Unit 1

Physical Quantities and Measurement

STUDENT'S LEARNING OUTCOMES

After studying this unit, the students will be able to:

- describe the crucial role of Physics in Science, Technology and Society.
- explain with examples that Science is based on physical quantities which consist of numerical magnitude and a unit.
- differentiate between base and derived physical quantities.
- list the seven units of System International (SI) alongwith their symbols and physical quantities (standard definitions of SI units are not required).
- interconvert the prefixes and their symbols to indicate multiples and sub-multiples for both base and derived units.
- write the answer in scientific notation in measurements and calculations.
- describe the working of Vernier Callipers and screw gauge for measuring length.
- identify and explain the limitations of measuring instruments such as metre rule, Vernier Callipers and screw gauge.
- describe the need using significant figures for recording and stating results in the laboratory.

This unit is built on

Measurement

-Science-VIII

Scientific Notation

-Maths-IX

This unit leads to:

Measurement

-Physics-XI

Major Concepts

1.1 Introduction to Physics
1.2 Physical quantities
1.3 International System of units
1.4 Prefixes (multiples and sub-multiples)
1.5 Scientific notation/ Standard form
1.6 Measuring instruments
- metre rule
- Vernier Callipers
- screw gauge
- physical balance
- stopwatch
- measuring cylinder

1.7 An introduction to significant figures

When you can measure what you are speaking about and express it in numbers, you know something about it. When you cannot measure what you are speaking about or you cannot express it in numbers, your knowledge is of a meagre and of unsatisfactory kind.

Lord Kelvin

FOR YOUR INFORMATION

Andromeda is one of the billions of galaxies of known universe.

INVESTIGATION SKILLS

The students will be able to:

- compare the least count/ accuracy of the following measuring instruments and state their measuring range:
  - (i) Measuring tape
  - (ii) Metre rule
  - (iii) Vernier Callipers
  - (iv) Micrometer screw gauge
- make a paper scale of given least count e.g. 0.2 cm and 0.5 cm.
- determine the area of cross section of a solid cylinder with Vernier Callipers and screw gauge and evaluate which measurement is more precise.
- determine an interval of time using stopwatch.
- determine the mass of an object by using different types of balances and identify the most accurate balance.
- determine volume of an irregular shaped object using a measuring cylinder.
- List safety equipments and rules.
- Use appropriate safety equipments in laboratory.

SCIENCE, TECHNOLOGY AND SOCIETY CONNECTION

The students will be able to:

- determine length, mass, time and volume in daily life activities using various measuring instruments.
- list with brief description the various branches of physics.

Man has always been inspired by the wonders of nature. He has always been curious to know the secrets of nature and remained in search of the truth and reality. He observes various phenomena and tries to find their answers by logical reasoning. The knowledge gained through observations and experimentations is called Science. The word science is derived from the Latin word scientia, which means knowledge. Not until eighteenth century, various aspect of material objects were studied under a single subject called natural philosophy. But as the knowledge increased, it was divided into two main streams; Physical sciences — which deal with the study of non-living things and Biological sciences — which are concerned with the study of living things.

Measurements are not confined to science. They are part of our lives. They play an important role to describe and understand the physical world. Over the centuries, man has improved the methods of measurements. In this unit, we will study some of physical quantities and a few useful measuring instruments. We will also learn the measuring techniques that enable us to measure various quantities accurately.

1.1 INTRODUCTION TO PHYSICS

In the nineteenth century, physical sciences were divided into five distinct disciplines; physics, chemistry, astronomy, geology and meteorology. The most fundamental of these is the Physics. In Physics, we study matter, energy and their interaction. The laws and principles of Physics help us to understand nature.

The rapid progress in science during the recent years has become possible due to the discoveries and inventions in the field of Physics. The technologies are the applications of scientific principles. Most of the technologies of our modern society throughout the world are related to Physics. For example, a car is made on the principles of mechanics and a refrigerator is based on the principles of thermodynamics.

In our daily life, we hardly find a device where Physics is not involved. Consider pulleys that make it easy to lift heavy loads. Electricity is used not only to

BRANCHES OF PHYSICS

Mechanics:
It is the study of motion of objects, its causes and effects.

Heat:
It deals with the nature of heat, modes of transfer and effects of heat.

Sound:
It deals with the physical aspects of sound waves, their production, properties and applications.

Light (Optics):
It is the study of physical aspects of light, its properties, working and use of optical instruments.

Electricity and Magnetism:
It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

Atomic Physics:
It is the study of the structure and properties of atoms.

Nuclear Physics:
It deals with the properties and behaviour of nuclei and the particles within the nuclei.

Plasma Physics:
It is the study of production, properties of the ionic state of matter - the fourth state of matter.

Geophysics:
It is the study of the internal structure of the Earth.

get light and heat but also mechanical energy that drives fans and electric motors etc. Consider the means of transportation such as car and aeroplanes; domestic appliances such as air-conditioners, refrigerators, vacuum-cleaners, washing machines, and microwave ovens etc. Similarly the means of communication such as radio, TV, telephone and computer are the result of applications of Physics. These devices have made our lives much easier, faster and more comfortable than the past. For example, think of what a mobile phone smaller than our palm can do? It allows us to contact people anywhere in the world and to get latest worldwide information. We can take and save pictures, send and receive messages of our friends. We can also receive radio transmission and can use it as a calculator as well.

(a) (b)

Figure 1.1 (a) a vacuum cleaner
(b) a mobile phone

However, the scientific inventions have also caused harms and destruction of serious nature. One of which is the environmental pollution and the other is the deadly weapons.

DO YOU KNOW?

Wind turbines are used to produce pollution free electricity.

QUICK QUIZ

1. Why do we study physics?
2. Name any five branches of physics.

1.2 PHYSICAL QUANTITIES

All measurable quantities are called **physical quantities** such as length, mass, time and temperature. A physical quantity possesses at least two characteristics in common. One is its numerical magnitude and the other is the unit in which it is measured. For example, if the length of a student is 104 cm then 104 is its numerical magnitude and centimetre is the unit of measurement. Similarly when a grocer says that each bag contains 5 kg sugar, he is describing its numerical magnitude as well as the unit of measurement. It would be meaningless to state 5 or kg only. Physical quantities are divided into **base quantities** and **derived quantities.**

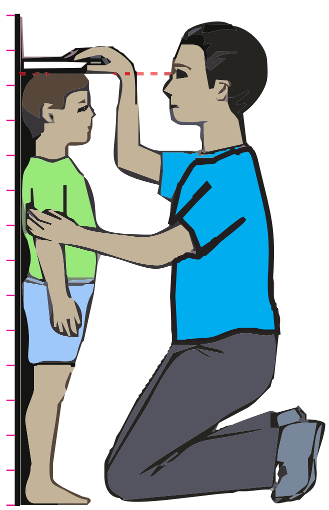


Figure 1.2: Measuring height.

BASE QUANTITIES

There are seven physical quantities which form the foundation for other physical quantities. These physical quantities are called the base quantities. These are length, mass, time, electric current, temperature, intensity of light and the amount of a substance.

Base quantities are the quantities on the basis of which other quantities are expressed.

DERIVED QUANTITIES

Those physical quantities which are expressed in terms of base quantities are called the derived quantities. These include area, volume, speed, force, work, energy, power, electric charge, electric potential, etc.

The quantities that are expressed in terms of base quantities are called derived quantities.

1.3 INTERNATIONAL SYSTEM OF UNITS

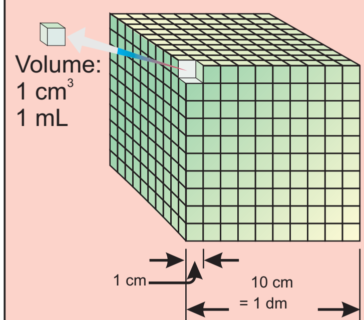
Measuring is not simply counting. For example, if we need milk or sugar, we must also understand how much quantity of milk or sugar we are talking about. Thus, there is a need of some standard quantities for measuring/comparing unknown quantities. Once a standard is set for a quantity then it can be expressed in terms of that standard quantity. This standard quantity is called a unit.

With the developments in the field of science and technology, the need for a commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information. The eleventh General Conference on Weight and Measures held in Paris in 1960 adopted a world-wide system of measurements called **International System of Units.** The International System of Units is commonly referred as **SI.**

BASE UNITS

The units that describe base quantities are called base units. Each base quantity has its SI unit.

Mini Exercise



Volume is a derived quantity

1 L = 1000 mL

1 L = $1\ dm^3$

$\therefore$ = $(10\ cm)^3$

= $1000\ cm^3$

$\therefore$ 1 mL = $1\ cm^3$

Express $1 m^3$ in litres L

Table 1.1 shows seven base quantities, their SI units and their symbols.

Table 1.1: Base quantities, their SI units with symbols

Quantity		Unit	
Name	**Symbol**	**Name**	**Symbol**
Length	*l*	metre	m
Mass	*m*	kilogramme	kg
Time	*t*	second	s
Electric current	*I*	ampere	A
Intensity of light	*L*	candela	cd
Temperature	*T*	kelvin	K
Amount of a substance	*n*	mole	mol

DERIVED UNITS

The units used to measure derived quantities are called derived units. Derived units are defined in terms of base units and are obtained by multiplying or dividing one or more base units with each other. The unit of area $(\text{metre})^2$ and the unit of volume $(\text{metre})^3$ are based on the unit of length, which is metre. Thus the unit of length is the base unit while the unit of area and volume are derived units. Speed is defined as distance covered in unit time; therefore its unit is metre per second. In the same way the unit of density, force, pressure, power etc. can be derived using one or more base units. Some derived units and their symbols are given in the Table 1.2.

Table 1.2: Derived quantities and their SI units with symbols

Quantity		Unit	
Name	**Symbol**	**Name**	**Symbol**
Speed	*v*	metre per second	ms^{-1}
Acceleration	*a*	metre per second per second	ms^{-2}
Volume	*V*	cubic metre	m^3
Force	*F*	newton	N or $(kg\ m\ s^{-2})$
Pressure	*P*	pascal	Pa or $(N\ m^{-2})$
Density	*ρ*	kilogramme per cubic metre	$kg\ m^{-3}$
Charge	*Q*	coulomb	C or (As)

QUICK QUIZ

1. How can you differentiate between base and derived quantities?
2. Identify the base quantity in the following:
   (i) Speed (ii) Area (iii) Force (iv) Distance
3. Identify the following as base or derived quantity: density, force, mass, speed, time, length, temperature and volume.

1.4 PREFIXES

Some of the quantities are either very large or very small. For example, 250 000 m, 0.002 W and 0.000 002 g, etc. SI units have the advantage that their multiples and sub-multiples can be expressed in terms of prefixes. Prefixes are the words or letters added before SI units such as kilo, mega, giga and milli. These prefixes are given in Table 1.3. The prefixes are useful to express very large or small quantities. For example, divide 20,000 g by 1000 to express it into kilogramme, since kilo represents 10^3 or 1000.

Table 1.3: Some Prefixes

Prefix	Symbol	Multiplier
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Thus $$20{,}000\text{ g} = \frac{20{,}000}{1000}\text{ kg} = 20\text{ kg}$$

or $$20{,}000\text{ g} = 20\times10^3\text{ g} = 20\text{ kg}$$

Table 1.4 shows some multiples and sub-multiples of length. However, double prefixes are not used. For example, no prefix is used with kilogramme since it already contains the prefix kilo. Prefixes given in Table 1.3 are used with both types base and derived units. Let us consider few more examples:

Table 1.4: Multiples and sub-multiples of length

1 km	10^3 m
1 cm	10^{-2} m
1 mm	10^{-3} m
1 μm	10^{-6} m
1 nm	10^{-9} m

(I) 200 000 ms^{-1} = 200×10^3 ms^{-1} = 200kms^{-1}

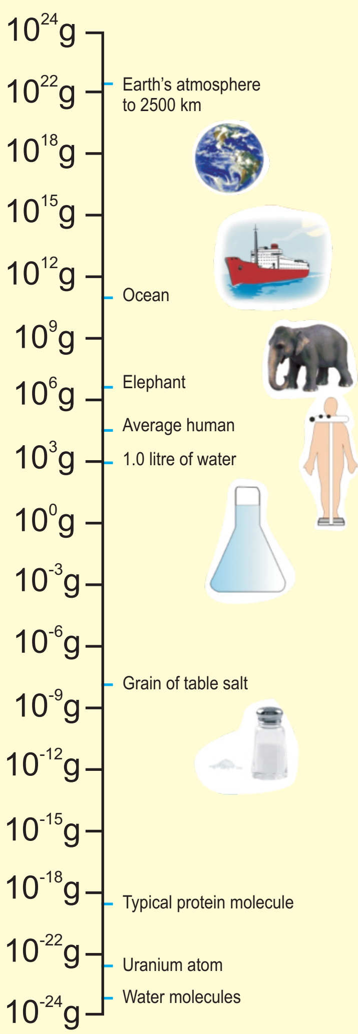
(ii) 4 800 000 W = $4\,800\times10^3$W = 4 800 kW

= 4.8×10^6W = 4.8 MW

(iii) 3 300 000 000 Hz = $3\,300\times10^6$ Hz = 3300 MHz

Tidbits

Mass of various objects



$= 3.3 \times 10^{3}$ MHZ $= 3.3$ Ghz

(iv) 0.00002 g $= 0.02 \times 10^{-3}$g $= 20 \times 10^{-6}$g

$= 20$ ug

(v) 0.000 000 0081m $= 0.0081 \times 10^{-6}$m $= 8.1 \times 10^{-9}$m

$= 8.1$ nm

1.5 SCIENTIFIC NOTATION

A simple but scientific way to write large or small numbers is to express them in some power of ten. The Moon is 384000000 metres away from the Earth. Distance of the moon from the Earth can also be expressed as 3.84×10^{8} m. This form of expressing a number is called the standard form or scientific notation. This saves writing down or interpreting large numbers of zeros. Thus

In scientific notation a number is expressed as some power of ten multiplied by a number between 1 and 10.

For example, a number **62750** can be expressed as **62.75×10^{3}** or **6.275×10^{4}** or **0.6275×10^{5}**. All these are correct. But the number that has one non-zero digit before the decimal i.e. **6.275×10^{4}** preferably be taken as the standard form. Similarly the standard form of **0.00045 s** is **4.5×10^{-4}s**.

1. Name five prefixes most commonly used.
2. The Sun is one hundred and fifty million kilometres away from the Earth. Write this
   (a) as an ordinary whole number.
   (b) in scientific notation.
3. Write the numbers given below in scientific notation.
   (a) 3000000000 ms^{-1} (b) 6400000 m
   (c) 0.0000000016 g (d) 0.0000548 s

1.6 MEASURING INSTRUMENTS

Measuring instruments are used to measure various physical quantities such as length, mass, time, volume, etc. Measuring instruments used in the past were not so reliable and accurate as we use today. For example, sundial, water clock and other time measuring devices used around 1300 AD were quite crude. On the other hand, digital clocks and watches used now-a-days are highly reliable and accurate. Here we shall describe some measuring instruments used in Physics laboratory.

FOR YOUR INFORMATION

Hubble Space Telescope orbits around the Earth. It provides information about stars.

THE METRE RULE

Figure 1.3: A metre rule

A metre rule is a length measuring instrument as shown in figure 1.3. It is commonly used in the laboratories to measure length of an object or distance between two points. It is one metre long which is equal to 100 centimetres. Each centimetre (cm) is divided into 10 small divisions called millimetre (mm). Thus one millimetre is the smallest reading that can be taken using a metre rule and is called its least count.

While measuring length, or distance, eye must be kept vertically above the reading point as shown in figure 1.4(b). The reading becomes doubtful if the eye is positioned either left or right to the reading point.

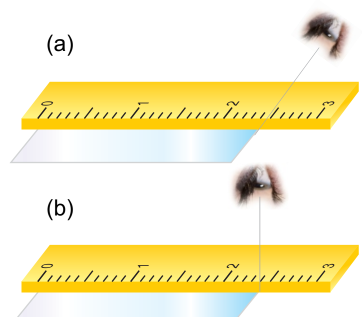


Figure 1.4: Wrong position of the eye to note the reading.
(b) Correct position of the eye to note the reading from a metre rule.

THE MEASURING TAPE

Measuring tapes are used to measure length in metres and centimetres. Figure 1.5 shows a measuring tape used by blacksmith and carpenters. A measuring tape consists of a thin and long strip of cotton, metal or plastic generally 10 m, 20 m, 50 m or 100 m long. Measuring tapes are marked in centimetres as well as in inches.

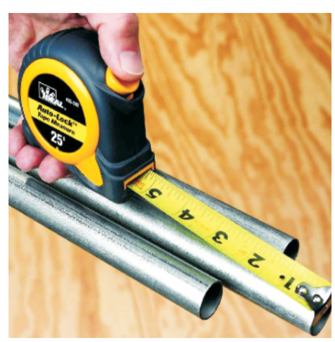


Figure 1.5: A measuring tape

VERNIER CALLIPERS

The accuracy obtained in measurements using a metre rule is upto 1 mm. However an accuracy greater than 1 mm can be obtained by using some

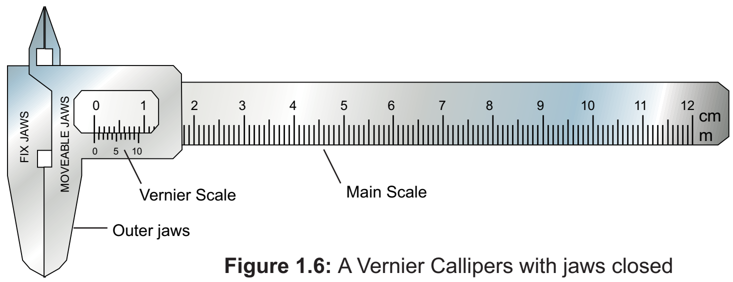


Figure 1.6: A Vernier Callipers with jaws closed

other instruments such as a Vernier Callipers. A Vernier Callipers consists of two jaws as shown in figure 1.6. One is a fixed jaw with main scale attached to it. Main scale has centimetre and millimetre marks on it. The other jaw is a moveable jaw. It has vernier scale having 10 divisions over it such that each of its division is 0.9 mm. The difference between one small division on main scale division and one vernier scale division is 0.1 mm. It is called least count (LC) of the Vernier Callipers. Least count of the Vernier Callipers can also be found as given below:

$$\text{Least count of Vernier Callipers} = \frac{\text{smallest reading on main scale}}{\text{no. of divisions on vernier scale}}$$

$$= \frac{1\,\text{mm}}{10\ \text{divisions}} = 0.1\ \text{mm}$$

Hence $\quad LC = 0.1\ \text{mm} = 0.01\ \text{cm}$

Mini Exercise

Cut a strip of paper sheet. Fold it along its length. Now mark centimetres and half centimetre along its length using a ruler. Answer the following questions:

1. What is the range of your paper scale?
2. What is its least count?
3. Measure the length of a pencil using your paper scale and with a metre ruler. Which one is more accurate and why?

Working of a Vernier Callipers

First of all find the error, if any, in the measuring instrument. It is called the zero error of the instrument. Knowing the zero error, necessary correction can be made to find the correct measurement. Such a correction is called zero correction of the instrument. Zero correction is the negative of zero error.

Zero Error and Zero Correction

To find the zero error, close the jaws of Vernier Callipers gently. If zero line of the vernier scale coincides with the zero of the main scale then the zero error is zero (figure 1.7a). Zero error will exist if zero line of the vernier scale is not coinciding with the zero of main scale (figure 1.7b). Zero error will be positive if zero line of vernier scale is on the right side of the zero of the main scale and will be negative if zero line of vernier scale is on the left side of zero of the main scale (figure 1.7c).

Taking a Reading on Vernier Callipers

Let us find the diameter of a solid cylinder using Vernier Callipers. Place the solid cylinder between jaws of the Vernier Callipers as shown in figure 1.8. Close the jaws till they press the opposite sides of the object gently.

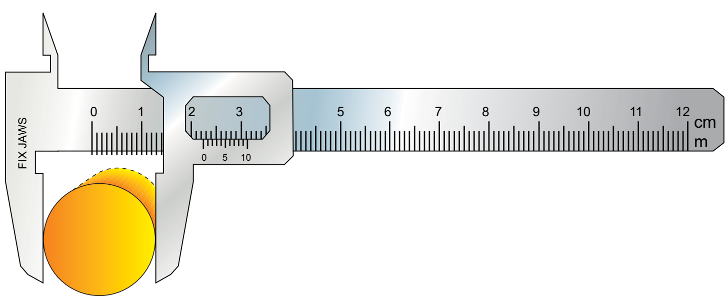


Figure 1.8: A cylinder placed between the outer jaws of Vernier Callipers.

Note the complete divisions of main scale past the vernier scale zero in a tabular form. Next find thevernier scale division that is coinciding with any division on the main scale. Multiply it by least count of Vernier Callipers and add it in the main scale reading. This is equal to the diameter of the solid cylinder. Add zero correction (Z.C) to get correct measurement. Repeat the above procedure and record at least three observations with the solid cylinder displaced or rotated each time.

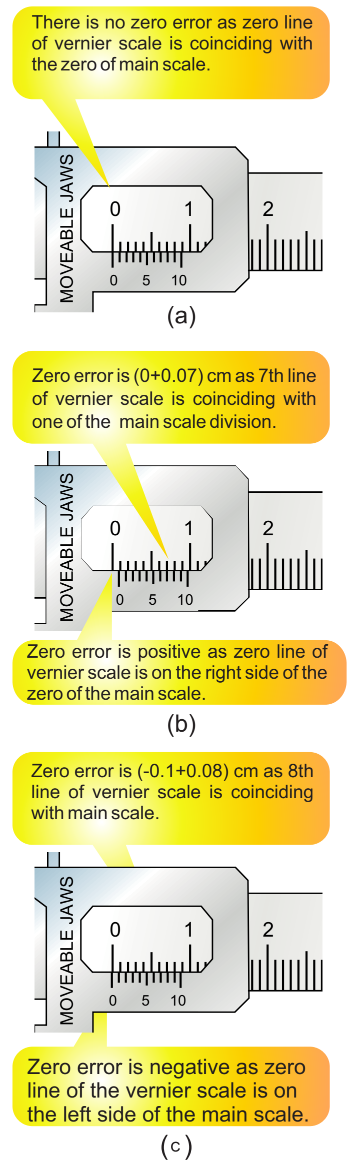


Figure 1.7: Zero Error
(a) zero
(b) +0.07 cm
© cm. -0.02

DIGITAL VERNIER CALLIPERS

Digital Vernier Callipers has greater precision than mechanical Vernier Callipers. Least count of Digital Vernier Callipers is 0.01 mm.

QUICK QUIZ

1. What is the least count of the Vernier Callipers?
2. What is the range of the Vernier Callipers used in your Physics laboratory?
3. How many divisions are there on its vernier scale?
4. Why do we use zero correction?

EXAMPLE 1.1

Find the diameter of a cylinder placed between the outer jaws of Vernier Callipers as shown in figure 1.8.

SOLUTION

Zero correction

On closing the jaws of Vernier Callipers, the position of vernier scale as shown in figure 1.7(b).

Main scale reading = 0.0 cm

Vernier division coinciding with main scale = 7 div.

Vernier scale reading = 7 x 0.01 cm
= 0.07 cm

Zero error =0.0 cm+0.07 cm
= +0.07 cm

zero correction (Z.C) = - 0.07 cm

Diameter of the cylinder

Main scale reading = 2.2 cm

(when the given cylinder is kept between the jaws of the Vernier Callipers as shown in figure 1.8).

Vernier div. coinciding with main scale div. = 6 div.

Vernier scale reading = 6 x 0.01 cm
= 0.06 cm

Observed diameter of the cylinder = 2.2 cm+0.06 cm
= 2.26 cm

Correct diameter of the cylinder = 2.26cm–0.07 cm
= 2.19 cm

Thus, the correct diameter of the given cylinder as found by Vernier Callipers is 2.19 cm.

SCREW GAUGE

A screw gauge is an instrument that is used to measure small lengths with accuracy greater than a Vernier Calliper. It is also called as micrometer screw gauge. A simple screw gauge consists of a U-shaped metal frame with a metal stud at its one end as shown in figure 1.9. A hollow cylinder (or sleeve) has a millimetre scale over it along a line called index line parallel to its axis. The hollow cylinder acts as a nut. It is fixed at the end of U-shaped frame opposite to the stud. A Thimble has a threaded spindle inside it. As the thimble completes one rotation, the spindle moves 1 mm along the index line. It is because the distance between consecutive threads on the spindle is 1 mm. This distance is called the pitch of screw on the spindle.

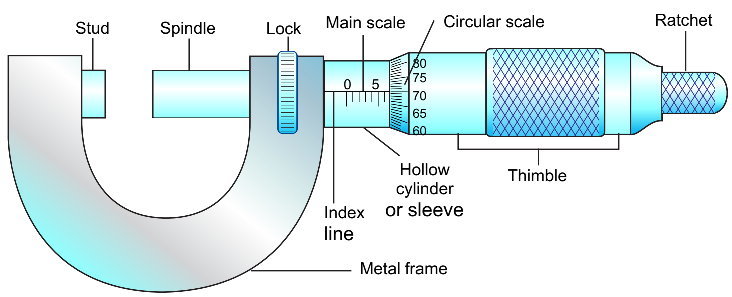


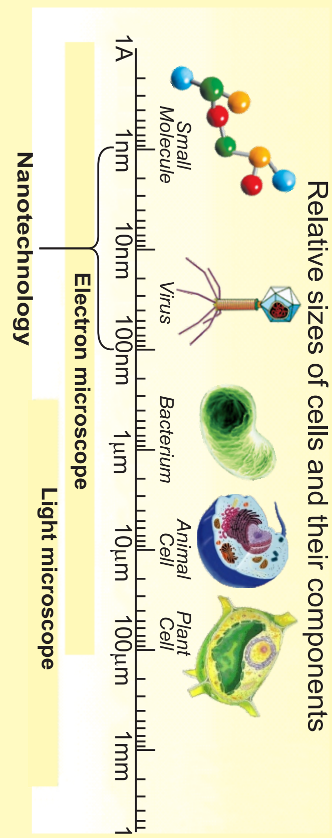
Figure 1.9: A micrometer screw gauge

The thimble has 100 divisions around its one end. It is the circular scale of the screw gauge. As thimble completes one rotation, 100 divisions pass the index line and the thimble moves 1 mm along the main scale. Thus each division of circular scale crossing the index line moves the thimble through 1/100 mm or 0.01 mm on the main scale. Least count of a screw gauge can also be found as given below:

$$\text{Least count} = \frac{\text{pitch of the screw gauge}}{\text{no. of divisions on circular scale}}$$

Tidbits

Relative sizes of molecules and micro-organisms



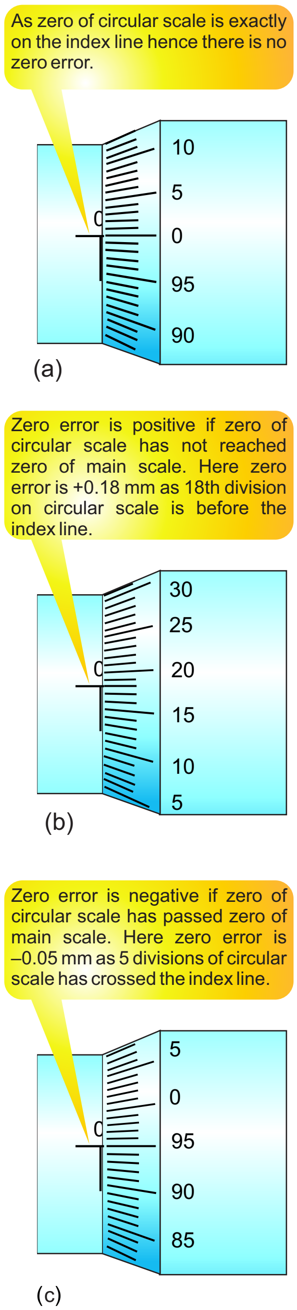


Figure 1.10: Zero Error in a screw gauge: (a) zero (b) + 0.18 mm (c) -0.05 mm.

$$= \frac{1\text{mm}}{100}$$

$$= 0.01 \text{ mm} = 0.001 \text{ cm}$$

Thus least count of the screw gauge is 0.01 mm or 0.001 cm.

WORKING OF A SCREW GAUGE

The first step is to find the zero error of the screw gauge.

ZERO ERROR

To find the zero error, close the gap between the spindle and the stud of the screw gauge by rotating the ratchet in the clockwise direction. If zero of circular scale coincides with the index line, then the zero error will be zero as shown in figure 1.10(a).

Zero error will be positive if zero of circular scale is behind the index line. In this case, multiply the number of divisions of the circular scale that has not crossed the index line with the least count of screw gauge to find zero error as shown in figure 1.10(b).

Zero error will be negative if zero of circular scale has crossed the index line. In this case, multiply the number of divisions of the circular scale that has crossed the index line with the least count of screw gauge to find the negative zero error as shown in figure 1.10(c).

EXAMPLE 1.2

Find the diameter of a wire using a screw gauge.

SOLUTION

The diameter of a given wire can be found as follows:

(i) Close the gap between the spindle and the stud of the screw gauge by turning the ratchet in the clockwise direction.

(ii) Note main scale as well as circular scale readings to find zero error and hence zero correction of the screw gauge.

(iii) Open the gap between stud and spindle of the screw gauge by turning the ratchet in anti clockwise direction. Place the given wire in the gap as shown in figure 1.11. Turn the ratchet so that the object is pressed gently between the studs and the spindle.

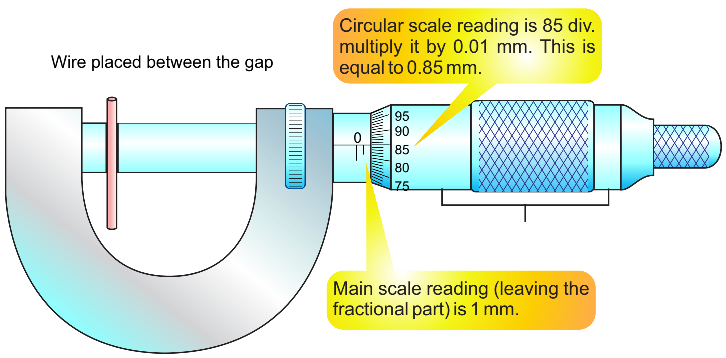


Figure 1.11: Measuring the diameter of a wire using micrometer screen gauge.

(iv) Note main scale as well as circular scale readings to find the diameter of the given wire.

(v) Apply zero correction to get the correct diameter of the wire.

(vi) Repeat steps iii, iv and v at different places of the wire to obtain its average diameter.

Zero correction

Closing the gap of the screw gauge (figure 1.12).

Main scale reading = 0 mm

Circular scale reading = 24 x 0.01 mm

Zero error of the screw gauge = 0 mm+0.24 mm

= + 0.24 mm

Zero correction Z.C. = -0.24 mm

Diameter of the wire (figure 1.11)

Main scale reading = 1 mm

(when the given wire is pressed by the stud and spindle of the screw gauge)

Mini Exercise

1. What is the least count of a screw gauge?
2. What is the pitch of your laboratory screw gauge?
3. What is the range of your laboratory screw gauge?
4. Which one of the two instruments is more precise and why?

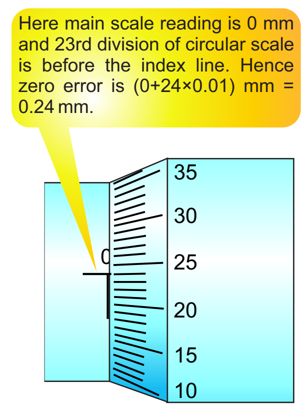


Figure 1.12: Zero error of the screw gauge

USEFUL INFORMATION

Least count of ruler is 1 mm. It is 0.1 mm for Vernier Callipers and 0.01mm for micrometer screw gauge. Thus measurements taken by micrometer screw gauge are the most precise than the other two.

No. of divisions on circular scale	= 85 div.
Circular scale reading	= 85x0.01 mm
	= 0.85 mm
Observed diameter of the given wire	=1mm+0.85 mm
	= 1.85 mm
Correct diameter of the given wire	= 1.85 mm - 0.24 mm
	= 1.61 mm

Thus diameter of the given wire is 1.61 mm.

MASS MEASURING INSTRUMENTS

Pots were used to measure grain in various part of the world in the ancient times. However, balances were also in use by Greeks and Romans. Beam balances such as shown in figure 1.13 are still in use at many places. In a beam balance, the unknown mass is placed in one pan. It is balanced by putting known masses in the other pan. Today people use many types of mechanical and electronic balances. You might have seen electronic balances in sweet and grocery shops. These are more precise than beam balances and are easy to handle.

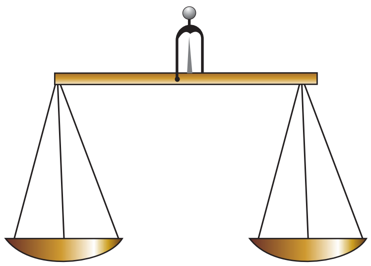


Figure 1.13: A beam balance

PHYSICAL BALANCE

A physical balance is used in the laboratory to measure the mass of various objects by comparison. It consists of a beam resting at the centre on a fulcrum

Mini Exercise

1. What is the function of balancing screws in a physical balance?
2. On what pan we place the object and why?

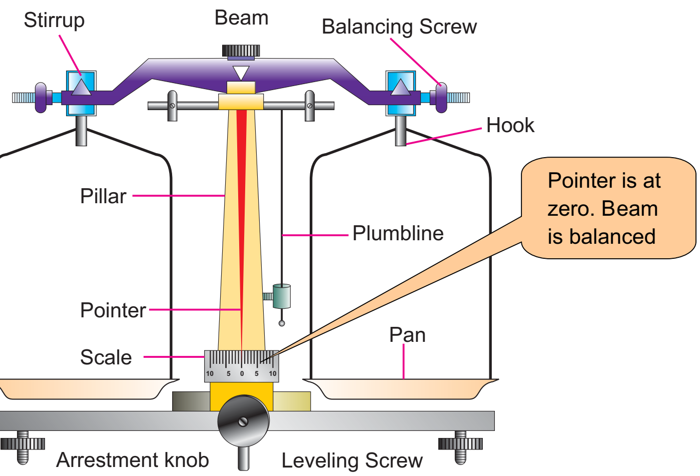


Figure 1.14: A physical balance

as shown in the figure 1.14. The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.
as shown in the figure 1.14. The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.

EXAMPLE 1.3

Find the mass of a small stone by a physical balance.

SOLUTION

Follow the steps to measure the mass of a given object.

(i) Adjusting the levelling screws with the help of plumbline to level the platform of physical balance.

(ii) Raise the beam gently by turning the arresting knob clockwise. Using balancing screws at the ends of its beam, bring the pointer at zero position.

(iii) Turn the arresting knob to bring the beam back on its supports. Place the given object (stone) on its left pan.

(iv) Place suitable standard masses from the weight box on the right pan. Raise the beam. Lower the beam if its pointer is not at zero.

(v) Repeat adding or removing suitable standard masses in the right pan till the pointer rests at zero on raising the beam.

(vi) Note the standard masses on the right pan. Their sum is the mass of the object on the left pan.

LABORATORY SAFETY EQUIPMENT

Fire extinguisher

LEVER BALANCE

A lever balance such as shown in figure 1.15 consists of a system of levers. When lever is lifted placing the object in one pan and standard masses on the other pan, the pointer of the lever system moves. The pointer is brought to zero by varying standard masses.

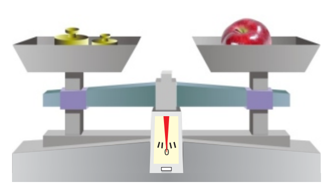


Figure 1.15: A lever balance

ELECTRONIC BALANCE

Electronic balances such as shown in figure 1.16 come in various ranges; milligram ranges, gram ranges and kilogramme ranges. Before measuring the mass of a body, it is **switched ON** and its reading is **set to zero**. Next place the object to be weighed. The reading on the balance gives you the mass of the body placed over it.

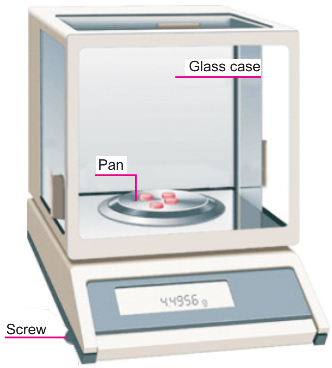


Figure 1.16: An electronic balance

USEFUL INFORMATION

The precision of a balance in measuring mass of an object is different for different balances. A sensitive balance cannot measure large masses. Similarly, a balance that measures large masses cannot be sensitive.

Some digital balances measure even smaller difference of the order of 0.0001g or 0.1 mg. Such balances are considered the most precise balance.

The most Accurate Balance

The mass of one rupee coin is done using different balances as given below:

(a) Beam Balance

Let the balance measures coin's mass = 3.2 g

A sensitive beam balance may be able to detect a change as small as of 0.1 g Or 100 mg.

(b) Physical Balance

Let the balance measures coin's mass = 3.24 g

Least count of the physical balance may be as small as 0.01 g or 10 mg. Therefore, its measurement would be more precise than a sensitive beam balance.

(c) Electronic Balance

Let the balance measures coin's mass = 3.247 g

Least count of an electronic balance is 0.001 g or 1 mg. Therefore, its measurement would be more precise than a sensitive physical balance. Thus electronic balance is the most sensitive balance in the above balances.

STOPWATCH

A stopwatch is used to measure the time interval of an event. There are two types of stopwatches; mechanical and digital as shown in figure 1.17 and 1.18. A mechanical stopwatch can measure a time interval up to a minimum 0.1 second. Digital stopwatches commonly used in laboratories can measure a time interval as small as 1/100 second or 0.01 second.

Figure 1.17: A mechanical stopwatch

How to use a Stopwatch

A mechanical stopwatch 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, it stops the watch while the third press brings the needle back to zero position.

The digital stopwatch 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.

Figure 1.18: A digital stopwatch

MEASURING CYLINDER

A measuring cylinder is a glass or transparent plastic cylinder. It has a scale along its length that indicates the volume in millilitre (mL) as shown in figure 1.19. Measuring cylinders have different capacities from 100 mL to 2500 mL. They are used to measure the volume of a liquid or powdered substance. It is also used to find the volume of an irregular shaped solid insoluble in a liquid by displacement method. The solid is lowered into a measuring cylinder containing water/liquid. The level of water/liquid rises. The increase in the volume of water/liquid is the volume of the given solid object.

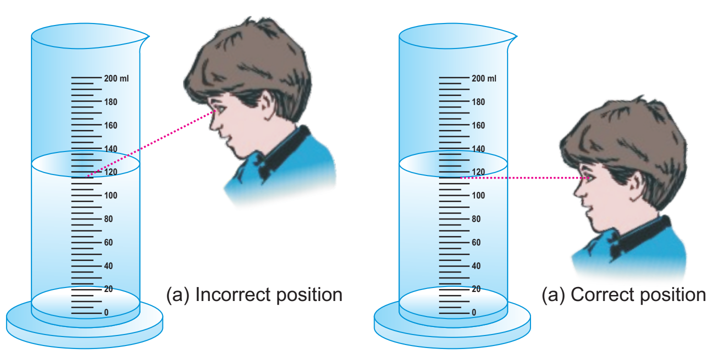


Figure 1.19(**a**) Wrong way to note the liquid level keeping eye above liquid level, (b) correct position of eye to note the liquid level keeping eye at liquid level.

LABORATORY SAFETY EQUIPMENTS

A school laboratory must have safety equipments such as:

- Waste-disposal basket
- Fire extinguisher.
- Fire alarm.
- First Aid Box.
- Sand and water buckets.
- Fire blanket to put off fire.
- Substances and equipments that need extra care must bear proper warning signs such as given below:

HOW TO USE A MEASURING CYLINDER

While using a measuring cylinder, it must be kept vertical on a plane surface. Take a measuring cylinder. Place it vertically on the table. Pour some water into it. Note that the surface of water is curved as shown in figure 1.19. The meniscus of the most liquids curve downwards while the meniscus of mercury curves upwards. The correct method to note the level of a liquid in the cylinder is to keep the eye at the same level as the meniscus of the liquid as shown in figure 1.19(b). It is incorrect to note the liquid level keeping the eye above the level of liquid as shown in figure 1.19 (a). When the eye is above the liquid level, the meniscus appears higher on the scale. Similarly when the eye is below the liquid level, the meniscus appears lower than actual height of the liquid.

MEASURING VOLUME OF AN IRREGULAR SHAPED SOLID

Measuring cylinder can be used to find the volume of a small irregular shaped solid that sinks in water. Let us find the volume of a small stone. Take some water in a graduated measuring cylinder. Note the volume V_i of water in the cylinder. Tie the solid with a thread. Lower the solid into the cylinder till it is fully immersed in water. Note the volume V_f of water and the solid. Volume of the solid will be $V_f - V_i$.

LABORATORY SAFETY RULES

The students should know what to do in case of an accident. The charts or posters are to be displayed in the laboratory to handle situations arising from any mishap or accident. For your own safety and for the safety of others in the laboratory, follow safety rules given below:

- Do not carry out any experiment without the permission of your teacher.
- Do not eat, drink, play or run in the laboratory.
- Read the instructions carefully to familiarize yourself with the possible hazards before handling equipments and materials.
- Handle equipments and materials with care.
- Do not hesitate to consult your teacher in case of any doubt.
- Do not temper with the electrical appliances and other fittings in the laboratory.
- Report any accident or injuries immediately to your teacher.

1.7 SIGNIFICANT FIGURES

The value of a physical quantity is expressed by a number followed by some suitable unit. Every measurement of a quantity is an attempt to find its true value. The accuracy in measuring a physical quantity depends upon various factors:

+ the quality of the measuring instrument
+ the skill of the observer
+ the number of observations made

For example, a student measures the length of a book as 18 cm using a measuring tape. The numbers of significant figures in his/her measured value are two. The left digit 1 is the accurately known digit. While the digit 8 is the doubtful digit for which the student may not be sure.

Another student measures the same book using a ruler and claims its length to be 18.4 cm. In this case all the three figures are significant. The two left digits 1 and 8 are accurately known digits. Next digit 4 is the doubtful digit for which the student may not be sure.

A third student records the length of the book as 18.425 cm. Interestingly, the measurement is made using the same ruler. The numbers of significant figures is again three; consisting of two accurately known digits 1, 8 and the first doubtful digit 4. The digits 2 and 5 are not significant. It is because the reading of these last digits cannot be justified using a ruler. Measurement upto third or even second decimal place is beyond the limit of the measuring instrument.

An improvement in the quality of measurement by using better instrument increases the significant figures in the measured result. The significant figures are all the digits that are known accurately and the one estimated digit. More significant figure means greater precision. The following rules are helpful in identifying significant figure:

(i) Non-zero digits are always significant.

(ii) Zeros between two significant figures are also significant.

(iii) Final or ending zeros on the right in decimal fraction are significant.

(iv) Zeros written on the left side of the decimal point for the purpose of spacing the decimal point are not significant.

(v) In whole numbers that end in one or more zeros without a decimal point. These zeros may or may not be significant. In such cases, it is not clear which zeros serve to

RULES TO FIND THE SIGNIFICANT DIGITS IN A MEASUREMENT

(i) Digits other than zero are always significant.

27 has 2 significant digits.

275 has 3 significant digits.

(ii) Zeros between significant digits are also significant.

2705 has 4 significant digits.

(iii) Final zero or zeros after decimal are significant.

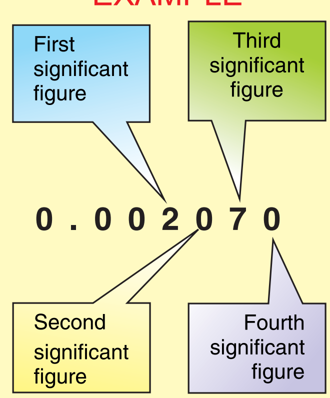
275.00 has 5 significant digits.

(iv) Zeros used for spacing the decimal point are not significant. Here zeros are placeholders only.

0.03 has 1 significant digit.

0.027 has 2 significant digits.

EXAMPLE



locate the position value and which are actually parts of the measurement. In such a case, express the quantity using scientific notation to find the significant zero.

Rounding the Numbers

(i) If the last digit is less than 5 then it is simply dropped. This decreases the number of significant digits in the figure.

For example,

1.943 is rounded to 1.94 (3 significant figure)

(ii) If the last digit is greater than 5, then the digit on its left is increased by one. This also decreases the number of significant digits in the figure.

For example,

1.47 is rounded to two significant digits 1.5

(iii) If the last digit is 5, then it is rounded to get nearest even number.

For example,

1.35 is rounded to 1.4 and 1.45 is also rounded to 1.4

EXAMPLE 1.4

Find the number of significant figures in each of the following values. Also express them in scientific notations.

a) 100.8 s b) 0.00580 km

c) 210.0 g

SOLUTION

(a) All the four digits are significant. The zeros between the two significant figures 1 and 8 are significant. To write the quantity in scientific notation, we move the decimal point two places to the left, thus

$$100.8\ s = 1.008 \times 10^{2}\ s$$

(b) The first two zeros are not significant. They are used to space the decimal point. The digit 5,8 and the final zero are significant. Thus there are three significant figures. In scientific notation, it can be written as 5.80×10^{-3} km.

(c) The final zero is significant since it comes after the decimal point. The zero between last zero and 1 is also significant because it comes between the significant figures. Thus the number of significant figures in this case is four. In scientific notation, it can be written as

$$210.0\ g = 2.100 \times 10^{2}\ g$$

SUMMARY

- Physics is a branch of Science that deals with matter, energy and their relationship.
- Some main branches of Physics are mechanics, heat, sound, light (optics), electricity and magnetism, nuclear physics and quantum physics.
- Physics plays an important role in our daily life. For example, electricity is widely used everywhere, domestic appliances, office equipments, machines used in industry, means of transport and communication etc. work on the basic laws and principles of Physics.
- A measurable quantity is called a physical quantity.
- Base quantities are defined independently. Seven quantities are selected as base quantities. These are length, time, mass, electric current, temperature, intensity of light and the amount of a substance.
- The quantities which are expressed in terms of base quantities are called derived quantities. For example, speed, area, density, force, pressure, energy, etc.
- A world-wide system of measurements is known as international system of units (SI). In SI, the units of seven base quantities are metre, kilogramme, second, ampere, kelvin, candela and mole.
- The words or letters added before a unit and stand for the multiples orsub-multiples of that unit are known as prefixes. For example, kilo, mega, milli, micro, etc.
- A way to express a given number as a number between 1 and 10 multiplied by 10 having an appropriate power is called scientific notation or standard form.
- An instrument used to measure small lengths such as internal or external diameter or length of a cylinder, etc is called as Vernier Callipers.
- A Screw gauge is used to measure small lengths such as diameter of a wire, thickness of a metal sheet, etc.
- Physical balance is a modified type of beam balance used to measure small masses by comparison with greater accuracy.
- A stopwatch is used to measure the time interval of an event. Mechanical stopwatches have least count upto 0.1 seconds. Digital stopwatch of least count 0.01s are common.
- A measuring cylinder is a graduated glass cylinder marked in millilitres. It is used to measure the volume of a liquid and also to find the volume of an irregular shaped solid object.
- All the accurately known digits and the first doubtful digit in an expression are called significant figures. It reflects the precision of a measured value of a physical quantity.

QUESTIONS

1.1 Encircle the correct answer from the given choices.

i. The number of base units in SI are:

(a) 3 (b)6 (c)7 (d)9

ii. Which one of the following unit is not a derived unit?

(a) pascal (b) kilogramme

(c) newton (d) watt

iii. Amount of a substance in terms of numbers is measured in:

(a) gram (b) kilogramme

(c) newton (d) mole

iv. An interval of 200u s is equivalent to

(a) 0.2 s (b) 0.02 s

(c) $2x10^{-4}$s (d) $2x10^{-6}$s

v. Which one of the following is the smallest quantity?

(a) 0.01 g (b) 2 mg

(c) 100 u g (d) 5000 ng

vi. Which instrument is most suitable to measure the internal diameter of a test tube?

(a) metre rule

(b) Vernier Callipers

(c) measuring tap

(d) screw gauge

vii. A student claimed the diameter of a wire as 1.032 cm using Vernier Callipers. Upto what extent do you agree with it?

(a) 1 cm (b) 1.0 cm

(c) 1.03 cm (d) 1.032 cm

viii. A measuring cylinder is used to measure:

(a) mass (b) area

(c) volume (d) level of a liquid

ix. A student noted the thickness of a glass sheet using a screw gauge. On the main scale, it reads 3 divisions while 8th division on the circular scale coincides with index line. Its thickness is:

(a) 3.8 cm (b) 3.08 mm

(c) 3.8 mm (d) 3.08 m

x. Significant figures in an expression are :

(a) all the digits

(b) all the accurately known digits

(c) all the accurately known digits and the first doubtful digit

(d) all the accurately known and all the doubtful digits

1.2 What is the difference between base quantities and derived quantities? Give three examples in each case.

1.3 **Pick out the base units in the following:**
joule, newton, kilogramme, hertz, mole, ampere, metre, kelvin, coulomb and watt.

1.4 **Find the base quantities involved in each of the following derived quantities:**
(a) speed (b) volume
(c) force (d) work

1.5 **Estimate your age in seconds.**

1.6 **What role SI units have played in the development of science?**

1.7 **What is meant by vernier constant?**

1.8 **What do you understand by the zero error of a measuring instrument?**

1.9 **Why is the use of zero error necessary in a measuring instrument?**

1.10 **What is a stopwatch? What is the least count of a mechanical stopwatch you have used in the laboratories?**

1.11 **Why do we need to measure extremely small interval of times?**

1.12 **What is meant by significant figures of a measurement?**

1.13 **How is precision related to the significant figures in a measured quantity?**

PROBLEMS

1.1 **Express the following quantities using prefixes.**
(a) 5000 g
(b) 2000 000 W
(b) 52 x10^{-10} kg
(c) 225x10^{-8}s
{(a) 5 kg (b)2MW
(c) 5.2 ug (d) 2.25 us }

1.2 **How do the prefixes micro, nano and pico relate to each other**?

1.3 **Your hair grow at the rate of 1 mm per day. Find their growth rate in nm s^{-1}**. (**11.57 nm s^{-1}**)

1.4 **Rewrite the following in standard form**.
(a) 1168x10^{-27} (b) 32x10^{-5}
(c) 725 x10^{-5} kg (d) 0.02 x10^{-8}
{(a) 1.168x10^{-24} (b) 3.2x10^{6}
(c)7.25g (d) 2x10^{-10}}

1.5 Write the following quantities in standard form.
(a) 6400 km
(b) 380 000 km
(c) 300 000 000 ms^{-1}
(d) seconds in a day
{(a) 6.4x10^{3} km (b) 3.8x10^{5} km
(c) 3x10^{8}ms1 (d) 8.64x10^{4}s}

1.6 On closing the jaws of a Vernier Callipers, zero of the vernier scale is on the right to its main scale such that 4th division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

(+0.04 cm, -0.04 cm)

1.7 A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5 mm. What is its least count?

(0.001 cm)

1.8 Which of the following quantities have three significant figures?

(a) 3.0066 m (b) 0.00309 kg

(c) 5.05×10^{-27} kg (d) 301.0 s

{(b) and (c)}

1.9 What are the significant figures in the following measurements?

(a) 1.009 m (b) 0.00450 kg

(c) 1.66×10^{-27} kg (d) 2001 s

{(a) 4 (b) 3 (c) 3 (d) 4}

1.10 A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area upto reasonable number of significant figures.

(36 cm2)