

Based on National Curriculum of Pakistan 2022-23

Model Textbook of

Physics

Grade

9

National Curriculum Council

Ministry of Federal Education and Professional Training



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Islamabad



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**Model Textbook of Physics
for Grade 9**



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Preface

This Model Textbook for Physic Grade 9 has been developed by NBF according to the National Curriculum of Pakistan 2022-2023. The aim of this textbook is to enhance learning abilities through inculcation of logical thinking in learners, and to develop higher order thinking processes by systematically building the foundation of learning from the previous grades. A key emphasis of the present textbook is creating real life linkage of the concepts and methods introduced. This approach was devised with the intent of enabling students to solve daily life problems as they grow up in the learning curve and also to fully grasp the conceptual basis that will be built in subsequent grades.

After amalgamation of the efforts of experts and experienced authors, this book was reviewed and finalized after extensive reviews by professional educationists. Efforts were made to make the contents student friendly and to develop the concepts in interesting ways.

The National Book Foundation is always striving for improvement in the quality of its textbooks. The present textbook features an improved design, better illustration and interesting activities relating to real life to make it attractive for young learners. However, there is always room for improvement, the suggestions and feedback of students, teachers and the community are most welcome for further enriching the subsequent editions of this textbook.

May Allah guide and help us (Ameen).

Dr. Raja Mazhar Hameed
Managing Director

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

اللہ کے نام سے شروع جو بڑا مہربان نہایت رحم والا ہے

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PHYSICAL QUANTITIES AND MEASUREMENT

UNIT

1

Which unit
was used by
ancient Egyptians
while building
pyramids?

Student Learning Outcomes (SLOs)

The students will

- [SLO: P-09-A-01] Differentiate between physical and non-physical quantities
- [SLO: P-09-A-02] Explain with examples that physics is based on physical quantities
- [SLO: P-09-A-03] Differentiate between base and derived physical quantities and units.
- [SLO: P-09-A-04] Apply the seven units of System International (SI)
- [SLO: P-09-A-05] Analyse and express numerical data using scientific notation
- [SLO: P-11-A-06] Analyse and express numerical data using prefixes.
- [SLO: P-09-A-07] Differentiate between scalar and vector quantities.
- [SLO: P-09-A-08] Justify that distance, speed, time, mass, energy, and temperature are scalar quantities.
- [SLO: P-09-A-09] Justify that displacement, force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength are vector quantities.
- [SLO: P-09-A-10] Determine, by calculation or graphically, the resultant of two vectors at right angles
- [SLO: P-09-A-11] Make reasonable estimates of physical quantities
- [SLO: P-09-A-12] Justify and illustrate the use of common lab instruments to measure length.
- [SLO: P-09-A-13] Justify and illustrate the use of measuring cylinders to measure volume.
- [SLO: P-09-A-14] Justify and illustrate how to measure time intervals using lab instruments.
- [SLO: P-09-A-15] Determine an average value for an empirical reading.
- [SLO: P-09-A-16] Round off and justify calculational estimates.
- [SLO: P-09-A-17] Critique and analyze experiments for sources of error.
- [SLO: P-11-A-09] Differentiate between precision and accuracy.
- [SLO: P-09-A-19] Determine the least count of a data collection instrument (analog) from its scale.

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.

Physics in Science: Physics is the most fundamental of all the sciences. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of physics. For example, biology uses the physics principles of fluid movement to understand how the blood flows through the heart, arteries, and veins. Chemistry relies on the physics of subatomic particles to understand why chemical reactions take place.

FIGURE 1.1 - PHYSICS AND TECHNOLOGY



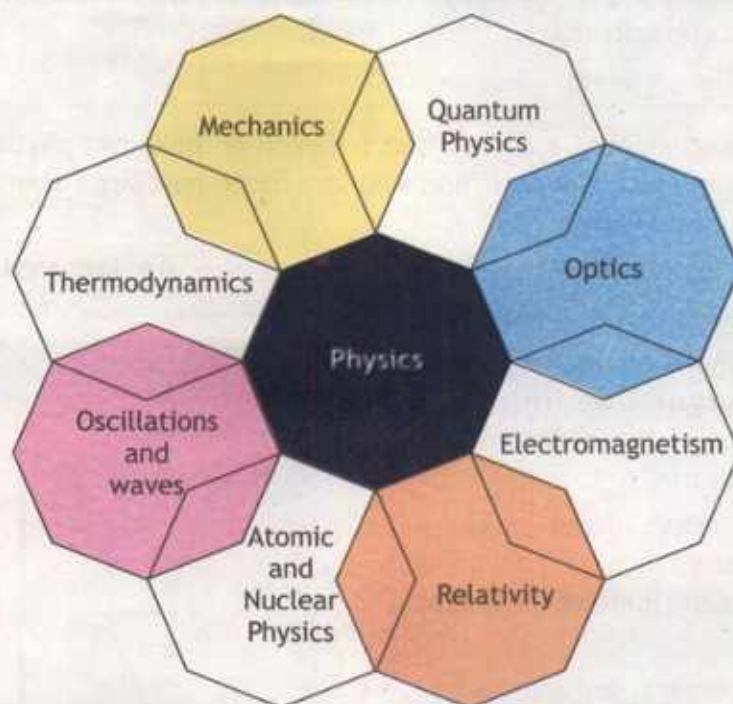
Physics and Technology: What are the technological devices that we use on a regular basis? Computers, smart phones, MP3 players, and internet come to our mind. What are technologies that you have only heard of? Rockets and space shuttles, Magnetically levitating trains, and microscopic robots that fight cancer cells in our bodies. All of these technologies, whether common place or exciting, are based on the principles of physics.

Physics is behind every technology and plays a key role in further development of these technologies, such as airplanes, computers, PET scans and nuclear weapons.



1.1.1 BRANCHES OF PHYSICS

Physics is vast and is therefore further subdivided in many other branches. These branches of physics are increasing as the technology is progressing, however the major branches of physics include mechanics, optics, oscillation and waves, thermodynamics, electromagnetism, astrophysics, quantum physics, atomic physics and nuclear physics.



The cubit was the measurement unit used by Egyptians to build the pyramid. The cubit is the measure from your elbow to the tip of your middle finger when your arm is extended.



Physics has strong connection with mathematics, to understand the nature physics we use mathematics as a tool. Therefore learning physics requires mathematical knowledge.



1.2 PHYSICAL AND NON-PHYSICAL QUANTITIES

“Physical quantities are those quantities which can be measured whereas non physical quantities are those quantities which can not be measured”.

Quantities like length, mass, time, density, temperature, can be defined and measured, therefore they are termed physical quantities while taste, feeling and color can not be measured so they are non physical quantities

POINT TO PONDER



Measurement is a comparison between an unknown physical quantity (like length, mass, time etc) and standard to see how large or small it is compared to that standard.

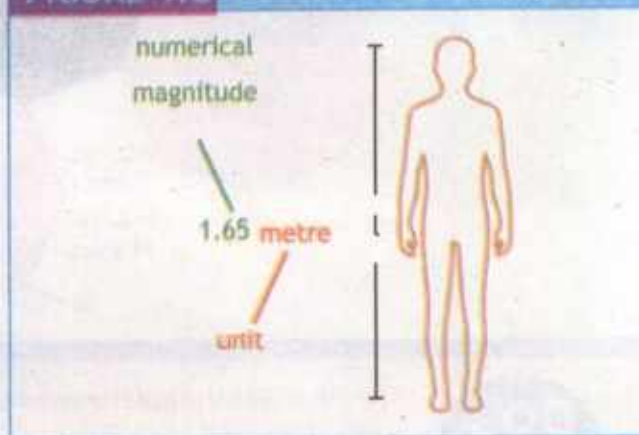
Unit is standard with which physical quantities are compared.

Measurement of a physical quantity consists of numerical magnitude (number representing the size of the quantity) and unit in which it is measured.

For example if the length of the person is 1.65 metres (5 foot and 5 inches), 1.65 is the numerical magnitude and meter is the unit as shown in figure 1.2.

To record a measurement, an appropriate unit is chosen and the size of quantity is then found with an instrument having a proper scale (like measuring tape).

FIGURE 1.2 LENGTH MEASUREMENT



1.2.1. BASE AND DERIVED PHYSICAL QUANTITIES

Base (or fundamental) physical quantities (like mass, length and time) are selected as the simplest form of physical quantities, such that all other physical quantities can be derived from them. The physical quantity obtained by multiplying or dividing base physical quantities are termed as the derived physical quantities.

1.3 INTERNATIONAL SYSTEM OF UNITS

‘A complete set of units for all physical quantities is called system of units’.

The international system of units is termed as System International (abbreviated as SI), a short form of the French name ‘Système International d’ Units’ which means ‘International System of Units’.



1.3.1. SYSTEM INTERNATIONAL (SI) BASE UNITS

In System International (SI) seven (07) physical quantities are chosen as base and their units are defined and standardized. These units are called base units. Each SI unit is defined carefully so that accurate and reproducible measurements can be made. The seven basic physical quantities, their SI base units and the symbols of SI units are given in the table 1.1.

TABLE 1.1 BASE UNITS FOR INTERNATIONAL SYSTEM OF UNITS			
SI Base Quantity		SI Base Unit	
Name	Symbol	Name	Symbol
length	l	meter	m
mass	m	kilogram	kg
time	t	second	s
electric current	I	ampere	A
temperature	T	kelvin	K
amount of substance	n	mole	mol
light intensity	I _v	candela	cd

1.3.2. SYSTEM INTERNATIONAL (SI) DERIVED UNITS

Units of derived quantities are obtained by multiplying and/or dividing base quantities. In SI units all other physical quantities can be derived from the seven base units.

For example, the unit for area is ' $m \times m = m^2$ ', in this example base unit of length is used. Similarly the unit for velocity is ' m/s ' and acceleration is ' m/s^2 '. Some derived units are given special names and symbols. For example force has derived units of ' $kg\ m/s^2$ ' which is given special name as 'newton' and represented as 'N'. Some derived quantities with derived units in terms of base units are given in table 1.2.

EXPLORE

<https://www.bipm.org/en/>

The BIPM is...

the international organization established by the Metre Convention in 1875 through which Member States act together to

TABLE 1.2 DERIVED UNITS FOR 'INTERNATIONAL SYSTEM OF UNITS'

Derived Quantity		SI Derived Unit	
Name	Symbol	Name	Symbol
area	A	square meter	m^2
volume	V	cubic meter	m^3
speed, velocity	v	meter per second	ms^{-1}
acceleration	a	meter per second squared	ms^{-2}
density	ρ	kilogram per cubic meter	kgm^{-3}
force	F	newton (N)	kgms^{-2}
pressure	P	pascal (Pa)	$\text{kgm}^{-1}\text{s}^{-2}$
energy	E, U	joule (J)	$\text{kgm}^2\text{s}^{-2}$

1.4 STANDARD FORM / SCIENTIFIC NOTATION

In physics we deal with numbers that are either very small or very large, for example, the width of the observable universe is approximately 880,000,000,000,000,000,000,000 metres (88 with 25 zeros). If we use this number often, it is not only time consuming but there are chances of reporting it wrong.

Scientific notation is an easy method of writing very large or small numbers in power of ten.



Standard form or scientific notation represents a number as the product of a number greater than 1 and less than 10 (called the mantissa) and a power of 10 (termed as exponent):

number = mantissa $\times 10^{\text{exponent}}$

Therefore the width of the observable universe can scientifically be written compactly as 8.8×10^{26} metres, where '8.8' is the mantissa and '26' is the exponent. Similarly the mass of earth is 5,980,000,000,000,000,000,000,000 kg which is written as 5.98×10^{24} kg and the diameter of hydrogen nucleus is about 0.0000000000000017 metres, which is 1.7×10^{-15} m.



1.5 PREFIXES TO POWER OF TEN

A mechanism through which numbers are expressed in power of ten that are given a proper name is called prefix.

Prefixes makes standard form or scientific notation further easier. Large numbers are simply written in more convenient prefix with units.

The thickness of a paper can be written conveniently in smaller units of millimetre instead of metre. Similarly the long distance between two cities may be expressed better in a bigger unit of distance, i.e., kilometre. Some prefixes in SI to replace powers of 10 are given in table 1.3.

TABLE 1.3 PREFIXES

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

For example

- the number of seconds in a day are:
 $86400 \text{ s} = 8.64 \times 10^4 \text{ s} = 86.4 \times 10^3 \text{ s} = 86.4 \text{ ks}$
- the distance to the nearest star alpha centauri is:
 $4.132 \times 10^{16} \text{ m} = 41.32 \times 10^{15} \text{ m} = 41.23 \text{ Pm}$
- the thickness of the page of this book is about:
 $4.0 \times 10^{-5} \text{ m} = 40 \times 10^{-3} \text{ m} = 40 \text{ mm}$
- the mass of grain of salt is:
 $1.0 \times 10^{-4} \text{ g} = 100 \times 10^{-2} \text{ g} = 100 \text{ mg}$



Volume is a derived quantity

$$1 \text{ L} = 1000 \text{ mL}$$

$$1 \text{ L} = 1 \text{ dm}^3$$

$$= (10 \text{ cm})^3$$

$$= 1000 \text{ cm}^3$$

$$1 \text{ mL} = 1 \text{ cm}^3$$



CAN YOU TELL?

Can you write the number in power of ten and choose prefix to the following numbers

- The mass of Sun is about 1,970,000,000,000,000,000,000,000 kg.
- radius of a hydrogen atom, is about 0.00000000005 m.
- The age of earth is about 143,300,000,000,000 s.

Can you express the following in terms of powers of 10.

- The thickness of sheet of paper is about 100,000 nanometers.
- Pakistan has a total installed power generation capacity of over 40,000 megawatt.
- A single hard disk capacity of computers has exceeded 30 terabyte.

EXAMPLE 1.1: SCIENTIFIC NOTATION

Convert the following numbers in Standard form / scientific notation.

- 149,530,000,000 m which is the average distance between earth and Sun.
- 0.0008 g which is the average mass of human hair.
- The number of seconds in a day.



SOLUTION

(a) For Standard form / scientific notation we can write the term as

$$\text{Distance} = 149530000000.0 \times 10^0 \text{ m}$$

For Standard form / scientific notation, in order to get mantissa (M), we have to move the decimal 11 digits towards left. Therefore, the power of 10 will be positive 11, that is

$$\text{Distance} = 1.4953 \times 10^{11} \text{ m}$$

Answer

Which is the average distance between earth and sun in standard form / scientific notation

(b) In Standard form / scientific notation we can write the term as

$$\text{Mass of hair} = 0.0008 \times 10^0 \text{ g}$$

$$\text{Mass of hair} = 8 \times 10^{-4} \text{ g}$$

Answer

(c) We know that there are 24 hours in a day, 60 minutes in an hour, and 60 s in a minute. These three relationships are conversion factors. As

$$1 \text{ d} = 86,400 \text{ s}$$



For Standard form/scientific notation we can write the term as:

$$1 \text{ d} = 86,400.0 \times 10^0 \text{ s}$$

$$1 \text{ d} = 8.64 \times 10^4 \text{ s}$$

Answer

EXAMPLE 1.2: PREFIXES

Write the numbers in standard/scientific notation and also represent using appropriate prefix.

(a) One ton of rice in gram

(b) The diameter of neutron is $0.0000000000000018 \text{ m}$.

SOLUTION

(a) One ton is equal to a mass of 1000 kilograms

$$1 \text{ ton} = 1000 \text{ kg}$$

As we know that: $1 \text{ kg} = 1000 \text{ g}$, therefore $1 \text{ ton} = 1000 \times 1000 \text{ g}$

$$1 \text{ ton} = 1,000,000 \text{ g} = 1,000,000.0 \times 10^0 \text{ g}$$

In scientific form: For Standard form / scientific notation in order to get mantissa (M), we have to move the decimal 6 digits towards left.

Therefore, the power of 10 will be positive 6, given by:

$$1 \text{ ton} = 1.0 \times 10^6 \text{ g}$$

Answer

Using prefix: As $10^6 = \text{Mega}$, therefore

$$1 \text{ ton} = 1.0 \text{ Mg}$$

Answer

(b) The diameter of proton is $0.0000000000000017 \text{ m}$, which can be written as

$$\text{Diameter of proton} = 0.0000000000000017 \times 10^0 \text{ m}.$$

$$\text{Diameter of proton} = 1.7 \times 10^{-15} \text{ m}$$

Answer

Using prefix: $10^{-15} = \text{femto}$, therefore

$$\text{Diameter of proton} = 1.7 \text{ fm}$$

Answer





1.6 SCALARS AND VECTORS

Does direction of wind matter when you fly a kite? You need to know the direction in which the air is blowing; otherwise, it will be difficult for you to keep your kite flying. Some physical quantities require direction to be specified completely. Therefore these directional properties can be used to categorize physical quantities as scalars and vectors.

1.6.1. SCALAR QUANTITIES OR SCALARS

Physical quantities which can be completely described only by its numerical magnitude (or size) with proper unit are termed as scalar quantities or simply scalars. Foreexamples distance, speed, time, mass, energy, and temperature etc are scalar quantities.

consider a man travels a distance of 4.5km but its direction is not specified but only this magnitude is given so it is said to be scalar quantity similarly we say that time is a scalar quantity, because when we say that time measurement is 30 s, here '30' is the numerical magnitude and 's' is proper unit. We does not need to state the direction of time.

Scalar quantities can be added, subtracted and multiplied by using ordinary rules of algebra. For example if we took 5 s to reach the door of the classroom and another 20 s to reach the gate of school, the total time we took is (5 s + 20 s) 25 seconds.

1.6.2. VECTOR QUANTITIES OR VECTORS

Physical quantities which require not only numerical magnitude (or size) with proper unit, but also the direction are termed as vector quantities or simply vectors. Vector quantities, such as displacement, force, weight, velocity, acceleration, momentum, electric field strength, and gravitational field strength, require both numerical magnitude and direction. When we refer to a vector quantity, we not only mention its numerical magnitude and unit, but also its direction. To fully describe a vector, its direction must be specified.

Since vector quantities are associated with direction, they cannot be added, subtracted, or multiplied using the usual rules of algebra. They follow their own set of rules known as vector algebra.

POINT TO PONDER



A coordinate system is used to locate the position of any point and that point can be plotted as an ordered pair (x, y) known as Coordinates. The horizontal number line is called 'X-axis' and the vertical number line is

called 'Y-axis' and the point of intersection of these two axes is known as the origin and it is denoted as 'O'. The reference frame is the coordinate system from which the positions of objects are described.

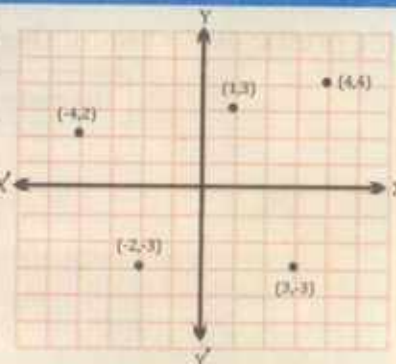


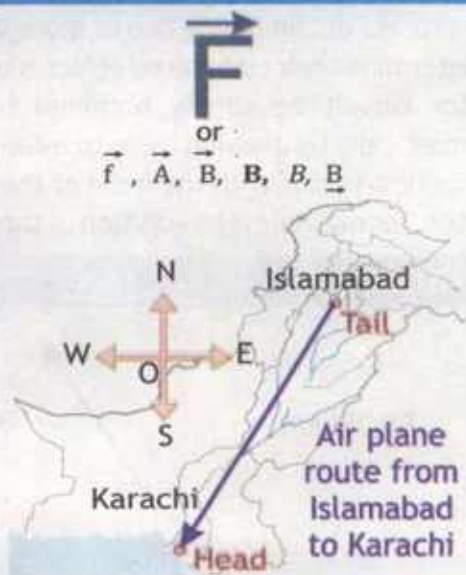


FIGURE 1.3 VECTOR REPRESENTATION

Symbolically a vector can be represented by a letter either capital or small. (e.g F and f or A and B) with an arrow over it.

Graphically a vector is represented by an arrow, the length of the arrow gives the magnitude with proper unit (under certain scale) and the arrow head points the direction of the vector. To use vectors we place them in coordinate axis.

Aeroplane route from Islamabad to Karachi is shown as a vector in figure. Here a Geographical Coordinate System having directions as North (N), East (E), West (W) and South (S) is used.



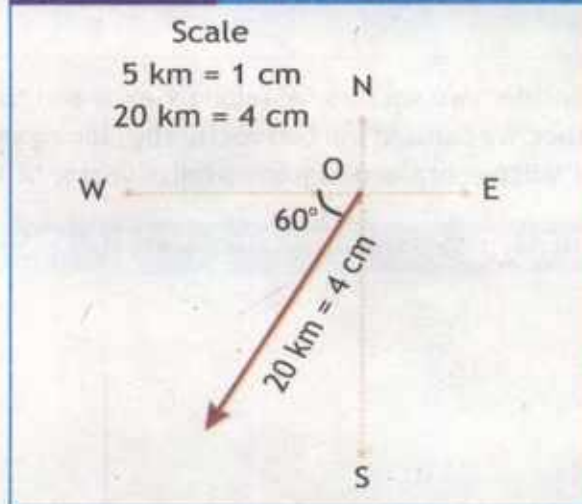
Steps to Represent a Vector in Coordinate System

The following method is used to represent a vector

1. Choose and draw a coordinate system.
2. Select a suitable scale.
3. Draw a line in the fixed direction. Cut the line equal to the magnitude of the vector according to the chosen scale.
4. Put an arrow along the direction of the vector.

For example the representation of helicopter as it moves to 20 km from origin towards 60° south of west is shown in the figure 1.4.

FIGURE 1.4 HELICOPTER MOTION



Since displacement, force, weight, velocity, acceleration, momentum, electric field strength, and gravitational field strength are vector quantities or vectors. They will require to follow the rules of vector addition. This means that when we combine two vectors, the resulting value must also result as a vector.

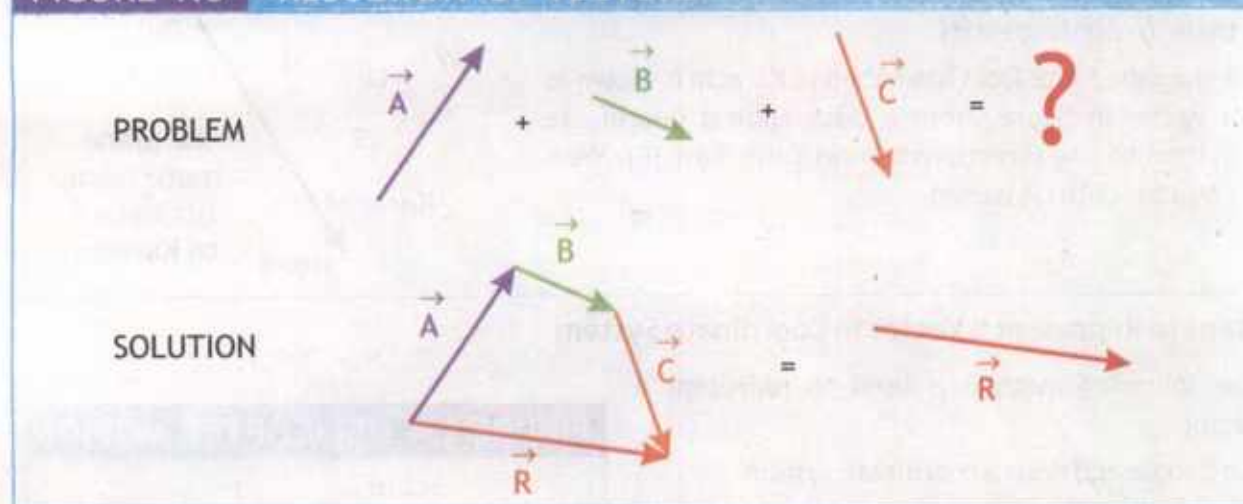


UNIT 1 PHYSICAL QUANTITIES AND MEASUREMENT

1.6.3. ADDING VECTOR QUANTITIES

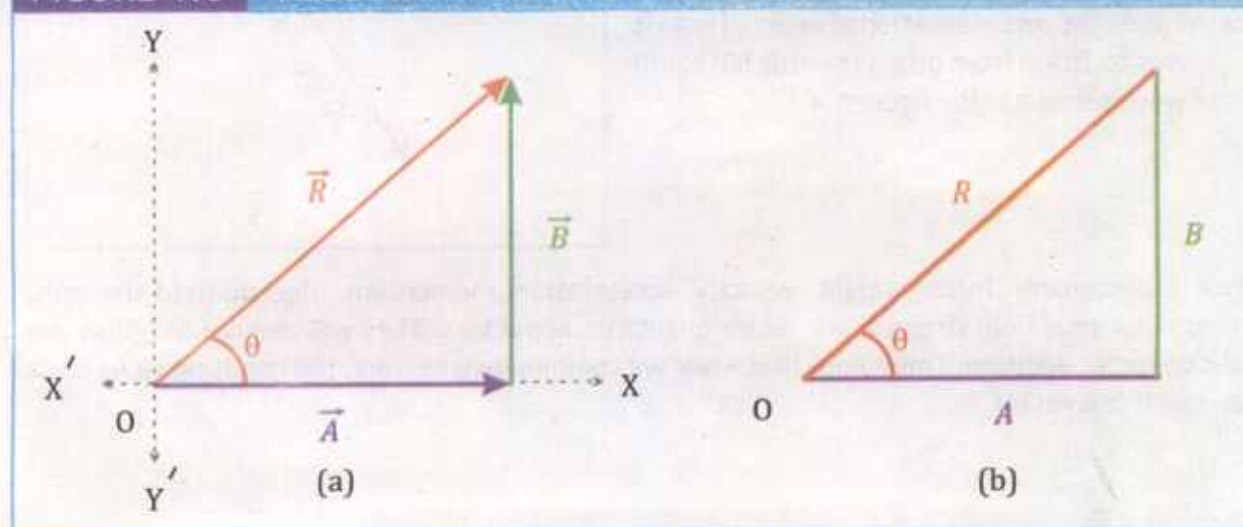
The process of combining two or more vectors into a single vector (called as resultant vector) to determine their cumulated effect is termed as vector addition. In vector algebra, the resultant vector cannot be simply obtained by adding vector values. Vectors may be added geometrically by drawing them to a common scale and placing them head to tail. Joining the tail of the first vector with the head of the last will give another vector which will be its **resultant vector**. For example, the addition of three vectors is shown in figure 1.5.

FIGURE 1.5 RESULTANT OF VECTORS



Consider two vectors ' $\vec{A}$ ' (along x-axis) and ' $\vec{B}$ ' (along y-axis), which are perpendicular to each other. We can add the two vectors by placing vector ' $\vec{B}$ ' on head of vector ' $\vec{A}$ ', the resultant vector ' $\vec{R}$ ' will be obtained by joining tail of vector ' $\vec{A}$ ' with head of vector ' $\vec{B}$ ', as shown in figure 1.6.

FIGURE 1.6 RESULTANT OF TWO VECTORS





POINT TO PONDER



Does vector addition depends on the order? Will it make any difference if we add vector ' $\vec{A}$ ' with vector ' $\vec{B}$ ' or vector ' $\vec{A}$ ' with vector ' $\vec{B}$ '.

1.7 MEASURING INSTRUMENTS

Physics is built on definitions that are expressed in terms of measurements. For measurements of physical quantities we need devices termed as measuring instruments. These range from simple objects such as rulers and stopwatches to Atomic Force Microscope (AFM) and Scanning Tunneling Electron Microscope (STEM).

All measuring instruments have some measuring limitations.

Least count is the minimum value that can be measured on the scale of measuring instrument. The measurement of every instrument is therefore limited to its least count.

1.7.1 METRE RULE AND MEASURING TAPE

We use ruler to draw margin lines on our notebooks. Have you ever used the scale on it to draw the lines with exact lengths? A meter rule is a physics laboratory tool, used to measure the length of objects.

Metre rules are one metre long (as compared to the standard metre). Metre Rulers usually have 1000 small divisions on them called millimetres. Such metre rulers have least count of 1 mm as shown in figure 1.7.

These instruments have similar scale on it as drawn on our rulers, principally rulers are shorter version of metre rule.

FIGURE 1.7 METRE RULE



A measuring tape is a flexible ruler used to measure larger distance or length. It consists of a ribbon of cloth, plastic, metal, or fiberglass with linear measurement markings on it. The tape is usually housed in a compact case, and it can be pulled out and locked in place to measure distances. The most common units of measurement on a measuring tape are inches and centimeters. Measuring tapes come in various lengths, typically ranging from a few feet to several meters.

POINT TO PONDER



Can you measure distances smaller than 1 mm on metre rule? Why?

CAN YOU TELL?



Some metre rulers like the one shown in the figure 1.7 are marked with inches and feet? What is the least count of metre rule on this scale?



ACTIVITY



In this activity the students will determine their height in metres and millimetres by making a paper scale and pasting it on the wall. The paper scale should be 2 m large with marking in metre, centimetre and millimetre.

They can form pair to measure each other heights, with paper scale.

1.7.2 VERNIER CALIPER

In physics sometimes we need to measure a length smaller than 1 mm. A vernier calliper can help take smaller than a millimetre reading.

'Vernier caliper is a device used to measure a fraction of a smallest division on scale by sliding another scale over it'.

It can be used to measure the thickness, diameter or width of an object and the internal, external diameter of hollow cylinder.

FIGURE 1.8 VERNIER CALLIPERS



There are two scales on vernier callipers.

A main scale which has markings of usually of 1 mm each and it contains jaw on its left end.

A sliding scale called vernier scale which has markings of some multiple of the marking on the main scale.

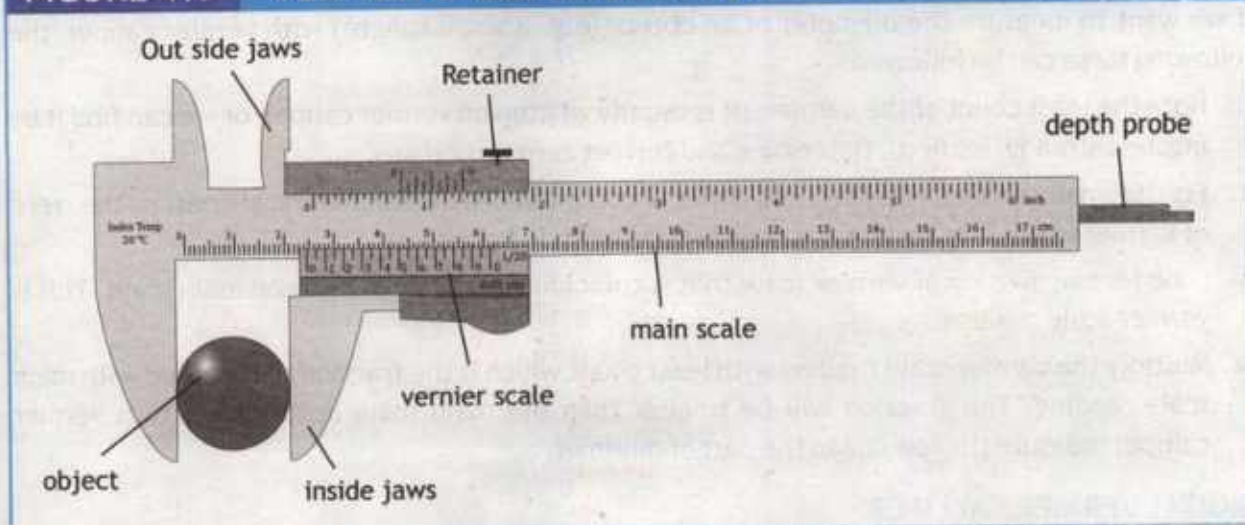
Minimum length which can be measured accurately with the help of a vernier callipers is called least count (vernier constant) of vernier callipers.

Least count can be obtained from dividing the value of smallest division on main scale by total number of divisions or vernier scale.

$$\text{Least Count} = \frac{\text{Smallest division on main scale}}{\text{Total number of divisions on vernier scale}}$$



FIGURE 1.9 VERNIER CALLIPER DIAGRAM



If the smallest main scale division is 1 mm and vernier scale division has 10 division on it then the least count of vernier caliper is:

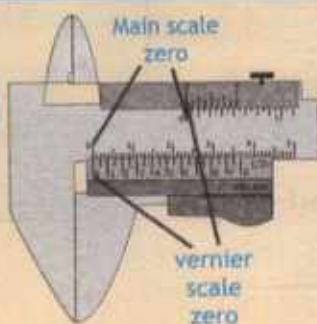
$$\text{Least Count} = \frac{1 \text{ mm}}{10} = 0.1 \text{ mm}$$



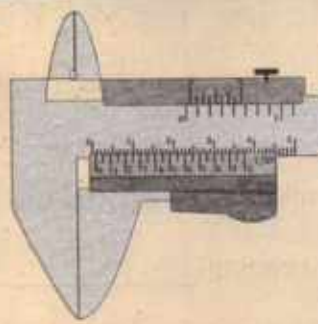
CAN YOU TELL?

What is the length of the object measured by metre rod if it is 20.14 cm measured by vernier callipers?

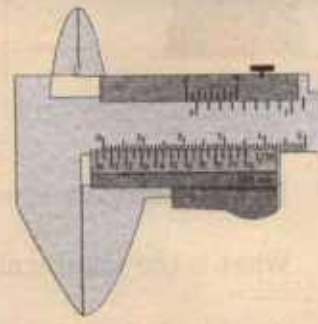
On closing the jaws of the vernier calipers, the zero of the vernier scale should coincide with the zero of the main scale. If their zeros does not coincide, there is an error in the instrument, called zero error. The zero error can be corrected which you will learn in laboratory work.



(a) There is no zero error as the zero line of vernier scale is coinciding with the zero of vernier scale.



(b) Zero error is positive as vernier scale is towards the right of the zero of main scale.



(c) Zero error is negative as vernier scale is towards the left of the zero of main scale.

TAKING MEASUREMENT WITH VERNIER CALLIPERS

If we want to measure the diameter of an object (e.g. a small sphere) with vernier caliper, the following steps can be followed.

- Note the least count of the vernier, (it is usually written on vernier caliper, or we can find it by method already learned). Determine and correct zero error if any.
- Fix the small sphere in the jaws and note the complete divisions of main scale past by the zero of vernier scale. This is main scale reading as shown in figure 1.6.
- Look for the division of vernier scale that is coinciding with any division on main scale. This is vernier scale reading.
- Multiply the vernier scale reading with least count which is the fraction to be added with main scale reading. This fraction will be smaller than the main scale least count, thus vernier calliper measure the reading to the part of millimetre.

DIGITAL VERNIER CALLIPER

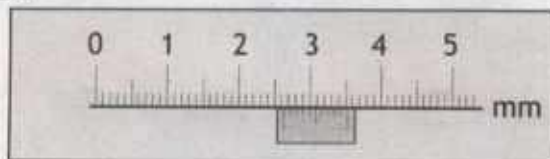
Digital Vernier Callipers has greater precision than mechanical vernier Callipers. Least count of Digital Vernier Callipers is 0.01 mm.



ACTIVITY



Read the following Vernier Caliper measurement, and answer the following questions.



If the main scale is in millimetre, what is the least count? _____

What is the main scale reading? _____

What is the vernier scale reading? _____

What is total reading of the measurement? _____



1.7.3 SCREW GAUGE

Screw gauge is also length measuring device and is used for measurements even smaller than vernier callipers. 'Screw Gauge is a device used to measure a fraction of a smallest division on scale by rotating circular scale over it'.

The distance traveled by the circular scale on linear (or main) scale in one rotation is called the pitch of the screw gauge.

The minimum length which can be measured accurately by a screw gauge is called least count of the screw gauge. The least count of screw gauge is found by dividing its pitch by the number of circular scale divisions.

FIGURE 1.10 SCREW GAUGE

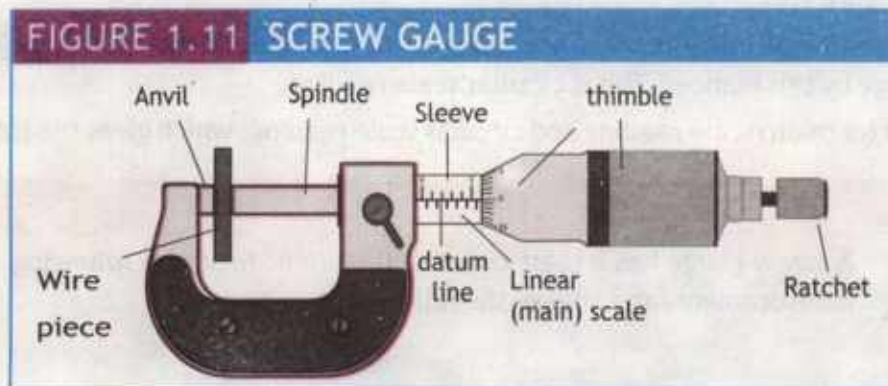


$$\text{Least Count} = \frac{\text{Pitch of Screw Gauge}}{\text{Total Number of Divisions on Circular Scale}}$$

If the pitch of the screw gauge is 0.5 mm and the number of divisions on circular scale is 50 then

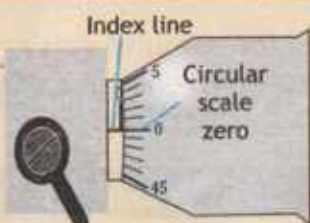
$$\text{Least Count} = \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm}$$

FIGURE 1.11 SCREW GAUGE

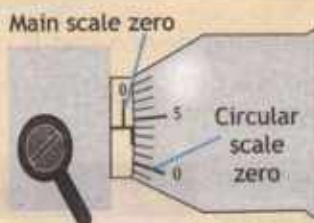


ZERO ERROR IN SCREW GAUGE

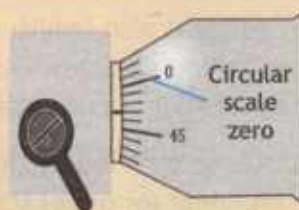
Turn the thimble until the anvil and spindle meet, datum line of the linear scale must meet with the zero on the thimble scale. If the zero mark on the thimble scale (or circular scale) does not lie directly opposite the datum line of the main scale we say that there is zero error. The zero error and its correction will be discussed in laboratory work.



(a) As zero of circular scale is exactly on the index line hence there is no zero error.



(b) Zero error is positive if zero of circular scale has not reached zero of main scale.



(c) Zero error is negative if zero of circular scale has passed zero of main scale.

TAKING MEASUREMENT WITH SCREW GAUGE

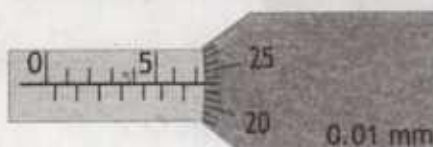
If we want to measure the diameter of an object (e.g a wire piece) with screw gauge, the following steps can be followed.

- Note the pitch and least count of the screw gauge and determine the zero error (if any).
- Place the object (e.g a wire piece) between with spindle and anvil. Now gently close the gap between the spindle and the anvil by turning the ratchet.
- Turn the ratchet until it starts to click. The ratchet prevents the user from exerting too much pressure on the object.
- Read the main scale reading, which is the reading shown (or unblocked) by circular scale as shown in figure 1.8.
- Identify the line of circular scale aligned with datum line, now multiply the least count of screw gauge by this number. This is circular scale reading.
- Add linear (or main) scale reading and circular scale reading, which gives the total reading.

ACTIVITY



A screw gauge has a least count of 0.01 mm. Read the following screw gauge measurement, and answer the following questions.



What is the main scale reading? _____

What is the circular scale reading? _____

What is total reading of the measurement? _____



CAN YOU TELL?



You have to measure the thickness of page and internal diameter of a beaker which instrument would you use vernier calliper or screw gauge? Why?

FOR YOUR INFORMATION

Least count of ruler is 1mm. It is 0.1mm for Vernier Callipers and 0.01mm for micrometer screw gauge.

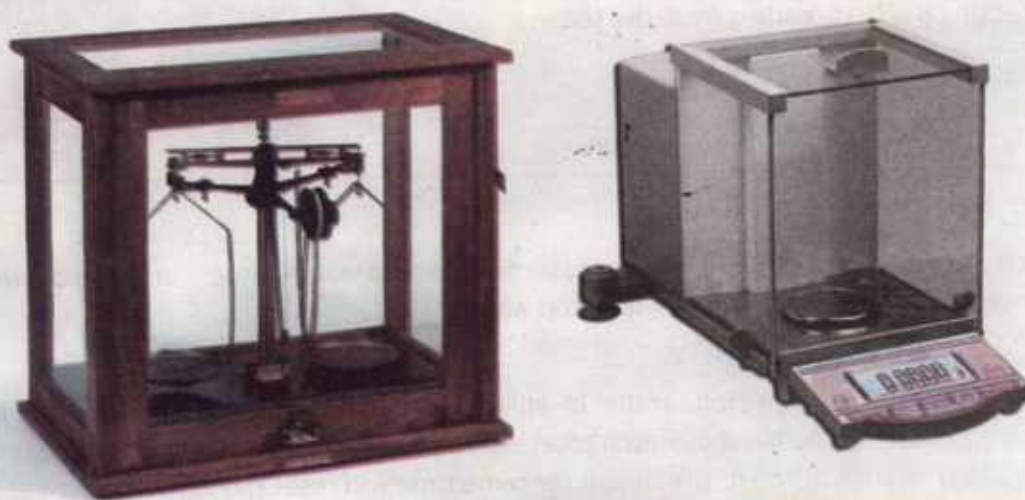
Thus measurements taken by micrometer screw gauge are the most precise than the other two.

1.7.4 PHYSICAL BALANCE

The balance (also balance scale, beam balance and laboratory balance) was the first mass measuring instrument invented. A physical balance as shown in figure 1.12 (a) is a very sensitive common balance which can measure weights in milligram order. It consists of a vertical pillar having a horizontal beam, resting on knife edge with two pans. A long pointer is attached to the middle of the beam.

Leveling screws are used to level the physical balance, while the pointer is set at the center of the scale by adjusting screws. It is placed in a protective glass case so that even dust and wind can not affect the accuracy of the instrument. A weight box containing standard weights comes with the balance. The mass of a body is found by placing the body in one pan, placing some standard weights in the other, and then calculating it from the standard weights placed and the resting point of the pointer.

FIGURE 1.12 PHYSICAL BALANCE

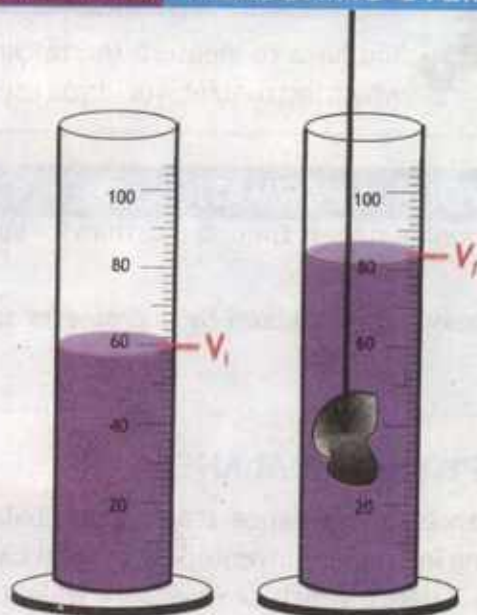




1.7.5 MEASURING CYLINDER

A measuring cylinder is a tool used in laboratories to measure the volume of liquids, chemicals, or solutions. It is also known as a graduated cylinder. Measuring cylinders are typically made of transparent plastic or glass and have a vertical scale in milliliters (ml) or cubic centimeters (cm^3). The volume of a liquid can be determined by measuring the height of the liquid in the cylinder. The least count of a measuring cylinder is usually 1 cm^3 , meaning that any volume change smaller than this cannot be measured. Measuring cylinders come in various sizes, ranging from small capacities of a few milliliters to larger capacities of several liters. The choice of cylinder size depends on the volume of the liquid being measured.

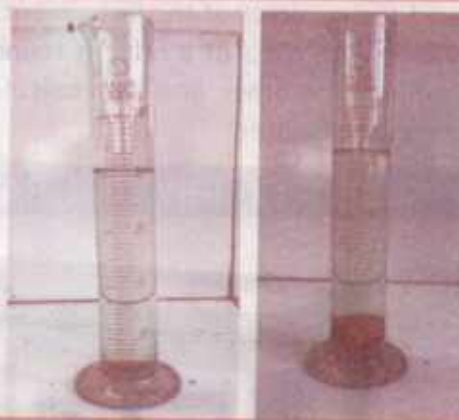
FIGURE 1.13 MEASURING CYLINDER



ACTIVITY



Measuring cylinder can be used for measuring the volume of an irregular solid body such as metallic bob as shown in figure. When the object is completely immersed the volume of the water is read again. The volume of the object is found by subtracting the first reading from the second.



1.7.6 STOP WATCH

The duration of specific interval of time is measured by a stop watch. Stop watch are of two main types i.e. mechanical stop watch and digital stop watch.

MECHANICAL / ANALOGUE STOP WATCH

It has two circular dials, a large circular dial in which a second hand of watch rotates and a small minute hand in which minute hand of watch rotates as shown in figure 1.14. The watch starts and stops by pressing the knob at top it, pressing it for some time will reset the watch back to zero.



FIGURE 1.14 MECHANICAL AND DIGITAL STOP WATCH



Generally the least count of analogue stop watch is 1 s and digital stop watch is 0.1 s

DIGITAL STOP WATCH

Digital stop watch are usually controlled by two buttons on the case as shown in the figure. Pressing the left button starts the timer and by pressing it again the time stops, thus the elapsed time is shown in the figure 1.14.

Pressing the right button resets the stopwatch to zero. The right button is also used to record split times or lap times.

1.8 ERRORS

Every measurement, no matter how carefully taken, has a certain amount of doubt known as error. Error is simply the uncertainty that arises during measurement. This means that all measurements are only approximate due to the presence of errors.

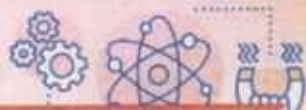
There are two main types of errors in measurement: systematic errors and random errors.

1.8.1 SYSTEMATIC ERRORS

Systematic errors tend to occur consistently in one direction, either positive or negative. Some sources of systematic errors include:

- (a) Instrumental errors, which result from imperfections in the design or calibration of the measuring instrument, as well as zero errors.
- (b) Imperfections in the experimental technique or procedure, such as changes in external conditions like temperature, humidity, or wind velocity, which can systematically affect the measurement.
- (c) Personal errors, which arise from an individual's bias, improper setup of the apparatus, or carelessness in taking observations without following proper precautions.

Systematic errors can be reduced by improving experimental techniques, choosing better instruments, and minimizing personal bias as much as possible. These errors can be estimated to some extent for a given setup, and the necessary adjustments can be made to the measurements.

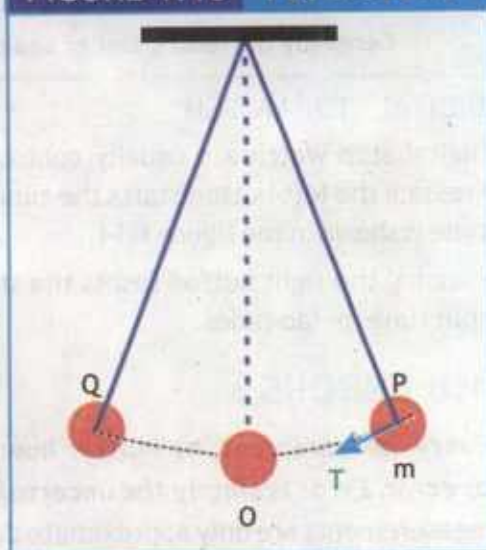


1.8.2 RANDOM ERRORS

Random errors are unpredictable and uncontrollable errors that can happen irregularly. These errors can be caused by fluctuations in experimental conditions or imperfections in measuring instruments. The person conducting the measurements can also introduce variability due to factors like reaction time or technique. Because of this, if the same person repeats an observation multiple times, they are likely to get different readings each time. To minimize random errors, it is important to take repeated measurements and use statistical analysis to account for the variability.

During measurements, it is always a good idea to take multiple of the same measurement and find the mean, as it reduces errors. A simple pendulum is simply a mass that swings back and forth about a fixed point as shown in figure 1.15. One single oscillation of a pendulum is when it swings back to the exact same position and achieves the same state of motion that it started at. For example, if the pendulum started swinging from its right most point (from its position of maximum amplitude), the mass would have to swing towards the left and then come back all the way to the right to complete one oscillation. The time taken to complete a single oscillation is called a period. To measure the period of a pendulum, you usually measure the time taken for ten oscillations and then calculate the mean.

FIGURE 1.15 PENDULUM



That is, you divide the total length of time by 10, to get the period of one oscillation. This will reduce the error in measurement as human reflexes are usually too slow to be completely accurate, and that inaccuracy can have a major impact on something as small as a period.

1.9 PRECISION AND ACCURACY

Precision and accuracy are both important factors in determining the reliability and validity of measurements and experimental results. While precision focuses on the consistency and repeatability of results, accuracy is concerned with how close the measured values are to the true or accepted values.

Precision can be thought of as the degree of agreement between repeated measurements of the same quantity. If a set of measurements consistently yields similar results, with little variation or scatter, then it is considered to be precise. This indicates that the measurement process is reliable and consistent, and that the results can be reproduced under the same conditions. For example, a scale that always gives the same weight within a margin of 0.1 kg is precise, even if it consistently overestimates the true weight by 0.5 kg (not accurate).



Accuracy, on the other hand, refers to how close a measured value is to the true or accepted value. It is a measure of the absence of systematic errors or biases in the measurement process. An accurate measurement is one that is close to the true value, regardless of whether it is consistently reproducible. For example, thermometer that consistently reads 2 degrees Celsius higher than the actual temperature is not accurate, even if its readings are very precise (always 2 degrees above).

precision focuses on the consistency and reproducibility of measurements, while accuracy assesses how close the average of those measurements is to the true value.

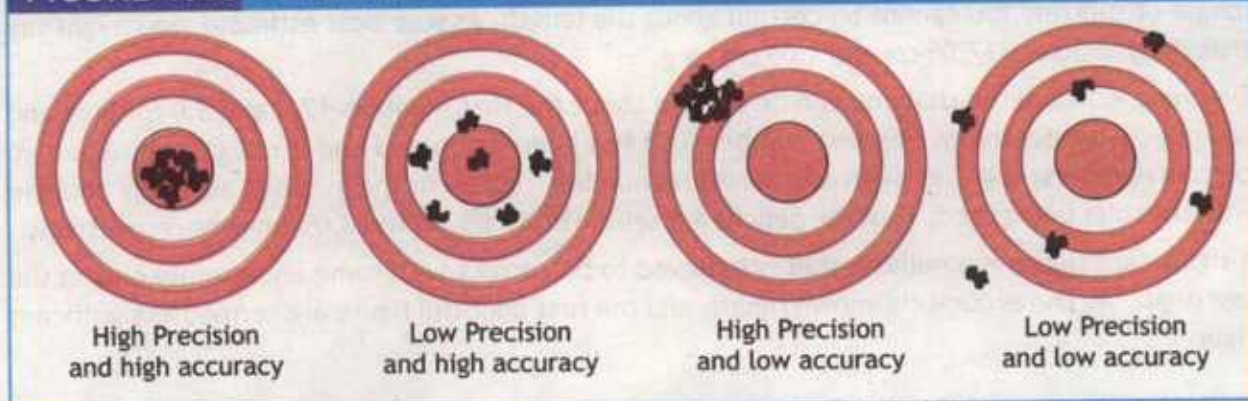
Imagine throwing darts at a target as shown in figure 1.16. If your darts land close to the center of the target (hitting the bullseye is ideal) your aim will be referred as accurate. Your darts are grouped tightly together, even if they're not in the center (a tight cluster off-center) your aim will be termed as precise, therefore, it's possible for something to be:

Accurate and precise: Your darts hit the bullseye and are tightly grouped.

Accurate but not precise: Your darts land near the center, but they're scattered all over the place.

Precise but not accurate: Your darts are tightly grouped, but they're all off-center in the same direction.

FIGURE 1.16 PRECISION AND ACCURACY



CAN YOU TELL?

Books in a library were counted one by one. There were a total of 57,000 books in the library. How many significant digits are there in the result? Will the result change if the books are measured in the packets of 10?

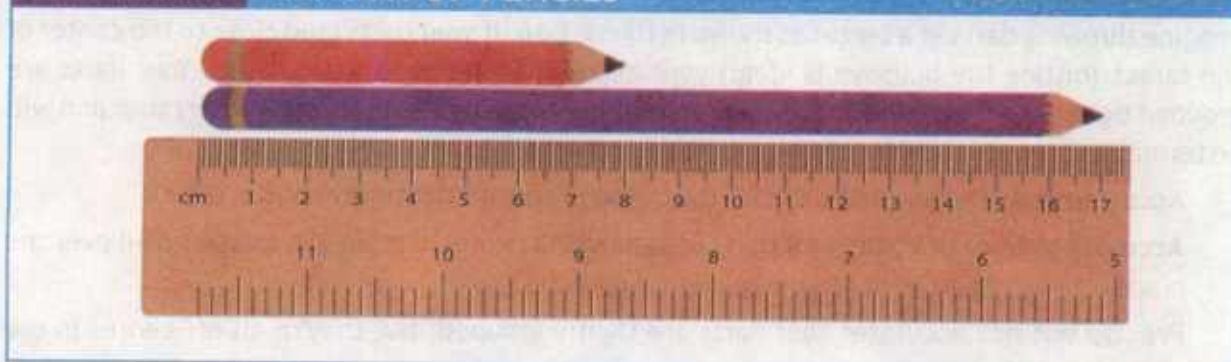
In practice, both precision and accuracy are desirable qualities in measurements. A measurement can be precise but not accurate, or accurate but not precise. Ideally, measurements should be both precise and accurate, meaning that they are both consistent and close to the true value. Achieving both precision and accuracy often requires careful calibration of instruments, control of experimental conditions, and consideration of sources of error.

1.10 SIGNIFICANT FIGURES

There are two types of values, exact and measured. Exact values are those that are counted clearly. For example while reporting 3 pencils or 2 books, we can indicate the exact number of these items.

The numerical value of any measurement will always contain some uncertainty. Suppose, for example, that you are measuring the length of two pencils as shown in figure 1.17.

FIGURE 1.17 LENGTH OF PENCILS



It seems clear that the length of blue pencil is greater than 17 cm but shorter than 17.1 cm, similarly the length of red pencil is greater than 8 cm but shorter than 8.1 cm. But how much longer or shorter? You cannot be certain about the length. As your best estimate, you might say that the pencils are 17.05 cm and 8.05 cm long.

Everyone would agree that you can be certain about the first numbers 17.0 and 8.0 for blue and red pencils respectively. The last number 0.05 has been estimated and is not certain. The two certain numbers, together with one uncertain number, represent the greatest accuracy possible with the ruler being used. Thus the pencils are said to be 17.05 cm and 8.05 cm long respectively.

A significant figure is a number that is believed to be correct with some uncertainty only in the last digit. 'All the accurately known figures and the first doubtful figure are termed as significant figures'.

MINI-LAB



Measure the length, width and thickness of physics textbook and report your observations in significant figures. Does your reading depends upon the instrument you used for measurement?

1.10.1 GENERAL RULES FOR WRITING SIGNIFICANT FIGURES

There are a few simple rules that help us determine how many significant figures are contained in a reported measurement:

1. All digits reported as a direct result of a measurement are significant.



- The reported NONZERO digits (all digits from 1 to 9) are always significant. For example the number of significant figures in 23.457 is 5.
- In figures reported as larger than the digit 1, the digit 0 is not significant when it follows a nonzero digit to indicate place. For example, in a report that '29,000 spectators watched a cricket match'. The digits 2 and 9 are significant but the zeros are not significant. In this situation, the 29 is the measured part of the figure, and the three zeros tell you an estimate of how many watched the match. If this figure is a measurement rather than an estimate, then to avoid confusion it is written in scientific notation with exact number of significant figures as in measurement e.g 2.90×10^5 showing three significant figures or 2.900×10^5 showing four significant figures or even 2.9000×10^5 showing 5 significant figures.
- In figures reported as smaller than the digit 1, zeros after a decimal point that come before nonzero digits are not significant and serve only as place holders. For example, 0.0029 has two significant figures: 2 and 9. The zeros after a nonzero digit indicate a measurement, so these zeros are significant. The figure 0.00290, for example, has three significant figures.

EXAMPLE 1.3: SIGNIFICANT FIGURE

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

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

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

$$5.80 \times 10^{-3} \text{ km.}$$

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

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

1.10.2 ROUNDING OFF NUMBERS AND SIGNIFICANT FIGURES

Rounding off numbers is an essential practice in scientific and quantitative contexts as it allows for the presentation of numbers with the appropriate level of precision. In these fields, accuracy and precision are crucial, and rounding off numbers helps to achieve this.



When dealing with measurements or calculations, it is often necessary to express the result in a more manageable or meaningful form. Rounding off numbers allows scientists and researchers to simplify complex figures without sacrificing the overall accuracy of the data.

Significant figures play a vital role in determining which digits in a number are reliable and meaningful. They indicate the precision of a measurement or calculation by identifying the digits that are known with certainty. By using significant figures, scientists can convey the level of uncertainty associated with a particular value. For example, consider a scientific experiment that measures the length of an object to be 3.5678 centimeters. While this measurement may be precise, it is not practical to report it with such detail. Rounding off the number to three significant figures, we can express it as 3.57 centimeters, which provides a more concise representation without compromising the accuracy of the measurement.

Rounding numbers is the act of approximating a number to a simpler value that is easier to use, understand, or work with. It includes reducing the number of digits while maintaining an appropriate level of accuracy for the situation.

A. Rounding rules for whole numbers: When rounding to a specific whole number of significant figures, we follow these steps:

1. Always choose the smaller place value for an accurate final result. Find the next smaller place to the right of the number being rounded off. For example, if rounding off a digit from the tens place, look at the digit in the ones place.
2. If the digit in the smallest place is less than 5, leave it as it is. Any digits after that become zero, which is called rounding down.
3. If the digit in the smallest place is greater than or equal to 5, add +1 to that digit. Any digits after that become zero, which is called rounding up.

B. Rounding rules for decimal numbers: The rules for rounding decimal numbers are as follows:

1. Find the digit you want to round and look at the digit to its right.
2. If the digits to the right are less than 5, treat them as zero.
3. If the digits to the right are 5 or greater, add 1 to that digit and treat all other digits as zero.

EXAMPLE 1.4: ROUNDING OFF

Round off the following numbers to

- | | | | |
|------------------------------|----------|-------------|-------------|
| (a) Two decimal points | i) 3.876 | ii) 657.873 | iii) 0.0857 |
| (b) Three significant digits | i) 24.68 | ii) 0.07683 | iii) 7,847 |

SOLUTION

a) In order to round off a number to two decimal points, we will drop all digits after the decimal except two.

- i) 3.876: Here the dropping digit is 6, which is greater than 5, so, it will be dropped by increasing the next digit 7. So, the answer is 3.88.



- ii) 657.873: Here the dropping digit is 3, which is smaller than 5, so, it will be dropped without any change to the next digit. So, the answer is 657.87.
- iii) 0.0857: Here the dropping digits are 5 and 7. After dropping 7 (which is greater than 5), the next digit will become 6 to get 0.086. Now by dropping 6, the next digit will become 9. So, the answer is 0.09.
- b) In order to round off a number to three significant digits, we will drop or replace with zero all digits except three significant digits.
- i) 24.68: Here we will drop the digit 8, which is greater than 5, so it will increase the next digit to 7. So, the answer is 24.7.
- ii) 0.07683: Here we will drop the digit 3, which is smaller than 5, so it will not change the next digit. So, the answer is 0.0768.
- iii) 7,847: As this is a whole number so, the digit 7 is replaced by zero. As it is greater than 5, so it will increase the next digit to 5. So, the answer is 7,850

SUMMARY

Physics is the branch of science which deals with the study of matter and energy.

Physical quantities are measurable quantities

System International (SI) is the system of units which consists of seven base units and a number of derived units.

Seven Base SI Units are metre (length), kilogram (mass), second (time), ampere (current), candela (luminous intensity), Kelvin (temperature) and mole (amount of substance).

Scientific Notation is an internationally accepted way of writing numbers in which numbers are recorded using the power of ten and there is only one non zero digit before the decimal.

Vernier calliper is a device used to measure a fraction of smallest scale division by sliding another scale over it.

Screw Gauge is a device used to measure a fraction of smallest scale division by rotatory motion of circular scale over it.

Stop Watch is an instrument used for measurement of time interval

Significant Figures are the accurately known digits and first doubtful digit in any measurement.



EXERCISE



MULTIPLE CHOICE QUESTIONS

Q1. Choose the best possible option.

- Which one of the following unit is not a derived unit?
A. pascal B. kilogram C. newton D. watt
- Amount of a substance in terms of numbers is measured in:
A. gram B. kilogram C. newton D. mole
- The number of significant figures in 0.00650 s are:
A. . 2 B. . 3 C. 5 D. 6
- Which of the following numbers show 4 significant digits?
A. 9000.8 B. 4 C. 5174.00 D. 0.001248
- Which of following prefix represents a largest value?
A. mega B. pico C. peta D. kilo
- Micrometer can be used to measure:
A. current B. force C. length D. mass
- The instrument best measures the internal diameter of a pipe is:
A. screw gauge B. vernier caliper C. metre rule D. measuring tape
- Least count of screw gauge is 0.01 mm. If main scale reading of screw gauge is zero and third line of its circular scale coincides with datum line then the measurement on the screw gauge is:
A. 0 mm B. 3 mm C. 0.03 mm D. 0.3 mm
- 9.483×10^3 m is the standard form of
A. 94.83 m B. 9.483 m C. 948.3 m D. 9483 m
- Which of the following is a base unit?
A. pascal B. coulomb C. meter per second D. mole
- The numbers having one significant digit is:
A. 1.1 B. 6.0 C. 7.1 D. 6×10^2
- Ratio of millimetre to micrometre is:
A. 1000 metre B. 0.001 metre C. 1000 D. 0.001
- 0.2 mm in units of meters is:
A. 0.0002 m B. 2×10^{-4} m C. both A and B D. none



SHORT RESPONSE QUESTIONS

QII. Give a short response to the following questions

1. How physics plays an important role in our life?
2. Estimate your age in minutes and seconds
3. What base quantities are involved in these derived physical quantities; force, pressure, power and charge.
4. Show that prefix micro is thousand times smaller than prefix milli.
5. Justify that displacement is a vector quantity while energy is a scalar quantity.
6. Screw gauge can give more precise length than vernier calipers. Briefly explain why?
7. Differentiate between mechanical stop watch and digital stop watch.
8. How measuring cylinder is used to measure volume of an irregular shaped stone?
9. What precaution should be kept in mind while taking measurement using measuring cylinder?
10. Why do we need to consider significant digits in measurements?
11. How random error can be reduced?
12. Differentiate between precision and accuracy.

LONG RESPONSE QUESTIONS

QIII. Give a detailed response to questions below.

1. Define Physics. Describe its revolutionary role in technology.
2. List with brief description of different branches of physics.
3. What are physical quantities? Distinguish between base physical quantities and derived physical quantities. Give at least three examples to show that derived physical quantities are derived from base physical quantities.
4. What do you mean by unit of a physical quantities? Define base units and derived units.
5. What are prefixes? What is their use in measurements?
6. What is scientific notation or standard form of noting down a measurement? Give at least five examples.
7. Describe construction and working of vernier calipers in detail.
8. What is screw gauge? What is its pitch and least count? How is it used to measure thickness of thin copper wire?
9. Define error. Differentiate between random and systematic error. How can these errors be reduced?
10. Differentiate between scalars and vectors. Justify that distance, speed, mass and energy are scalars while displacement, velocity, acceleration and force are vectors.
11. Justify and illustrate the use of a measuring cylinder to measure the volume of a liquid.
12. Differentiate between precision and accuracy.



NUMERICAL RESPONSE QUESTIONS

QIV. Solve the questions given below.

1. Write the following numbers in scientific notations

a. 1234 m

b. 0.000023 s

c. 469.3×10^5 m

d. 0.00985×10^7 s

2. Express the followings measurements using prefixes

a. 27.5×10^{-10} m

b. 0.00023×10^{-2} s

3. If a boy has age of 15 years 2 months and 10 days, convert his age in

a. seconds

b. milli seconds

c. mega seconds

4. How many kilometers are there in 25 micrometers?

5. What is pitch and least count of:

a. Vernier calipers if smallest division on main scale is 1mm and total divisions on vernier scale are 20.

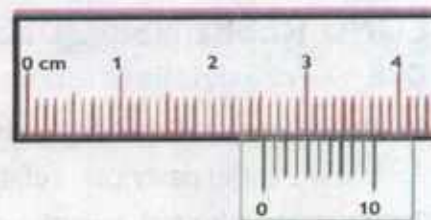
b. Screw gauge if smallest division on its main scale is 0.5 mm and its movable scale has 50 divisions.

6. Look at the measurement of vernier calipers:

a. What is its main scale reading?

b. What is its coinciding division on vernier scale?

c. Calculate total reading on the vernier calipers?



7. Look at the figure of screw gauge, let a small steel ball is place between its thimble and anvil then:

a. What is its main scale reading?

b. What is coinciding division of circular scale?

c. Calculate the total diameter of the ball?

