بسم اللہ الرحمٰن الرحیم
شروع اللہ کے نام سے جو بڑا مہربان نہایت رحم کرنے والا ہے

A TEXTBOOK OF

PHYSICS XI

BALOCHISTAN TEXTBOOK BOARD, QUETTA

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According to the National Curriculum 2006 under the National Textbook and Learning Materials Policy 2007.
N.O.C No. 907-09/CB/PA Dated: 18/07/2019. Office of the Director Bureau of Curriculum & Extension Centre, Balochista, Quetta.

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Unit 1

MEASUREMENTS

Major Concepts (19 PERIODS)

- The scope of Physics
- SI base, supplementary and derived units
- Errors and uncertainties
- Use of significant figures
- Precision and accuracy
- Dimensionality

Conceptual Linkage

This chapter is built on Measurement Physics IX

Students Learning Outcomes

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

- Describe the scope of Physics in science, technology and society.
- State SI base units, derived units, and supplementary units for various measurements.
- Express derived units as products or quotients of the base units.
- State the conventions for indicating units as set out in the SI units.
- Explain why all measurements contain some uncertainty.
- Distinguish between systematic errors (including zero errors) and random errors.
- Identify that least count or resolution of a measuring instrument is the smallest increment measurable by it.
- Differentiate between precision and accuracy.
- Assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties.
- Quote answers with correct scientific notation, number of significant figures and units in all numerical and practical work.
- Check the homogeneity of physical equations by using dimensionality and base units.
- Derive formulae in simple cases using dimensions.

INTRODUCTION

Among the creatures, human being is the only creature who has ability of thinking, reasoning and researching. On account of this ability, he is trying to gain knowledge about the origin, creation and organization of this vast universe and the different related laws governing it. He also endeavours to explain the hidden natural reservoirs and forces (acting and reacting) which cause various events in the universe. In the past, man was reluctant to think about the universe but at present, he wishes to make an abode on moon or on any other planet. Quantization rules of electrons in an atom, a solar system and a massive body like galaxy all these have become part of the study and observation of the mankind. Similarly, a man researches to reason out that how the life of living things (plants and animals) get possibility to exist and evaluate only on earth? How days and nights are formed by the spin motion of the earth? How changing of seasons are timed by orbital motion of the earth? In the same way, how the process of evaporization, condensation and sterilization take place? In short, the knowledge about the nature in terms of research, observations and practical applications are known as science. Gradually, due to rapid research, the volume of knowledge about science increases. Therefore, science is basically classified into two main classes; Biological sciences which deals with study of living things and Physical sciences which deals with study of non-living things. Physical sciences can be further sub divided into five main branches i.e.; Chemistry, Geology, Astronomy, Meteorology and Physics. The word Physics comes from the Greek word 'Physis' Physika or Physikos meaning the knowledge of the nature and natural world.

On the other hand, Physics is the study of properties of matter and energy and the mutual relationship between them. This chapter deals with the scope of physics in science, technology and our society. Therefore, we will explain the international system (SI) for weights and measures. Similarly, we will also study errors, uncertainties, significant figures, precision, accuracy and dimensions of physical quantities and their usage in this chapter.

1.1 THE SCOPE OF PHYSICS

Physics is based on experimental observations, quantitative measurements and concerned with the fundamental laws of the universe. Therefore, physics is the most basic branch of physical sciences.

Like electrons around the nucleus, all the other subjects of physical sciences are revolving around the physics. Now there is no denial of the fact that physics has countless contributions in the field of science and technology and its role in the development of our society is dynamic.

The principles of physics have not only brought tremendous changes in every walk of life but also changed the life style of mankind by the wonderful contexts of infrastructures. On one hand, the appliances of physics have introduced an industrial revolution in the world. On the other hand, these have turned the world into a global village by fast audio and video communication system via radio, television, mobile, computer and internet system. In all these modes of telecommunication systems, the carrier signal is electromagnetic wave whose speed is equal to speed of light ($3 \times 10^8\ ms^{-1}$). In addition, the existed vast libraries and archives which contained millions of books and documents, all these information and knowledge have been confined to tiny chips. These chips have been developed from the basic ideas of physics. Similarly, in medical sciences, diagnose and treatment of incurable diseases now have become possible by introducing considerable advancements and achievement of modern technology such as transplantation, radiotherapy, chemotherapy, x-rays, magnetic resonance imaging (MRI), computer tomography (CT Scan), LASER surgery, operation without surgery by nano robots.

In the field of engineering, all sort of appliances such as microwave ovens, vacuum cleaners, washing machines, air-conditioners, refrigerators, engines, electric motors, generators, submarines, airplanes, excavators, robots and many more which are working under the various laws and principles of physics and they have made our lives easy and comfort.

In the same way, the role of physics in genetic engineering and transgenetic organism in the development of new species cannot be neglected. Summing up, the involvement of physics in each section of life is a universal truth.

Physics has a number of branches which are listed in the box. But all the work and research of physics has been basically classified into two main

Physics and Technology

One of the most exciting technological advances in the world today is the field of nanotechnology. Nanorobots or nanomachines have been used to remove obstructions in the circulatory system and kills cancerous tumors with precision: Researchers from McGill University have achieved a spectacular breakthrough in nanotechnology.

Different Branches of Physics

Classical Physics

Mechanics
Optics (Light)
Sound (Acoustics)
Electromagnetism
Heat & Thermodynamics

Modern Physics

Atomic Physics
Nuclear Physics
Molecular Physics
Plasma Physics
Quantum Physics
Space Physics
Solid State Physics
Nanotechnology
Laser Physics
Fluid Dynamics
Aero Dynamics
Hydro Dynamics

classes, which are named as classical physics and modern physics.

The physics upto the end of 19^{th} century is known as classical physics which consists of Newton's laws of motion, gravitational laws, laws of thermodynamics, kinetic theory, Maxwell's theory of electromagnetic wave and the laws about optical phenomenon. However, the physics after the 19^{th} century is known as modern physics which includes discovery of x-rays and radioactivity, Michelson-Morley experiment, Max Planck's quantum theory, Einstein's special theory of relativity, Bohr's atomic theory, De-Broglie hypothesis, Schrodinger wave equations and Heisenberg uncertainty principle. All these new researches have brought a revolution in the field of physics and other scientific disciplines.

Interdisciplinary Branches of Physics

Astro Physics
Bio Physics
Chemical Physics
Relatavistics Physics
Low Temperature Physics
Condensed Matter Physics
Engineering Physics
Geo Physics
Mathematical Physics
Medical Physics

1.2 PHYSICAL QUANTITIES

Physics is an experimental science where the measurements are made and we usually use some quantities to describe the results of these measurements. Thus the quantities which can be measured are known as physical quantities. For example, mass length, time, distance, velocity, force, weight, momentum, work, power etc. On the other hand, all the laws and equations of Physics can be expressed in terms of these physical quantities. Physical quantities can be classified into two classes, i.e. base quantities and derived quantities.

Base Quantities

The quantities which are independent and cannot be expressed in terms of other physical quantities are known as base quantities. There are seven base quantities such as; mass, length, time, temperature, current, amount of substance and intensity of light.

Derived Quantities

The quantities which can be expressed in terms of fundamental quantities using arithmetical operations of product or quotient rule are known as derived quantities. For example, velocity, acceleration, momentum, force, work, power etc.

Product rule:

According to this rule two or more physical quantities are multiplied such that their product gives a new resultant physical quantity. For example, momentum is derived by the product of mass and velocity. i.e.,

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

$$\vec{p} = m\vec{v}$$

Quotient rule:

According to this rule, one physical quantity is divided by another and their quotient gives a new resultant physical quantity. For example, velocity is the quotient of displacement and time. i.e.,

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

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

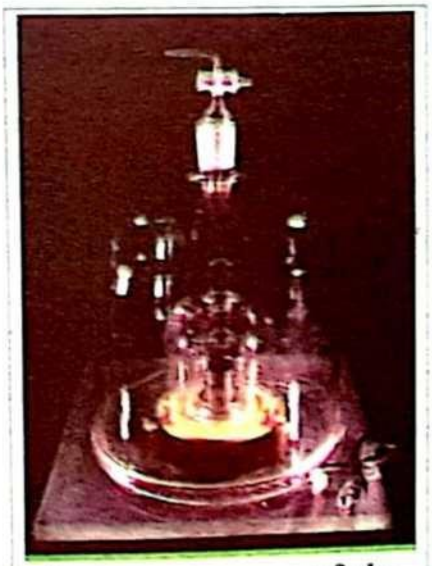
1.3 INTERNATIONAL SYSTEM OF UNITS

The standard and justified measurement of a physical quantity is called unit. e.g. kilogram, meter, second, newton, joule, watt, radian, etc.

In 1960, a general conference on weight and measure was held in Paris. After prolong discussion, the international committee for weights and measures agreed to introduce a common system of units all over the world and they recommended a metric system for measurements which is called International System of Units (SI). The SI unit is an improved form of MKS (Metre, Kilogram and Second) system. SI unit is replaced by CGS (centimeter, gram and second) and FPS (Foot, pound and second).

There are three main routes of the SI units

(i) Base Units
(ii) Derived Units
(iii) Supplementary Units



An accurate copy of the International Standard Kilogram kept at Sevres, France, is housed under a double bell jar in a vault at the National Institute of Standards and Technology.

1.3.1 Base Units

The units of base quantities are known as base units. Base units are isolated and cannot be derived from any other units. There are seven base units which are listed in table 1.1.

Table 1.1: Base S.I Units

Base Quantity	Unit	Symbol
Mass	kilogram	kg
Length	metre	m
Time	second	s
Electric Current	ampere	A
Temperature	kelvin	K
Intensity of Light	candela	cd
Amount of substance	mole	mol

1.3.2 Derived Units

The units of derived quantities are called derived units. These derived units can be obtained under the arithmetical operations of product or quotient rules which are explained as:

Product Rule

According to this rule, when two or more units and multiplied such that their product gives a new resultant unit. e.g. metre cube (m^3) is the unit of volume and it can be obtained by the product of base units as:

$$\text{Volume} = (\text{length}) \times (\text{breadth}) \times (\text{height})$$

The derived unit for volume is $(m)(m)(m) = m^3$

Quotient Rule

According this rule, when a unit is divided by another unit such that their quotient gives a new resultant unit. e.g. Watt (W) which is the unit of power and it can be obtained by the quotient of base units as

$$P = \frac{\text{work}}{\text{time}} = \frac{\text{Joule}}{\text{second}}$$

$$= \frac{kg\,m^2\,s^{-2}}{s} = kg\,m^2\,s^{-3}$$

$$P = \text{watt}$$

Some other derived SI units are mentioned in table 1.2.

Table 1.2: Derived SI Units

Derived Quantity	Unit	Symbol	In terms of Base units
Force	newton	N	$kg\,m\,s^{-2}$
Work, Energy	joule	J	$N\,m = kg\,m^2\,s^{-2}$
Power	watt	W	$Js^{-1} = kg\,m^2\,s^{-3}$
Pressure, stress	pascal	Pa	$\frac{N}{m^2} = kg\,m^{-1}\,s^{-2}$
Co-efficient of Viscosity	poise	H	$\frac{N-s}{m^2} = kg\,m^{-1}s^{-1}$
Electric Charge	coulomb	C	A . s
Frequency	hertz	Hz	s^{-1}
Moment of Inertia	kilogram metre square	$kg\,m^2$	$kg\,m^2$

1.3.3 Supplementary Units

The two units could not find a room in base units nor in derived units in the general conference for weights and measures held in 1960 in Paris. These two units are called supplementary SI units. Supplementary SI units are radian and steradian, both are geometrical units and dimensionless.

(a) Radian

Radian is a two dimensional plane angle and it is defined as, "the angle subtended at the centre of a circle by an arc equal in length to the radius of circle", as shown in Fig.1.1. and it is equal to the ratio between lengths of the arc to the radius.

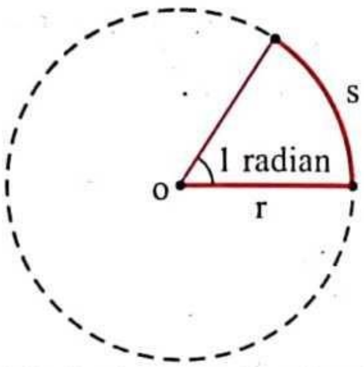


Fig.1.1: A plane angle of radian subtended by an arc whose length is equal to the radius.

Let an angle 'θ', which is subtended by an arc of length 'S' along a circle of radius 'r' then;

$$\theta = \frac{S}{r}(\text{rad}) \quad ......(1.1)$$

For one revolution,

Length of the boundary of the circle (S) = $2\pi r$ (circumference)

Thus, equation 1.1. becomes

$$\theta = \frac{2\pi r}{r} = 2\pi \text{ radians}$$

Now if length of the arc 's' = radius 'r'.

Again equation (1.1) becomes $\theta = \frac{r}{r}(\text{rad})$.

Thus, $\theta = 1\,\text{radian}$, as shown in Fig 1.1.

For Your Information

NIST F-1 Cesium Atomic Clock

NIST-F1 is the world's most accurate time and frequency standard. This atomic clock developed at the NIST (National Institute of Standard and Technology) laboratories in Boulder, Colorado USA. NIST-F1 defines Coordinated Universal Time (UTC). The official world time.

The uncertainty of NIST-F1 is continually improving. In 2000 the uncertainty was about 1×10^{-15}, but as of January 2013, the uncertainty has been reduced to about 3×10^{-16}, which means it would neither gain nor lose a second in more than 100 million years. First atomic clock was developed in 1945.

Importance of Units

In September 1999, after nine months and travelling 650 million kilometers, the Mars climate Orbiter (robotic space probe) suddenly disappeared. The 'root cause' of this loss was the faulty unit conversion.

(b) Steradian

Steradian is a three dimensional solid angle. It is defined as "the angle subtended at the center of a sphere by a surface of sphere and it is equal to the ratio between subtended spherical area to the square of the radius".

$$\text{Angle } \theta = \frac{\text{spherical area}}{r^2} \text{(steradian)} \ldots\ldots (1.2)$$

But, spherical area $= 4\pi r^2$

$$\text{Angle } \theta = \frac{4\pi r^2}{r^2} \text{(steradian)} = 4\pi \text{ steradians}$$

Now if the spherical area = 1 m^2 and radius r = 1 m

Then equation (1.2) becomes

$$\text{Angle } \theta = \frac{1 m^2}{1 m^2} \text{ (steradian)}$$

$$\text{Angle } \theta = 1 \text{ steradian as shown in Fig.1.2.}$$

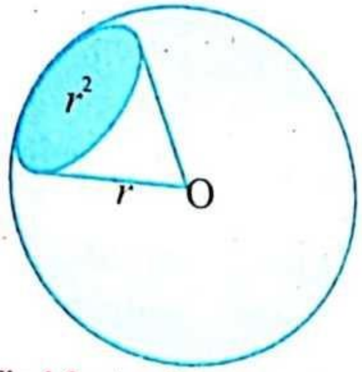


Fig.1.2: A solid angle of steradian subtended by surface area equal to the square of the radius.

1.3.4 Conventions for indicating SI units

A unit system has a great importance in physics as well as in any other subject of science, because a value or a result without unit is meaningless. Therefore, a special care is required in the expression of unit and writing of prefixes. In this regard, there are some rules which are related with the using of units and these are summarized as;

I. The unit's name should not be written with a capital initial letter, even if named after a scientist.
For example: newton, pascal, watt, kelvin

II. The symbols of the units named after scientist should be written by an initial capital letter.
For example: N for newton, Pa for pascal, W for watt, K for kelvin

III. The prefix should be written before the unit without any space.
For example: 1×10^{-6} m is written as $1\mu m$.

IV. One space is always to be left between the numbers and the symbols of the unit and also between the symbols for a compound unit such as force, momentum, etc.

Approximate values of some time intervals in seconds

Event	Time Interval
Life span of most unstable particle	10^{-24}
Time required for light to cross a nuclear distance	10^{-22}
Period of X-rays	10^{-19}
Period of atomic vibration	10^{-15}
Life time of an excited state of an atom	10^{-8}
Period of radio wave	10^{-6}
Period of sound wave	10^{-10}
Wink of eye	10^{-1}
Time between successive heart beats	10^{0}
Time taken by light from Sun to Earth	10^{2}
Time period of satellite	10^{4}
Rotation period of Earth	10^{5}
Rotation & revolution periods of the moon	10^{6}
Revolution period of the Earth	10^{7}
Travel time for light from the nearest star	10^{8}
Age of Egyptian pyramids	10^{11}
Time since dinosaurs became extinct	10^{17}

For example: It is not correct to write 2.3m. But the correct representation is 2.3 m; Similarly, kg m s^{-2} and not as $kgms^{-2}$.

V. Compound prefixes are not allowed. For example: 1μμm may be written as 1pm.

VI. No full stop or other punctuation marks should be used within or at the end of symbols.
For example: 50 m and not as 50 m.

VII. The symbols of the units do not take plural form. For example: 10 kg not as 10 kgs.

VIII. When temperature is expressed in Kelvin, the degree sign is omitted.
For example: 273 K not as 273°K
(If expressed in Celsius or Fahrenheit scale, degree sign should be included. For example, 100°C and not 100 C)

IX. When a multiple of a base unit is raised to a power, the power applies to the whole multiple and not the base unit alone. Thus $1km^2 = 1\ (km)^2 = 1\times10^6\ m^2$.

X. Only accepted symbols should be used.
For example: Ampere is represented as A and not as amp. or am; second is represented as s and not as sec.

1.4 SCIENTIFIC NOTATION

Sometimes, we come across a value or a result of a physical quantity which has extremely large or small magnitude. For example, the number of molecules in one mole is 602,300,000,000,000,000,000,000. Similarly, the radius of hydrogen atom is 0.000,000,000,053 m. Such notations are difficult ways of expression. Therefore, these values can be simplified in a decimal form under a process known as scientific notation or standard form. According to this process the given value is expressed in term of some power of ten multiplied by a number which lies between 1 and 10. Thus the number of molecules in one mole is written in terms of scientific notation is 6.023×10^{23} molecules and the radius of the hydrogen atom is 5.3×10^{-11} m. According to the rule only one non-zero digit should be written on the left of the decimal point. For example, the standard form of 120000 is 1.2×10^5 but not 12×10^4.

1.5 PREFIXES

The magnitude of physical quantities vary over a wide range. When the values of physical quantities are very large or very small then it is difficult to express them in terms of the fundamental units. For this, we introduce larger and smaller units by using specific letters before the fundamental units. These letters are known as prefixes and these are represented by fixed values in the form of power of ten. For example, the prefix 'kilo' abbreviated as 'k'. It is always equal to 1000 or 10^3. The prefixes can further be explained by the following examples.

I. Mass of bag is 2000 g
   $2000\ g = 2 \times 10^3 g = 2$ kilogram $= 2$ kg

II. Size of living cell is 0.000001 m
   $0.000001\ m = 1 \times 10^{-6}\ m = 1$micro m $= 1\mu m$

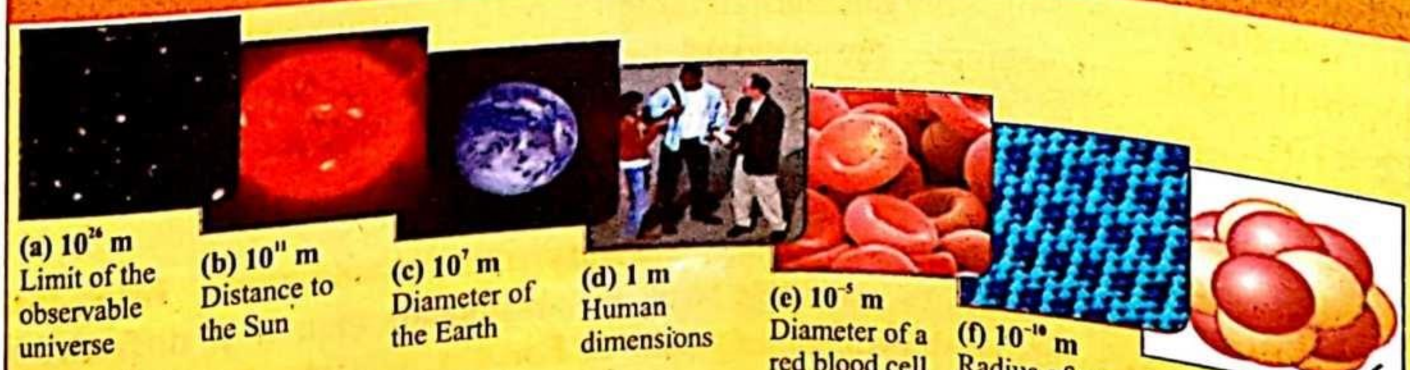
III. Time for speed of sound to travel in air through 0.35 m is 0.001 s.
   $0.001 s = 1 \times 10^{-3}\ s = 1$milli second $= 1$ ms

Different prefixes and their values are given in table 1.3.

Table 1.3: Prefixes and their values

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

Some typical lengths in the Universe



(a) 10^{26} m Limit of the observable universe
(b) 10^{11} m Distance to the Sun
(c) 10^{7} m Diameter of the Earth
(d) 1 m Human dimensions
(e) 10^{-5} m Diameter of a red blood cell
(f) 10^{-10} m Radius of an atom
(g) 10^{-14} m Radius of an atomic nucleus

1.6 SIGNIFICANT FIGURES

The number of accurately known digits and the first doubtful digit are called significant figures. It is explained as;

The measurement of physical quantities made by related instruments often involves some errors or uncertainties. These uncertainties are due to the following factors:

(i) The least count of measuring instruments
(ii) Quality and condition of the apparatus
(iii) Skill of the observer
(iv) Different recorded observations by the same apparatus.

In the presence of these complications, the reported result contains both certain and uncertain digits and the total number of all these certain and uncertain digits are known as significant figures.

For example, let the reported mass of a sphere is 1.53 kg. In this case 1 and 5 are certain digits while 3 is uncertain and the measured value has three significant figures. Similarly, the reported length of a simple pendulum is 102.5 cm, this value has four significant figures, the digits 1, 0 and 2 are certain while 5 is uncertain.

1.6.1 Rules for determining the number of significant figures

The number of significant figure of a measured value can be determined under the following rules.

I. All the non-zero digits are significant (1,2,3,4,5,6,7,8,9).

II. Zero may or may not be significant and it is explained as;

a) All the zeros between two non-zero digits are significant, whether decimal point exists or does not exist.
e.g. 2003, 2.003, 20.03, in all these cases significant figures are four.

b) Zero to the right of a significant figure may or may not be significant.
e.g. 6000 calories can be written as
6×10^3 calories (1 Significant figure)
6.0×10^3 calories (2 Significant figure)
6.00×10^3 calories (3 Significant figure)
6.000×10^3 calories (4 Significant figure)

c) The terminate zero in a number with decimal point are significant e.g. 0.2300, 0.1540, 3.600
All these three numbers have four significant figures each.

d) If the number is less than one, the zero on the right of decimal point and to the left of the 1st non zero digit are not significant. e.g. 0.00123 in this case zeros are not significant and the number of significant figures is three, i.e., $0.00123 = 1.23 \times 10^{-3}$.

e) When the measurement is reported in scientific notation, then the figures other than power of ten are significant figures. e.g. 6.40×10^{24}kg has three significant figures.

III. No change occurs in the number of significant figures by changing the unit of the measured value. e.g. 23.15 mm = 2.315 cm = 0.02315 m
All these numbers have four significant figures each.

IV. When measurements are added or subtracted, the answer contains no more decimal places than the least accurate measurement (less decimal number value).
The following examples will clarify these rules.

$$\begin{array}{r} 2355.2342 \\ +\ 23.24 \\ \hline 2378.47 \end{array} \quad \begin{array}{r} 15600.00 \\ +\ 172.49 \\ \hline 15772.49 \end{array} \quad \begin{array}{r} 15600 \\ +\ 172.49 \\ \hline 15772 \end{array} \quad \begin{array}{r} 13.7 \\ +\ 1.3 \\ \hline 15.0 \end{array}$$

Keep the same number of decimal places as the factor with the least amount.

V. When measurements are multiplied or divided, the answer contains no more significant figures than the least accurate measurement (least significant figure value). Some examples:

$$\begin{array}{r} 13.1 \\ \times\ 2.25 \\ \hline 29.5 \end{array} \quad \begin{array}{r} 13.100 \\ \times\ 2.2500 \\ \hline 29.475 \end{array} \quad \begin{array}{r} 15310 \\ \times\ 2.3 \\ \hline 35213 \end{array} \quad \begin{array}{r} 1.00 \\ \times\ 10.04 \\ \hline 10.04 \end{array}$$

Keep the same number of significant figures as the factor with the least number of significant figures.

Examples

4767	4 significant figures (all 1-9 digits are significant)
0.0008	1 significant figure (zeros locate only the decimal position)
14.90	4 significant figure (In decimal figure zero is significant)
7000.0	5 significant figure (In decimal figure zero is significant)
8500	4 significant figure
1.121	4 significant figures
1.08701	6 significant figures
0.00254	3 significant figures (2,5 and 4 are significant)
0.2540	4 significant figures (2, 4, 5 and last 0 are significant)
2.15×10^3	3 significant figures (2, 1, and 5)

1.7 ERRORS AND UNCERTAINTIES

When an observer is making a measurement by using some measuring instruments, he makes an effort to determine precise and accurate result. But it is a difficult job for him because the measuring instruments contain some uncertainties.

These uncertainties are called errors and these are due to the following factors.

(a) Zero error and faulty or poor condition of the instrument.
(b) Irrelevant experimental technique or procedure.
(c) Lack of experience in the setting and using of the apparatus.
(d) Taking observation without precautions.

The error in the measurement can be minimized by using the instrument which contains small uncertainty. For example, between metre rod and vernier callipers, the measurement by using vernier callipers is more reliable than metre rod, because it has small uncertainty.

The errors in measurement can be classified into two main classes.

(i) Systematic Error (ii) Random Error

1.7.1 Systematic Errors

The errors that appear in measurement and repeat in same magnitude and sign under the same conditions are called systematic errors. Such errors are due to the following factors i.e., the zero error in instrument, poor calibration of instrument and incorrect marking.

Systematic error can be removed by using some standard instruments.

1.7.2 Random Errors

The errors that appear in measurement and repeat in different magnitude and sign under the same conditions are called random errors. Such errors occur due to the following reasons, i.e., personal error, lack of sensitivity of the instrument, environmental factors (temperature, humidity etc.) and wrong technique of measurement.

Random error can be minimized by applying statistical method i.e. repeating the measurement several times and taking an average of these measurements.

1.8 PRECISION AND ACCURACY

When physical quantities are measured by using the measuring instruments then there are some uncertainties or errors exist in the measurement and it is due to the various factors. These uncertainties or errors can be explained in terms precision and accuracy which are related with the reported result of any measured quantity. Now the terms precision and accuracy can be distinguished as:

1.8.1 Precision

The precision of a measurement is associated with the least count of the measuring instrument. This shows that precise measurement depends upon the resolution or limit of measuring instrument. Precision depends upon absolute uncertainty e.g. absolute uncertainty of a metre rod is 1 mm or 0.1 cm and the absolute uncertainty of a Vernier callipers is 0.1 mm or 0.01 cm. It may be noted that the smaller the least count of the measuring instrument, the more precise will be the measurement. e.g. screw gauge is more precise than that of vernier callipers and vernier callipers is more precise than that of metre rod.

1.8.2 Accuracy

The accuracy of a measurement is associated with the fractional uncertainty or relative uncertainty. This shows that accuracy depends upon the closeness of calculated value with the actual value of the quantity. Lesser is the fractional uncertainty or percentage uncertainty of the result, the more accurate will be the measurement.

> All the measurements are subject to uncertainties.
> The accuracy of a measurement describes how well the result agrees with an accepted value.
> The precision of an instrument is limited by the smallest division on the measurement scale.

$$\text{Fractional Uncertainty} = \frac{\text{Least Count}}{\text{Measured value}}$$

$$\text{Percentage Uncertainty} = \frac{\text{Least Count}}{\text{Measured value}} \times 100$$

Now precision and accuracy can further be explained by the following examples. Let, the length of an object is measured by metre rod is 19.5 cm as shown in Fig.1.3, then;

Absolute Uncertainty (least count) = $\pm 0.1\,\text{cm}$

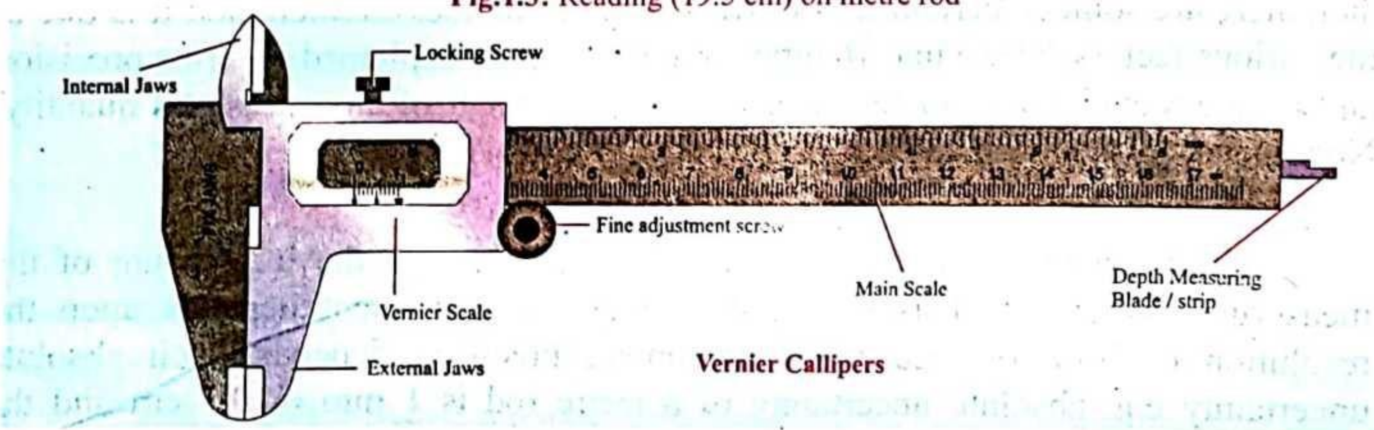
$$\text{Fractional Uncertainty} = \frac{0.1\,\text{cm}}{19.5\,\text{cm}}$$

$$\text{Fractional Uncertainty} = 0.005$$

$$\text{Percentage Uncertainty} = \frac{0.1}{19.5} \times 100$$

$$\text{Percentage Uncertainty} = 0.5\%$$

Fig.1.3: Reading (19.5 cm) on metre rod



Vernier Callipers

Similarly, the length of another object as measured by a vernier callipers is 0.51 cm as shown in Fig.1.4 then;

Absolute Uncertainty (least count) = $\pm 0.01\text{cm}$

$$\text{Fractional Uncertainty} = \frac{0.01\,\text{cm}}{0.51\,\text{cm}}$$

$$\text{Fractional Uncertainty} = 0.019 = 0.02$$

$$\text{Percentage Uncertainty} = \frac{0.01\,\text{cm}}{0.51\,\text{cm}} \times 100$$

$$\text{Percentage Uncertainty} = 2\%$$

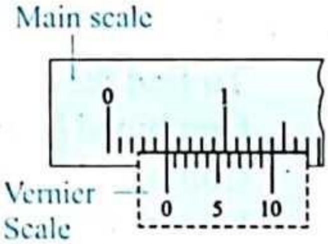


Fig.1.4: Reading (0.5 cm) on vernier Calliper

In the first example the reading 19.5cm is taken by metre rod and it is less precise but is more accurate having more absolute uncertainty and less percentage uncertainty or error. Whereas in the second example, the reading 0.51 cm is taken by vernier callipers which is more precise but less accurate having less absolute uncertainty or least count and more percentage uncertainty.

1.8.3 Assessment of total uncertainty in the final result

The experiments show that the measurement of a physical quantity contains some errors or uncertainties and to calculate the final result, the arithmetic operations may have to be performed. The total uncertainty in the final result does not depend only on the uncertainty of the individual but also on the arithmetic operations as well. The total uncertainty in the final result can be found using the following rules.

(a) If two measured quantities are added or subtracted, then their absolute uncertainties are added.

(b) If two (or more) measured quantities are multiplied or divided, then their relative uncertainties are added.

(c) If a measured quantity is raised to a power, then the relative uncertainty is multiplied by that power.

1.8.4 For addition and subtraction:

Absolute uncertainties are added.

For example, suppose we measure a length of a rod by using metre rod. The positions of two ends 'A' & 'B' of the rod are recorded as:

$$A = 11.6 \pm 0.1 \text{ cm and } B = 39.8 \pm 0.1 \text{ cm.}$$

To find the total length of rod we subtract the two points that is

$$\text{Length of rod} = B - A = (39.8 \pm 0.1) - (11.6 \pm 0.1) \text{ cm}$$

$$\text{Length of rod} = B - A = 28.2 \pm (0.1 + 0.1) \text{ cm}$$

$$\text{Length of rod} = B - A = 28.2 \pm 0.2 \text{ cm}$$

For example, Akmal and Ajmal are acrobats. Akmal is 165 ±2 cm tall, and Ajmal is 135 ±3 cm tall. If Ajmal stands on top of Akmal's head, how far is his head above the ground?

To find the combined height of Akmal and Ajmal, we add the two heights.
Combined height = Height of Akmal + Height of Ajmal
Combined height = 185 cm + 145 cm = 330 cm
Uncertainty in combined height = 2 cm + 3 cm = 5 cm
So the uncertainty in Combined height = 330 cm ±5 cm

1.8.5 For multiplication and division:

Percentage uncertainties are added.

For example, Find the value of force 'F' and determine the total uncertainty by using F = ma, where m = 60 ± 0.5 kg and a = 5.0 ± 0.2 ms^{-2}.
The maximum possible uncertainty in the value of force is determined as follows:

The Percentage uncertainty for m = $\frac{0.5}{60} \times 100$ = about 0.8%

The Percentage uncertainty for a = $\frac{0.2}{5} \times 100$ = about 4%

The result is thus given as F = ma = 60 × 5 = 300 N with a percentage uncertainty of 4.8 %.

Thus the total result

$$F = 300\ N \pm 4.8\%$$

$$F = 300\ N \pm \frac{4.8}{100} \times 300$$

$$F = 300 \pm 14.4\ N$$

Precision is the degree of correctness to which a measurement can be reproduces.

1.8.6 For power factor

If absolute uncertainty of a measurement is known and that measurement occurs interms of power in the given formula, then total percentage uncertainty is calculated by multiplying the power with percentage uncertainty.

For Example

The calculation of the area of cross-section of a cylinder, we use the formula $A = \pi r^2$.

Percentage uncertainty in area of cross-section = 2 × %age uncertainty in radius 'r'.

When uncertainty is multiplied by power factor, then it increases the precision demand of measurement. If the radius of the cylinder is measured as 1.95 cm by vernier callipers with least count 0.01 cm, then the radius 'r' is recorded as:

$$r = 1.95 \pm 0.01\ cm$$

Absolute uncertainty = least count = ± 0.01 cm

Percentage uncertainty in r (radius) = $\frac{0.01}{1.95} \times 100\% = 0.512\% = 0.5\%$

Total percentage uncertainty in area of cross-section = A = 2 × 0.5

Total percentage uncertainty in area of cross-section = 1.0 %

Thus area of cross-section $A = \pi r^2$

$$A = 3.14 \times (1.95)^2 = 11.94\ \text{cm}^2$$

So the area of cross section = A = 11.939 cm^2 with 1.0 % uncertainty

The uncertainty is $\frac{1.0}{100} \times 11.939\ \text{cm}^2 = 0.12\ \text{cm}^2$

Hence the result should be recorded as $A = 11.94 \pm 0.12\ \text{cm}^2$.

1.9 DIMENSIONS

The concept of dimension was introduced by Joseph Fourier. It is a method of analysis in which different physical quantities are expressed in terms of their base quantities, such as, mass, length and time. On the other hand, a dimension analysis is a mathematical technique which is being used for the following purposes; to explain the nature of physical quantities, to test the correctness of an equation, to provide a method of changing of units, to assist in recapitulating the formula and to suggest relations between fundamental constants.

For example; torque, work and energy are different physical quantities but dimensionally, they have same nature. Similarly, a distance can be measured in any unit such as feet, metre, kilometre or even in light year but it is always a distance and its dimension is length. In order to learn the expression of physical quantities in terms of their dimension, we use some rules which are related to the process of dimensions and these are summarized as;

I. Dimensions of physical quantities are represented by capital letters in square brackets such as [M L T]

II. The dimension of mass is [M], the dimension of length is [L] and the dimension of time is [T].

III. The dimensions of the majority of physical quantities are expressed in terms of three dimensions [M], [L] and [T].

IV. The quantity which does not exist in the given expression then the power of its dimension is taken as zero such as, the dimension of velocity $\left[M^0L^1T^{-1}\right]$.

V. The quantity which is placed in denominator, the power of its dimensions is taken as a negative integer. e.g. $v = \frac{s}{t} = \frac{[L]}{[T]} = \left[M^0LT^{-1}\right]$

VI. The integers or specific physical quantities which are defined in terms of ratio has no dimension, such as 2, 3, π, angle, strain etc.

Different physical quantities and their dimensions are mentioned in the table 1.4.

Table 1.4: Different physical quantities and their dimensions

Physical Quantity	Formula	SI Unit	Dimensional Formula
Distance	Length	m	$[L]$
Displacement	Length	m	$[L]$
Wavelength	Length	m	$[L]$
Area	Length×Breadth	m^2	$[L] \times [L] = [M^0 L^2 T^0]$
Volume	Length × breadth × height	m^3	$[L] \times [L] \times [L] = [M^0 L^3 T^0]$
Density	Mass / Volume	$kg\ m^{-3}$	$\frac{[M]}{[L^3]} = [M L^{-3} T^0]$
Speed	Distance / time	$m\ s^{-1}$	$\frac{[L]}{[T]} = [M^0 L T^{-1}]$
Velocity	Displacement / time	$m\ s^{-1}$	$\frac{[L]}{[T]} = [M^0 L T^{-1}]$
Acceleration	Velocity / time	$m\ s^{-2}$	$\frac{[L]}{[T^2]} = [M^0 L T^{-2}]$
Momentum	Mass × Velocity	$kg\ m\ s^{-1}$	$[M] \times [LT^{-1}] = [M L T^{-1}]$
Force	Mass × Acceleration	N (Newton)	$[M] \times [L T^{-2}] = [M L T^{-2}]$
Pressure	Force / Area	$N\ m^2$ or Pa	$\frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$
Work	Force × displacement	J (joule)	$[MLT^{-2}] \times [L] = [ML^2 T^{-2}]$
Torque	Force × moment arm	N m	$[MLT^{-2}] \times [L] = [ML^2T^{-2}]$
Power	Work / Time	W (watt)	$\frac{[ML^2T^{-2}]}{[T]} = [ML^2T^{-3}]$

Physical Quantity	Formula	SI Unit	Dimensional Formula
Impulse	Force × Time	kg ms^{-1}=Ns	$[MLT^{-2}] \times [T] = [M L T^{-1}]$
K.E	½ m v^2	J (joule)	$[M][LT^{-1}]^2 = [ML^2T^{-2}]$
P.E	Mgh	J (joule)	$[M][LT^{-2}]\,[L] = [ML^2T^{-2}]$
Stress	Force / Area	Pa (Pascal)	$\dfrac{[MLT^{-2}]}{[M^0L^2T^0]} = [M^0L^{-1}T^{-2}]$

1.9.1 Principle of homogeneity of dimensions

As a mathematical equation is developed under the various arithmetical operations. If the dimensions of both sides i.e., right hand side and left hand side of the given equation are identical then it is considered as homogenous equation. For example, we test the dimensional homogeneity of the equation $v_f = v_i + at$

Dimensional formula of final velocity $v_f = [LT^{-1}]$

Dimensional formula of initial velocity $v_i = [LT^{-1}]$

Dimensional formula of acceleration and time, $at = [LT^{-2}] \times [T] = [LT^{-1}]$

$L.H.S = v_f = [LT^{-1}]$

$R.H.S = v_i + at = [LT^{-1}] + [LT^{-1}] = 2[LT^{-1}]$

Here 2 is an integer and dimensionless. So $R.H.S = [LT^{-1}]$

This proves that L.H.S = R.H.S

∴ Dimensions on both sides of the equation are the same. Hence, the equation is dimensionally correct.

Example 1.1

The rotational kinetic energy of a body is given by $K.E_{rot} = \frac{1}{2}I\omega^2$, where ω is the angular velocity of the body. Using this equation, find out the dimensional formula for the moment of inertia I.

Solution:

As we know that rotational kinetic energy $= (K.E.)_{rot} = \frac{1}{2}I\omega^2$

or $$I = \frac{2(K.E.)_{rot}}{\omega^2}$$

Using principle of homogeneity of dimensions.

Dimensions of rotational kinetic energy $= (K.E.)_{rot} = [ML^2T^{-2}]$

Dimensions of angular velocity = $\omega = [T^{-1}]$

We get $$I = \frac{2\left[ML^2T^{-2}\right]}{\left[T^{-1}\right]^2}$$

$$I = \frac{2\left[ML^2T^{-2}\right]}{\left[T^{-2}\right]}$$

$$I = 2\left[ML^2T^0\right]$$

As 2 is an integer and dimensionless, so it should be neglected.

Hence the dimensions of moment of inertia are $=\left[ML^2T^0\right]$

Example 1.2

Test the dimensional homogeneity of the following equation

$$E = mgh + \frac{1}{2}mv^2$$

where E is the total energy, m is the mass, g is the acceleration due to gravity, h is the height and v is the velocity.

Solution: LHS = Total Energy = $E = [ML^2T^{-2}]$

$$RHS = mgh + \frac{1}{2}mv^2 = [ML^2T^{-2}] + \frac{1}{2}[ML^2T^{-2}]$$

$$RHS = \frac{3}{2}[ML^2T^{-2}]$$

Here $\frac{2}{3}$ is a numerical constant and dimensionless, so it should be ignored.

Therefore,

$$RHS = [ML^2T^{-2}]$$

Hence it is proved that dimensions of LHS = dimensions of RHS

Check Your Concept

- What are the dimensions of g/G?
- What are the dimensions of η/ρ?

1.9.2 Deriving a possible formula

If we have some idea about the physical quantities which depend to one another then we can use the method of dimensional analysis to develop an equation or formula relating these physical quantities.

To derive an equation or formulae we must consider the following rules.

(i) Identify that how many factors depend upon the required quantity.

(ii) All these factors are written in terms of mass, length and time dimensions.

(iii) Equating the powers of M, L and T on both sides of the dimensional equation, three equations are formed by which the value of unknown powers can be calculated.

(iv) By substituting these values in the equation, the real form of relation is achieved.

Example 1.3

Derive an expression for the time period (T) of a simple pendulum by using dimensional analysis.

Solution:

Let 'T' be the time period of a simple pendulum and it may depend upon the following factors,

(i) mass of the bob of the pendulum (m).

(ii) length of the pendulum (ℓ)

(iii) acceleration due to gravity (g)

(iv) angle θ which the thread makes with the vertical.

All these relations can be expressed as;

Let $T \propto m^a$, $T \propto \ell^b$, $T \propto g^c$, $T \propto \theta^d$

By combining all these results;

$$T \propto m^a \ell^b g^c \theta^d$$

$$T = K m^a \ell^b g^c \theta^d \quad \text{......(1.1)}$$

where K is constant and dimensionless

Equation (1.1) in terms of dimension is expressed as,

- $[T]^1 = [M]^a [L]^b \left[LT^{-2}\right]^c \left[LL^{-1}\right]^d$
- $M^0L^0T^1 = M^aL^bL^cT^{-2c}L^dL^{-d}$
- $M^0L^0T^1 = M^aL^{b+c+d-d}T^{-2c}$
- $M^0L^0T^1 = M^aL^{b+c}T^{-2c}$

For Your Information

$\text{Angle} = \dfrac{\text{Arc length}}{\text{Radius}}$

$\text{Angle} = \dfrac{\text{Meter}}{\text{Meter}}$

$\text{Angle} = LL^{-1}$

Angle is dimensionless

By comparing the powers of respective terms we get,

$$a = 0 \quad \text{......(1.2)}$$

$$b + c = 0 \quad \text{......(1.3)}$$

$$-2c = 1$$

and $$c = -\frac{1}{2} \quad \text{......(1.4)}$$

Putting the value of c in equation (1.3) we get the value of b i.e.

$$b = \frac{1}{2}$$

Thus, putting the values of a, b and c in eq. (1.1)

$$T = K\, m^0 \ell^{\frac{1}{2}} g^{\frac{-1}{2}} \theta^0$$

$$T = K\, m^0 \ell^{\frac{1}{2}} g^{\frac{-1}{2}} \theta^0 \qquad m^0 = 1 \text{ and } \theta^0 = 1$$

$$T = K \ell^{\frac{1}{2}} g^{\frac{-1}{2}}$$

$$T = K \frac{\ell^{\frac{1}{2}}}{g^{\frac{1}{2}}} = K \frac{\sqrt{\ell}}{\sqrt{g}}$$

$$T = K \sqrt{\frac{\ell}{g}}$$

Example 1.4

Derive the relation for speed of sound 'v' through a gas using dimension analysis.

Solution:

The velocity of sound depends upon pressure 'P', and density 'ρ' of the medium i.e.

$$V \propto P^a \rho^b$$

$$V = K P^a \rho^b \quad ......(1.5)$$

where 'K' is a dimensionless constant and hence eq. (1.5) can be expressed in terms of dimensions as;

$$[M^0 L^1 T^{-1}] = [ML^{-1}T^{-2}]^a [ML^{-3}]^b$$

$$[M^0 L^1 T^{-1}] = [M^a L^{-a} T^{-2a}][M^b L^{-3b}]$$

$$[M^0 L^1 T^{-1}] = [M^{a+b} L^{-a-3b} T^{-2a}] \quad ......(1.6)$$

By comparing the powers of the respective terms in eq. (1.6) we get;

$$a + b = 0 \quad ......(1.7)$$

$$-a - 3b = 1 \quad ......(1.8)$$

$$-2a = -1$$

$$a = \frac{1}{2} \quad ......(1.9)$$

Putting the value of a in eq. (1.7)

$$\frac{1}{2} + b = 0$$

$$b = -\frac{1}{2} \quad ......(1.10)$$

Thus, putting the values of a and b in equation (1.5), we get

Hence, $$v = K\, P^{\frac{1}{2}} \rho^{\frac{-1}{2}}$$

$$v = K\sqrt{\frac{P}{\rho}}$$

Where K is an arbitrary constant and experimentally its value is 1.

$$v = \sqrt{\frac{P}{\rho}}$$

1.10 LIMITATIONS OF DIMENSIONAL ANALYSIS

Although the technique of dimensional analysis is useful and helpful in many cases but, it has some limitations which are listed below:

I. The method cannot be used to determine the value of dimensionless constants. They have to be determined either by experimental or mathematical analysis

II. This method cannot be used to relations involving trigonometric, logarithmic and exponential functions.

III. Dimensional analysis does not indicate whether a physical quantity is a scalar or vector. For example, speed and velocity both have same dimensions $\left[M^0LT^{-2}\right]$.

IV. Dimensional analysis cannot be used to derive the exact form of a physical relation if the physical quantity depends upon more than three physical quantities (i.e., M, L and T).

V. Dimensional analysis provides the correctness of the given relation only dimensionally but it does not give the physical correctness of the relation e.g.

$T = 2\pi\sqrt{\frac{\ell}{g}}$ It is correct dimensionally.

$T = \frac{1}{2\pi}\sqrt{\frac{\ell}{g}}$ It is correct both dimensionally but not physically.

SUMMARY

- **Physics:** Physics is the branch of science which deals with the study of matter and energy and their mutual interaction.
- **Physical Quantities:** The quantities which can be measured and have proper units are called physical quantities.
- **Unit:** The quantity used as a standard of measurement is called unit.
- **International system (SI):** The international committee for weights and measures introduced a metric system for measurement which is called

international system (SI) of unit and it consists of seven base units, two supplementary units and a number of derived units.

- **Scientific notation**: A method of expressing of too large or too small value in terms of some power of ten multiply by a number is called scientific notation or standard form.
- **Significant Figures:** A reported result by an observer always contain both certain and uncertain digits. The number of these certain digits and first uncertain digit are known as significant figures.
- **Uncertainty:** Due to the poor condition of the instrument, irrelevant experimental technique and carelessness of the observer the reported result contains some errors which are called uncertainty.
- **Systematic Error:** The errors which appear in measurement due to known causes are known as systematic error. These errors repeat in same magnitudes and signs.
- **Random Error:** The errors which appear in measurement due to unknown causes are known as random errors. These errors repeat in different magnitudes and signs.
- **Precision:** Precision of a measurement depends upon the least count of the instrument. Smaller the least count, more precise is the measurement.
- **Accuracy:** The accuracy of the measurement depends upon fractional uncertainty. Smaller the fractional uncertainty more is the accuracy of the measurement.
- **Dimensional analysis:** A mathematical technique which explains the nature of the physical quantities is known as dimensional analysis. It can be used to analyze the homogeneity of a mathematical equation and deriving a possible formula.

EXERCISE

Choose the best option.

1. The main contribution of modern physics is

(a) Newton's laws of motion (b) Thermodynamics laws
(c) Kinetic theory (d) Special theory of relativity

2. The branch of physics which deals with the properties and interaction of nuclear particles (protons and neutrons) is called

(a) Molecular physics (b) Plasma physics
(c) Nuclear physics (d) Solid State Physics

3. The fundamental physical quantities which form the basis of the SI units are
(a) Force weight and time (b) Mass, length and time
(c) Mass, length and force (d) Mass, energy and time

4. Which one of the following is base physical quantity?
(a) Pressure (b) Temperature (c) Density (d) Energy

5. Which list of units contains three base quantities and two derived quantities?
(a) Kelvin, newton, second, kilogram, ohm
(b) Volt, joule, ampere, coulomb, meter
(c) Kilogram, meter, second, mole, kelvin
(d) Mole, hertz, kelvin, joule, newton

6. Light year is the unit of
(a) Time (b) Distance (c) Speed (d) Velocity

7. $\mu m \times mm$ is equal to
(a) $10^9 m$ (b) $10^{-9} m$ (c) $10^9 m^2$ (d) $10^{-9} m^2$

8. The derived unit joule in terms of base units is
(a) $kg\ m\ s^{-2}$ (b) $kg\ m^2\ s^{-2}$ (c) $kg\ m^{-1}\ s^{-2}$ (d) $kg\ m^{-2}\ s^{-2}$

9. The scientific notation of a measured value 0.0092 m
(a) $9.2\times10^3 m$ (b) $9.2\times10^{-3} m$ (c) $9.2\times10^5 m$ (d) $9.2\times10^{-5} m$

10. By using vernier callipers, the length of an object is measured by four students. Which one of the following is correct?
(a) 4.5 cm (b) 4.51 cm (c) 4.510 cm (d) 4.5100 cm

11. What is the absolute precision of the referred result 8.52 cm.?
(a) 1 cm (b) 0.1 cm (c) 0.01 cm (d) 0.001 cm

12. The number of significant figures of the value 0.0202 is
(a) Two (b) Three (c) Four (d) Five

13. Which one of the following measurement is the most significant?
(a) 203000 (b) 203×10^3 (c) 20.3×10^4 (d) 2.03×10^5

14. The length of a body is measured as 3.51 m, if the accuracy is 0.01 m, then the percentage uncertainty in the measurements is
(a) 3.51 % (b) 0.035 % (c) 0.28 % (d) 28.65%

15. The dimensions of moment of inertia is
(a) $[MLT^0]$ (b) $[ML^2T^0]$ (c) $[ML^{-2}T^0]$ (d) $[M^2LT^0]$

16. Which pair of physical quantities has same dimensions?
(a) Velocity and acceleration (b) Mass and weight
(c) Inertia and moment of inertia (d) Work and potential energy

SHORT QUESTIONS

1. Differentiate between base and derived quantities.
2. How can you obtain the derived physical quantities by using the arithmetic operations?
3. Convert one year into months, days, hours, minutes and seconds.
4. When and where the system of international (SI) for weight and measure came into being?
5. Which physical quantity has unit but has no dimension?
6. Write down the following in scientific notation
(a) Angstrom (A^{o}) (b) Pico metre (c) mega pixels
7. How can you derive the unit of watt in term of base units?
8. Identify three physical quantities which have no units and no dimensions?
9. What is the difference between systematic error and random error?
10. Between precise and accurate measurement, which one is more reliable?
11. What are three causes of errors in measurement by instruments?
12. How can you minimize the error of a reported result?
13. How accuracy is increased by decreasing the limit of precision?
14. Write three examples when zeros are not considered as significant figures.
15. How many expected number of significant figures are in 7000?
16. What do you know about the uncertainty of an instrument?
17. Which physical quantities have the same dimension? Give an example.
18. Find the dimension of gravitational constant G by using $F = G\frac{m_1 m_2}{r^2}$.
19. According to Hook's law, the restoring force F due to a body attached to a spring is given by $F = -kx$. Calculate the dimensions of the spring constant k.

COMPREHENSIVE QUESTIONS

1. State and explain the scope, importance and applications of physics in our daily life activities.
2. Describe the physical quantities with all its classes and justify that how can you obtain derived quantities by using product and quotient rules?
3. When and where was established the international system of units? Explain all the branches of SI units.
4. Explain conventions used for indicating SI units.

5. What is role of scientific notation and prefixes in the expression of too large or too small quantities.
6. Explain the significant figures with all its rules.
7. What do you know about;
   a) errors and uncertainties.
   b) precision and accuracy.
8. What are the dimensions of physical quantities? How can you explain the nature of physical quantities by using the dimensions analysis.
9. What is the role of dimension analysis in the derivation of formula and explanation of homogeneity of a mathematical equation.

NUMERICAL PROBLEMS

1. How much distance is covered by light in one year when its speed in space is $3 \times 10^8 \text{ m s}^{-1}$. **($9.5 \times 10^{15}$ m)**
2. Mass of neutron is 1.67×10^{-27} kg. Calculate the number of neutrons in a piece of metal whose net mass is one gram. **(5.99×10^{23} neutrons)**
3. Prove that nano seconds in one second is more than the number of seconds in one year.
4. Convert the following (a) 20 m s^{-1} into km h^{-1}, (b) $3\times10^8 \text{ m s}^{-1}$ into km h^{-1}, (c) 220 km h^{-1} into m s^{-1} **(a) 72 km h^{-1}, (b) 1.08×10^{10} km h^{-1} (c) 61 m s^{-1}**
5. (a) Express the following values in terms of prefixes.
   (I) 0.62×10^4 g, (II) 2×10^7 m, (III) 4×10^{-5}s
   (b) Express the following values in terms of scientific notation.
   (I) 0.000036, (II)140000, (III) 107000000
   (a) (I) 6.2 kg, (II) 20 Mm, (III) 40μs
   (b) (I) 3.6×10^{-5}, (II) 1.4×10^5 (III)1.07×10^8
6. The radius of a rod is 0.24 cm. Find its cross sectional area with appropriate significant figures. **(0.18 cm^2)**
7. How many significant figures are there in the given values?
   (a) 32.900, (b) 2003, (c) 2.0, (d) 0.0007, (e) 2.73×10^6
   (a) 5, (b) 4, (c) 2, (d) 1, (e) 3
8. Add the given values 12, 13.5, 15.432. Give the answer to correct significant figures. **(41)**
9. Verify that the given equation $S = v_i t + at^2$ is dimensionally correct.
10. The centripetal force 'F' acting on a particle (moving uniformly in a circle) depends on the mass 'm' of the particle, its velocity 'v' and radius 'r' of the circle. Derive dimensionally the formula for the centripetal force 'F'.