or $$[a] = \frac{[LT^{-1}]}{[T]} = [LT^{-1}][T^{-1}]$$

or $$[a] = [LT^{-2}]$$

Dimension Of Force

As

$$\text{Force} = F = \text{Mass} \times \text{Acceleration}$$

or $$F = ma$$

$\therefore$ Dimension of force $= [F] = [m][a]$

or $$[F] = [M][LT^{-2}] = [MLT^{-2}]$$

Dimensional Formulae

The dimensions of a physical quantity are represented by enclosing the letters M, L, T in square brackets as [M], [L] and [T]. These symbols are called dimensional formul

Dimensional Equations

The equations such as $[V] = [L^3]$ and $[F] = [MLT^{-2}]$ are used to represent dimensions of a physical quantity, are called dimensional equations.

Dimensional Analysis

The method of dimensions used to check the correctness of a given equation or formula and can also derive it, called dimensional analysis.

Uses Of Dimensions

(i) Checking Homogeneity Of Equation

To check the correctness of an equation, the dimensions of the quantities on both sides of the equation must be the same. This is called "The principle of homogeneity of dimensions".

(ii) Deriving A Possible Formula

The success of this method to derive a relation for a physical quantity depends on the correct guessing of various factors on which the physical quantity depends.

Numeric

The quantity which has no dimension is called a numeric.

FOR YOUR INFORMATION

- Computer chips are made from wafers from the metalloid silicon, a semiconductor.
- Mass is thought as a form of energy according to Einstein's famous equation $E = mc^2$. According to this equation, 1kg mass is actually 9×10^{16} J energy.
- To produce the entire range of colours in colour printing, only four colours Cyan, Magneta, Yellow and Black are used.
- The primary standard for the unit of time is cesium atomic frequency standard kept at the National Institute of Standards and Technology in Colorado (USA).
- The travel time of light from
  - Moon to Earth = 1 min 20s
  - Sun to Earth = 8 min 20s
  - Pluto to Earth = 5 h 20s
- Age of universe = 5×10^{17} s
- Age of Earth = 1.4×10^{17} s
- One Year = 3.2×10^{7} s
- One Day = 8.6×10^{4} s or 86400s
- Time between normal heartbeats = 8.0×10^{-1} s or 0.8s
- Period of audible sound waves = 1.0×10^{-3} s
- Period of typical radio waves = 1.0×10^{-6} s
- Period of vibration of an atom in a solid = 1.0×10^{-13} s
- Period of visible light waves = 2.0×10^{-15} s

Fsc Physics Chapter 1

SHORT QUESTIONS & ANSWERS

1.1 Name several repetitive phenomena occurring in nature, which could serve as reasonable time standards.

Ans. Any phenomenon that repeats itself after regular time intervals can be used as a time standard. The rotation of the Earth on its axis, which determines the length of the day, has been used as a time standard from the earliest times. Some other repetitive phenomena, which can be adopted to define a time standard, are (i) Heart beat (ii) Human pulse rate (iii) Oscillations of a simple pendulum (iv) Revolution of the moon around the Earth (v) Characteristic vibrations of crystals such as quartz crystal (vi) Radioactive decay rate of some substances i.e. Half life of a radioactive substance.

1.2 Give the drawbacks to use the period of a pendulum as a time standard.

Ans. The main drawback of a pendulum to adopt it as a time standard is the dependence of its time period on the value of 'g' at any place. Hence, the period of a pendulum of fixed length will be different at places where value of 'g' changes. The other requirements of a simple pendulum are that it should be free from frictional effects. Practically, it is difficult to devise an ideal simple pendulum.

1.3 Why do we found it useful to have two units for the amount of substance, the kilogram and the mole?

Ans. The amount of substances can be estimated by two methods

(i) By weighing for which the unit is kilogram

(ii) By counting the number of entities contained in the substance for which the unit is mole

1.4 Three students measured the length of a needle with a scale on which minimum division is 1mm and recorded as (i) 0.2145 m (ii) 0.21 m (iii) 0.214 m which record is correct and why?

Ans. The least count of a scale is 1 mm or 0.001 m. Hence, we can measure the length up to that accuracy. Thus, the record number (iii) 0.214 m is correct.

1.5 An old saying is that "A chain is only as strong as its weakest link". What analogous statement can you make regarding experimental data used in a computation?

Ans. The analogous statement of old saying, "A chain is only as strong as its weakest link" is that the result of an experimental data is as accurate as any of the least accurate measurement used in the computation.

1.6 The period of a simple pendulum is measured by a stopwatch. What type of errors is possible in the time period?

Ans. When a stopwatch is used to measure the time period of a vibration, one possible type of error is the zero error in the stopwatch, which is a systematic error and can be corrected by applying correction factor. The other is the human reaction time to start and to stop the stopwatch. It is called personal error.

1.7 Does a dimensional analysis give any information on constant of proportionality that may appear in an algebraic expression? Explain.

Ans. The method of dimensional analysis doesn't give any information about the dimensionless constant i.e. number only. The value of the constant of proportionality has to be determined either by experimentally or theoretically.

1.8 Write the dimensions of (i) Pressure (ii) Density

Ans. (i) Dimensions of Pressure $= \dfrac{\text{Dimensions of Force}}{\text{Dimensions of Area}}$

$$[P] = \frac{[M][L][T^{-2}]}{[L^2]}$$

or $$[P] = [M][L^{-1}][T^{-2}]$$

(ii) Dimensions of Density $= \dfrac{\text{Dimensions of Mass}}{\text{Dimensions of Volume}}$

$$[\rho] = \frac{[M]}{[L^3]}$$

or $$[\rho] = [M][L^{-3}]$$

1.9 The wavelength 'λ' of a wave depends on the speed 'v' of the wave and its frequency 'f'. Knowing that

$[\lambda] = [L]$, $[v] = [LT^{-1}]$ and $[f] = [T]^{-1}$

Decide which of the following is correct, $f = v\lambda$ or $f = \dfrac{v}{\lambda}$

Ans. (i) To check $f = v\lambda$

The dimensions of left hand side

$[f] = [T]^{-1}$

The dimensions of right hand side

$[v\lambda] = [LT^{-1}] \times [L] = [L^2T^{-1}]$

Thus, the dimensions on the two sides are not same; hence, the equation is not dimensionally correct.

(ii) $f = \dfrac{v}{\lambda}$

The dimensions of left hand side

$[f] = [T]^{-1}$

The dimensions of right hand side

$$\frac{[v]}{[\lambda]} = \frac{[LT^{-1}]}{[L]} = [T^{-1}]$$

As dimensions of left hand side are the same as that of right hand side, hence, this equation is dimensionally correct.

MEASUREMENTS

SCIENCE

The desire to know about things, events and natural phenomenon around us is called science.

The word 'SCIENCE' actually comes from the Greek word 'SCIO' meaning 'to know'. Science is the sum of human knowledge which man has gained through ages. In past, this knowledge was limited but as the knowledge expands, its complete study become impossible. Therefore science was divided into different branches. The two main branches of science are

(i) Physical Science

(ii) Biological Science

PHYSICAL SCIENCE

It deals with the non-living objects and such functions of living objects which are similar to non-living objects.

Physical science is divided into Physics, Chemistry, Astronomy, Geology etc.

BIOLOGICAL SCIENCE

It deals with living objects only.

Biological science is divided into Zoology (science of animals), Botany (science of plants)

PHYSICS

Physics is the branch of physical science which deals with the study of matter and energy and the relationship between them. It also explains the natural phenomenon with the help of fundamental laws and principles.

The word 'PHYSICS' actually comes from the Greek word meaning 'nature'. Therefore physics is a science dealing with the study of nature and various natural phenomena.

BRANCHES OF PHYSICS

Physicists at the end of 19th century began to believe that everything about physics has been discovered. But at the start of 20th century, some new experimental facts showed that the laws discovered by previous scientists need some modification. After that some new branches of physics came into existance given as

1. NUCLEAR PHYSICS

That branch of physics which deals with the atomic nuclei. It is related to neutrons and protons which form the atomic nuclei. Neutrons and protons are called nucleons.

2. PARTICLE PHYSICS OR HIGH ENERGY PHYSICS

That branch of physics which deals with the properties and behaviour of elementary particles.

3. RELATIVISTIC MECHANICS

That branch of physics which deals with those objects which are moving with velocities approaching to that of light.

4. SOLID STATE PHYSICS

That branch of physics which deals with the structure and properties of solids.

OTHER MAIN AND NEW BRANCHES

Physics is the most fundamental of all sciences and can be said as mother of all sciences

Some other main branches of physics are

* Mechanics * Heat and Thermodynamics * Optics
* Electromagnetism * Atomic Physics * Molecular Physics
* Plasma Physics * Space Physics * Quantum Mechanics.

Some new branches of physics are

* Biophysics * Physical Chemistry
* Astrophysics * Health Physics etc.

SCOPE OF PHYSICS

Physics is one of the fundamental sciences from which other supplementary sciences are produced such as nuclear physics, solid state physics, particle physics, relativistic mechanics, etc.

Physics is the most fundamental science deals with the world of extremely large such as universe, the world of extremely small such as electrons, protons, neutrons, mesons etc, and the world of middle sized things from molecule to earth.

It studies such things like laws of motion, the structure of space and time, the nature of different type of forces in the universe, the interaction between different particles and so on.

It has an important role in the other fields of science and gave birth to new branches such as biophysics, astrophysics, physical chemistry, health physics, electronics etc.

Physics has also played an important role in the development of technology and engineering. The information media and fast means of communication are due to physics. The computer networks are products of chips which also developed from the basic ideas of physics.

Hence we can say that physics is the basic building blocks of science.

PHYSICAL QUANTITIES

Those quantities which are measured physically or detected by their physical effect are called physical quantities.

For example, Mass, length, time, velocity, force etc

TYPES OF PHYSICAL QUANTITIES

These are divided into two catagories

(i) Base Quantities

(ii) Derived Quantities

BASE QUANTITIES

Those physical quantities which are not defined in terms of other quantities, called base quantities.
OR
The minimum number of those physical quantities in terms of which other physical quantities can be defined, called base quantities.

The typical examples of base quantities are Mass, Length and Time.

MEASUREMENT OF A BASE QUANTITY

The measurement of a base quantity is based on two steps
(i) Choice of a standard
(ii) To setup a procedure for comparing the quantity with the standard.

CHARACTERISTICS OF AN IDEAL STANDARD

An ideal standard has two main characteristics
(i) It is assessible.
(ii) It is invariable.

DERIVED QUANTITIES

Those physical quantities which are defined in terms of other physical quantities.
OR
Those physical quantities which are obtained by multiplying and dividing base quantities.

For example, velocity, acceleration, force, energy, power, density, momentum, torque etc.

NOTE:

Physical quantities are the building blocks of physics used to express the laws of physics. To represent a physical quantity, we need magnitude and unit.

MAGNITUDE

The numerical value of a physical quantity is called its magnitude.

UNIT

The standard name of a physical quantity by which it is known through the whole world, called its unit.

For Example, Force is measured in newton (N), so N is the unit of force or standard name.

In 10N, 10 is the magnitude and N is the unit of force which is a physical quantity.

TYPES OF UNITS

Units also tells us the nature of the physical quantity. So units are also divided into two catagories

(i) Base Units
(ii) Derived Units

BASE UNITS

The units of base quantities are called base units.
OR The units in which base quantities are measured are called base units.

In SI-units, there are seven base units in which seven base quantities are measured given as

BASE QUANTITY	BASE UNIT	SYMBOL
Length	meter	m
Mass	kilogram	kg
Time	second	S
Electric Current	ampere	A
Thermodynamic Temp.	kelvin	K
Luminous Intensity	candela	cd
Amount of Substance	mole	mol

DERIVED UNITS

The units of all other physical quantities derived from the base and supplementary units are called derived units.

For example, the units of velocity, density, acceleration, momentum, force, work, energy, power etc are the derived units.

Some of derived units are given as

Derived Quantity	Derived Unit	Symbol	In Terms Of Base Units
Force	newton	N	$kg.m.s^{-2}$
Work	joule	J	$N.m = kg.m^2.s^{-2}$
Power	watt	W	$J.s^{-1} = kg.m^2.s^{-3}$
Pressure	pascal	Pa	$N.m^{-2} = kg.m^{-1}.s^{-2}$

International System Of Units or SI-Units

In 1960, an international organisation of which the most developing contries are member, called "General Conference Of Weights And Measures" has been agreed to establish a new system of units. This system of units is called "International System Of Units" or "SI-Units".

Now SI-units are being used by world's scientific community in all scientific works. SI-units are built up from three kinds of units.

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

Definition

A system of units for measurement of physical quantities and accepted internationally is called international system of units or SI-units.

Base Units Of SI

The SI system has seven base units for the physical quantities length, mass, time, temperature, electric current, luminous intensity and amount of substance.

Definitions of base units are given as

Metre

The SI-unit of length is metre denoted by 'm'.

Definition: One metre is the distance travelled by the light wave in vacuum during a time of 1/299,792,458 seconds.

The SI-unit of mass is kilogram denoted by Kg.

DEFINITION: One kilogram is the mass of platinium (90%) and iridium (10%) alloy cylinder, 3.9 cm in diameter and 3.9 cm in height kept at International Bureau of Weights and measures in France.

This mass standard was set up in 1901.

SECOND

The SI-unit of time is second denoted by s.

DEFINITION: One second is the time during which 9,192,631,770 vibrations of Cesium-133 atom take place.

This time standard was set up in 1967.

KELVIN

The SI-unit of thermodynamic temperature is kelvin denoted by K.

DEFINITION: One kelvin is the fraction $1/273.16$ of the thermodynamic temperature of the tripple point of water. Tripple point of a substance is that temperature at which solid, liquid and vapour states are in equilibrium. The tripple point of water is 273.16 K.

This temperature standard was set up in 1967.

AMPERE

The SI-unit of electric current is ampere denoted by A.

DEFINITION: One ampere is that constant current which if maintained in two straight parallel conductors of infinite length of negligible circular cross-section and placed 1 metre apart in vacuum would produce between these conductors a force equal to 2×10^{-7} N/m (newton per metre) of length.

This standard unit was set up in 1971.

CANDELA

The SI-unit of luminous intensity or intensity of light is candela denoted by cd.

DEFINITION: One candela is the intensity of light in the perpendicular direction of a surface of 1/600000 square meter of a black body radiator at the temperature of freezing platinium under a pressure of 101325 newton per square metre.

This standard unit was set up in 1967.

MOLE

The SI-unit of amount of substance is mole denoted by mol.

DEFINITION: One mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0·012 Kg of carbon-12.

This standard unit was set up in 1971.

SUPPLEMENTAR UNITS OF SI

Certain units of SI have not been decided as base units or derived units by General Conference on Weights and Measures. These units are called supplementary units.

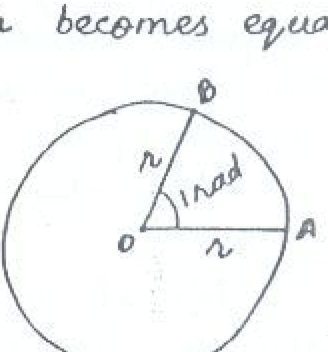
For the time being, there are only two supplementary units of the quantities plane angle and solid angle given as

(i) Radian
(ii) Steradian

RADIAN

The supplementary unit of plane angle is radian denoted by rad.

DEFINITION: If length of arc length becomes equal to the radius of the circle, then the angle subtended at the centre of the circle will be one radian.



From figure

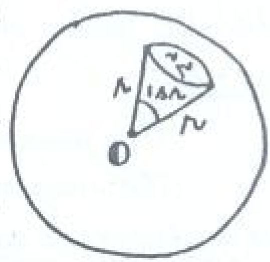
arc $AB = r$

then

$m\angle AOB = 1$ rad.

The supplementary unit of solid angle is steradian denoted by sr.

DEFINITION: One steradian is the solid angle subtended at the centre of a sphere by an area of its surface equal to the square of the radius of the sphere.



DERIVED UNITS OF SI

SI-units of all other physical quantities derived from the base and supplementary units are called derived units.

For example, the units of velocity, acceleration, force, work, momentum and power etc. are the derived units because the units of these quantities are the combination of two or more base and supplementary units.

RADIAN (SECOND DEFINITION)

The radian is the plane angle between two radii of a circle which cut off on the circumference an arc, equal in length to the radius

METRE (OTHER DEFINITIONS)

Before 1960, metre was defined as the distance between two lines marked on the bar of an alloy of platinium (90%) and iridium (10%) kept under controlled conditions at the International Bureau of Weights and Measures in France.

In 1960, metre was redefined as

One metre is a length equal to 1,650,763·73 wavelengths in vacuum of the orange red radiation emitted by the Krypton-86 atom.

SECOND (OTHER DEFINITION)

One second is 1/86400 part of an average day of the year 1900 A.D.

SCIENTIFIC NOTATION

Numbers are expressed in standard form called scientific notation which use power of ten.

The internationally accepted form is that there should be only one non-zero digit left of decimal.

EXAMPLES

The number 134·7 should be written as $1{\cdot}347 \times 10^2$.

The number 0·0023 should be written as $2{\cdot}3 \times 10^{-3}$.

CONVENTIONS FOR INDICATING UNITS

While using SI-units following points must be kept in mind given as

(i) Full name of the unit does not begin with a capital letter even if named after a scientist e.g. newton.

(ii) The symbol of the unit named after a scientist has initial capital letters such as N for newton.

(iii) The prefix should be written before the unit without any space such as 6×10^{-6} m is written as 6 μm.

(iv) A combination of base units is written each with one space apart. For example, newton metre is written as N m.

(v) Compound prefixes are not allowed. For example, 1 μμF may be written as 1 pF.

(vi) A number like $5{\cdot}0 \times 10^4$ cm may be expressed in scientific notation as $5{\cdot}0 \times 10^2$ m.

(vii) 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. For example, $1\,\text{Km}^2 = 1(\text{Km})^2 = 1 \times 10^6\,\text{m}^2$.

(viii) Measurements in practical work must be recorded in the most suitable units. For example, micrometer screw gauge measurement in mm but before the result, all the measurements must be converted into SI-base units.

PREFIXES

Prefixes are used to represent the large or small numbers as multiple of ten.

1 Light Year $= 946 \times 10^{13}$ m $= 9.46 \times 10^{15}$ m $= 9.46$ Pm

Similarly, for smaller number like

Radius of Proton $= 12 \times 10^{-16}$ m $= 1.2 \times 10^{-15}$ m $= 1.2$ fm

Some commonly used prefixes are given as

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

ERRORS

An action or an opinion that is not correct and causes problems or affects the result of a measurement is called error.

REASONS FOR ERROR

The error may occur in a measurement due to

1. Negligence or inexperience of a person.
2. The faulty apparatus.
3. Unsuitable method or technique.

TYPES OF ERROR

There are two types of errors

(i) Random Error

(ii) Systematic Error

RANDOM ERROR

Random error is said to occur when repeated measurements of the quantity give different values under the same conditions. It is due to some unknown causes.

Removal Of Random Error

Repeating the measurements several times and taking an average can reduce the effect of random error.

Systematic Error

Systematic error is the effect that influences all the measurements of a particular quantity equally. It produces the same difference in reading.

Reasons For Systematic Error

The systematic error can occur due to
(i) Zero error of the measuring instrument.
(ii) Incorrect marking on the measuring instrument.

Removal Of Systematic Error

It can be reduced by comparing the instrument with other more accurate instrument and a correction factor can be applied.

Uncertainties

A situation that causes feeling doubt about the results of measurements. Uncertainty is also described as an error in measurements.

Reason's For Uncertainty

Uncertainty may occur due to following reasons.
(i) The state of instrument is not good enough.
(ii) Natural variations of the object.
(iii) Natural fault or weakness in the senses of a person.

Significant Figures

In any measurement, the accurately known digits and the first doubtful digit are called significant figures.

OR

The figures which represent a measured quantity are called significant figures.

In order to decide how many significant figures are to be retained in the final result, we can follow the following rules given as

(i) All digits 1, 2, 3, 4, 5, 6, 7, 8, 9 are significant. However, zeros may or may not significant. In case of zeros, the following rules may be adopted.

(a) A zero between two significant figures is significant. e.g; 50012, 3012 etc.

(b) Zeros to the left of significant figures are not significant. e.g; none of zeros in 0·00467 or 02·59 is significant.

(c) Zeros to the right of a significant figure may or may not be significant. In decimal fraction, zeros to the right of a significant figure are significant. For example, all the zeros in 3·570 or 7·4000 are significant.

However, in numbers like 8,000 kg, the number of significant zeros found out by the accuracy of the measuring instrument. If the least count of the measuring instrument is 1kg, then there are four significant figures in 8000 kg written in scientific notation as 8.000×10^3 kg. If least count is 10 kg, then there will be three significant figures and written as 8.00×10^3 kg in scientific notation and so on.

(d) When a measurement is recorded in scientific notation, the figures other than powers of 10 are all significant. For example, 6.50×10^4 there are three significant figures in it.

(ii) **MULTIPLICATION AND DIVISION OF NUMBERS**

In multiplying and dividing, the numbers of significant figures in the product quotient is equal to the least number of significant figures of the quantities to be multiplied or divided. For example,

$$5.47 \times 19.89 = 108.7983 = 109$$

$$19.89 \div 5.47 = 3.63619 = 3.64$$

(iii) Addition And Subtraction Of Numbers

In adding and subtracting numbers, the number of decimal places retained in the answer should be equal to the smallest number of decimal places in any of the quantities being added or subtracted. In this case, number of significant figures is not important. It is only the position of the decimal which is important.

For example, we want to add the following quantities expressed in metres.

Case (i)

$$\begin{array}{r} 72.1 \\ 3.42 \\ +\ 0.003 \\ \hline 75.523 \end{array}$$

Correct Answer = 75.5 m

Case (ii)

$$\begin{array}{r} 2.7543 \\ 4.10 \\ +\ 1.273 \\ \hline 8.1273 \end{array}$$

Correct Answer = 8.13 m

In case (i), the number 72.1 has the smallest decimal places and hence the answer is rounded off to the same decimal positions which is then 75.5 m.

In case (ii), the number 4.10 has the smallest decimal places and hence the answer is rounded off to the same decimal positions which is then 8.13 m.

Similarly, we proceed for subtraction as

Case (i)

$$\begin{array}{r} 99.8 \\ -\ 55.42 \\ \hline 44.38 \end{array}$$

Correct Answer = 44.4

Case (ii)

$$\begin{array}{r} 60.5 \\ -\ 3.2 \\ \hline 57.3 \end{array}$$

Correct Answer = 57.3

Dependence Of Number Of Significant Figures

In any measurement, the number of significant figures depends upon the following factors.

1. Degree Of Precision or Accuracy Of Measurin Device

The number of significant figures increases with increasing accuracy of measuring device.

For example, if we measure the length of a straight line with a metre rod (marked in cm and mm), with a vernier callipers and with a screw gauge, the accuracy of measurement goes on increasing and the number of significant figures also increases. If length of the line measured with a metre rod is '14.1 cm', the number of significant figures is three. If it is measured with a vernier callipers as '14.15 cm', the number of significant figures is four and with a screw gauge as '14.156 cm', then the number of significant figures is five. Hence, as we improve the quality of measuring device and techniques, the number of significant figures will increase.

2. Size Of Body

The number of significant figures will increase with increase in size of the body.

For example, mass of a small bob is 5.67 gram having number of significant figures three and that of a large bob is 14.56 gram having four significant figures.

3. Degree Of Approximation

The number of significant figures decreases with increase in degree of approximation of measured quantities.

For example, if the radius of earth is taken as 6389 km, the number of significant figures is four. If it is taken as 6390 km approximately, then the significant figures is three and if it is 6400 km approximately, then the number of significant figures is two.

Rounding Off Data

A process in which number of significant figures in a measured quantity is reduced to desired value is called rounding off data.

Rules For Rounding Off Data

1. If the first digit to be dropped is less than 5, the last digit retained should remain unchanged. For example, 15.53 is rounded off as 15.5.

2. If the first digit to be dropped is more than 5, the digit to be retained is increased by 1. For example, 12·36 is rounded off as 12·4.

3. If the digit to be dropped is 5, the previous digit which is to be retained is increased by 1 if it is odd and retained as such if it is even. For example, 12·35 is rounded off as 12·4 and 12·45 as 12·4.

More examples of numbers which are rounded off to three significant figures given as

43·75	is rounded off as	43·8
56·8546	is rounded off as	56·9
73·650	is rounded off as	73·6
64·350	is rounded off as	64·4

PRECISION

Precision means that the observations made with different experiments are very close to each other.

The precision of a measurement is found out by the device being used. The smaller a physical quantity, the more precise instrument should be used.

ABSOLUTE UNCERTAINTY

Absolute uncertainty is equal to the least count of the measuring instrument. It is also called the precision of the instrument.

For example, if the length of an object measured as 25·5 cm by using a metre rod having smallest division in millimetre (mm), it is the difference of two readings of the initial and final positions. The uncertainty in the reading is ±0·05 cm which is now doubled and is called absolute uncertainty equal to ±0·1 cm. So, absolute uncertainty is equal to the least count of the measuring instrument. Hence

Precision or Absolute Uncertainty = Least Count
= 0·1 cm

Precise Measurement

A precise measurement is one which has less precision or absolute uncertainty.

Accuracy

Accuracy means that the result obtained with different experiments are close to the standard value.

The accuracy of a measurement depends on the fractional uncertainty or percentage uncertainty.

Fractional Uncertainity

The ratio of least count of measuring device to the measured value is called fractional uncertainty.

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

Percentage Uncertainty

It is the ratio of least count of measuring device to the measured value and then taken percentage.

$$\text{Percentage Uncertainty} = \frac{\text{Least Count}}{\text{Measured Value}} \times \frac{100}{100} = ---\%$$

or $$\text{Percentage Uncertainty} = \text{Fractional Uncertainty} \times \frac{100}{100}$$

Accurate Measurement

An accurate measurement is one which has less fractional uncertainty or percentage uncertainty or error.

Assessment Of Total Uncertainty In The Final Result

In order to assess the total uncertainty or error, it is necessary to assess the likely uncertainities in all the factors involved in that calculation. The maximum possible uncertainty or error in the final result can be found as follows.

1. For Addition And Subtraction

When the resulting values are added or subtract, the total uncertainty in the final uncertainty in the final result is found by adding absolute uncertainties in relative measurements.

For example, the distance x found by the difference between two separate measurements

$$x_1 = 10.5 \pm 0.1 \text{ cm}$$

and $x_2 = 26.8 \pm 0.1$ cm is

$$x = x_2 - x_1 = 26.8 - 10.5$$

or $x = 16.3 \pm 0.2$ cm

2. For Multiplication And Division

If corresponding measurements are multiplied or divided, then their percentage uncertainties are added to find the total uncertainty in the final result.

For example, if

$$V = 5.2 \pm 0.1 \text{ V}$$

$$I = 0.84 \pm 0.05 \text{ A}$$

then $R = V/I$ is found as

$$\%\text{age uncertainty for } V = \frac{0.1}{5.2} \times \frac{100}{100} = \text{about } 2\%$$

$$\%\text{age uncertainty for } I = \frac{0.05}{0.84} \times \frac{100}{100} = \text{about } 6\%$$

Hence, total uncertainty in R is 8%. So

$$R = \frac{V}{I} = \frac{5.2}{0.84} = 6.19 \text{ ohms with \%age uncertainty of } 8\%$$

or $R = 6.2 \pm 0.5$ ohms

3. For Power Factor

If power factor is involved in measurements, then multiply the percentage uncertainty by that power.

For example, in the calculation of the volume of a sphere using relation $V = 4/3\, \pi r^3$, then

$$\%\text{age uncertainty in } V = 3 \times \%\text{age uncertainty in radius } r$$

Let

$$\text{Radius of sphere} = r = 2.25 \pm 0.01 \text{ cm}$$

$$\therefore \%\text{age uncertainty in } r = \frac{0.01}{2.25} \times \frac{100}{100} = 0.4\%$$

$$\text{Total \%age uncertainty in } V = 3 \times 0.4\% = 1.2\%$$

So, volume of sphere is

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times (2.25)^3$$

or $V = 47.689\ cm^3$ with %age uncertainty of 1.2%

or $V = 47.7 \pm 0.6\ cm^3$

4. For Uncertainty In The Average Value Of Many Measurements

For this purpose, following method is adopt.

(i) Find the average value of measured values.

(ii) Find the difference between each measured value and average value.

(iii) The mean deviation or mean difference is the uncertainty in the average value.

For example, the six readings of the micrometer screw gauge to measure the diameter of a wire in mm are

1.20, 1.22, 1.23, 1.19, 1.22, 1.21

Then

$$\text{Average} = \frac{1.21 + 1.22 + 1.23 + 1.19 + 1.22 + 1.21}{6}$$

Average = 1.21 mm

Now, the difference between each measured value and average value, neglecting the sign is

0.01, 0.01, 0.02, 0.02, 0.01, 0.00

Now mean deviation or mean difference is

$$\text{Mean Deviation} = \frac{0.01 + 0.01 + 0.02 + 0.02 + 0.01 + 0.00}{6}$$

Mean Deviation = 0.01 mm

Hence, total uncertainty in mean or average value is

$$1.21 \pm 0.01\ mm$$

5. For Uncertainty In Timing Experiment

Experiments in which time period of a vibrating body is found, the uncertainty in the time period is found out by dividing the least count of timing device by the number of vibrations.

For example, the time of 30 vibrations of a simple pendulum found by a stop watch with least count of 0.1 s is 54.6 s.

Thus, time period of simple pendulum is

$$T = \frac{54.6}{30} = 1.82\,s \quad \text{with uncertainty } \frac{0.1}{30} = 0.003\,s$$

So, time period T is written as

$$T = 1.82 \pm 0.003\,s$$

Dimensions Of Physical Quantities

Every basic measureable physical quantity represented by a specific symbol written with square brackets is called a dimension.

Explanation

Dimension describe the physical nature of a quantity. The dimension of a physical quantity can be determined if we express that physical quantity in terms of symbols of base units. The dimensions of all physical quantities are measured in the dimensions of three base quantities mass, length and time given as

Dimension of Mass = [M]
Dimension of Length = [L]
Dimension of Time = [T]

Examples

Dimension Of Speed

As

$$\text{Speed} = \frac{\text{Length}}{\text{Time}} = \frac{L}{t}$$

$$\therefore \text{Dimension of speed} = \frac{\text{Dimension of Length}}{\text{Dimension of Time}}$$

or $$[v] = \frac{[L]}{[T]} = \left[\frac{L}{T}\right] = [LT^{-1}]$$

Dimension Of Acceleration

As

$$\text{Acceleration} = \frac{\text{Velocity}}{\text{Time}} = \frac{v}{t}$$

$$\therefore \text{Dimension of acceleration} = [a] = \frac{[v]}{[t]}$$