccurate. The results of the measurements vary from person to person because size of the unit is different for different person. For example, the units like a cubit or a foot would depend on the person making measurement. This created problems in trade between different countries and obviously in the day to day transactions. In order to overcome the limitations of body parts as units, and to bring about uniformity in the measurement system, the need for exact measurement was felt. For this, a standard of measurements had to be developed which is acceptable to everybody.

The problem of measuring lengths acurately was first solved by the Egyptians as far back as in 3000 B.C. It was done by defining the standard cubit. It was defined to be equal to the distance between the elbow and tip of the middle finger of the Pharaoh ruling Egypt at that time. Measuring sticks of length exactly equal to that of standard cubit were made. In this way they made sure that the cubit was the same length all over Egypt. Similar efforts were made by other rulers also. For example, the British King Henry-I (1100-1137) decreed that a yard would exactly be equal to the distance from the top of his nose to the end of his thumb on outstretched arm. Queen Elizabeth-I declared a mile to be exactly equal to eight furlongs. A furlong (furrow long) was the distance a pair of oxen could plough in a field without stopping to rest. It was found to be 220 yards.

These standards proved to be useful but were short lived, as once a given ruler went out of power or died, the system was not followed and a newer system came into being. Further, since different countries and the different provinces in a given country were governed by different rulers; they followed different systems of units. As a consequence, by the eighteenth century a large number of units for mass, length, area and volume came to be in widespread use. Let us now learn about the systems of units followed in India in different historical periods.

1.2.2 Indian measurement system

The measurement system in India also has evolved a great deal from the ancient times.

(a) Indian measurement system in the ancient period

In ancient periods in India, the lengths of the shadows of trees or other objects were used to know the approximate time of the day. Long time durations were expressed in terms of the lunar cycles, which even now is the basis of some calendars. Excellent examples of measurement practices in different historic periods are available. For example, about 5000 years ago in the Mohenjodaro era, the size of bricks all over the region was same. The length, breadth and width of bricks were always in the ratio of 4:2:1 and taken as a standard .

Similarly around 2400 years ago during the Chandragupta Maurya period there was a well-defined system of weights and measures. The government at that time ensured that everybody used the same weights and measures. According to this system, the smallest unit of length was 1 Parmanu. Small lengths were measured in anguls. For long distances Yojan was used. One Yojan is roughly equal to 10 kilometres..

Different units of measurements used in the period of Chandragupta Maurya

8 Parmanus	=	1 Rajahkan (dust particle from the wheel of a chariot)
8 Rajahkans	=	1 Liksha (egg of lice)
8 Likshas	=	1 Yookamadhya
8 Yookamadhyas	=	1 Yavamadhya
8 Yavamadhyas	=	1 Angul
8 Anguls	=	1 Dhanurmushti

(Reference: Kautilaya's *Arthashastra*)

The Indian medicine system, Ayurveda, also had well-defined units for the measurement of the mass and volume. The measurement system was strongly followed to ensure the proper quantity of medicine for particular disease.

(b) Indian measurement system in the medieval period

In the medieval period also the measurement system was in practice. As described in **Ain-i-Akbari** by Abul Fazl-i-Allami, during the period of Moghul Emperor Akbar, the gaz was used as the unit of measuring length. Each gaz was divided into 24 equal parts and each part was called Tassuj. This system was extensively used to measure land pieces, for construction of buildings, houses, wells, gardens and roads. You should know that, the gaz was widely used as a unit of length till the metric system was introduced in 1956. Even today in many parts of our country, particularly in the rural areas, gaz is being used as a unit of length.

(c) Indian measurement system during British period

In order to bring about uniformity in the system of measurement and the weights used, a number of efforts were made during the British period. The British rulers wanted to connect Indian weights and measures to those being used in Great Britain at that time. During this period the inch, foot, and yard were used to measure length whereas grain, ounce, pounds, etc. were used to measure mass. These units and weights were used in India till the time of Independence in 1947. The essential units of mass used in India included Ratti, Masha, Tola, Chhatank, Seer and Maund. Raatti is a red seed whose mass is approximately 120 mg. It was widely used by goldsmiths and by practitioners of traditional medicine system in India.

Relation between various units of mass used during the British period

8 Ratti	1 Masha
12 Masha	1 Tola
5 Tola	1 Chhatank
16 Chhatank	1 Seer
40 Seer	1 Maund
1 Maund	100 Pounds troy (exact)

INTEXT QUESTIONS 1.2

1. Name the smallest unit of length during the Chandragupta Maurya period.
2. List the parts of human body which can be used for measurements.
3. Why cannot the parts of human body be used for accurate measurement?
4. In which period was 'gaz' introduced as a unit to measure length?

1.3 THE MODERN MEASUREMENT SYSTEMS

Immediately after the French Revolution (1790) the French scientists took lead in establishing a new system of weights and measures. They advocated the establishment of national standards for the purpose and the use of decimal arithmetic system. This led to the birth of metric system which like our Hindu-Arabic counting system is based on the multiples and subdivisions of ten.

The meter was defined as one ten millionth ($1/10^7$) of the distance between north pole to the equator on the meridian running near Dunkirk in France and Brcelona in Spain.

After detailed deliberations the basic unit of length and mass were defined and their working standards were prepared. The working standard for meter was prepared by marking two lines a metre apart, on a platinum-iridium bar. Similarly, a platinum - iridium cylinder was constructed, equal to the mass of 1 cubic decimetre of water, as the working standard for mass. These two standards have been preserved at the International Beurau of Weights and Measures at Serves near Paris. The copies of these were prepared and sent to different countries. As regards the time, the concept of hour, minute and second based on

the rotation of earth was retained. An international treaty, called Metre Convention was signed in 1875 to follow metric system through out the world for trade and commerce.

In the course of development of units a number of systems were adopted. Two systems which were extensively used were the cgs and mks systems. The cgs system was based on centimetre, gram and second as the units for length, mass and time while mks system used metre, kilogram and second for the same. In 1958 it was realised that the units defined as standard needed to be redefined. Since 1983, it is defined as the length of the path travelled by light in vacuum in 1/299,792,458 of a second.The new exercise of redefining the system of units led to the birth of SI system of units which is currently the system in use. Let us learn the SI system in details.

1.4 SI UNITS

An international system of units, called SI units, was adopted at the 11th General Conference on Weights and Measures (CGPM) in 1960. SI is an abbreviation of the French name "Le Systeme Internationale de Unite's".

The base SI units are independent of each other

You know that measurements are concerned with quantities like length, mass, time, density etc. Any quantity which can be measured is called a physical quantity. The SI system of units is based on seven **base units** corresponding to seven base physical quantities. These are the physical quantities, in terms of which other physical quantities can be measured. The names and symbols of the base physical quantities and their corresponding SI units are given in Table 1.1. The precise definitions and the standards for the base SI units are given under Appendix-I.

Table 1.1 Names and symbols of the base physical quantities and the corresponding SI units.

Base physical quantity	Symbol of Physical quantity	Name of SI Unit	Symbol for SI Unit
length	l	metre	m
mass	m	kilogram	kg
time	t	second	s
electric current	I	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
Luminous intensity	I	candela	cd

Note: The other measurements for temperature are in degree celsius (°C) and Fahrenheit (F).

Perhaps you may be confused by mass and amount of substance and also with luminous intensity as given in Table 1.1. The mass of a body is the amount of matter contained in the body, while a mole is the amount of any substance equal to its molecular mass expressed in grams. For example,

1 mole of HCl = 36.46 g

2 moles of HCl = 36.46 × 2 = 72.92 g

Luminous intensity is the amount of light emitted by a point source per second in a particular direction.

ACTIVITY 1.2

Take a thermometer at your home. Observe the measuring marks on a thermometer along with a parent.

(i) Write down the two types of measuring marks indicating on the thermometer.

(ii) Measure your temperature and record it in °C (degree celsius) and F (Fahrenheit)

(iii) In case you find it difficult to understand, you can contact your nearest Doctor or nurse or ANM

Note: Commonly, body temperature between 98.2°F-98.6°F is expressed in Fahrenheit.

1.4.1 Derived Units

The base or fundamental SI units like length, mass, time, etc. are independent of each other. The SI units for all other physical quantities such as area, density, velocity can be derived in terms of the base SI units and are called **derived units**. In order to find the derived unit for a physical quantity we have to find out the relationship between the physical quantity and the base physical quantities. Then substitute the units of the base physical quantities to find the desired derived unit. Let us take some examples to learn how to derive units for physical quantities in terms of base units.

Example 1. Derive the SI unit for area of a surface.

In order to derive the unit, we need to find out the relationship between area and the base physical quantities. As you know that the area of a surface is the product of its length and breadth. So, as the first step we write area as

$$\text{Area} = \text{length} \times \text{breadth}$$

Since breadth is also a kind of length, we can write,

$$\text{Area} = \text{length} \times \text{length}$$

Then to find the derived unit for area, we substitute the units of the base physical quantities as

Unit of area = metre × metre = $(\text{metre})^2$ = m^2

Thus, the SI unit of area is m^2 and is pronounced as squared metre. Similarly you can check that volume would have the SI unit as m^3 or cubic metre.

Example 2. Find the derived unit for force.

You know that force is defined as

Force = mass × acceleration = mass × (change in velocity/time)

Since, change in velocity = Length/time

So, Force = mass × (length/time) × (1/time) = mass × $(\text{length}/\text{time}^2)$

The SI unit of force can be found by substituting the SI units of the base physical quantities on the right side of the expression.

Thus, ⇒ SI unit of force = kg m/s^2 = kg ms^{-2}

Some commonly encountered physical quantities other than base physical quantities, their relationship with the base physical quantities and the SI units are given in Table 1.2.

Table 1.2 Some examples of derived SI units of the commonly used physical quantities

Derived Quantity	Dimensions	Name of Unit	Symbol of the Unit
area	Length × length	square meter	m^2
volume	Length × length × length	cubic metre	m^3
speed, velocity	Length/time	metre per second	$m\ s^{-1}$
acceleration	(Length/time)/time	metre per second squared	$m\ s^{-2}$
wavenumber	1/length	reciprocal metre	m^{-1}
density	$\text{Mass}/(\text{length})^3$	kilogram per cubic metre	$kg\ m^{-3}$
Work	$(\text{Mass} \times \text{length}^2)/(\text{time})^2$	kilogram square metre per square second	$kg\ m^2/s^2$

A number of physical quantities like force, pressure, etc. are used very often but their SI units are quite complex. Due to their complex expression it becomes quite inconvenient to use them again and again. The derived SI units for such physical quantities have been assigned special names. Some of the physical quantities whose SI units have been assigned special names are compiled in Table 1.3.

Table 1.3 Names and symbols of the derived SI units with Special names

Physical Quantity	Derived SI unit	Special name assigned to the Unit	Symbol assigned to the special name
frequency	s^{-1}	Hertz	Hz
force	$m.kg.s^{-2}$	Newton	N
Pressure or stress	$m^{-1}.kg.s^{-2}$	Pascal	Pa
Energy or work	$kg.m^{2}.s^{-2}$	Joule	J
Power	$kg.m^{2}.s^{-3}$	Watt	W

INTEXT QUESTIONS 1.3

1. Differentiate between base units and derived units.
2. What is the difference between mass and amount of a substance?
3. Derive the unit of Pressure. (Pressure = Force/Area)
4. Which term of measurement is commonly used by the announcer of your favourite radio programme?
5. Observe a bulb/tube light at your home for the unit measurement written on it. From Table 1.3 find out the physical quantity it measure?
6. Veena, Mohindar and Alam went to market. Veena brought milk with a litre measure, Mohindar brought ribbon by a measuring mark on the table and Alam brought vegetables using stones. Which of them did not use the appropriate measurement while purchasing goods? Explain while given the names of right measurement.

1.4.2 SI Prefixes

When we make measurements of physical quantities, quite often the quantity being measured is too large as compared to the base unit of the physical quantity. Look at some of the following examples,

Mass of earth = 5,970,000,000,000,000,000,000,000 kg

Radius of Sun = 6,96,000,000 m

Approximate distance between Mumbai and Delhi = 1,400,000 m

Other possibility is that the physical quantity is too small as compared to the base unit of the physical quantity. Look at some of the examples,

Radius of a hydrogen atom = 0.000,000,000,05 m

Mass of an electron (m_e) = 0.000,000,000,000,000,000,000,911 kg

You can see from the examples given above that when the physical quantity being measured is either too large or too small as compared to the standard unit, then the value of the physical quantity is quite inconvenient to express.

The numbers given above can be simplified by using what is called scientific notation of numbers. In this notation system we represent the numbers as power of ten. In this notation system we can rewrite the above examples as

Mass of Earth = 5.97×10^{24} kg

Radius of Sun = 6.96×10^{8} m

Approximate distance between Mumbai and Delhi = 1.4×10^{6} m

Radius of a hydrogen atom = 5×10^{-11} m

Mass of an electron (m_e) = 9.11×10^{-31} kg

In scientific notation the numbers become relatively easier, but are still not convenient because they carry exponents. In order to simplify the numbers further, the SI system of units has recommended the use of certain prefixes. These prefixes are used along with the SI units in such a way that the physical quantity being measured can be expressed as a convenient number. The SI prefixes have been defined to cover a wide range of 10^{-24} to 10^{+24} of a unit and are given in Table 1.4.

Table1.4: SI Prefixes for multiples and sub multiples of units

Multiple	Prefix	Symbol	Sub multiple	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	m
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

1.4.3 How do we use SI prefixes?

In order to use SI prefixes, we have to keep a basic rule in mind. The rule is that the prefix is chosen in such a way that the resulting value of the physical quantity has a value between 0.1 and 1000. Let us illustrate it with examples.

Radius of Sun = 6.96×10^8 m = 696×10^6 m = 696 Mm (696 mega metre)

Alternatively = 6.96×10^8 m = 0.696×10^9 m = 0.696 Gm (0.696 giga metre)

INTEXT QUESTIONS 1.4

Rewrite the following measurements of length using suitable SI prefixes.

(i) effective radius of a proton; 1.2×10^{-15}m __________

(ii) radius of human red blood cell; 3.7×10^{-6}m ________

(iii) radius of our galaxy; 6×10^{19}m __________________

You must follow the following rules while using SI prefixes.

Note:

- No space is required between the prefix and the symbol of the unit e.g., nanogram is written as ng and not as n g.
- The prefixes are used only with the units and not alone e.g., 10 µ does not convey anything, it has to be 10 µm, 10 µg, etc.
- You can use only one prefix at a time e.g. 10^{-12} g is represented as 1 pg and not as 1 mmg.
- SI prefix is not used with the unit °C.
- The power to which a prefixed unit is raised applies to the whole unit, including the prefix e.g. 1 km^2 = $(1000\ m)^2$ = 10^6 m^2 and not 1000 m^2.

Having learnt about the base SI units, the method of obtaining the derived SI unit for a given physical quantity and also the need and usage of prefixing SI units, let us now learn about the grammatical rules for using SI units in general.

1.4.4 Rules for Representing SI Units

The SI units are the result of the attempt of scientists to evolve a common international system of units that can be used globally. It is therefore important that the words and the grammar is logical and defined unambiguously i.e. everyone uses the system of units in the same manner. In order to achieve this objective, a number of grammatical rules have been framed. The most commonly used rules are given below:

- While writing the value of physical quantity, the number and the unit are separated by a space. For example, 100 mg is correct but not 100mg.
- No space is given between number and °C, degree, minute and second of plane angle.
- The symbols of the units are not changed while writing them in plural e.g. 10 mg is correct but not 10 mgs.

- The symbols of the units are not followed by a full stop except at the end of a sentence, e.g. 10 mg. of a compound is incorrect.
- In writing the SI unit obtained as a combination of units a space is given between the symbols. Thus m s represents metre second while ms stands for milli-second. That is if the units are written without leaving any space, the first letter may be taken as a prefix.
- For numbers less than unity zero must be inserted to the left of the decimal point e.g. writing 0.928 g is correct but not .928 g.
- Symbols of units derived from proper names are represented by using capital letters. When written in full, the unit should not be written in plural e.g. 30.5 joule or 30.5 J is correct but 30.5 Joules or 30.5 j is not correct.
- When using powers with a unit name the modifier squared or cubed is used after the unit name e.g. second squared, gram cubed etc. Area and volume are exception in such cases the qualifier for the power comes first e.g. square kilometer or cubic centimetre etc.
- For representing unit symbols with negative exponent, the use of the solidus (/) sign should be avoided. If used, no more than one solidus should be used e.g. the unit for gas constant (JK^{-1} mol^{-1}) may be represented as J/K mol but not as J/K/mol.

The rules mentioned earlier for the use of SI prefixes are to be followed along with these rules.

WHAT YOU HAVE LEARNT

- Measurement is a basic skill which forms an essential part of our day to day activities irrespective of what we do.
- It is a process of comparison and involves counting of the number of times a chosen scale is used to make the measurement.
- Measurement is essential for accurate determination of a physical quantity. It is helpful in day to day transactions, trade and scientific endeavours.
- The unit of physical quantity is a standard value in terms of which other quantities of that kind are expressed.
- To be useful, a unit must be relevant to the quantity being measured, be convenient and also well defined so that it is understood by every body in an unambiguous way.
- In the ancient times parts of 'human body' were used for measurement but these led to conflicts and confusions because these were arbitrary, non uniform and led to results which were not reproducible.

- Currently, we follow an international system of units, called SI units. This system is based on seven base units which correspond to seven base physical quantities namely length, mass, time, temperature, amount of substances, light intensity and electric current.
- The units for all other physical quantities can be derived in terms of the base SI units and are called derived units. Some of the derived units have been given special names.
- SI prefixes are used in cases where the quantity being measured is too large or too small as compared to the base unit of the physical quantity.
- The grammar of SI units must be followed while writing them.

TERMINAL EXERCISE

1. Which of the following is not an SI unit?

   A. Metre   B. Pound
   C. Kilogram   D. second

2. If the mass of a solution in 10 μg it is the same as

   A. 10^{-6} g   B. 10^{-12} g
   C. 10^{-9} g   D. 10^{-3} g

3. Indicate whether the following statements are True or False. Write T for true and F for false

   (i) SI units are arbitrary   (ii) $1\ mm^2 = 10^{-3}\ m^2$
   (iii) 10^{-15} g = 1 mpg   (iv) SI unit for pressure is Pascal

4. Represent the following measurements by using suitable SI prefixes

   (i) 2×10^{-8} s   (ii) 1.54×10^{-10} m
   (iii) 1.98×10^{-6} mol   (iv) 200 000 kg

5. Give the SI units used while buying :.

   A. Silk ribbon   B. Milk
   C. Potatoes

6. Give the common unit to measure our body temperature and write its SI unit

7. What are the advantages of SI units?

APPENDIX-I

(a) **Mass**: The SI unit of mass is kilogram. One kilogram is the mass of a particular cylinder made of Platinum–Iridium alloy, kept at the International Bureau of Weights and Measures in France. This standard was established in 1887 and there has been no change because this is an unusually stable alloy. Prototype kilograms have been made out of this alloy and distributed to member states. The national prototype of India is the Kilogram no 57. This is preserved at the National Physical Laboratory, New Delhi.

(b) **Length**: The SI unit of length is metre. Earlier the metre (also written as meter) was defined to be $1/10^7$ times the distance from the Equator to the North Pole through Paris. This standard was abandoned for practical reasons. In 1875, the new metre was defined as the distance between two lines on a Platinum-Iridium bar stored under controlled conditions. Such standards had to be kept under severe controlled conditions. Even then their safety against natural disasters is not guaranteed, and their accuracy is also limited for the present requirements of science and technology. In 1983 the metre was redefined as the distance travelled by light in vacuum in a time interval of 1/ 299792458 seconds. This definition establishes that the speed of light in vacuum is 299792458 metres per second.

(c) **Time**: The SI unit of time is second. The time interval second was originally defined in terms of the time of rotation of earth about its own axis. This time of rotation is divided in 24 parts, each part is called an hour. An hour is divided into 60 minutes and each minute is subdivided into 60 seconds. Thus, one second is equal to $1/86400^{th}$ part of the solar day. But it is known that the rotation of the earth varies substantially with time and therefore, the length of a day is a variable quantity, may be very slowly varying.

The XIII General Conference on Weights and Measures in 1967 defined one second as the time required for Cesium–133 atom to undergo 9192631770 vibrations. The definition has its roots in a device, which is named as the atomic clock.

(d) **Temperature**: The SI unit of temperature is kelvin (K). The thermodynamic scale on which temperature is measured has its zero at absolute zero, and has its lower fixed point corresponding to 273.15 K at the triple point of water (0°C). One unit of thermodynamic temperature (1K) is equal to 1/273.15 of the thermodynamic temperature of the triple point of water.

(e) **Electric current**: The SI unit of electric current is the ampere (A). One ampere is defined as the magnitude of current that when flowing through two long parallel wires, each of length equal to 1 m, separated by 1 metre in free space, results in a force of 2×10^{-7} N between the two wires.

(f) **Amount of substance**: The SI unit of amount is mole (mol). One mole is defined as the amount of any substance, which contains, as may elementary units, as there are atoms in exactly 0.012 kg of C-12 isotope of carbon.

(g) **Luminous intensity**: The SI unit of luminous intensity (I) is candela (Cd). The candela is defined as the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × 1012 hertz and that has a radiant intensity of 1/683 watt per steradian in that direction.

ANSWERS TO INTEXT QUESTIONS

1.1

1. Measurement may be defined as a kind of counting. It refers to counting of the number of times a chosen scale is used to make the measurement. For example :An inch tape to measure length, or a graded cylinder to measure volume.
2. A unit is a measure, device or a scale in terms of which we make physical measurement.
3. A standard unit must have the following characteristics to be useful
   - relevant
   - convenient
   - well defined

1.2

1. Parmanu
2. Arm, Angul, Cubit, etc.
3. Because the parts of human body may vary from person to person and we cannot trust on our senses to measure exactly and accurately.
4. During the period of Moghul emperor Akbar.

1.3

1. (a) Fundamental units are only seven in number whereas derived units are very large in number.

   (b) Fundamental units are independent of each other but derived units are obtained from fundamental units.
2. Mass of a body is the amount of matter contained in a body while the amount of the substance is equal to its molecular mass.
3. Unit of pressure = Unit of force/Unit of area = $kg\ ms^{-2} / m^2 = kg\ m^{-1}s^{-2}$
4. Hz
5. Watt
6. Mohindar and Alam, meter scale, kilogram

1.4

(i) 1.2 fm (ii) 3.7 mm (iii) 60 E m

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MODULE - 2

MATTER IN OUR SURROUNDINGS

2. Matter in our Surroundings
3. Atom and Molecules
4. Chemical Reaction and Equations
5. Atomic Structure
6. Periodic Classification of Elements
7. Chemical Bonding
8. Acids, Bases and Salts