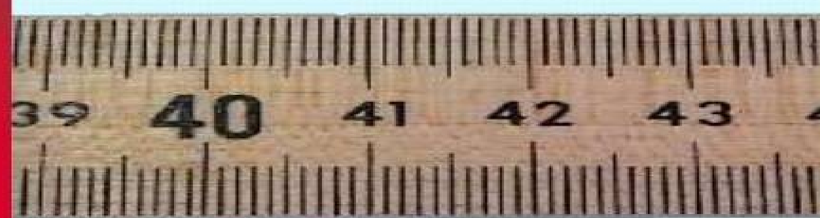
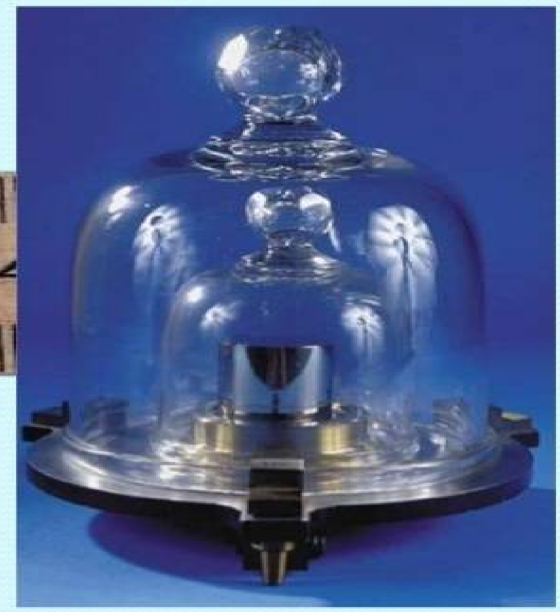
UNITS AND MEASURMENT

Fundamental units

The physical quantities which can be treated as independent of other physical and are not usually defined in terms of other physical quantities are called physical quantities. Such as-





STANDARD
MEASURES

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Temperature	kelvin	K
Time	second	s
Amount of Substance	mole	mol
Luminous Intensity	candela	cd
Electric Current	ampere	a

Derived units

The physical quantities whose defining operations are based on other physical quantities are called as derived units. Such as-

- speed (v) = distance / time * unit: m/s
- acceleration (a) = velocity / time * unit: m/s/s = m/s^2
- force (F) = mass x acceleration *unit: kgm/s^2
- energy (E) = force x distance *unit: kgm^2/s^2 = Nm=J
- charge (Q) = current x time *unit: As = C

SYSTEM OF UNITS

I. **cgs system-** Set up in France. It is based on centimeter, gram and second as the fundamental units of length, mass and time respectively.

II. **fps system-** It is a British system based on foot, pound and second as the fundamental units of length, mass and time respectively.

III. **mks system-** It is also a French system based on meter, kilogram and second as the fundamental units of length, mass and time respectively.

IV. **SI: The international system of units-** It is a metric system of units consisting of seven base quantities – length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity and two supplementary units- plane angle and solid angle

Advantages of SI

1. SI is a coherent system of units i.e system based on a certain set of fundamental units, from which all derived units are obtained by multiplication or division without introducing numerical factors.
2. SI is a rational system of units as it assigns only one unit to be a particular physical quantity. For example, joule is the unit for all types of energy. This is not so in other systems of units.

3. SI is an absolute system of units. There are no gravitational units on the system. This use factor 'g' is thus eliminated.
4. SI is a metric system i.e the multiples and sub multiples of units are expressed as power of 10.
5. In current electricity, the absolute units on the SI, like ampere for current, volt for potential difference, ohm for resistance, Henry for inductance, farad for capacity and so on.

DEFINATION OF BASIC UNITS

1. Meter (m)
2. Second (s)
3. Kilogram (kg)
4. Kelvin (K)
5. Ampere (A)
6. Candela (cd)
7. Mole (mol) = 6.02×10^{23}

Unit of length (meter)

- The meter is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.
- The 1889 definition of the meter, based on the international prototype of platinum-iridium, was replaced by the 11th CGPM (1960) using a definition based on the wavelength of krypton 86 radiation. This change was adopted in order to improve the accuracy.

Unit of mass (kilogram)

- The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
- The international prototype of the kilogram, an artifact made of platinum-iridium, is kept at the BIPM under the conditions specified by the 1st CGPM in 1889 (CR, 34-38) when it sanctioned the prototype and declared:
- This prototype shall henceforth be considered to be the unit of mass.

Unit of time (second)

- The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.
- The unit of time, the second, was at one time considered to be the fraction 1/86 400
- of the mean solar day. The exact definition of "mean solar day" was left to the
- astronomers. However measurements showed that irregularities in the rotation of the
- Earth made this an unsatisfactory definition

Unit of electric current (ampere)

- The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 × 10−7 newton per meter of length.

Unit of thermodynamic temperature (kelvin)

- The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
- Because of the manner in which temperature scales used to be defined, it remains common practice to express a thermodynamic temperature, symbol T, in terms of its difference from the reference temperature $T0 = 273.15$ K, the ice point.

Unit of amount of substance (mole)

1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol."
2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

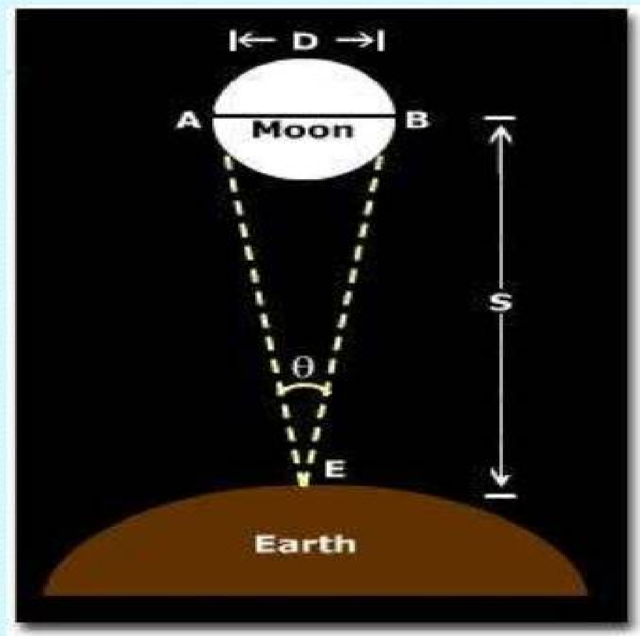
Unit of luminous intensity (candela)

- The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.
- It follows that the spectral luminous efficacy for monochromatic radiation of frequency of 540 × 1012 hertz is exactly 683 lumens per watt, K(λ555) = 683 lm/W = 683 cd sr/W (the wavelength λ of radiation of this frequency is about 555 nm).


eLearnin
scale

Determination of Diameter of Moon

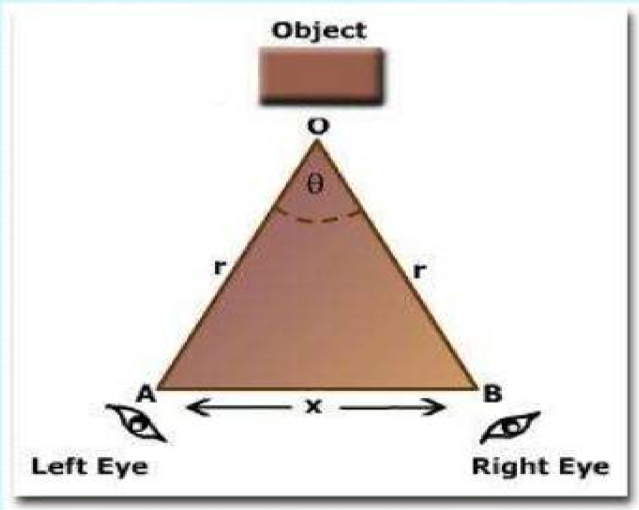
- Let moon be the astronomical object of diameter D. Let E be the point on earth's surface. A telescope is focused on moon's surface and its image is observed as shown in figure is measured. S is the distance between moon and the Earth's surface.
- The diameter AB of moon is considered as a circular arc of radius S.
- Diameter of the moon can be found by knowing q and S.
- This above formula holds good only if S is very large and D can be considered as a small arc of radius S.



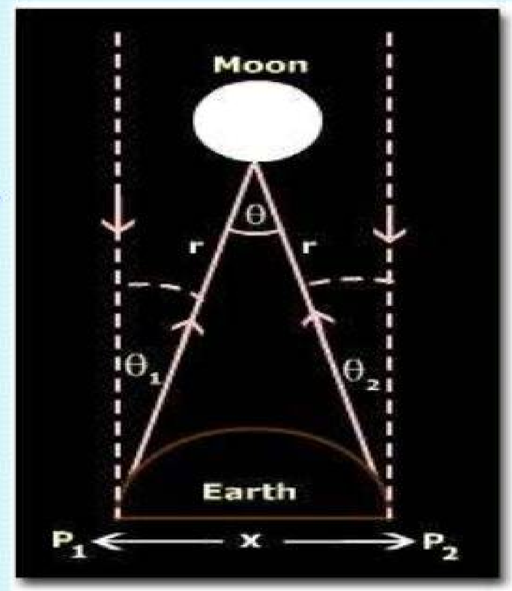
Determination of distance of moon from earth (by parallax method)

- Let the object O be viewed with our eyes which is at a distance of r, making an angle between the two eyes as shown in the diagram.
- The angle q, caused by the two lines drawn from the position of the two eyes to the object, is called angle of parallax.
- If we can consider OA and OB as radius of a circle and the distance x (AB) as arc of the circle, then we have.

$$\therefore\ \theta = \frac{a \times AB}{r} \approx \frac{x}{r} \qquad \therefore \text{i.e., } r = \frac{x}{\theta}$$



- However, if we consider O, referred in the above diagram to be the moon or a nearby star, then the angle q is too small in the view of the large astronomical distance and the place of observation. Hence, in order to have a better and valid point of observation, two points on the surface of the Earth is taken as the basis for observation instead of the two eyes. In order to have simultaneous observation of the moon, we select a very distant star at O and measure the angle between O and the two points on the Earth, as shown in the diagram below

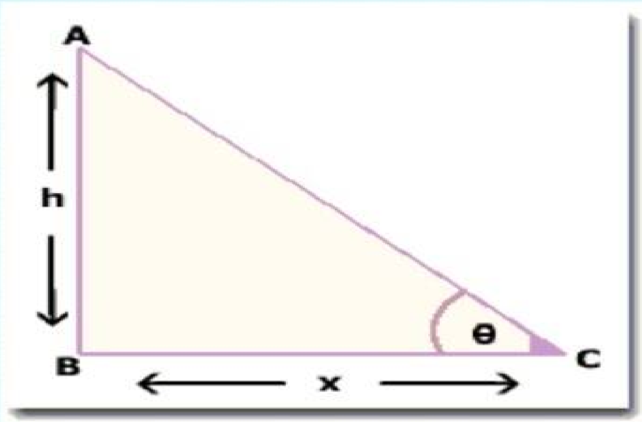


$\therefore$ We have $\theta = \theta_1 + \theta_2$ (Parallax angles)

Also $r = \frac{x}{\theta} = \frac{x}{\theta_1 + \theta_2}$

To Determine the Height of an Electric Pole

- Let AB be an electric pole, standing upright, on the ground. Let the point C be the observation point i.e., the observer standing. Therefore, BC is a horizontal distance on the ground and angle is subtended between the base and the top of the electric pole. The point C is also called as the elevation of the electric pole and the distance from BC to the point between the point of observation and the foot of the electric pole is x and 'h' is one height of the electric pole.



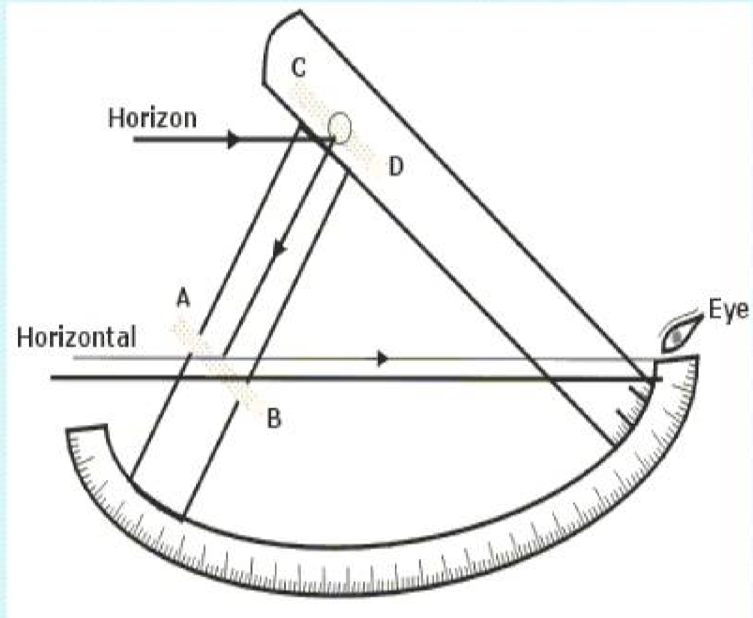
$\therefore$ We have, as per trigonometry

$$\tan\theta = \frac{\text{opposite side}}{\text{adjacent side}} \qquad \therefore \text{opposite side} = \text{adjacent side} \times \tan\theta$$

- i.e., h = x tan q, where the values of x and q could be known and the height of the electric pole be determined. This method is called Triangulation method.

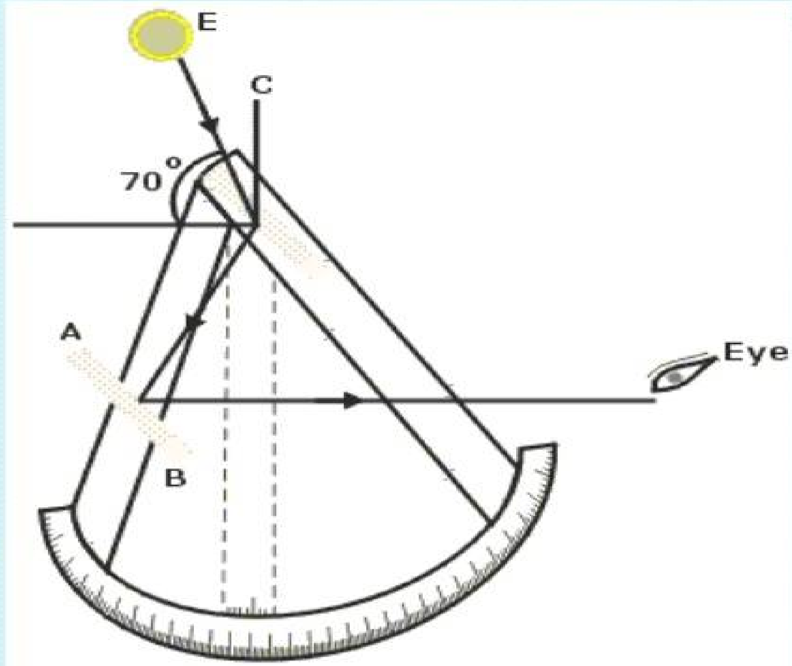
To Determine the Height using a Sextant

- AB and CD are two mirrors fixed, as in the diagram, parallel to each other and facing each other, i.e., the reflection on CD is seen on AB. A small telescope and a vernier travelling over a scale, graduated in degrees, constitute the sextant.
- The sextant is fixed firmly to view the horizon, when the reading on the scale is zero, i.e., the reading when the horizon is seen through both the mirrors.



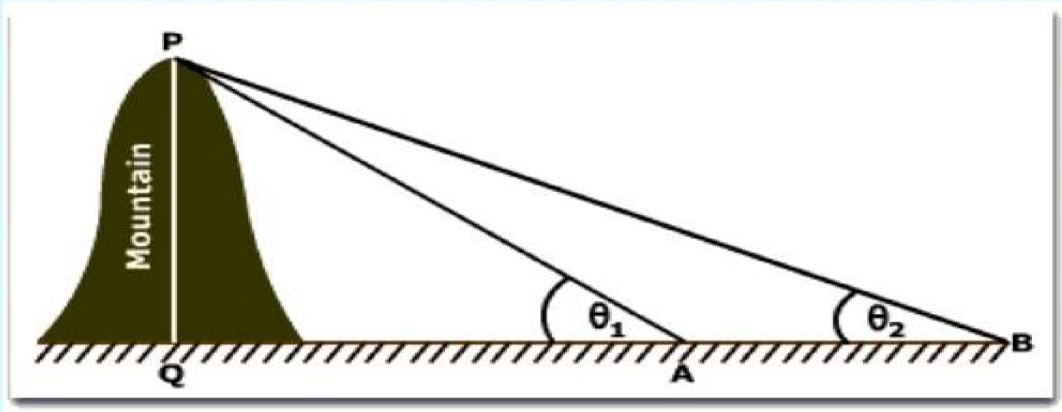
(a)

- The arm of the sextant is a rotated until the reflected image of the sun is seen while the horizon is still seen directly, as in figure.
- Then, the angle between the horizontal and CE is twice the angle through which the arm is rotated. Since the graduations on the scale is double the angle through which the arm is rotated, the direct setting gives the reading straightaway.



(b)

To Determine the Height of an Inaccessible Mountain



- Let PQ be the symbolic representation of the mountain (h), inaccessible for direct measurement. Let A and B be two points of elevation subtending angles q_1 and q_2 of the top of the mountain at P. Since the distance AB is a known quantity, - a horizontal entity say x, applying trigonometry, we have,

$$\tan \theta_1 = \frac{PQ}{QA} \quad \text{and} \quad \tan \theta_2 = \frac{BQ}{QP} = \frac{PQ}{QB}$$

$$\text{i.e., } QA = \frac{PQ}{\tan \theta_1} = h \,.\, \cot \theta_1 \qquad (1)$$

$$\text{Similarly, } \quad QB = PQ \cot \theta_2 = h \,.\, \cot \theta_2 \qquad (2)$$

$$(2) - (1) \text{ gives } BQ - QA = h \cot \theta_2 - h \cot \theta_1$$

$$QA + AB - QA = h\,(\cot \theta_2 - \cot \theta_1)$$

$$AB = h \cot(\theta_2 - \theta_1)$$

$$\tan\theta_1 = \frac{PQ}{QA} \quad \text{and} \quad \tan\theta_2 = \frac{BQ}{QP} = \frac{PQ}{QB}$$

$$\text{i.e., } QA = \frac{PQ}{\tan\theta_1} = h \cdot \cot\theta_1 \qquad (1)$$

$$\text{Similarly } QB = PQ\cot\theta_2 = h \cdot \cot\theta_2 \qquad (2)$$

$$(2) - (1) \text{ gives } BQ - QA = h\cot\theta_2 - h\cot\theta_1$$

$$QA + AB - QA = h(\cot\theta_2 - \cot\theta_1)$$

$$AB = h\cot(\theta_2 - \theta_1)$$

$$\therefore h = \frac{AB}{\cot(\theta_2 - \theta_1)} = \frac{x}{\cot\theta_2 - \cot\theta_1}$$

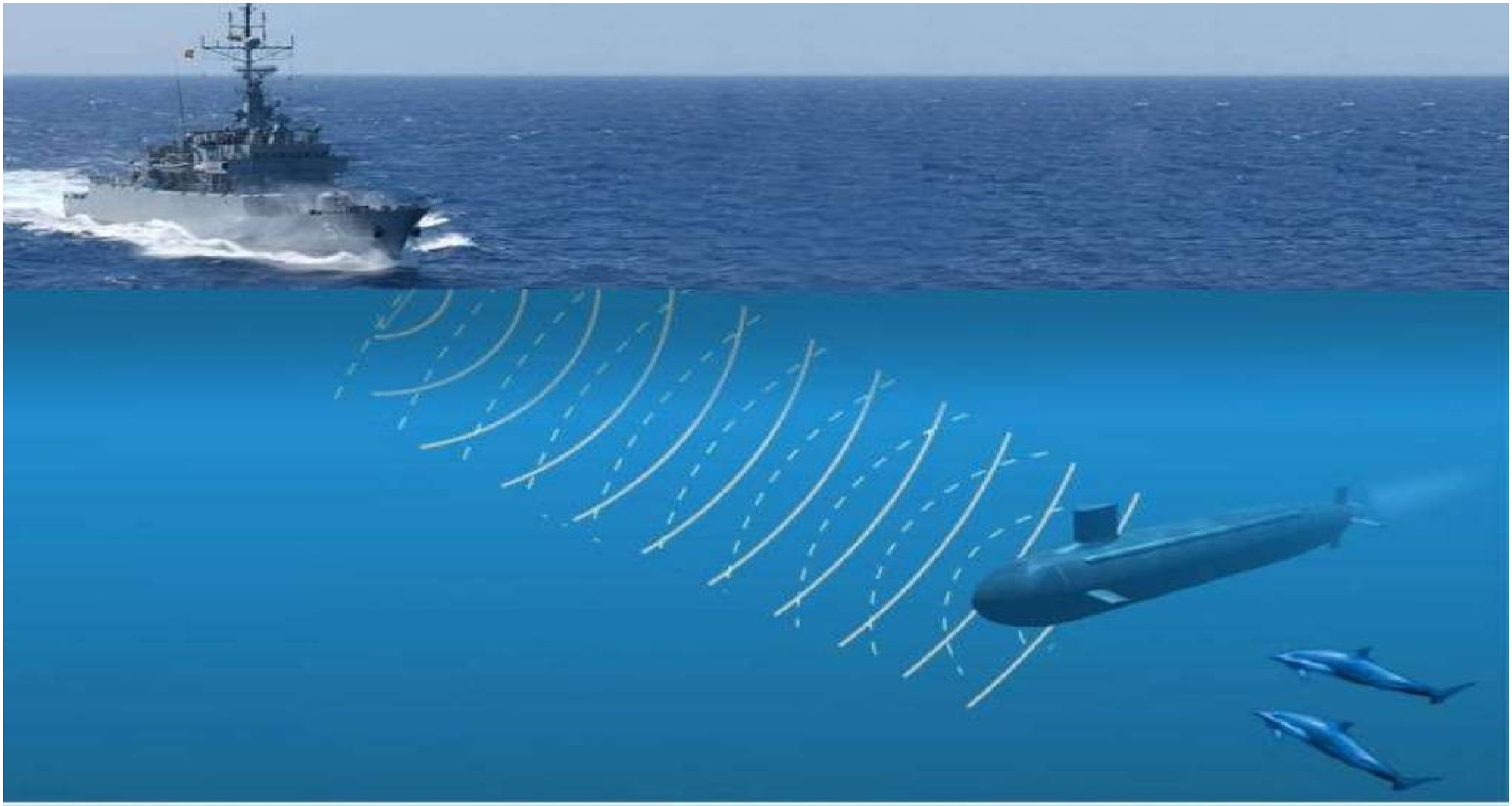
- where the values of x, q_1 and q_2 are known as h is evaluated.

To Measure the Distance of a Submarine (Echo Method)

- Ultrasonic waves are transmitted through the ocean and if on its path any submerged objects are encountered, then as per law, the waves are reflected back to the origin. The time of sending the wave and the time of receiving the reflected wave are worked out and the distance of the submerged object (submarine in this case) is worked out by the formula

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

- where s is the distance between the point of transmission, v is the velocity of sound waves sent and t is the total time taken by the waves to travel to and fro.



Warships using sonar to find submarines. It's thought the war ships sonar disrupts dolphins ultrasound system.

DIMENSIONAL ANALYSIS

- The dimensions of a physical quantity are the powers to which the fundamental quantities are raised to represent that physical quantity.
- The equation which expresses a physical quantity in terms of the fundamental units of mass, length and time, is called dimensional equation.
- According to this principle of homogeneity a physical equation will be dimensionally correct if the dimensions of all the terms in the all the terms occurring on both sides of the equation are the same.

Main uses of the dimensional analysis

- There are three main uses of the dimensional analysis-
- (a) To convert a unit of given physical quantities from one system of units to another system for which we use

$$n2 = n1[M1/M2]a[L1/L2]b[T1/T2]c$$

- (b) To check the correctness of a given physical relation.
- (c) To derive a relationship between different physical quantities.

Advantages of Dimensional Analysis

- Dimensional equations are used to validate the correctness of a physical equation.
- Dimensional equations are used to derive correct relationship between different physical quantities.
- Dimensional equations are used to convert one system of units to another.
- Dimensional equations are used to find the dimension of a physical constant.

Limitations of Dimensional Analysis

- Dimensional analysis has no information on dimensionless constants.
- If a quantity is dependent on trigonometric or exponential functions, this method cannot be used.
- In some cases, it is difficult to guess the factors while deriving the relation connecting two or more physical quantities.
- This method cannot be used in an equation containing two or more variables with same dimensions.
- It cannot be used if the physical quantity is dependent on more than three unknown variables.
- This method cannot be used if the physical quantity contains more than one term, say sum or difference of two terms.

SIGNIFICANT FIGURES

For counting of the significant figure rule are as:

- All non- zero digits are significant figure.
- All zero between two non-zero digits are significant figure.
- All zeros to the right of a non-zero digit but to the left of an understood decimal point are not significant. But such zeros are significant if they come from a measurement.
- All zeros to the right of a non-zero digit but to the left of a decimal point are significant.
- All zeros to the right of a decimal point are significant.
- All zeros to the right of a decimal point but to the left of a non-zero digit are not significant. Single zero conventionally placed to the left of the decimal point is not significant.
- The number of significant figures does not depend on the system of units.

ACCURACY AND PRECISSION

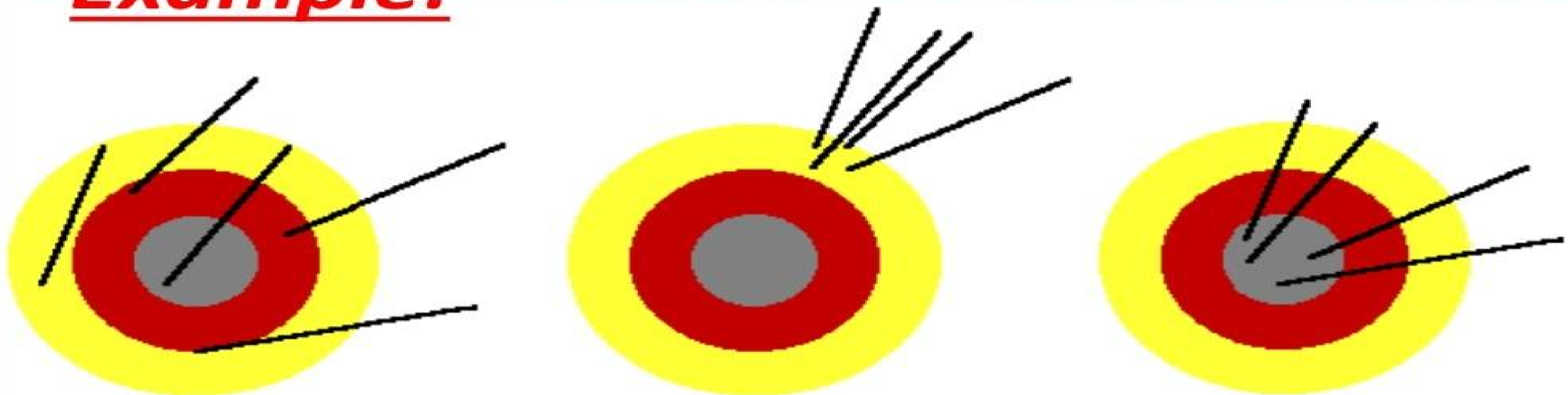
ACCURACY

The accuracy of a measurement is its relation to the true, nominal, or accepted value. It is sometimes expressed as a percentage deviation from the known value. The known or true value is often based upon reproducible measurements.

PRECISSION

A measure of how close a series of measurements are to one another. A measure of how exact a measurement is.

Example:



• Accurate • Not Precise	• Not Accurate • Precise	• Accurate and • Precise

ERRORS IN A MEASURMENT

Random Error

- Any factors that randomly affect measurement of the variable across the sample.
- For instance, each person's mood can inflate or deflate performance on any occasion.
- Random error adds variability to the data but does not affect average performance for the group.

Systematic Error

- Any factors that systematically affect measurement of the variable across the sample.
- Systematic error = bias.
- For instance, asking questions that start "do you agree with right-wing fascists that..." will tend to yield a systematic lower agreement rate.
- Systematic error does affect average performance for the group.

Relative Error:

- Relative error is the ratio of the absolute error of the measurement to the accepted measurement. The relative error expresses the "relative size of the error" of the measurement in relation to the measurement itself.
- When the accepted or true measurement isknown, the relative error is found using

which is considered to be a measure of accuracy.

$$E_{relative} = \frac{E_{absolute}}{x_{accepted}}$$

Percentage Error

- It is the relative error measured in percentage.
  So,
  Percentage Error =

  mean absolute value/mean value X 100

  $$= \Delta a_{mean} / a_m X 100$$

$$\text{Percent of Error} = \frac{|\text{measured value - actual value}|}{\text{actual value}} \cdot 100\%$$

- The relative error expressed in percent is called percentage error.
- The error is communicated in different mathematical operations as detailed below:

The error is communicated in different mathematical operations as detailed below:

(i)	For $x = (a \pm b)$,	$\Delta x = \pm (\Delta a + \Delta b)$
(ii)	For $x = a \times b$,	$\Delta x/x = \pm (\Delta a/a + \Delta b/b)$
(iii)	For $x = a/b$,	$\Delta x/x = \pm (\Delta a/a + \Delta b/b)$
(iv)	For $x= a^n b^m /c^p$	$\Delta x/x = \pm (n\Delta a/a +m \Delta b/b + p\Delta c/c$

16 MCQ'S

1 . 1KWH is unit of

1. Time
2. Power
3. Energy
4. Stress

Ans- 3. Energy

2. Unit of Intensity of magnetic induction field is

1. N/Am
2. Tesla
3. Wb/m^2
4. All above

Ans- 4. All above

3. Which of the following has no units?

1. Thermal capacity
2. Magnetic susceptibility
3. Angular acceleration
4. Moment of a magnet

Ans-2. Magnetic susceptibility

4.Which one of the following units is a fundamental unit?

1. watt
2. joule/sec
3. ampere
4. newton

Ans- 3. ampere

5. kg m/sec is the unit of

1. Impulse
2. Angular acceleration
3 . Capacity of condenser
4. Acceleration.

Ans- Impulse

6. Which of the following is a common unit of a physical quantity in M.K.S & S.I systems.

1. ampere
2.kelvin
3. mole
4. joule/sec

Ans- 4. joule/sec

7. Which of the following is Unit of length?

1. Lunar Month
2. Kelvin
3. candela
4. Light year

Ans- 4. Light year

8. rad / sec is the unit of

1. Angular displacement
2. Angular velocity
3. Angular acceleration
4. Angular momentum

Ans- 3. Angular acceleration

9. Which of the following is not a unit of power .

1. Watt
2. joule/hr
3. Nm/sec
4. N/sec

Ans- 4.N/sec

10. If the unit of force were 20N, that of power were 1MW and that of time were 1 millisecond then the unit of length would be

a) 20m
b) 50m
c) 100m
d) 1000m

Ans-b)50m

11. The physical quantity having units of mass is

1.Density

2.Momentum

3. Inertia

4. Moment of force

Ans- 3. Inertia

12.A force 100N acts on a body.If the units of mass and length are doubled and unit of time is halved,then the force in the new system changes to

a)160N

b) 1.6 N

c) 16N

d) 1600N

Ans-d) 1600N

13. The electric resistance of a conductor is 54 ohm. If the unit of mass and length are tripled, units of time and electric current are doubled .Then the value of new electric resistance.

a)540 ohm
b) 1080 ohm
c) 1620 ohm
d)1944 ohm

Ans-d)1944 ohm

14.Which of the following is a derived unit ?

1. ampere
2. mole
3. candela
4. newton

Ans-4. newton

15) The power of a motor is 150W.If the unit of force is doubled, unit of velocity is tripled what will be the new unit of power.

a) 600W b)750W

c) 900W d) 300w

Ans- c) 900W

16. The fundamental unit which is common in F.P.S and M.K.S systems is

1. foot 2. sec

3.kilo gram 4. pound

Ans- 2. sec


THE END