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CHAPTER

Units and Measurements

LEARNING OBJECTIVES

After reading this chapter, the student will be able to

- Understand the need of measurement in science and engineering and principles of units and homogeneity
- Know the some basic terms such as physics, fundamental physical quantity, fundamental and derived units, dimensions, accuracy, precision, errors, percentage error.
- Utilize the use of dimensional equations and to check the correctness of error in measurement
- Develop an understanding about dimensions of physical quantities and significant figures.

PHYSICS

Physics is the basic science which deals with nature and natural phenomenon.

Science and engineering are based on measurements and comparisons. Science works according to the scientific method. The scientific method accepts only reason, logic and experimental evidence to differentiate between what is scientifically correct and what is not. The real strength of physics *i.e.*, science lies in the fact that it continuously keeps challenging itself.

Physics is the most fundamental scientific discipline and its main goal is to understand how the universe behaves.

NEED OF MEASUREMENT AND UNIT

Science and engineering are based on observations. Measurement is the process of comparing of an unknown quantity with standard one. Whereas the instrument is a device used for comparing the unknown physical quantity with standard quantity of same nature.

PHYSICAL QUANTITY

"All the quantities which can be measured are called physical quantity". For example, mass, length, time, velocity etc.

Unit : "The standard used to measure a physical quantity is known as unit".

For example, when we say that a distance is equal to 5 meter, it means that meter is the standard or unit which is contained 5 times in that distance and 5 is the numerical value. Thus the numerical value alongwith the standard *i.e.*, unit is needed to completely express a physical quantity.

i.e., $\boxed{q = nu}$

where, q = physical quantity
n = numerical value
u = standard or unit of the physical quantity.

PROPERTIES OF UNIT

A unit selected to measure a physical quantity must posses the following properties:

1. They must be well defined
2. They should be easily available and reproducible.
3. They should not vary with time and space.
4. They should be accepted internationally.

REQUIREMENTS OF STANDARD OR UNIT

There are a various units for measuring same physical quantities in different countries. Physical quantities like length have been measured in meter, centimeter, foot, yards etc. Similarly mass have been measured in kilograms, grams, pound etc. It was necessary to come up with a certain system of unit which can be accepted and used all over the world.

Fundamental and Derived Units:

FUNDAMENTAL UNIT: Those physical quantities which are independent of each other and can be explained independently are known as fundamental quantities and their respective units are known as fundamental or base units.

DERIVED UNIT: Those physical quantities which can be explained with the help of fundamental quantities are known as derived quantities and their respective units are known as derived units.

For example, the physical quantity velocity is derived or explained with the help of displacement *i.e.*, length and time

i.e., $$\text{Velocity} = \frac{\text{Displace}}{\text{Time}} = \frac{\text{Length}}{\text{Time}} = \frac{\text{m}}{\text{s}}$$

Hence velocity is derived physical quantity and its unit m/s is derived unit.

SYSTEMS OF UNITS

There are four systems of unit namely C.G.S. system, F.P.S. system M.K.S. system and S.I. system.

C.G.S. System : In this system
C – Stands for **centimeter**
G – Stands for **gram**
S – Stands for **second**.

In this system physical quantity, length mass and time are measured in centimeter, gram and seconds respectively.

F.P.S. System : It is a British system of unit in which
F – Stands for **foot**
P – Stands for **pound**
S – Stands for **second**.

In this system the physical quantities length, mass and time are measured in foot, pound and seconds respectively.

M.K.S. System : This system was set up in France in which
M – Stands for **meter**
K – Stands for **kilogram**
S – Stands for **second**.

This system is closely related to C.G.S. system.

INTERNATIONAL SYSTEM OF UNITS (S.I. SYSTEM)

This system is the modified form of M.K.S. system and is accepted all over the world. This system includes seven fundamental quantities such as length, mass, time, temperature, current electricity, luminous intensity and amount of substance.

Fundamental Quantities with their Units

S.No.	Name of Physical Quantity	Unit	Abbreviations Symbol
1.	Length	Meter	m
2.	Mass	Kilogram	kg
3.	Time	Second	s
4.	Electric current	Ampere	A
5.	Temperature	Kelvin	K
6.	Luminous intensity	Candela	Cd
7.	Amount of substance	Mole	mol

Besides the seven fundamental physical quantities and their respective fundamental units there are two supplementary physical quantities and their respective units.

Supplementary Quantities and their Units

S.No.	Name of Physical Quantities	Unit	Abbreviation/Symbol
1.	Plane angle	Radian	Rad
2.	Solid angle	Steradian	Sr.

SI PREFIXES

The magnitudes of physical quantities vary over a wide range. Following are the S.I. prefixes

Powers of 10	Prefix	Symbol
18	exa	E
15	peta	P
12	tera	T
9	giga	G
6	mega	M
3	kilo	K
2	hecto	h
1	deka	da

Powers of 10	Prefix	Symbol
–1	dece	d
–2	centi	c
–3	milli	m
–6	micro	μ
–9	nano	n
–12	pico	p
–15	femto	f
–18	atto	a

DEFINITIONS OF FUNDAMENTAL UNITS

We briefly mentioning the definitions of the fundamental units as follows:

Metre : It is the unit of length. The distance travelled by light in $\frac{1}{299,792,458}$ second is called 1 meter.

Kilogram : One kilogram is the mass of a cylinder made of platinum-iridium alloy kept at the International Bureau of weights and measure at severes near Paris (France).

Second : One second is the time taken by light of specified wavelength emitted by a Cs – 133 (cesium – 133) atom to execute 9, 192, 631, 770 vibrations.

Ampere : The ampere is that current which when move in each of the two straight parallel conductors of infinite length and negligible cross-section placed one meter apart in vacuum produces a force of 2×10^{-7} N/m between the conductors.

Kelvin : One kelvin is $\frac{1}{273.16}$ of the thermodynamical temperature of the triple point of water.

Candela : The Candela is the Luminous intensity of a black body of surface area $\frac{1}{6,00,000}$ square meter placed at the temperature of freezing platinum and at pressure of 101, 352 Nm^{-2} perpendicular to its surface.

Mole : One mole is the amount of substance that contains as many elementary entities (atoms or molecules) as there are atoms in 0.012 kg of pure carbon – 12 (C – 12) and this number is called Avogadro's number and its value is 6.023×10^{23}.

Radian: One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the Circle.

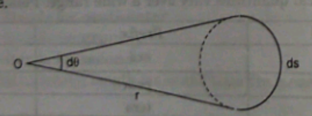

Fig. 1.1.

$$d\theta = \frac{ds}{r} \text{ radian}$$

where, ds = arc of the length

and $d\theta$ = angle subtended at the centre of a circle.

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

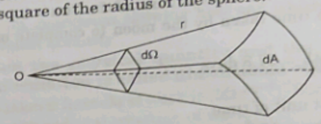

Fig. 1.2.

$$d\Omega = \frac{dA}{r^2}$$

where, $d\Omega$ = Solid angle

dA = area of spherical surface

r = radius of the sphere.

SOME PRACTICAL UNIT

(a) Macrocosm measurement (very large distance) :

1. **Astronomical unit (AU):** It is the average distance of the centre of the Sun from the centre of the Earth.

$$1AU = 1.496 \times 10^{11} \simeq 1.5 \times 10^{11} \text{ m}$$

2. **Light year (LY):** One light year is the distance travelled by light in the free space in one year. The velocity of light in vacuum $(c) = 3 \times 10^8 \text{ ms}^{-1}$.

$$\therefore \quad 1 \text{ Year} = 365 \times 24 \times 60 \times 60 \text{ second}$$

$$\therefore \quad 1 \text{ Light Year} = V \times t$$

$$\text{or,} \quad 1 \text{ Light Year} = 3 \times 10^8 \times 365 \times 24 \times 60 \times 60 \text{ m}$$

$$\text{or} \quad 1 \text{ LY} = 9.46 \times 10^{15} \text{m}$$

Par Sec : One par sec is the radius of a circle at the centre of which on an are of the circle, 1 AU long subtends an angle 1^{11}.

$$1 \text{ par sec} = 3.1 \times 10^{16} \text{ m}$$

$$1 \text{ par sec} = 3.26 \text{ Ly}$$

(a) **Some useful units of length:**

1 inch = 0.0254 m

1 foot = 0.3048 m

1 yard = 0.9144 m

1 mile = 1.609×10^3 m

1 nautical mile = 1.82×10^3 m

(b) **Micro-Cosm measurement (very small distance):**

1 micron (μ) = 10^{-6} m

1 nanometer (nm) = 10^{-9} m

1 angstrom (Å) = 10^{-10} m

1 fermi (fm) = 10^{-15} m

(c) **Measuring heavy masses:**

1 tonne or 1 metric ton = 10^3 kg

1 quintal = 100 kg

1 slug = 14.57 kg

Chandra Shekhar Limit (C.S.L.) is the largest practical unit of mass

1 C.S.L. = 1.4 times of mass of the Sun = 1.4 solar mass.

(*d*) **Lunar month:** The time taken by the moon to complete one revolution around the earth in its orbit.

1 Lunar month = 27.8 days

(*e*) **Shake:**

Shake is the smallest unit of time

1 shake = 10^{-8} second = 10 nano seconds.

ADVANTAGES OF SI UNITS

The SI system of units has following advantages:

(*a*) It is closely related to the MKS system of unit.

(*b*) In SI system, only one unit is used for one physical quantity. Therefore, it is rationalised system of units.

(*c*) All derived units can be obtained by suitable manipulation of base and supplementary units and no numerical factors are encountered, therefore, it is a coherent system of units.

(*d*) In SI system, ,multiples can be expressed as suitable powers of 10.

DIMENSIONS

The unit of mass, length and time are denoted by the capital letters [M], [L] and [T] which merely indicate their nature and not their magnitude. Since the unit of area is the product of two unit lengths, We have the unit of area represented by

$$[L] \times [L] = [L^2]$$

and Similarly, the unit of volume being the product of three unit lengths is represented by

$$[L] \times [L] \times [L] = [L^3]$$

We express this by saying that the unit of area has two dimensions in length and the unit of volume has three dimensions in length. Since neither the unit of area nor that of volume depends upon mass and time, their dimensions are said' to be zero in both mass and time and we may therefore, represent these units as $[M^0L^2T^0]$ and $[M^0 L^3 T^0]$ respectively.

Thus the dimensions of a physical quantity are the powers to which the fundamental units of mass, length and time are to represent it.

Thus if a derived unit depends upon the *n*th power of a fundamental unit, then it is said to be of *n* dimensions in that fundamental unit.

For example,

$$\text{Velocity} = \frac{\text{Diplacement or Length}}{\text{Time}} = \left[\frac{L}{T}\right] = [L\,T^{-1}]$$

Therefore, the dimensions of the velocity are 1 in length and –1 in time. Since it is independent of mass, its dimension in mass is zero and we may therefore represent it by $[M^0\,LT^{-1}]$. Again since acceleration = $\frac{\text{Velocity}}{\text{Time}}$ the dimensions of the unit of acceleration are

$$\frac{\left[M^0\,L\,T^{-1}\right]}{[T]} = [M^0\,LT^{-2}]$$

DIMENSIONAL FORMULAE AND EQUATIONS

A dimensional formula is an expression showing how and which of the fundamental units enter into the unit of a physical quantity".

The relation between the physical quantity and the fundamental quantities expressed in the form of equation is called dimensional equation.

For example, the dimensional formula of work is $[ML^2T^{-2}]$. But when we put it in the form, $W = [ML^2T^{-2}]$, it is called a dimensional equation of work.

PRINCIPLE OF HOMOGENEITY

According to the principle of homogeneity "a physical relation is dimensionally correct if the dimensions of fundamental quantities are the same in each and every term on either side of the equation".

This principle basically signifies that only similar physical quantities can be added, subtracted or equated.

For example, we consider the following relation:

$$s = ut + \frac{1}{2}at^2$$

Here, s = displacement

u = initial velocity

t = time interval

a = uniform acceleration.

The dimensions of each term of both side are as follows:

Dimension of 's' = $[M^0LT^0]$

Dimension of 'ut' = $[M^0LT^{-1}] \times [M^0L^0T] = [M^0LT^0]$

Dimensions of 'at^2' = $[M^0LT^{-2}] \times [M^0L^0T^2] = [M^0LT]$

$$\therefore\ s = ut + \frac{1}{2}at^2$$

or $[M^0LT^0] = [M^0LT^0] + [M^0LT^0]$ $\left[\because \frac{1}{2} \text{ has no dimension}\right]$

or $[M^0LT^0] = [M^02LT^0] = [M^0LT^0]$

Since dimension on R.H.S. are the same as that on L.H.S. therefore is the relation is dimensionally correct.

If a physical relation is not dimensionally homogeneous, then the equation in incorrect.

DIMENSIONLESS QUANTITIES

"Some quantities are ratios comparing one quantity with the other of the same kind and their numerical values are independent of the system of units chosen, they are known as dimensionless quantities".

For example, specific gravity, strain in elasticity, refractive index etc.

Longitudinal strain is defined are the ratio of increase in length to the original length.

Therefore,

$$\text{Strain} = \frac{\text{Increase in length}}{\text{Original length}} = \frac{l}{L}$$

$$\text{Strain} = [L^0]$$

$\therefore$ Dimensionless quantity this indicates that strain is a pure number and hence it is dimensionless.

USES OF DIMENSIONAL EQUATIONS

The following are the uses of dimensional equations:

(a) To check the correctness of an equation.

(b) To convert unit of one system into another.

(c) To restate a forgotten formula.

(d) To derive relationship between different physical quantities.

(a) **TO CHECK THE CORRECTNESS OF A EQUATION:** To check the correctness of the given equation.

We shall write the dimensions of the equations of the quantities of both the sides of the equation.

For example,

$$t = 2\pi\sqrt{\frac{l}{g}}$$

Here, t = time period

l = length of pendulum

g = acceleration due to gravity

Now, Dimensions of 't' = [T] = $[M^0L^0T]$

Dimensions of 'l' = [L] = $[M^0LT^0]$

Dimensions of 'g' = $[LT^{-2}] = [M^0LT^{-2}]$

$$\therefore \quad [M^0L^0T] = \sqrt{\frac{[M^0LT^0]}{[M^0LT^{-2}]}} \qquad [\because 2\pi \text{ is dimensionless}]$$

or, $[M^0L^0T] = \sqrt{T^2} = [T]$

or, $[M^0L^0T] = [M^0L^0T]$

Since the dimensions of L.H.S. is equal to the dimensions of R.H.S. Thus, the given relation is correct.

(b) **TO CONVERT UNIT OF ONE SYSTEM INTO ANOTHER:** The conversion of one system of unit into another unit is based on the fact that magnitude of a physical quantity remains the same whatever be the system of its measurement.

Let us suppose we have a physical quantity Q. Let n_1 and n_2 be numerical values of the physical quantity when measured is the two systems having units of size u_1 and u_2 respectively then,

$Q = n_1u_1$ first system of unit

and $Q = n_2u_2$ Second system of unit

$\therefore \quad Q = n_1u_1 = n_2u_2$

Let the physical quantity Q has the dimensional formula $[M^aL^bT^c]$.

Let M_1, L_1 and T_1 are the fundamental units of mass, length and time in the one system of unit and M_2, L_2 and T_2 are the fundamental units of mass, length and time in second system of unit. Then,

$Q = n_1\,[M_1^a\,L_1^b\,T_1^c]$ in first system of unit

and $Q = n_2\,[M_2^a\,L_2^b\,T_2^c]$ in second system of unit

$\therefore \quad n_1[M_1^a\,L_1^b\,T_1^c] = n_2\,[M_2^a\,L_2^b\,T_2^c]$

$$\therefore \quad n_2 = n_1\left[\frac{M_1^a}{M_2^a}\frac{L_1^b}{L_2^b}\frac{T_1^c}{L_2^c}\right] = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

Therefore, if we know the value of a physical quantity in one system of units we can find its value in the other system of units.

(c) **TO RESTATE A FORGOTTEN FORMULA:** If the physical quantities involved in a relation are known but the powers of these physical qualities are not known then we can use the principle of homogeneity of dimensions to obtain the correct relation.

For example a relation is written as

$$F = 4\pi^2\,fmr$$

where, F = force

f = frequency,

m = mass

and r = radius.

If we want to know the powers of f, m and r in the above equation, then principle of homogeneity of dimensions is applied.

Let us suppose f, m and r have the powers a, b and c respectively.

By equating the dimensions of M, L and T of the two sides of the relation. We can find the values of a, b and c.

Dimensions of L.H.S. = [F] = $[MLT^{-2}]$

On the R.H.S., $4\pi^2$ has no dimension, therefore only f, m and r are enter into dimensional equation.

$\therefore$ Dimensions of R.H.S. = $[T^{-1}]^a\,[M]^b\,[L]^c$

For equation to be correct, the dimensions of M, L and T on equal the two sides must be the equal *i.e.*,

$$[MLT^{-2}] = [M]^b\,[L]^c\,[T^{-1}]^a$$

Equating the powers of M, L and T on both the sides, we have,

$$a = 2, b = 1, c = 1$$

$\therefore$ Correct equation is $F = 4\pi^2 f^2 mr$

(d) **TO DERIVE RELATIONSHIP BETWEEN DIFFERENT PHYSICAL QUANTITIES:** If we know the factors upon which a given physical quantity depends, we can find the relation between the physical quantities.

For example, let us suppose that we want to deduce an expression for the time period of a simple pendulum.

The factors on which the time period T may depend upon

(i) Mass of the bob, m

(ii) Length of the pendulum, l

(*iii*) Acceleration due to gravity, g and

(*iv*) Anglé of swing, θ

Let $$T = Km^x l^y g^z \theta^w$$

Putting dimensions both the sides we can write

$$[T] = [M]^x [L]^y [LT^{-2}]^z \quad (\theta \text{ is omitted as it does not have any dimension})$$

Now equating the indices both the sides, we have,

$$x = 0;$$
$$y + z = 0 \quad \text{and} \quad -2z = 1$$
$$\therefore \quad z = -\frac{1}{2} \text{ and } y = \frac{1}{2}$$

Therefore, $$T = kl^{1/2}g^{-1/2}$$
$$\therefore \quad T = k\sqrt{\frac{l}{g}}$$

The value of k is found out experimentally to be equal to 2π

$\therefore$ Time period, $T = 2\pi\sqrt{\frac{l}{g}}$.

LIMITATIONS OF DIMENSIONAL ANALYSIS

Dimensional analysis though seems to be very helpful, but it has its own limitations. The drawbacks are

(*i*) It gives no information or a little information about pure numerics and dimensional quantities involved in various physical relations. They are to be determined by some other ways may be by calculation or by experiment.

(*ii*) It is restricted solely to physical relationships which are power functions. Relationships involving exponential or trigonometrical functions are not dealt with.

(*iii*) Dimensions of some physical quantities may not represent the same thing. For example, moment of force and work have the same dimension but they are entirely different quantities. The former being vector and the other is scalar.

(*iv*) This dimensional analysis is of no use in deciding the exact form of a physical relation which depends on more than three quantities.

True value : "The true value of a measurement is the value obtained by a perfect measurement".

The true value is obtained after an infinite series of measurements performed under same conditions with an instrument without systematic errors.

Measured value : "A measured value is the value of an object being measured, provided by a measuring instrument or measuring device". It is expressed as the product of numerical value and the unit".

Accuracy : "The accuracy of a measurement is a measures of how close the measured value is to the true value of a physical quantity".

Precision : Precision describes the limitation of the measuring instrument. It is determined by the least count of the measuring instrument. Smaller the least count, greater is the precision of the measuring instrument. Precision is independent of accuracy.

Least count : "The smallest measurement that can be taken accurately by a measuring instrument is called least count of that instrument".

For example, a vernier callipers may have least count of 0.1 mm whereas a micrometer screw gauge have a least count of 0.01 mm.

LIMIT OF PRECISION

"The limit of precision of a measuring device is $\pm\frac{1}{2}$ of the smallest devision of measurement of the device.

For example a meter scale marked in millimeter has a limiting precision of $\pm$ 0.5 mm or $\pm$ 0.05 cm. A vernier calipers that can measure nearest to 0.1 mm has a limiting precision of $\pm$ 5 mm or $\pm$ 0.005 cm. Therefore, if the length of a rod measured by a meter scale is 25.3 cm, the measurement can be written as 25.3 $\pm$ 0.05 cm. This means that true value of length most likely lies between (25.3 cm + 0.05 cm) = 25.25 cm and (25.3 cm – 0.05 cm) = 25.25 cm. Sometimes limiting precision is taken equal to the least count of the device.

ERROR

The difference between the true value and the measured value of a physical quantity is known as error or the uncertainty in a measurement is known as error.

There are mainly two types of error

1. Systematic errors
2. Random errors or Non systematic errors.

1. SYSTEMATIC ERRORS : Due to known causes the errors that appear in a measurement is known as systematic error. For example,

(*i*) In correct design or calibration of the instrument.

(*ii*) Limitations of the method used for measurement.

(*iii*) In correct reading or interpretation of the instrument

(*iv*) lack of accuracy of the formula being used.

2. RANDOM ERRORS: These error occur due to unknown causes which is beyond the control of the experimenter. They arise even when the most careful measurement of the same physical quality is taken in the same way with the same equipment by the same experimenter. So these errors are inherently random in nature and hence they are to be treated by statistical method.

In order to minimise random errors, measurements are repeated many times and arithmatic mean of all measurements is taken as the true value of the measured quantity. If number of observations is made n time the random error is reduced to $\frac{1}{n}$ times.

ABSOLUTE ERROR

The difference in the magnitude of true value and the measured value of a physical quantity is called absolute (actual) error.

i.e., Absolute error = true value of the physical quantity – measured value of the physical quantity.

The absolute errors can be positive in certain cases and negative in certain other cases.

Let A be a physical quantity which is measured n times and let the measured values are $A_1, A_2, A_3, \ldots A_n$.

$$\therefore \quad \text{Arithmatic mean} = \frac{A_1 + A_2 + A_3 + \cdots + A_n}{n}$$

or $$A_m = \frac{1}{n}\sum_{i=1}^{i=n} A_i$$

Thus, the arithmatic mean A_m is taken as the true value of the quantity. According to the definition, absolute errors is the individual measured values of the quantity are

Absolute error,
$$\Delta A_1 = A_m - A_1$$
$$\Delta A_2 = A_m - A_2$$
$$\Delta A_3 = A_m - A_3$$
$$\ldots\ldots\ldots\ldots$$
$$\ldots\ldots\ldots\ldots$$
$$\boxed{\Delta A_n = A_m - A_n}$$

MEAN ABSOLUTE ERROR : The arithmatic mean of all the absolute errors in the measured value is known as mean absolute error. It is denoted by ΔA_{mean}

i.e., $$\Delta A_{mean} = \frac{|\Delta A_1| + |\Delta A_2| + \ldots + |\Delta A_n|}{n}$$

or, $$\Delta A_{mean} = \frac{1}{n}\sum_{i=1}^{i=n} |A_i|$$

It is also known as final absolute error.

$\therefore$ We can write

$$A = A_m \pm \Delta A_{mean}$$

Hence the measurement of the physical quantity lies between $A_m + \Delta A_{mean}$ and $A_m - A_{mean}$

RELATIVE ERROR: The ratio of mean absolute error to the mean value or true value of the quantity being measured is called relative error or fractional error.

i.e., $$\text{Relative error} = \frac{\text{Mean absolute error}}{\text{Mean value}}$$

or, $$\text{Relative error} = \frac{\varnothing A_{mean}}{A_m}$$

PERCENTAGE ERROR : The relative error is expressed in percentage is called percentage error i.e., percentage of error = $\frac{\varnothing A_{mean}}{A_m} \times 100$.

Example: ***A student measures the time period of oscillation of a simple pendulum. In successive measurements, the readings turn out to be 2.56 second, 2.63 second, 2.71 second, 2.42 second and 2.80 second. Find the absolute error, relative error and percentage error.***

Solution: Given, the absorbed values of time period

$$t_1 = 2.56\text{ s}, t_2 = 2.63\text{ s}, t_3 = 2.71\text{ s}, t_4 = 2.42\text{ s and } t_5 = 2.80\text{ s}.$$

$\therefore$ The mean period of oscillation of a simple pendulum

$$t_m = \frac{2.56 + 2.63 + 2.71 + 2.42 + 2.80}{5} = \frac{13.12}{5}$$
$$= 2.624\text{ s}.$$

$\therefore$ The mean time period of oscillation to the second decimal place, $t_m = 2.62$ s.

Now, the absolute errors in the each measurement are

$$t_m - t_1 = 2.62 - 2.56 = +0.06\text{ s}$$
$$t_m - t_2 = 2.62 - 2.63 = -0.01\text{ s}$$
$$t_m - t_3 = 2.62 - 2.71 = +0.09\text{ s}$$
$$t_m - t_4 = 2.62 - 2.42 = +0.20\text{ s}$$
$$t_m - t_5 = 2.62 - 2.80 = -0.18\text{ s}$$

$\therefore$ Mean absolute error

$$\Delta t_{mean} = \frac{0.06 + 0.01 + 0.09 + 0.20 + 0.18}{5} = \frac{0.54}{5}\text{ s}$$
$$= 0.11\text{ second}.$$

Time period of simple pendulum, $t = (2.62 \pm 0.11)$ second.

Therefore, t lies between $(2.62 + 0.11)$ second and $(2.62 - 0.11)$ second.

i.e., 2.73 second and 2.51 second.

Now, the relative error

$$= \pm\frac{\text{Mean absolute error}}{\text{Mean value}} = \pm\frac{0.11}{0.62}$$

i.e., Relative error = 0.041

And hence percentage error

$$= \text{Relative error} \times 100$$
$$= \pm 0.41 \times 100 = \pm 4.1\%.$$

SIGNIFICANT FIGURE : Significant figure is the number digits used to express the measurement of a physical quantity such that the last digit in it is doubtful, but the rest all are accurate or assured.

For example, when a measured distance is 576.8 m, it has 4 significant figures 5, 7, 6 and 8. The digits 5, 7 and 6 are certain and reliable digits, while 8 is doubtful. Similarly the radius measured by screw gauge is 3.24 cm, it has three significant figures 3, 2 and 4. The digit 3 and 4 are certain and reliable while digit 4 is doubtful.

The larger the number of significant figures in a measurement the greater is the precision of the measurement and vice-versa.

RULES FOR COUNTING THE NUMBER OF SIGNIFICANT FIGURES : Following are the rules for determining the number of significant figures in a measurement.

(*i*) All non-zero digits are counted, *e.g.*, 156.25 gram contains five significant figures.

(*ii*) All the zeroes between the numerals 1 and 9 are counted, *e.g.*, 105.003 meter contains six significant figures.

(*iii*) In a measurement involving decimal, the position of decimal is ignored.

(*iv*) All the zeroes after the last numeral are counted.

(*v*) All the zeroes before the first numeral are ignored.

(*vi*) The powers of ten are not counted as significant figure.

Significant figures in calculations : During calculations the following rule is obeyed for identifications of the number of significant figures.

1. In addition or subtraction, the number of decimal places in the result should be equal to the smallest number of decimal places of any term in the sum or subtraction.
2. In multiplication or division, the number of significant figures in the result should be equal to the number of significant figures of the least precise term in multiplication or division

For example, Find the area enclosed by a circle of a diameter 1.06 m to correct number of significant figures.

Solution:

Given, $r = \frac{D}{2} = \frac{1.06}{2} = 0.5$

As we know, Area $= \pi r^2 = 3.14 \times (0.53)^2 = 0.882026 \text{ m}^2 = 0.882 \text{ m}^2$

Rounded off to three significant figures since diameter contains only three significant figures.

SOLVED NUMERICAL PROBLEMS

Example 1. ***Calculate the volume of a cylinder with a diameter of 9.9 cm and a height of 13.5 cm.***

Solution: Volume of cylinder

$$V = \text{area of base} \times \text{height} = \pi \times r^2 \times h$$

$$= \pi \times \left(\frac{D}{2}\right)^2 \times h = \frac{\pi}{4} \times (9.9)^2 \times 13.5$$

$$= 1039.19 \text{ cm}^3 = 1.0391 \times 10^3 \text{ cm}^3$$

Since the least precise quantity is the diameter and is known to 2 significant figures, therefore answer must be expressed two significant figures.

$\therefore$ $V = 1.0 \times 10^3 \text{ cm}^3$.

Example 2. ***5.75 gram of the substance occupies 1.2 cc. Find the density of the substance to correct significant figures.***

Solution : $\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{5.75}{1.2} = 4.7916$ g/cc

Since the least precise quantity is the volume (1.2 cc) and is known to two significant figures, the answer must have two significant figures.

$\therefore$ Density = 4.8 g/cc.

Example 3. ***Perform the following operation to correct number of significant figures, $6.8 \times 10^4 \text{ s} \times 3.1 \times 10^5$ second.***

Solution: As we know that to add quantities of different exponents, we must first express then with same exponent.

$\therefore$ $6.8 \times 10^4 + 3.1 \times 10^5 = 6.8 \times 10^4 + 31 \times 10^4 = 37.8 \times 10^4$ second

Since the least precise term is known to one decimal place the final result must be expressed to one decimal place.

After rounding off the answer is 3.8×10^5 second.

Example 4. ***Find the value of 10 joules on a system which has 10 cm, 100g and 30 seconds as the fundamental units.***

Solution: Joule is the SI unit of work

Let n_1 is the S.I. unit whereas n_2 is the new unit.

SI Units	*New system of units*
$n_1 = 10\text{J}$	$n_2 = ?$
$M_1 = 1$ kg	$M_2 = 100$ g
$L_1 = 1$ m	$L_2 = 10$ cm
$T_1 = 1$ s	$T_2 = 30$ s

Now we know that,

$$[\text{Work}] = [F \times S] = [\text{ML}^2\text{T}^{-2}]$$

$$a = 1, b = 2, c = 2$$

Now $$n_2 = \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c = 10 \left[\frac{1 \text{ kg}}{100 \text{ g}}\right]^1 \left[\frac{1 \text{ m}}{10 \text{ cm}}\right]^2 \left[\frac{1 \text{ s}}{30 \text{ s}}\right]^{-2}$$

$$= 10 \left[\frac{1000 \text{ g}}{100 \text{ g}}\right]^1 \left[\frac{100 \text{ cm}}{10 \text{ cm}}\right]^2 \left[\frac{1 \cancel{s}}{30 \cancel{s}}\right]^{-2} = 10\,[10]^1\,[10]^2 \left[\frac{1}{30}\right]^{-2}$$

$$= 10 \times 10 \times 100 \times 900 = 9 \times 10^6 \text{ New units}$$

$\therefore$ $10\text{J} = 9 \times 10^6$ New units. **Ans.**

Example 5. ***If the units of length and force be each increased force times, show that the unit of energy is increased sixteen times.***

Solution: We have unit of energy = Unit of force × unit of distance

$$= [\text{MLT}^{-2}] \times [\text{L}] = [\text{ML}^2\text{T}^{-2}]$$

Now if the unit of force and distance be made four times each they would be 4 (M L T^{-2}) and 4 L, respectively and therefore, the new unit of energy would, be $4 \text{ M L T}^{-2} \times 4\text{L} = 16[\text{ML}^2\text{T}^{-2}]$, which is 16 times ML^2T^2, the ordinary unit.

Thus we see that by increasing the unit of force and length four times each, the unit of energy is increased sixteen times. **Ans.**

Example 6. ***Test by the method of dimensions the accuracy of the relation $t = 2\pi\sqrt{(k^2 + t^2)lg}$ for the time period of a compound pendulum.***

Solution: If the relation be correct, the dimensions of the terms on either side of the sign of equality must be the same.

Let us put the relation as

$$t = 2\pi \sqrt{\frac{k^2}{lg} + \frac{l}{g}}$$

Now the dimensions of t = [T]

Now the dimensions K^2 = [L^2]

K being the radius of ratio

the dimensions of l = [L]

the dimensions of g = [LT^{-2}]

Therefore, the dimensions of the terms on the right hand side are

$$= \sqrt{\frac{\cancel{L^2}}{\cancel{L}\,\cancel{L}\,T^{-2}} + \frac{\cancel{L}}{\cancel{L}\,T^{-2}}} = \sqrt{T^2 + T^2} = \sqrt{2T^2}$$

$$= T\sqrt{2}. \text{ Ans.}$$

Example 7. *The circular scale of a spherometer is decided into 200 equal divisions, if its least count is 0.005 mm then what is the distance between two consecutive threads of the spherometer screw?*

Solution: We known that the distance between two consecutive thread is known as pitch of the spherometer.

Now we know that

$$\text{Least count} = \frac{\text{Pitch}}{\text{No. of circular scale division}}$$

or,
$$0.005 \text{ mm} = \frac{\text{Pitch}}{200}$$

$\therefore$ Pitch = 200 × 0.005 mm = 1.000 mm = 1.00 mm. **Ans.**

Hence, the distance between two consecutive threads of a spherometer is 1 mm.

Example 8. *In a given side callipers 10 divisions of its vernier coincides with its 9 main scale division. If one main scale division is equal to 0.5 mm then find its least count.*

Solution: $\therefore$ 10 divisions of vernier scale = 9 main scale divisions

$\therefore$ 1 division of vernier scale = $\frac{9}{10}$ main scale divisions

$= \frac{9}{10} \times 0.5$ mm

= 0.45 mm

Now we know that

Least count of a slide callipers = Value of 1 MSD – Value of VSD

= 0.5 mm – 0.45 mm = 0.005 mm.

Therefore the least count of slide callipers equal to 0.05 mm. **Ans.**

MULTIPLE CHOICE QUESTIONS

1. Which is a fundamental quantity? **[JUT-2019]**
   (*a*) length (*b*) velocity (*c*) acceleration (*d*) force
2. How many significant digits are in 0.04058? **[SBTEJ-2018]**
   (*a*) 4 (*b*) 5 (*c*) 6 (*d*) 3

3. A physical quantity is measured and the result is expressed as nu where u is the unit used and n is the numerical value. If the result is expressed in various units then
   (*a*) $n \propto$ size of u (*b*) $n \propto u^2$ (*c*) $n \propto \sqrt{u}$ (*d*) $n \propto \frac{1}{u}$
4. Which of the following set enter into the list of fundamental quantities in any system of units?
   (*a*) Length, mass and velocity (*b*) Length, time and velocity
   (*c*) Mass, time and velocity (*d*) Length, time and mass
5. A dimensionless quantity
   (*a*) never has a unit (*b*) always has a unit
   (*c*) may have a unit (*d*) does not exist.
6. A unitless quantity
   (*a*) never has a non-zero dimension (*b*) always has a non- zero dimension
   (*c*) may have a non-zero dimension (*d*) does not exist.
7. The dimension $ML^{-1}T^{-2}$ may corresponds to
   (*a*) Work done by a force (*b*) Linear momentum
   (*c*) Pressure (*d*) Energy per unit volume.
8. Choose the in correct statement
   (*a*) A dimensionally correct equation may be correct
   (*b*) A dimensionally correct equation may not be correct.
   (*c*) A dimensionally in correct equation may be incorrect.
   (*d*) A dimensionally incorrect equation may be incorrect.
9. Which of the following has no dimension?
   (*a*) Angle (*b*) Work (*c*) Force (*d*) Speed
10. The length of a rod is (11.05 ± 0.05) cm. Which is the total length of two such rods?
    (*a*) (22.10 ± 0.15) cm (*b*) (22.10 ± 0.10) cm
    (*c*) (22.10 ± 0.05) cm (*d*) (22.15 ± 0.10) cm
11. The dimensions of gravitational constant are
    (*a*) [ML^2T^{-2}] (*b*) [$M^{-1}L^{-2}T^{-2}$] (*c*) [$M^{-1}L^{+3}T^{-2}$] (*d*) [$ML^{-3}T^{-2}$]
12. Which one of the following has the dimensions of pressure?
    (*a*) [$ML^{-1}T^{-2}$] (*b*) [$M^{-1}L^{-1}T^{-1}$] (*c*) [$ML^{-2}T^{-2}$] (*d*) [MLT^{-2}]
13. The significant figure in 3400 is
    (*a*) 1 (*b*) 2 (*c*) 3 (*d*) 4
14. Length can not be measured in
    (*a*) light year (*b*) Micron (*c*) fermi (*d*) debye
15. The dimensions of energy are
    (*a*) [ML^2T^2] (*b*) [$M^2L^2T^{-2}$] (*c*) [MLT^{-2}] (*d*) [MLT^{-1}]
16. The correct number of significant figures in 0.0003056 is
    (*a*) Six (*b*) Four (*c*) Seven (*d*) Eight
17. The unit of electric current is
    (*a*) Ampere (*b*) Coloumb (*c*) Faraday (*d*) Newton

18. 1 angstrom (Å) is equal to
(*a*) 10^{-8} m (*b*) 10^{-6} m (*c*) 10^{-8} m (*d*) 10^{-10} m

19. A student measured the thickness of a glass slab using a spherometer with least count 0.001 cm. The correct listing is
(*a*) 0.234 cm (*b*) 0.234 m (*c*) 0.230 mm (*d*) 2.34 cm

20. When the two jaws of a vernier calliper are in touch zero of vernier scale lies to the right of zero of main scale and coinciding vernier division is **. If vernier constant is 0.1 mm, the zero correction is
(*a*) + 0.03 mm (*b*) + 0.03 cm (*c*) – 0.03 cm (*d*) – 0.03 mm

21. If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be
(*a*) 6% (*b*) 4% (*c*) 8% (*d*) 10%

22. Parsec is the unit of
(*a*) time (*b*) distance (*c*) frequency (*d*) acceleration

23. What is the percentage error in volume of a sphere, when error in measuring its radius is 2%?
(*a*) ± 2% (*b*) ± 3% (*c*) ± 4% (*d*) ± 6%

24. Joule × sec is the unit of
(*a*) energy (*b*) momentum
(*c*) angular momentum (*d*) power

25. Dimensional formula of force is
(*a*) $[M^0L^2T^{-2}]$ (*b*) $[MLT^{-2}]$ (*c*) $[ML^2T^{-2}]$ (*d*) $[ML^2T^{-1}]$

26. The dimensional formula of Plank's constant (*h*) is
(*a*) $[ML^{-2}T^{-3}]$ (*b*) $[ML^2T^{-2}]$ (*c*) $[ML^2T^{-1}]$ (*d*) $[ML^{-2}T^{-2}]$

27. The dimensions of velocity is
(*a*) $[M^0L^2T^{-2}]$ (*b*) $[M^0L^2T^{-2}]$ (*c*) $[MLT^2]$ (*d*) $[M^0LT^{-1}]$

28. The dimensional formula of bulk modulus of elasticity is
(*a*) $[ML^{-2}T^{-2}]$ (*b*) $[M^1L^2T^{-2}]$ (*c*) $[M^1L^2T^{-2}]$ (*d*) $[M^1L^{-1}T^{-2}]$

29. The dimensions of calories are
(*a*) $[ML^2T^{-2}]$ (*b*) $[ML^2T^{-2}]$ (*c*) $[ML^{-2}T^{-1}]$ (*d*) $[ML^2T^{-1}]$

30. If the unit of length mass and time each be doubled, the unit of work is increased
(*a*) Two times (*b*) Four times (*c*) Six times (*d*) No change

31. The dimensional formula of impulse
(*a*) $[MLT^{-2}]$ (*b*) $[MLT^{-1}]$ (*c*) $[ML^2T^{-1}]$ (*d*) $[M^2LT^{-1}]$

32. The unit of coefficient of thermal conductivity is
(*a*) Watt-kelvin-m (*b*) Watt/m-k (*c*) J/c (*d*) Joule

33. The dimensional formula of latent heat is
(*a*) $[M^0L^2T^{-2}]$ (*b*) $[MLT^{-2}]$ (*c*) $[ML^2T^2]$ (*d*) $[ML^2T^{-1}]$

34. The dimensions of $1/\sqrt{\mu_0\varepsilon_0}$ the same as that of
(*a*) Velocity (*b*) Time (*c*) Capacitance (*d*) Distance

35. Which of the following has not been expressed in proper unit
(*a*) Stress/strain = N/m^2 (*b*) Surface tension = N/m
(*c*) Energy = kg × m/s (*d*) Pressure = N/m^2

36. According to Newton, the viscous force acting between liquid layers of area *A* and velocity gradient $\Delta v/\Delta z$ is given by $F = \eta A \dfrac{\partial v}{\partial z}$ where η is a constant called coefficient of viscosity, the dimension of η are
(*a*) $[ML^2T^{-2}]$ (*b*) $[M^0L^0T^0]$ (*c*) $[ML^2T^2]$ (*d*) $[ML^{-1}T^{-1}]$

37. The dimensions of the quantities is one of the following pairs are same. Identify the pairs
(*a*) Torque and work (*b*) Angular momentum
(*c*) Energy and Young's modulus (*d*) Light year and frequency

38. Plane angle and solid angle are
(*a*) Primary fundamental unit (*b*) Secondary fundamental unit
(*c*) Supplementary units (*d*) Derived units.

39. By the surface, the solid angle subtended at the centre of a sphere, whose area is equal to the surface of the radius of the sphere is known as
(*a*) Radian (*b*) Steradian (*c*) Candela (*d*) Lux

40. At the centre, the plane angle subtended by an arc of a circle equal to the radius of the circle is known as
(*a*) Steradian (*b*) Candela (*c*) Lumen (*d*) Radian

41. Another name of fundamental units is
(*a*) Base units (*b*) Atoms
(*c*) The metric system (*d*) Letter symbol

42. Which of the following metric prefixes could replace 10^{-9}?
(*a*) nano (*b*) mega (*c*) kilo (*d*) micro

43. The S.I. unit for amount of substance is
(*a*) mole (*b*) mole fraction (*c*) kilogram (*d*) gram

44. Select the odd one out in the following measurement units
(*a*) kilogram (*b*) gram (*c*) meter (*d*) second

45. The metric system is also called as
(*a*) CGS (*b*) MKS (*c*) SI (*d*) None of these

46. What is the name of physical quantities which are independent of each other?
(*a*) Fundamental quantity (*b*) Derived quantity
(*c*) Numerical quantity (*d*) None of these

47. What is the standard unit for length?
(*a*) meter (*b*) inch (*c*) kilometer (*d*) centimeter

48. Which of the quantity consists of unit as newton-second?
(*a*) Impulse (*b*) Acceleration (*c*) Speed (*d*) Velocity

49. Which of the quantity consists of unit as Pascal?
(*a*) Temperature (*b*) Pressure (*c*) Force (*d*) Impulse

50. Which one of the following units is a fundamental unit?
(*a*) newton (*b*) ampere (*c*) watt (*d*) joule/sec

51. Which of the following quantity consists of SI unit as Hertz?
(*a*) Charge (*b*) Force (*c*) Frequency (*d*) Power

52. What is the S.I. units of mass length and time respectively?
(*a*) g, m and s (*b*) kg, cm and s (*c*) g, cm and s (*d*) kg, m and s

53. How many fundamental units are there?
(a) 4 (b) 6 (c) 7 (d) 8

54. What is the S.I. unit of angle?
(a) Steradian (b) Candela (c) Radian (d) Degree

55. Which of the following is a common unit of a physical quantity in MKS and SI system?
(a) Ampere (b) Kelvin (c) Mole (d) Joule/see

56. The fundamental unit which is common is FPS and MKS system is?
(a) Foot (b) See (c) Kilogram (d) Pound

57. Which of the following is unit of length?
(a) Lunar month (b) Kelvin (c) Candela (d) Light year

58. The physical quantity having units of mass is
(a) Density (b) Momentum (c) Inertia (d) Moment of force

59. Which of the following system is a British system?
(a) C.G.S. system (b) R.P.S. system (c) M.K.S. system (d) None of these

60. Which of the following is not a unit of time?
(a) Second (b) Month (c) Year (d) Light year

61. Unit of strain is
(a) m/s (b) kg m (c) no unit (d) Nm

62. How many significant figures are in 0.04058?
(a) 4 (b) 5 (c) 6 (d) 3

63. The volume of a cube of 1 side, 1 cm is equal to
(a) 10^{-6} m (b) 10^{-3} m (c) 10^{-9} m (d) None of these

64. 1 Meter is equal to
(a) 1.05×10^{-16} ly (b) 2.0×10^{-6} ly (c) 2.0×10^{-10} ly (d) None of these

65. 1 light year (ly) is equal to
(a) 9.46×10^{15}m (b) 10×10^{16}m (c) 1.5×10^{8}m (d) None of these

66. Which of the following is the mast precise device for measuring length?
(a) A vernier callipers with 20 divisions on the main scale
(b) A snow gauge of pitch 1 mm and 100 divisions on the circular scale.
(c) An optical instrument that can measure length to within in a wave length of light
(d) None of these.

67. State the number of significant figures in the following 6.320J
(a) 1 (b) 4 (c) 3 (d) None of these

68. Which of the following time measuring devices is most precise?
(a) A wall clock (b) A stop watch (c) A digital watch (d) An atomic clock

69. A physical quantity which has a unit but no dimension is
(a) Plane angle (b) Strain (c) Mole (d) None of these

70. Mass is given by the relation
(a) Velocity/acceleration (b) Force/velocity
(c) Force/acceleration (d) None of these

71. A thin copper wire of length L increase in length by 2% when heated from T_1 to T_2. If a copper cube having side 10 L is heated from T_1 to T_2, what will be the percentage error in area of one face of the cube?
(a) 4% (b) 6% (c) 8% (d) None of these

72. Which of the following system of units is not based on units of mass, length and time alone?
(a) SI (b) MKS (c) FPS (d) CGS

73. Which of the following is smallest unit?
(a) Millimeter (b) Angstrom (c) Fermi (d) Meter

74. The dimensional formula of wave number is
(a) $[M^0L^0T^{-1}]$ (b) $[M^{-1}L^{-1}T^0]$ (c) $[M^0L^{-1}T^0]$ (d) $[M^0L^0T^0]$

75. Zero error of an instrument introduces
(a) Systematic error (b) Random error
(c) Both (d) None of these

76. A vernier callipers has 20 divisions on the vernier scale which coincide with 19 divisions on the main scale. The least count of the instrument is 0.1 mm, the main scale divisions are of
(a) 0.5 mm (b) 1 mm (c) 2 mm (d) 1/4 mm

77. A student measured the diameter of a wire using a screw gauge with least count 0.001 cm and listed the measurements. The correct measurement is
(a) 5.3 cm (b) 5.32 cm (c) 5.320 cm (d) 5.3200 cm

78. 1 A.V. is equal to
(a) 3×10^8 m (b) 10^{10} m (c) 1.5×10^{11} m (d) 10^7 m

79. A spring balance is used to measure
(a) The weight of a body (b) The mass of a body
(c) Both mass and weight of a body (d) None of the above

80. A physical quantity is one of which
(a) Cannot be measured (b) Can be measured
(c) Is a scalar quantity (d) Is a vector quantity

81. The volume of are sphere is 1.76 cc the volume of 25 such spheres to correct significant figures is
(a) 44.00 cc (b) 44.0 cc (c) 44 cc (d) 0.44×10^2 cc

82. The length of a rod is measured with ordinary meter rod and is found to be exactly 3 cm. The measurement will be recorded as
(a) 3 cm (b) 3.0 cm (c) 3.00 cm (d) 3.000 cm

83. One student the length of a rod with a ruler and find it to be 6.8 cm. The accuracy in measurement is about
(a) 3% (b) 5% (c) 1.5% (d) 10%

84. The length of a rod is given 8.1 cm. The least count of the measuring device is
(a) 0.1 mm (b) 0.01 mm (c) 0.001 mm (d) 1 mm

85. The errors in measuring the mass and volume of a body are 5% and 2% respectively. The error in measuring density will be

(a) 7% (b) 10% (c) 3% (d) 2.5%

86. The dimension of sin θ is

(a) [L^2] (b) [M] (c) [ML] (d) No dimension

87. A physical quantity P is given by

$$P = ab^2c^3d^4$$

The percentage error in the measurement of a, b, c and d is 0.5% each. The error in the measurement of P will be

(a) 2.5% (b) 8% (c) 5% (d) 6%

ANSWERS

1. (a)	2. (b)	3. (d)	4. (d)	5. (c)	6. (a)
7. (c, d)	8. (c)	9. (a)	10. (b)	11. (c)	12. (a)
13. (b)	14. (d)	15. (a)	16. (b)	17. (a)	18. (d)
19. (a)	20. (c)	21. (a)	22. (b)	23. (d)	24. (c)
25. (c)	26. (c)	27. (a)	28. (d)	29. (a)	30. (a)
31. (b)	32. (b)	33. (a)	34. (a)	35. (c)	36. (d)
37. (a)	38. (c)	39. (b)	40. (d)	41. (a)	42. (a)
43. (a)	44. (b)	45. (b)	46. (a)	47. (a)	48. (a)
49. (b)	50. (b)	51. (c)	52. (d)	53. (c)	54. (c)
55. (d)	56. (b)	57. (d)	58. (c)	59. (b)	60. (d)
61. (c)	62. (a)	63. (a)	64. (a)	65. (a)	66. (c)
67. (a)	68. (d)	69. (a)	70. (c)	71. (a)	72. (a)
73. (c)	74. (c)	75. (a)	76. (b)	77. (c)	78. (c)
79. (a)	80. (b)	81. (b)	82. (b)	83. (c)	84. (d)
85. (a)	86. (d)	87. (c)			

SHORT AND LONG TYPE QUESTIONS

1. What do you understand by fundamental and derived units? [SBTEJ-2018]
2. Define the term – accuracy, precision, absolute error and percentage error.
3. What is the importance of measurement in science and engineering?
4. What are the desirable features of fundamental units?
5. What is a coherent system of units?
6. Define astronomical unit light year and parsec. How they are related?
7. What is the difference between nm, mN and Nm?
8. If $f = a^2$, relative error in f would be how many times the relative error in a?
9. Define dimensions of a physical quantity. What is dimensional formula?
10. Explain the principle of homogeneity of dimensions. Find its uses.
11. What are the limitations of dimensional analysis?
12. Derive expression using the method of dimensions, for the time period of a simple pendulum.

13. What is SI unit of length? Why is this unit defined in terms of wavelength of light radiation?
14. What is system of unit? Explain.
15. State and explain unit of a physical quantity.
16. What are the needs of measurement in engineering and science?
17. Define the term-accuracy precision and error with example, explain absolute error, relative error and percentage error.
18. What do you understand by the term-least count of a measuring instrument?
19. What is significant figures?
    Write the rules to identify significant figures. Find the number of significant figures of the following:
    (a) 1.080 (b) 0.0018 (c) 1.08 (d) 5.98×10^{12}
20. Define astronomical unit, light year and par sec. How are they related? Name three physical quantities which have same dimensions.
21. It velocity, time and force are choosen as base quantities then find the dimensions of mass.
22. Which of the following is the most precise device for measuring length and why?
    (a) A vernier callipers with 20 divisions on the main scale.
    (b) A screw gauge of pitch 1 mm and 100 divisions on the circular scale.
    (c) An optical instrument that can measure length to within wavelength of light?