UNIT -1 PHYSICAL WORLD

1. What is science?

Systematic and organized knowledge about the various natural phenomena which is obtained by careful experiments, keen observation and accurate readings.

Science (from Latin scientia 'knowledge')

- In Sanskrit it is called sastra (vijyan) and in Urdu it is called elm.

Science may be divided into two types

A. Biological science

The science which deals with the living organism is called biological sciences. The main parts of biological science are botany, zoology, forensic science etc.

B. Physical science

The science which deals with the non living organism is called physical sciences. The main parts of physical science are

i. Chemistry

The branch of science which deals with the study of every substance, there structure, composition and change in which the reaction takes parts.

ii. Physics

The branch of science which deals with the study of nature and the natural phenomenon is called physics.

2. What is the attitude of science?

In science a solution is suggested for a problem. This solution is tried, if it works properly than it is adopted otherwise it is replaced by a better solution to the same problem.

Thus scientific attitude requires a flexible, open minded approach toward solving a problem in which other important points are not neglected without any reason.

3. Scientific methods

The step by step approaches used by the scientist in study of nature and natural phenomenon and establishing the law which govern this phenomenon is called the scientific methods.

Generally it involves the following steps:-

1. By taking a large number of the systematic observations.
2. Studying these observations and making qualitative reasoning.
3. Suggesting a mathematical method to the observations.
4. Predicting new phenomenon on the suggested model.
5. Modifying the new theory if necessary in the light of new evidences.

4. **Scientific theory**

A set of the laws according to which the behavior of a physical system can be explained is called the scientific theory. In science, no any theory is final.

5. **Principal of physics**

In physics there are two basic principal works.

i. Unification

In physics many problems can be explained by a few concepts and the theory, this phenomenon is called unification.

ii. Reductionism

Sometime a problem is studded under a certain condition; at the same time that problem may be studied in some other conditions. E.g.

✓ The macroscopic properties of matter may be studied under thermodynamics while the microscopic property may be studied under quantum mechanics.

6. **Scope of the physics**

The physics have very wide scopes; every event which occurs around us is governed by the one or more branches of the physics.

There are mainly two branches of the physics

1. **Classical physics**

The branch of the physics which deals with the macroscopic property of the matter is called classical mechanics or classical physics.

2. **Quantum physics**

The branch of the physics which deals with the microscopic property of the matter is called quantum mechanics or quantum physics.

7. ***Some other branches of the physics***

A. Mechanics

The branch of the physics which deals with the study of the equilibrium of the objects or the motion of the objects is called mechanics.

B. Optics

The branch of physics which deals with the nature of light is called optics.

C. Thermodynamics

The word thermodynamics is made up of two word thermo and dynamics. Thermo means heat and dynamics means motion, hence thermodynamics may be defined as the branch of physics which deals with motion of heat is called thermodynamics.

D. Electrodynamics

It deals with the electric and magnetic property of the charges and the magnetic bodies is called electrodynamics.

E. Relativity

It is the theory of invariance in nature. It deals with the motion of the particles having speeds comparable to the speed of light.

F. Meso-scopics physics

These days a new physics is developing which is intermediate between the macroscopic and microscopic physics; it deals with the study of a few or hundreds of the atoms.

8. Physics in relation to the other branches of the sciences:

a. Physics in relation to mathematics

Mathematics provides the necessary formulas to obtain a mathematical relation to a given physical problems, mathematics is also called the language of physics.

b. Physics in relation to chemistry

In chemistry the structure of matter, their constituents, bonding between the atoms and complex chemical reactions are studied with the techniques provided by the physics such as radioactivity, x ray diffraction, etc

c. Physics in relation to biological sciences

The instruments or the technique such as x ray, ultrasound, M.R.I, sonography, endoscopy to investigate a patient in biological science is provided by the physics. Thus physics is greatly related to biological sciences.

d. Physics in relation to astronomy

The motion of the planets and the stars, and to discover the stars, we need the instrument telescope which is provided by the physics.

☞ Doppler Effect predicted the big bang theory of the universe

e. Physics in relation to geology

Diffraction techniques help to study the crystal structure of the various rocks. Radioactivity is used to estimate the age of the rocks and fossils.

f. Physics in relation to seismology

The movement of the earth crust and types of the waves so generated helps a lot in the study of earthquake and its effect.

g. Physics in relation to meteorology

By studying variation of the pressure with temperature, we can forecast weather.

h. Physics in relation to society

The discovery in physics greatly affects society. E.g.

- The development of the telephone, helped us to communicate
- The discovery of the radio and TV helps us to communicate and to entertainment.
- The launches of satellites help to detect weather etc.
- The computer, laser, superconductivity, nuclear energy, changed the status of the society.

i. Physics in relation to technology

Physics and technology are two sides of a coin. If a physical law is in books than it is physics but when it is implemented then it becomes technology.

S.NO.	PHYSICS	TECHNOLOGY
1	Electromagnetic waves	Radio, television, radar, and wireless communication etc.
2	Newton's laws of gravitation	satellite
3	X ray	radiotherapy
4	Silicon chip	computer electronics

9. Fundamental forces in nature

There are basically four fundamental forces in nature

a. Gravitational force

The force of attraction between two bodies due to their mutual interaction is called gravitational force. It is directly proportional to product of the masses and inversely proportional to square of distance between them. I.e.

$$F = G\frac{m_1 m_2}{r^2}$$

Important properties of the gravitational force

- It is a universal attractive force.
- It obeys inverse square law.
- It is long range force, and does not need any material medium for their propagation.
- It is weakest force in nature
- Gravitational force between two bodies does not depend upon the presence of the other bodies.
- It is central force.
- It is conservative force.
- The field particle or the origin of this force is graviton.

b. Electromagnetic Force

The force between two charges due to their mutual interaction is called Electromagnetic force. It is directly proportional to product of the charges and inversely proportional to square of distance between them. I.e.

$$F = k\frac{q_1 q_2}{r^2}$$

Important properties of the Electromagnetic force

- It may be attractive or repulsive.
- It obeys inverse square law.
- It is long range force, and does not need any material medium for their propagation.
- Electromagnetic force between two bodies does not depend upon the presence of the other bodies.
- It is central force.
- It is conservative force.
- The field particle or the origin of this force is exchange of photon between two charges.
- It is 10^{36} time stronger then the gravitational force.

c. Strong nuclear force

The force of which bounds the nucleons (neutron and proton) inside a nucleus are called strong nuclear force.

Important property of strong nuclear force

- ✓ It is strongest force in the nature, 10^{38} times stronger than gravitational force.
- ✓ It is short range force.
- ✓ It is non central force and non conservative force.
- ✓ It have charge independence character i.e. the force between n-n, p-n, p-p is equal.
- ✓ It occurs due to exchange of the particle called π meson.

d. Weak nuclear force

The force which occurs between the elementary particles involving in a nuclear process is called the weak nuclear force.

Important properties of the weak nuclear force

- ➢ The messenger particles that transmit the weak nuclear force between the elementary particles are massive vector bosons.
- ➢ Any process which uses neutrino and antineutrino has weak nuclear force.
- ➢ Weak nuclear force is 10^{25} time stronger than gravitational force.
- ➢ It is short range force and operates up to a range equal to the size of nucleus (10^{-15}m)

Some important points of the fundamental forces:

Fundamental Force	Relative Strength	Range	Particles on which force acts	Messenger Particles
Gravitational force	1	Infinite	All particles	Graviton
Weak nuclear force	10^{25}	Very short with in nucleus	Elementary particles	Vector Bosons
Electromagnetic force	10^{36}	Infinite	Charged particles	Photons
Strong nuclear force	10^{38}	Very short with in nuclear size		π meson

10. Conservation laws

In physics we usually deal with the following four conservative laws.

1. Law of conservation of the energy

According to law of conservation of the energy, energy can neither be created nor be destroyed it can be converted from one form to another form.

- The potential energy of the water converts into kinetic energy when water falls from a dam and then converts into electric energy by the help of a turbine.

2. Law of conservation of the linear momentum

It states that if no any external force act on the system than the total momentum of the system remains constant.

3. law of conservation of angular momentum

It states that if there is no any external torque is acting on the system then the angular momentum of the system remains conserved.

4. Law of conservation of the charge

It states that the total charge on an isolated system remains constant or charge can neither be created nor be destroyed.

11. Some great physicists and their discoveries

S. No.	Name of the scientist	Country	Discovery
1.	**Homi Jahangir Bhabha**	India	Cosmic ray showers
2.	**J. C. Boss**	India	Ultra short radio waves
3.	**S.N. Boss**	India	Boss Einstein statistics
4.	**C.V. Raman**	India	Inelastic scattering of the light(Raman effect)
5.	**M.N. Saha**	India	Thermal ionization
6.	**G.N. Ramachandran**	India	Triple helical structure of protein molecules.
7.	**S. Chandershekhar**	America(Ib)	Evaluation of the stars, Chandershekhar limit
8.	**Abdus Salam**	Pakistan	Unification of weak and electromagnetic interaction
9.	**Alfred Noble**	Sweden	Dynamite
10.	**Ampere**	France	Magnetism due to current
11.	**Niels Bohr**	Denmark	Quantum model of H- atom
12.	**James Chadwick**	England	Neutron
13.	**Albert Einstein**	Germany	Theory of relativity, mass energy equivalence, photoelectric effect
14.	**Galileo**	Italy	Law of inertia
15.	**C. Huygens**	Holland	Wave theory of light
16.	**Wernes Heisenberg**	Germany	Uncertainty Principle, Quantum Mechanics
17.	**Kelvin**	England	Thermodynamic scale of temperature
18.	**Marconi**	Italy	Wireless telegraphy
19.	**R.A Millikan**	America	Charge on electron
20.	**Isaac Newton**	England	Law of motion, law of gravitation, reflecting telescope
21.	**Oersted**	France	Magnetic effect of current
22.	**Max. Planck**	Germany	Quantum theory of radiations
23.	**Robert Boyles**	England	Boyles law
24.	**Ernest Rutherford**	England	Nuclear modal of atom
25.	**W.K. Roentgen**	Germany	x-ray
26.	**E. Schrödinger**	Germany	Wave mechanics
27.	**J.J. Thomson**	England	Electron
28.	**J.D. Van Der Walls**	Dutch	Expansion of gas and liquid
29.	**Volta**	Italy	Discovered first battery
30.	**James Watt**	England	Steam engine

1(b) Units and Measurement

12 PHYSICAL QUANTITIES:-

The quantities which obey law of physics are called physical quantity. Everything in this nature that we see or measure is physical quantity. To study physical quantity we need number and units.

$\Rightarrow$ Physical quantity =number + unit

Number: -

How many times a physical quantity is taken is called number.

Unit:-

The standard by which we measure physical quantity is called unit.

13 MEASUREMENTS

Hence measurement of a physical quantity =numerical value of the physical quantity× size of the unit or $Q = nu$

For example, let length of a rod = 5m=500cm.

Here smaller the size of the unit larger is the numerical value, thus numerical value(n) is inversely proportional to size(u) of the unit.

So $n \propto \frac{1}{u}$

Or $nu = constant$

Also we may write $n_1u_1 = n_2u_2$

A good unit will have the following characteristics.

It should be (a) well defined (b) easily accessible (c) invariable (d) easily reproducible

Question:1 **The SI unit of force is Newton such that 1N = 1kg ms^{-2}. In C.G.S. system, force is expressed in Dyne. How many dyne of force is equivalent to a force of 5 N?**

Solution: Let 1 N = n dynes $\Rightarrow$ $\left(\frac{1kgm}{s^2}\right) = n\left(\frac{g-cm}{s^2}\right)$

Or $\frac{1000g(100)cm}{s^2} = n\left(\frac{g-cm}{s^2}\right) \Rightarrow n = 10^5$ $\therefore$ 5 N = 5 × 10^5 dyne.

Units can be divided into two parts

(a) Fundamental units. (b) Derived units

(a) Fundamental units:-

The units which can neither be derived from another unit, nor can they be further resolved.

E.g. Length, mass, time is the fundamental units.

(b) Derive Units:-

The units which can be expressed in the form of fundamental units are called derived units.

$$speed = \frac{\text{Distance covered}}{\text{time taken}}$$

Therefore, units of speed = $\frac{\text{unit of distance i.e. length}}{\text{unit of time}} = \frac{metre}{second} = ms^{-1}$

Rules for writing units

- The symbol of a unit, which is not a name of a person, is written in small letter.

  E.g.: metre (m) kilogram (kg)

- The symbol of a unit, which is given on the name of a person, is written with a capital initial letter.

  E.g.: Newton (N), Kelvin (K)

- Full name of a unit, even if it is named after a person is written with a lower initial letter.
  E.g.: Newton, Kelvin.
- A compound unit formed by multiplication of two or more units is written after putting a dot or leaving a space between the two symbols.
  E.g.: Newton metre – N.m or N m.
- A unit in its short form is never written in plural.
  i.e.5 Newton may be written as 5N not 5Ns

14 SYSTEMS OF UNITS

(a) The F.p.s. system

In this system of unit's fps represents foot, pound, second for the measurement of length mass time respectively. It was the British system of measurement.

(b) The c.g.s system

In this system of unit's c.g.s represent centimeter, gram, second for the measurement of length mass time respectively.

(c) The m.k.s system

In this system of unit's m.k.s represents metre, kilogram, second for the measurement of length mass time respectively.

- Now a day's only c.g.s. and m.k.s. system of units are used. The cgs system is used for small quantities.

(d) International system of units (SI)

The S.I system of units was developed by General Conference of Weight and Measurement in 1971. It consists of 7 fundamental units and 2 supplementary units.

S.No.	Basic physical quantity	Fundamental units	Symbol
1.	Mass	kilogram	kg
2.	Length	metre	m
3.	Time	second	s
4.	Temperature	Kelvin	K
5.	Electric current	Ampere	A
6.	Luminous intensity	Candela	cd
7.	Quantity of matter	mole	mol
S.No.	**supplementary quantity**	**supplementary unit**	**Symbol**
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

Aberration in power of ten

S.No	POWER	PREFIX	SYMBOL	S.No	POWER	PREFIX	SYMBOL
1	10^{-1}	deci	d	**10**	10^{1}	deca	da
2	10^{-2}	centi	c	**11**	10^{2}	hecto	h
3	10^{-3}	milli	m	**12**	10^{3}	Kilo	k
4	10^{-6}	micro	μ	**13**	10^{6}	mega	M
5	10^{-9}	nano	n	**14**	10^{9}	giga	G
6	10^{-10}	Angstrom	A^{0}	**15**	10^{12}	tera	T
7	10^{-12}	pico	p	**16**	10^{15}	peta	P
8	10^{-15}	fermi or femto	f	**17**	10^{18}	exa	E
9	18^{-18}	atto	a				

15. **Characteristics of a system of unit/properties of SI units:-**

1. It is well defined.
2. It is of suitable size i.e. neither too large nor too small in comparison to the quantity to be measured.
3. It is easily reproducible at all places.
4. It does not change with time and from place to place.
5. It does not change with change in its physical condition, such as temperature, pressure, etc.
6. It is accessible easily.
7. It is internationally accepted.

16 Advantages of the SI system of the unit over other system of unit

1. Si is **coherent system** of the unit:- all derived unit can be obtained by simple multiplication or division of the units and the numbers
2. Si is **rational**:-it uses only one unit for one physical quantity e,g all form of energy are measured in joule.
3. It is **metric system** :- multiple and submultiples of SI unit can be expressed in power of 10
4. It is **absolute system**: - it does not use gravitational units. The use of g is not required.
5. It is internationally accepted.

17 INTRODUCTIONS TO PHYSICAL QUANTITIES AND THEIR S.I. UNITS

(a) MASS

The quantity of matter contained in a body is called mass. It can never be zero for a body.

The SI unit of mass is ***kilogram***

One kilogram is defined as the mass of one cubic decimeter of water at 4^0C (the temperatures of water at which its density is maximum or

One kilogram is defined as the mass of a platinum-iridium cylinder placed at international Bureau of weight and measurement near Paris, France.

Measurement of Mass

There are two types of mass of a body.

I Inertial mass

The mass under the effect of an external force rather than gravity is called inertial mass. It is measured by spring balance

ii. Gravitational mass

When the body is under the effect of gravity, than the measured mass is called gravitational mass, it is measured by a physical balance.

☞ Both inertial mass and gravitational mass are equal.

Difference between mass and weight

Mass	Weight
The quantity of matter contained in a body is called mass.	The force with which a body is pulled toward centre of earth is called weight.
Mass is a measure of inertia	Weight is a measure of gravity.
It is scalar quantity	it is a vector quantity
It cannot be zero	it is zero at centre of earth
It is essential property of a material body	It is not essential property of a material body
Not affected by presence of other body	affected by presence of the other body
Its unit are g, kg,	Its unit are dyne, Newton etc.

SOME IMPORTANT PARACTICAL UNITS OF MASS

1 atomic mass unit =1.66$\times 10^{-27}$kg *1 tone or 1 metric ton 1000kg*

1 quintal =100kg *1 slug = 14.57kg* *1 pound =1lb=0.4536kg*

☞ *1 Chandra Shekher limit= 1CSL=1.4 time the mass of the sun.(largest unit of mass)*

(b) *LENGTH*

Length is defined as the separation between two points in free space.

It is measure in **metre.**

One metre is defined as the path followed by light in vacuum in 1/299,792,458 of a second

Measurement of length

Now a day we can measure length from 10^{-16} m (diameter of electron) to 10^{26}(size of universe)

Measurement of length is done by two methods

1 Direct method 2 indirect method

i. Direct method

In this method length is measured by instruments i.e. by metre scale, a vernier caliper, a screw gauge, or a speedometer. The minimum distance measured by these instruments is called *least count* of the instrument.

ii. Indirect method used in length measurement:-

It is used to measure height of a tower, poles, mountains, distance of moons and other celestial objects from earth.

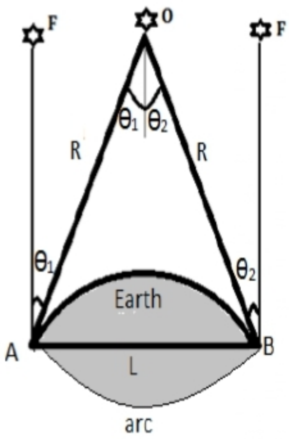
(a) Measurement of the large distance

- **Parallax method:-**

This method is used for measuring distance of planet and stars distance less than 100 light year.

Parallax means the change in position of an object w.r.t. background when we shift our eyes sidewise.

Let a star which is fixed at O is seen from earth from two different points A and B having equal distance R from the star. Let the distance between A and B is L which may be taken as the arc because L << R. Then the parelactic angle θ can be given as



$$\theta = \frac{arc}{radious} = \frac{L}{R} \qquad (1)$$

The angle θ can only be measured if the position of O is measured at the same time, which is not possible. Than another star F is considered whose distance does not change with time such that.

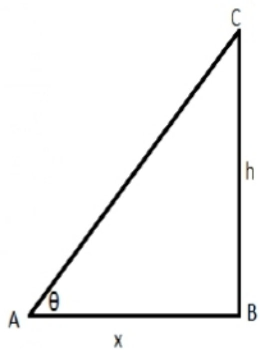
$$\theta = \theta_1 + \theta_2$$

Than from (1) $$R = \frac{L}{\theta 1 + \theta 2}$$

Hence distance from stars can be measured.

(b) Triangular method for the measurement of an accessible object

Suppose h is the height of a tower or a tree which is to be measured. Then this method is used. Let A is the point of observation having x distance from the base of the tree B. now place a sextant at c and measure the angle of elevation θ.



Now from right angle triangle ABC, we have

$$tan\theta = \frac{BC}{AB} = \frac{h}{x}$$

Or height $$h = x\ tan\theta$$

By knowing the distance x , the height h can be determined.

(c) Triangular method for the height of an inaccessible object

Let AB is the height of the object which is to be measured. By using a sextant we measure first angle C then angle D As shown in fig.

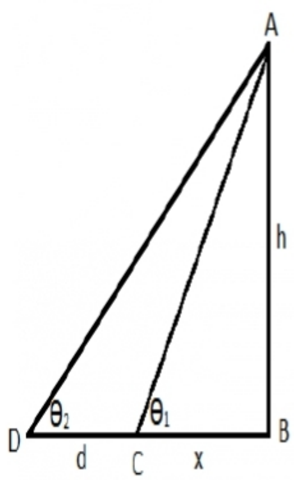
Now from right angle triangle ABC $$cot\theta_1 = \frac{CB}{AB} = \frac{x}{h}$$

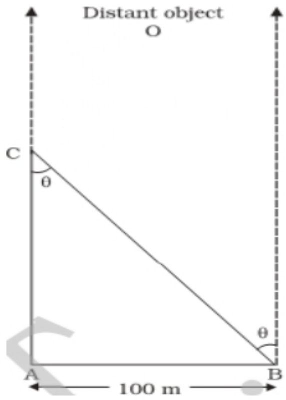
And in triangle ABD $$cot\theta_2 = \frac{BD}{AB} = \frac{d+x}{h}$$

$$cot\theta_2 - cot\theta_1 = \frac{d+x}{h} - \frac{x}{h} = \frac{d}{h}$$

$$h = \frac{d}{cot\,\theta_2 - cot\,\theta_1}$$

Knowing d, the height h can be determined.





Example2: A man wishes to estimate the distance of a nearby tower from him. He stands at a point A in front of the tower C and spots a very distant object O in line with AC. He then walks perpendicular to AC up to B, a distance of 100 m, and looks at O and C again. Since O is very distant, the direction BO is practically the same as AO; but he finds the line of sight of C shifted from the original line of sight by an angle θ = 40^0 (θ is known as parallax) estimate the distance of the tower C from his original position A.

Answer We have, parallax angle $\theta = 40^0$

From Fig., $AB = AC\tan\theta$ and $AC = \frac{AB}{\tan\theta} = \frac{100\,m}{\tan 40^0} = \frac{100\,m}{0.8391} = 119\,m$

(d) Determination of the distance of a far away star by intensity method

This method based on the inverse square law of intensity. I.e the intensity of the illumination at a point is inversely proportional to the square of distance from the source of light.

Suppose I_1 is the intensity of the far away star and I_2 is the intensity of the nearby star taken on a photographic plate. Let r_1 and r_2 is the respective distances of stars.

Than from inverse square law of intensity

$$\frac{I_1}{I2} = \frac{r_2^2}{r_1^2} \quad \text{Or} \quad r_1 = r_2\left[\frac{I2}{I_1}\right]^{\frac{1}{2}}$$

Knowing the distance r_2 of the nearby star, the distance r_1 of the far away star can be calculated. This method is used to measure the distance of the stars more than 100 light years.

Q. what do you mean by inferior and superior planet?

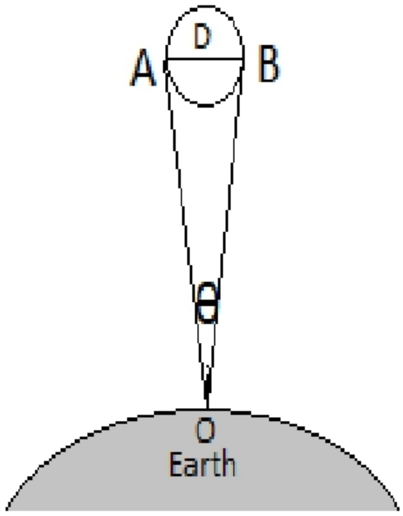
- **Inferior planet**

The planets which are closer to the sun then earth are called inferior planet (mercury and Venus)

- **Superior planet:**

The planets which are closer to the earth then sun are called superior planet (Jupiter, Saturn, Uranus, Neptune, and Pluto)

(e) Measurement of the diameter of the moon



Suppose AB=D is the diameter of the moon which is to be measured by an observer O on the earth. As shown in the fig.

Now from triangle OAB

$$\theta = \frac{arc}{radious}$$

$$= \frac{AB}{OB} = \frac{D}{S}$$

$$Or \quad D = \theta S$$

Hence $linear\ diameter = distance \times angular\ separation.$

Knowing the value of S and θ the diameter D can be measured.

Example: 3 the moon is observed from two diametrically opposite points A and B on Earth. The angle θ subtended at the moon by the two directions of observation is $1^o\ 54'$. Given the diameter of the Earth to be about $1.276\ \times 10^7 m$, compute the distance of the moon from the Earth.

Answer We have $\theta\ = 1^\circ 54'\ = 114'\ = (114 \times\ 60)''\ \times 4.85 \times\ 10^{-6}\ rad\ =\ 3.32\ \times 10^{-2} rad,$

Since $1'' = 4.85\ \times 10^6\ \ rad$ Also $b\ = AB = 1.276\, m\ \times 10^7$

We have the earth-moon distance, $D = \frac{b}{\theta} = \frac{1.276\ m\ \times 10^7}{3.32\ \times 10^{-2}} = 3.84\ \times 10^8\ m$

Example: 4 The Sun is angular diameter is measured to be 1920″. The distance D of the Sun from the Earth is $1.496\ \times 10^{11}$ m. What is the diameter of the Sun?

Answer Sun is angular diameter $\alpha\ = 1920''\ = 1920 \times\ 4.85 \times\ 10^{-6}\ rad\ = 9.31 \times\ 10^{-3}\ rad$

Sun is diameter $d\ =\ \alpha\ D = 9.31\ \times 10^{-3} \times 1.496\ \times 10^{11}\ = 1.39\ \times 10^{\ 9} m$

(f) Reflection or echo method

This method is based on the speed of the sound. To find the distance of a hill a gun is fired toward the hill, the time interval between the instant of the firing and instant of the hearing is noted. During this time interval the sound travels 2S distance with v velocity.

So the distance traveled by the light may be given as $2S = v \times t$

Or $$S = \frac{v \times t}{2}$$

(g) Laser method

The word *laser means light amplification by the stimulated emission of the radiations*.

A laser beam is sent toward moon and its reflected pulse is received. If t is time elapsed between the instants of light sent and light received back, then the distance of the moon from the earth is given by

$$S = \frac{c \times t}{2}$$

Where $c = 3 \times 10^8$ m/s is the velocity of the light traveled.

(h) RADAR method

The word RADAR means radio detection and ranging. Radar is used to measure the distance of a nearby planet. A radio wave is sent from a transmitter and after reflection from the planet received by a detector. Then the distance travelled by the radio waves can be given as

$$S = \frac{c \times t}{2}$$

This method is also used to measure the height and the distance of an aeroplane.

(i) SONAR method

The word sonar means sound navigation and ranging. On sonar, ultrasonic wave of frequency greater than 20,000Hz are transmitted through the ocean. They are reflected by the rock or the submerged rocks and received by the receiver. Then the distance travelled by the sound waves toward rock can be given as

$$S = \frac{v \times t}{2}$$

(ii) Measurement of the small distance

Small distances such as size of atom, molecules are measured by electron microscope, Avogadro method, Rutherford α particle scattering method etc.

Measurement of the small distance *(Size of molecule of oleic acid)*

Oleic acid is a soapy liquid with large molecular size. Dissolve 1 cm^3 of oleic acid in 20 cm^3 of alcohol and then re-dissolve 1cm^3 of this solution in 20 cm^3 of alcohol. Then the concentration of oleic acid is 1/400 cm^3 of alcohols. We than determine approximate volume of each drop (V cm^3). Now pour n drops of this solution on surface of water. We stretch the film carefully, as alcohol is evaporate, a very thin film of left on water surface. We measure the area A of film using graph paper.

Volume of the n drops of the solution $= nV\ cm^3$.

Amount of oleic acid in the solution $= \frac{nV}{400}\ cm^3$.

Thickness of oil film $t = \frac{volume\ of\ film}{area\ of\ film} = \frac{nV}{400A}$ cm.

The value of t is found to be of order of 10^{-9} m.

SOME IMPORTANT PARACTICAL UNITS OF DISTANCE

(a)**For large distance**

1. Astronomical Unit (AU):-

The average distance from center of earth to center of moon

$$1\ AU = 1.496\times10^{11}\ m \simeq 1.5\times10^{11} m$$

2. Light year (ly):-

The distance travelled by light in vacuum in one year

$$1\ ly = 3\times10^{8}\times365\times24\times60\times60 = 9.46\times10^{15}\ m$$

3 parsec:-

It is the distance at which an arc of length equal to one astronomical unit subtends an angle of one second.

$$1\ parsac = \frac{1AU}{1''} = \frac{1.496\times10^{11} m}{(1/3600)\times(\pi/180) rad} \simeq 3.1\times10^{16} m$$

Relation between AU, ly, Parsec

1 ly=6.3×10^4 AU	1 Parsec =3.28 ly	1 Parsec=2.07×10^5 AU

(c) ***Practical unit for measuring area***

1 barn =$10^{-28}$$m^2$ **1 acre= 4047m^2** **1 hectare =$10^4$$m^2$**

(c) TIME

Time is defined as the duration between two events. The SI unit of time is second.

One second is defined as the duration of 9,192,631,770 vibrations between two hyperfine levels of cesium-133 atom in ground states.

Measurement of Time:-

Time is measured by solar clock, quartz crystal clock, atomic clock, decay of elementary particle, age of rocks, earth etc

Some practical units for the measurement of the time

- Solar day

The time taken by the earth to compete one rotation about its own axis w.r.t the sun is called a solar day. 1 solar day =24hour= 86400 s

- Sedrial day

The time taken by the earth to compete one rotation about its own axis w.r.t a distant star is called a Sedrial day.

- Solar year

The time taken by the earth to compete one revolution around the sun in its orbit is called a solar year. 1 solar year=365.25 average solar day

- Tropical year:

The *year in which there is total eclipse is called one tropical year.*

- Leap year

The year which is total divisible by number 4 is called leap year, in this year the month of February have 29 days.

- Lunar month

The time taken by the moon to complete one revolution around the earth is called one lunar month. 1lunar month =27.3 days

✓ *The smallest unit of time is shake 1 shake=10^{-8}s*

✸ Now a days we can measure time from 10^{-24} to 10^{17}second (from life time of unstable particles in nucleus to age of universe)

(e) CURRENT:

Rate of flow of charge in a conductor is called current. It is measured in Ampere.

One Ampere current is defined as the current between two parallel straight conductors of infinite length, negligible area of cross-section and placed one metre distance apart in vacuum would produce a repulsive force equal to 2×10^{-7}. N.

(f) TEMPRATURE:

Temperature is defined as the degree of hotness or coldness of a body. It is measured in Kelvin

One Kelvin is defined as the 1/273.16 the fraction of temperature at the triple point (the point at which ice water and water vapor coexist) of the water

(g) LUMIONUS INTENSITY:

Luminous intensity is defined as the amount of light emitted per second by a source. It is measure in candela.

One candela is defined as the light emitted perpendicularly by 1/60,000 sq. m area of a black body at freezing point of platinum at 2042k temperature and 101,325N/m^2 pressure.

(g) QUANTITY OF MATTER

Amount of a substance contain in a body. It is measure in mole

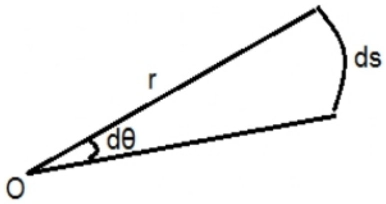
One mole is defined as amount of substance which contains same number of atoms as there are atoms in 0.012kg of carbon C-12.

SUPPLYMEANTRY UNIT

1 PLANE ANGLE

Plane angle is defined as the angle between two planes. It is measured in radian.

One radian is defined as the angle subtended at the centre of the circle by an arc of length equal to radius of the circle.



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

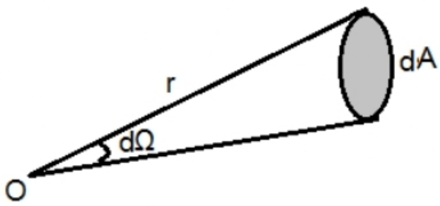
1 radian=57.7^0

2 SOLID ANGLE

Solid angle is defined as the angle at the centre of sphere

It is measure in steradian.

One steradian is defined as the angle subtended at the centre of sphere by its surface whose area is equal to the square of radius of the sphere.



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

Example:5 Calculate the angle of (a) 1^0 (b) 1′ and (c) 1″ in radians.

Use $360^0 = 2\pi$ rad, $1^0 = 60'$ and 1′ = 60 ″

Answer (a) we have $360^0 = 2\pi\, rad$ So $1^0 = \left(\frac{\pi}{180}\right) rad = 1.745 \times 10^{-2}\ rad$

(b) $1^0 = 60' = 1.745 \times 10^{-2}\, rad$ $so\ 1' = 2.908 \times 10^{-4}\ rad \approx 2.91 \times 10^{-4}\, rad$

(c) $1' = 60'' = 2.90810^{-4}\ rad$ $so\ 1'' = 4.84710^{-4}\, rad \approx 4.8510^{-6}\ rad$!

(c) DIMENSIONAL ANALYSIS

18 DIMENSIONS

Dimensions of a physical quantity may be defined as the powers to which the fundamental units be raised in order to represent that quantity.

For example: we know, Area = length x breadth.

Thus unit of area = L × L = L^2. Since unit of mass M and time T are not being used for the measurement of area, the unit of area can be represented by $M^0L^2T^0$. Powers 0, 2, 0 of fundamental units are called the dimensions of area in mass, length and time respectively.

**** Dimensional equation**

The equation, which indicates the units of a physical quantity in terms of the fundamental units, is called dimensional equation.

Eg: Dimensional equation of velocity is $[V] = M^0LT^{-1}$.

1) Area = length x breadth = L x L = $L^2 = M^0L^2T^0$

2) Volume = $L^3 = M^0L^3T^0$

19 DIMENTIONAL FORMULAS AND SI UNIT OF SOME PHYSICAL QUANTITY

S.No	PHYSICAL QUANTITY	Formula	Dimensional formula	SI unit
1	Length	Length	$[M^0L^1T^0]$	m
2	Mass	Mass	$[M^1L^0T^0]$	kg
3	Time	Time	$[M^0L^0T^1]$	sec
4	Area	Length × breadth	$[M^0L^2T^0]$	m^2
5	Volume	Length × breadth× height	$[M^0L^3T^0]$	m^3
6	Density	$\frac{mass}{volume}$	$[M^1L^{-3}T^0]$	kgm^3
7	Speed OR Velocity	$\frac{distance}{time}$	$[M^0L^1T^{-1}]$	ms^{-1}
8	Acceleration	$\frac{velocity}{time}$	$[M^0L^1T^{-2}]$	ms^{-2}
9	Linear Momentum	Mass × velocity	$[M^1L^1T^{-1}]$	$kgms^{-1}$
10	Force	Mass × acceleration	$[M^1L^1T^{-2}]$	Newton(N)
11	Work	Force × displacement	$[M^1L^2T^{-2}]$	Joule (J)
12	Energy	Amount of work	$[M^1L^2T^{-2}]$	Joule (J)
13	Power	$\frac{work}{time}$	$[M^1L^2T^{-3}]$	Watt (W)
14	Pressure	$\frac{force}{area}$	$[M^1L^{-1}T^{-2}]$	Pa or Nm^{-2}
15	Torque	Force × distance	$[M^1L^2T^{-2}]$	Nm
16	Gravitational constant	$\frac{force \times distance^2}{mass^2}$	$[M^{-1}L^3T^{-2}]$	Nm^2kg^{-2}
17	Impulse	Force × time	$[M^{-1}L^3T^{-2}]$	Ns
18	Stress	$\frac{force}{area}$	$[M^1L^{-1}T^{-2}]$	Nm^{-2}
19	Strain	$\frac{change\ in\ dimention}{original\ dimention}$	$[M^0L^0T^0]$	-
20	Coefficient of elasticity	$\frac{stress}{strain}$	$[M^1L^{-1}T^{-2}]$	Nm^{-2}

21	Surface tension	$\frac{force}{length}$	$[M^1L^0T^{-2}]$	Nm^{-1}
22	Surface energy	$\frac{work}{area}$	$[M^1L^0T^{-2}]$	Jm^{-2}
23	Coefficient of viscosity	$\frac{force \times distance}{area \times velocity}$	$[M^1L^{-1}T^{-1}]$	$Nm^{-2}s$ or Pas
24	Angle	$\frac{arc}{radious}$	$[M^0L^0T^0]$	No unit
25	Angular velocity	$\frac{angle}{time}$	$[M^0L^0T^{-1}]$	$Rads^{-1}$
26	Angular acceleration	$\frac{angular\ velocity}{time}$	$[M^0L^0T^{-2}]$	$Rads^{-2}$
27	Moment of inertia	Mass $\times distance^2$	$[M^1L^2T^0]$	Kgm^2
28	Radius of gyration	Distance	$[M^0L^1T^0]$	M
29	Angular momentum	mass × velocity × radius	$[M^1L^2T^{-1}]$	Kgm^2s^{-1}
30	T-ratio (sin. Cos.tan)	$\frac{length}{length}$	$[M^0L^0T^0]$	No unit
31	Frequency	$\frac{1}{time\ period}$	$[M^0L^0T^{-1}]$	s^{-1}
32	Relative density	$\frac{density\ of\ substance}{density\ of\ water}$	$[M^0L^0T^0]$	No unit
33	Velocity gradient	$\frac{velocity}{time}$	$[M^0L^0T^{-1}]$	s^{-1}
34	Force constant	$force/displacement$	$[M^1L^0T^{-2}]$	Nm^{-1}
35	Heat or enthalpy	Energy	$[M^1L^2T^{-2}]$	J
36	Specific heat	$\frac{heat}{mass \times temprature}$	$[M^0L^2T^{-2}K^{-1}]]$	$Jkg^{-1}k^{-1}$
37	Latent heat	$\frac{heat}{mass}$	$[M^0L^2T^{-2}]$	Jkg^{-1}
38	Thermal conductivity	$\frac{heat \times distance}{area \times temp \times time}$	$[M^1L^1T^{-3}K^{-1}]$	$Js^{-1}m^{-1}k^{-1}$
39	Entropy	$\frac{heat}{temprature}$	$[M^1L^2T^{-2}K^{-1}]$	Jk^{-1}
40	Universal gas constant	$\frac{PV}{nT}$	$[M^1L^2T^{-2}K^{-1}mol^{-1}]$	$Jmol^{-1}k^{-1}$
41	Electric charge	Time × current	$[M^0L^0T^1A^1]$	C (coulomb)
42	Electric potential	$\frac{work}{charge}$	$[M^1L^2T^{-3}A^{-1}]$	V (volt)
43	Resistance	$\frac{potential}{current}$	$[M^1L^2T^{-3}A^{-2}]$	Ohm
44	Capacitance	$\frac{charge}{potential}$	$[M^{-1}L^{-2}T^4A^2]$	Farad
45	Inductance	$\frac{emf}{current\ /time}$	$[M^1L^2T^{-2}A^{-2}]$	Henry
46	Electric field intensity	$\frac{force}{charge}$	$[M^1L^1T^{-3}A^{-1}]$	Nc^{-1} or vm^{-1}
47	Conductance	$\frac{1}{resistance}$	$[M^{-1}L^{-2}T^3A^2]$	Mho
48	Resistivity	$\frac{RA}{l}$	$[M^1L^3T^{-3}A^{-2}]$	Ohm meter
49	Conductivity	$\frac{1}{resistivity}$	$[M^{-1}L^{-3}T^3A^2]$	
50	Electric dipole moment	charge× 2l	$[M^0L^1T^1A^1]$	Cm
51	Magnetic field	$\frac{f}{qv\sin\theta}$	$[M^1L^0T^{-2}A^{-1}]$	Tesla (T)
52	Magnetic flux	Magnetic field× area	$[M^1L^2T^{-2}A^{-1}]$	Wb (Weber)
53	Magnetic moment	Current ×area	$[M^0L^2T^0A^1]$	Am^2
54	Pole strength	$\frac{magnetic\ moment}{magnetic\ length}$	$[M^0L^1T^0A^1]$	Am
55	Logarithm, A number	No formula	$[M^0L^0T^0]$	No unit

20 Different types of variables and constants:

I. Dimensional variable

The physical quantity having dimensional formula and variable value is called dimensional variable. E.g. area, volume, velocity, force

II. Dimensional constant

The physical quantity having dimensional formula and constant *value is called dimensional* constant. *Gravitational constant, Planck's constant*

III. Dimensionless variable

The physical quantity having no dimensional formula but have variable value is called Dimensionless *variable. E.g. angle, strain*

IV. Dimensionless constant

The physical quantity having no dimensional formula and have constant value is called Dimensionless *constant. Π, e, etc.*

21 Principle of homogeneity

An equation representing a physical quantity will be correct if the dimensions of each term on both sides of the equation are the same. This is called the principle of homogeneity of dimensions.

22 Uses of dimensional analysis

1. To check the correctness of an equation.
2. *To convert one system of unit into another system*
3. To derive the correct relationship between physical quantities.

(1) **To check the correctness of an equation.**

An equation is correct only if the dimensions of each term on either side of the equation are equal.

Example:6 Check the accuracy of the equation $S=ut+\frac{1}{2}at^2$

Ans given formula is $S=ut+\frac{1}{2}at^2$

Taking dimensions on both sides, $L = LT^{-1}T + LT^{-2}T^2$

i.e. $L = L + L$

According to principle of homogeneity, the equation is dimensionally correct.

Example:7 Let us consider an equation $\frac{1}{2}mv^2 = m\,g\,h$. Check whether this equation is dimensionally correct.

Answer the dimensions of LHS are $[M][L\,T^{-1}]^2 = [M][\,L^2\,T^{-2}] = [M\,L^2\,T^{-2}]$
The dimensions of RHS are $[M][L\,T^{-2}][L] = [M][L^2\,T^{-2}] = [M\,L^2\,T^{-2}\,]$

The dimensions of LHS and RHS are the same and hence the equation is dimensionally correct

Question: **8 The equation of state of some gases can be expressed as $\left(P+\frac{a}{V^2}\right)(V-b)=RT$. Here, *P* is the pressure, *V* the volume, *T* the absolute temperature, and *a*, *b*, *R* are constants. Find the dimensions of *a*.**

Solution: Dimensions of $\frac{a}{V^2}$ will be same as dimensions of pressure

$$\frac{[a]}{[L^3]^2} = ML^{-1}T^{-2} \quad \text{so} \quad [a] = \mathbf{ML^5T^{-2}}$$

(2) *To* convert one system of unit into another system

This is based on the principal that the magnitude of the physical quantity remains same, whatever is its unit.

Suppose a physical quantity Q having u_1 and u_2 units with corresponding numbers n_1 and n_2.

Then $Q = n_1u_1 = n_2u_2$

Again suppose that $M_1L_1T_1$ are the fundamental units in one system and $M_2L_2T_2$ are the fundamental units of mass length and time in second system.

If the dimension formula of the physical quantity is $Q = M^a L^b T^c$

Then $u_1 = M_1^a L_1^b T_1^c$

And $u_2 = M_2^a L_2^b T_2^c$

So $n_1[M_1^a L_1^b T_1^c] = n_2[M_2^a L_2^b T_2^c]$

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

This equation may be used to find the numerical value of the second system of unit.

Q.9 **convert one joule of energy into erg?**

Here joule is the SI unit of the energy and erg is the cgs unit of the energy. The dimensional formula of energy is $ML^{2}T^{-2}$. So $a = 1, b = 2 \text{ and } c = -2$

Si	*CGS*
$M_1 = 1kg = 1000g$	$M_2 = 1g$
$L_1 = 1m = 100cm$	$L_2 = 1cm$
$T_1 = 1s$	$T_2 = 1s$
$n_1 = 1joule$	$n_2 = ?\,erg$

So $n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$ or $n_2 = 1\left[\frac{1000}{1}\right]^1 \left[\frac{100}{1}\right]^2 \left[\frac{1}{1}\right]^{-2}$

$= 1\times10^3\times10^4 = 10^7$

$\therefore \quad 1 \quad Joule = 10^7 \; erg$

(3) To derive the correct relationship between physical quantities.

Dimensions can be used to derive the relation between physical quantities.

Question To derive an expression for period of oscillation of a simple pendulum.

The period of oscillation (T) of a simple pendulum may depend on (1) Length of the pendulum (L); (2) Mass of bob (m) and (3) the acceleration due to gravity (g).

Then $T = kl^x m^y g^z$

Taking dimensions on both sides $M^0 L^0 T^1 = L^x \times M^y \times [L^1 T^{-2}]^z$

Equating dimensions of M, L and T,

$$x + z = 0$$

$$y = 0$$

$$-2z = 1$$

Hence $z = -\frac{1}{2}$ and $x = \frac{1}{2}$

By putting the values we get $T = kl^{\frac{1}{2}} m^0 g^{-\frac{1}{2}}$

Or $T = k\sqrt{\frac{l}{g}}$

The value of constant k cannot be found by dimensional method. The value of k is found to be 2π using some other methods.

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

Question:10 **In a new system of units, unit of mass is taken as 50 kg, unit of length is taken as 100 m and unit of time is 1 minute. What will be the weight of a body in this system, if in SI system, its weight is 10 N.**

Solution: Let the weight of the body in new system is X units $\Rightarrow$ 10 N = X units

Let M_1, L_1, T_1 and M_2, L_2, T_2 be the symbols for mass, length and time in the two system respectively, then $10[M_1 L_1 T_1^{-2}] = X[M_2 L_2 T_2^{-2}]$

$M_1 = 1\text{kg}, M_2 = 50\text{kg}, L_1 = 1\text{m}, L_2 = 100\text{m}, T_1 = 1\text{s}, T_2 = 60\text{s}$

$$\Rightarrow \quad X = \frac{10}{50} \times \frac{1}{100} \times \left(\frac{1}{60}\right)^{-2} = \frac{36000}{5000} = 7.2 \text{units}$$

$\therefore$ 10 N = 7.2 units

23 Limitations of dimensional analysis.

- This method gives us no information about dimensionless constants.
- We cannot use this method if the physical quantity depends on more than three other physical quantities.
- This method cannot be used if the left hand side of the equation contains more than one term.
- Often it is difficult to guess the parameters on which the physical quantity depends.

1(d) Significant figures AND error

24 Significant figures:

Significant figures give the number of meaningful digits in a number.

The significant figures are the number of digits used to express the measurement of the physical quantity such that the last digit in it is doubtful and the rest all digits are accurate.

The number of significant figures depends on the accuracy of the instrument. More the number of significant figures in a measurement, more accurate the measurement is.

25 Rules to determine the significant figures:

(1) All zeros in between the numerals 1 to 9 are counted.

(2) In a measurement involving decimal, the position of decimal is disregarded.

(3) All zeros after the last numeral are counted.

(4) The zeros preceding the first numeral are not counted.

(5) All the zeros to the right of the last non-zero digit (trailing zeros) in a number without a decimal point are not significant, unless they come from experiment.

Thus 123 m = 12300 cm = 123000 mm has three significant figures. The trailing zeros are not significant. But if these are obtained from a measurement, they are significant.

26 Rules for rounding off to the required number of significant figures:

(1) If the digit to be dropped is less than 5, the digit immediately preceding it remains unchanged.

(2) If the digit to be dropped is more than 5, the digit immediately preceding it is increased by 1.

(3) If the digit to be dropped is 5, then the preceding digit is made even by

(a) Increasing it by 1 if it is odd,

(b) Keeping it unchanged if it is even.

27 Significant figures in calculations

(1) Significant figures in multiplication and division.

The result of multiplying or diving two or more numbers can have no more significant figures than those present in the number having the least significant figures.

Eg: (1) $a = 10.43$ [sig fig 4] $b = 2.8612$ [sig fig 5]

Than $a \times b = 29.842316 = 29.84\ [sig\ fig\ 4]$

(2) $a = 16000$, [sig fig 5] & $b = 4.580$ [sig fig 4]

Then $\frac{a}{b} = \frac{16000}{4.580} = 3493.449782 = 3493[sig\ fig\ 4]$

(2) Significant figures in addition and subtraction.

In adding or subtracting, the least significant digit of the sum or difference occupies the same relative position as the least significant digit of the quantities being added or subtracted. Here number of significant figures is not important; position is important.

Eg: (1) 204.9 [9 is least sig.digit. Position – 1st decimal place]

2.10 [0 is least digit. Position 2nd decimal place]

+ 0.319 [9 is least sig. Digit. Position 3rd decimal place.]

= 207.319 = 207.3

In sum, the least sig. Fig should come in the first decimal place.

Eg: (2) If a = 10.43 and b=2.8612

Then a – b= 10.43 – 2.8612

= 7.5688 = 7.57.

Example11. 5.74 g of a substance occupies 1.2 cm^3. Express its density by keeping the significant figures in view.

Answers There are 3 significant figures in the measured mass whereas there are only 2 significant figures in the measured volume. Hence the density should be expressed to only 2 significant figures.

$$Density = \frac{5.74}{1.2} g\ cm^{-3} = 4.8\ g\ cm^{-3}$$

Example12. Each side of a cube is measured to be 7.203 m. What are the total surface area and the volume of the cube to appropriate significant figures?

Answer The number of significant figures in the measured length is 4. The calculated area and the volume should therefore be rounded off to 4 significant figures.

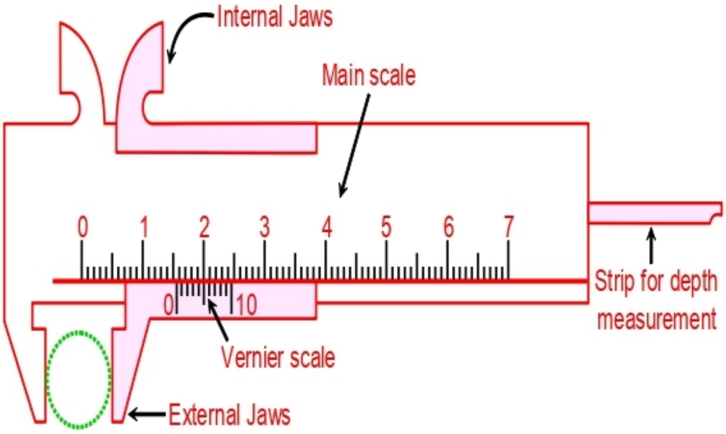
Surface area of the cube = $6(7.203)^2 m^2 = 311.299254\, m^2 = 311.3\, m^2$

Volume of the cube = $(7.203)^3\ m^3 = 373.714754\, m^3 = 373.7\, m^3$

ACCURACY AND PRECISION OF INSTRUMENTS

Accuracy of an instrument represents the closeness of the measured value of actual value. Precision of an instrument represents the resolution of the instrument. It depends on least count.

- *Least count of an instrument is the least measurement, which can be made accurately with that instrument.*
  Least count of an ordinary metre scale is 0.1 cm, 0.01 cm is the least count of vernier calipers and 0.001 cm is that for screw gauge.



For example a physical quantity is measured from two instruments *A* and *B*. The reading of *A* is 2.54 cm (say) and that of *B* is 2.516 cm. The actual value is 2.53 cm. The first reading is closed to actual value, it has more accuracy. The second reading is less accurate, but the instrument B has greater resolution as it can measure up to 3 decimal places.

28 Errors in Measurements

Difference between the value obtained in a measurement and the true value of the quantity is called error in that measurement.

The following are the commonly occurring errors:

(1) **Constant error**:
If the error in a series of readings taken with an instrument is same, the error is said to be constant error.

(2) **Systematic errors**:
Errors, which are due to known causes and act according to a definite law are called systematic errors.

(a) Instrumental errors:

These errors are due to the defect of the instrument.

Eg: 1. Zero error in screw gauge and vernier.

2. Faulty calibration of thermometer, metre scale etc.

(b) Personal error:

This is due to the mode of observation of the person taking the reading. E.g.: Parallax error.

(b) Error due to imperfection:

This is due to imperfection of the experimental setup.

Eg: Whatever precautions are taken, heat is always lost from a calorimeter due to radiation.

(c) Error due to external causes:

These are errors caused due to change in external conditions like temp, pressure, humidity etc.

Eg: With increase in temperature, a metal tape will expand. Any length measured using this tape will not give corrects reading.

(3) **Random Error**:
The errors, which occur irregularly and at random in magnitude and direction, are called random errors. These errors are not due to any definite cause and so they are also called ***accidental errors.***

Random errors can be minimized by taking several measurements and then finding the arithmetic mean. The mean is taken as the true value of the measured quantity.

Let a quantity measured n times give values $a_1, a_2 \ldots\ldots\ldots a_n$, then the possible value a of the quantity is

$$\bar{a} = \frac{a_1 + a_2 \ldots\ldots\ldots + a_n}{n}$$

The arithmetic mean $\bar{\boldsymbol{a}}$ is taken as the true value of the quantity.

(4) **Gross Errors**:
The errors caused by the carelessness of the person are called gross errors. It may be due to

(1) Improper adjustment of apparatus

(2) Mistakes while taking and recording readings etc.

(5) **Absolute Errors**:

The magnitude of the difference between the true value of the quantity measured and the individual measured value is called the absolute error.

$$Absolute\ error \quad = \quad True\ value - measured\ value.$$

If $a_1, a_2, \ldots, a_n$ are the measured values and $\boldsymbol{\bar{a}}$ is the true value,

Then absolute error,

$$\Delta\overline{a_1} = \boldsymbol{\bar{a}} - a_1$$

$$\Delta\overline{a_2} = \boldsymbol{\bar{a}} - a_2 \qquad \text{and so on.}$$

(5) **Mean absolute error**:

The arithmetic mean of the absolute error of the different measurements taken is called mean absolute error.

If $\Delta\overline{a_1}, \Delta\overline{a_2}, \ldots\ldots \Delta\overline{a_n}$ are the absolute errors in the measurements $a_1, a_2, a_3, \ldots a_n$, then

$$\overline{\Delta a} = \frac{\Delta a_1 + \Delta a_2 + \Delta a_3 + \Delta a_4 + \cdots \ldots \ldots . + \Delta a_n}{n}$$

7) **Relative and percentage errors**.

The ratio of the mean absolute error to the true value of the measured quantity is called relative error.

$$Relative\ error = \frac{\overline{\Delta a}}{\bar{a}} \qquad \text{And} \quad \text{percentage } Error = \frac{\overline{\Delta a}}{\bar{a}} \times 100\%$$

Example13. We measure the period of oscillation of a simple pendulum. In successive measurements, the readings turn out to be 2.63 s, 2.56 s, 2.42 s, 2.71s and 2.80 s. calculate the absolute errors, relative error or percentage error.

Answer The mean period of oscillation of the pendulum $T = \frac{(2.63 + 2.56 + 2.42 + 2.71 + 2.80)\,s}{5} = 2.624\ s = 2.62\ s$

The errors in the measurements are

$$2.63\,s - 2.62\,s = 0.01\,s$$
$$2.56\,s - 2.62\,s = -0.06\,s$$
$$2.42\,s - 2.62\,s = -0.20\,s$$
$$2.71\,s - 2.62\,s = 0.09\,s$$
$$2.80\,s - 2.62\,s = 0.18\,s$$

The arithmetic mean of all the absolute errors (for arithmetic mean, we take only the magnitudes) is

$$\Delta Tmean = \frac{[(0.01 + 0.06 + 0.20 + 0.09 + 0.18)s]}{5} = \frac{0.54s}{5} = 0.11\ s$$

That means, the period of oscillation of the simple pendulum is (2.62 ± 0.11) s i.e. it lies between (2.62 + 0.11) s and (2.62 - 0.11) s or between 2.73 s and 2.51 s. As the arithmetic Mean of all the absolute errors is 0.11 s, there is already an error in the tenth of a second. Hence there is no point in giving the period to a hundredth. A more correct way will be to write T = 2.6 ± 0.1 s

The relative error or the percentage error is $\delta a = \frac{01}{2.6} \times 100 = 4\%$

30 Combination of errors

(1) Error in a sum or difference: —

Let two quantities A and B have errors Δ A and Δ B respectively in their measured values. We have to calculate the error Δ Z in their sum Z = A + B.

$$\therefore Z \pm \Delta Z = (A \pm \Delta A) + (B \pm \Delta B)$$
$$(Z \pm \Delta Z) - Z = \{(A \pm \Delta A) + (B \pm \Delta B)\} - (A + B)$$
$$\therefore \pm \Delta Z = \pm \Delta A \pm \Delta B$$
$$\therefore \text{ Maximum value of } \Delta Z = \Delta A + \Delta B$$

We will get the same result even if we take the difference.

- ✓ *When two quantities are added or subtracted, the absolute error in the final result is the sum of the absolute errors in the quantities.*

Example14 The temperatures of two bodies measured by a thermometer are $t_1 = 20^0C \pm 0.5^0C$ and $t_2 = 50^0C \pm 0.5^0C$. Calculate the temperature difference and the error there in.

Answer $t' = t_2 - t_1 = (50^0C \pm 0.5^0C.) - (20^0C \pm 0.5^0C)$ or $t' = 30^0C \pm 1^0C$

(2) ***Error in a product or quotient***

Let A and B be two quantities and Z be their product. ie Z = AB. If $A \pm \Delta A$ and $B \pm \Delta B$ are the measured values of A and B, then

$$Z \pm \Delta Z = (A \pm \Delta A)(B \pm \Delta B) = AB \pm A\Delta B \pm \Delta A B \pm \Delta A \Delta B$$

Dividing LHS by Z and RHS by AB, $\frac{Z \pm \Delta Z}{Z} = \frac{AB}{AB} \pm \frac{A\Delta B}{AB} \pm \frac{\Delta A B}{AB} \pm \frac{\Delta A \Delta B}{AB}$

$$= 1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta B}{B} \pm \frac{\Delta A}{A}$$

ie, ΔA and ΔB being small. So neglecting $\frac{\Delta A \Delta B}{AB}$

Hence the maximum possible relative error or fractional error in Z is $\frac{\Delta Z}{Z} = \frac{\Delta B}{B} \pm \frac{\Delta A}{A}$

The result is true for division also.

Therefore, when two quantities are multiplied or divided, the relative error of the result is equal to the sum of relative errors of the quantities.

Example15. the resistance $R = \frac{V}{I}$ where V = (100 ± 5) V and I = (10 ± 2) A. Find the percentage error in R.

Answer The percentage error in V is 5% and in I it is 2%. The total error in R would therefore be 5% + 2% = 7%.

Example16. Two resistors of resistances R_1 = 100 ±3 ohm and R_2 = 200 ± 4 ohm are connected in series. Find the equivalent resistance of the series combination. Use the relation $R = R_1 + R_2$,

Answer the equivalent resistance of series combination $R = R_1 + R_2 = (100 \pm 3)\, ohm + (200 \pm 4)\, ohm = 300 \pm 7\, ohm$

(3) *Error when a quantity is raised to a power.*

Consider a quantity $X = x^n$

Taking logarithm on both sides, $\log X = \log x^n = n \log x$.

Differentiating, we get $\frac{\Delta X}{X} = n\frac{\Delta x}{x}$

Thus if a quantity has to be raised to a power n, then the relative error of the result is n times the relative error of that quantity.

Example17. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1 s resolution. What is the accuracy in the determination of g?

Answer $T = 2\pi\sqrt{\frac{L}{g}}$. Here, $T = \frac{t}{n}$ and $\Delta T = \frac{\Delta t}{n}$. Therefore, $\frac{\Delta T}{T} = \frac{\Delta t}{t}$

The errors in both L and t are the least count errors. Therefore, $\left(\frac{\Delta g}{g}\right) = \left(\frac{\Delta L}{L}\right) + 2\left(\frac{\Delta T}{T}\right) = \frac{0.1}{20.0} + 2\frac{1}{90} = 0.027$ Thus, the percentage error in g is $100\left(\frac{\Delta g}{g}\right) = 100\left(\frac{\Delta L}{L}\right) + 2 \times 100\left(\frac{\Delta T}{T}\right) = 3\%$

Example18. A physical quantity P is related to four observables a, b, c and d as follows: $P = \frac{a^3b^2}{\sqrt{cd}}$. The percentage errors of measurement in a, b, c and d are 1%, 3%, 4% and 2%, respectively, What is the percentage error in the quantity P ?

Ans $3 \times 1 + 2 \times 3 + \frac{1}{2} \times 4 + 2 \times 1 = 13$

	Some important questions
1.	How is SI is a coherent system of units
2.	Why parallex method is not useful for measuring distances of star more than 100 light year.
3.	Do all physical quantity has same dimensions? If no, name three physical quantity which are dimensionless.
4.	Velocity of a particle depends on time t as v=at^2+bt+c where v is in m/s and t in s. what are unit of a,b,c,
5.	Justify L+L=L and L-L=L
6.	Which of given measurement more accurate and why? (a) 5.0g (b) 5.00g(c) 5g

31 Selected objectives (for competitive entrance exam)

1.	**Light year is a unit of** a. time b. mass c. distance. d. energy
2	**Which unit is not for length** a. Parsec b. light year c. Angstrom d. nano.
3	**Wavelength of ray of light is 0.00006m. it is equal to** a. 6micron b. 60micron. c. 600micron d. 0.6micron
4	**Which is the correct unit for measuring the nuclear radii** a. micron b. millimeters c. Angstrom d. Fermi.
5.	**Kilowatt hour is the unit of** a. electric charge b. energy. c. power d. force
6.	**Dimensional formula for impulse is same as the dimensional formula of** a. momentum. b. force c. torque d. rate of change of momentum
7.	**Which physical quantity have same dimension** a. force, power b. torque , energy. c. torque, power d. force , power
8.	**Planks constant has dimension has dimension of** a. energy b. linear momentum c. work d. angular momentum.
9.	**The physical quantity that has no dimension is** a. angular velocity b. linear momentum c. angular momentum d. strain.
10.	**The resistance R =V/I where V=100±5volts and I=10±0.2Amperes.What is the total error in R** a. 5% b. 7%. c. 5.2% d. 5/2%
11.	**If L=2.331 cm, B=2.1cm than L+B is** a. 4.431cm b. 4.43cm c. 4.4cm. d. 4cm
12.	**Number of significant fig in all given number 25.12, 2009,4.156 and 1.217×10^7** a. 1 b. 2 c. 3 d. 4.
13.	**A physical quantity A is related to four observations a,b,c and d are as A=$\frac{a^2b^3}{c\sqrt{d}}$. The % error of the measurement in a, b, c and d are 1%, 3%, 2% and 2% respectively. what is the % error in A** a. 12% b. 7% c. 5% d. 14%.
14.	**An Indian scientist who won noble prize for physics is** a. J.C. Bose b. H.J. Bhabha c. M.N. saha d. C.V.Raman.
15.	**If error in radius is 3% .what is the error in volume of the sphere** a . 3% b.27% c.9 %. d. 6%
16.	**Albert Einstein got noble prize in physics for his work on** a. special theory of relativity b. general theory of relativity c. photoelectric effect. d. theory of specific heat.