(A Vaisesika Series Document)

UNITS & MEASUREMENTS

Physics class 11

Chishant (PGT Physics)
KENDRIYA VIDYALAYA,
MASJID MOTH SADIQ NAGAR
NEW DELHI
www.chishant.vaisesika.org.in
www.vlearn.me

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- **Fundamental** Or **Base Units:** The units for the fundamental or base quantities are called **fundamental** or **base units**.
- **Derived Units**: The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called **derived units**.
- **System Of Units** : A complete set of these units, both the base units and derived units, is known as the **system of units**

- The base units for length, mass and time in these systems were as follows :
  - ✓ In CGS system they were centimeter, gram and second respectively.
  - ✓ In FPS system they were foot, pound and second respectively.
  - ✓ In MKS system they were meter, kilogram and second respectively.

In SI, there are seven base units as given in Table 1.

SI Base Units

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

The Meter

the distance light travels in a vacuum in 1/299,792,458 of a second.

The Kilogram

It is defined to be the mass of a platinum-iridium cylinder, housed at the International Bureau of Weights and Measures near Paris.

The Second

the second was redefined as the time required for 9,192,631,770 Cesium atom vibrations

The Ampere

One ampere is defined as the amount of electric current that will produce an attractive force of 2.7 x 10^{-7} newton per meter of separation between the two wires (the newton is the derived unit of force).

Kelvins

The kelvin, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

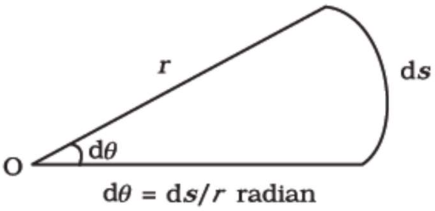
The mole

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.

The candela

The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

- Besides the seven base units, there are two more units that are defined for
  (a) Plane angle dθ as the ratio of length of arc d*s* to the radius *r* and



  (b) Solid angle dΩ as the ratio of the intercepted area d*A* of the spherical surface, described about the apex O as the centre, to the square of its radius *r.*
- Standard unit of a solid angle is the **Steradian (sr)**. (Mathematically, the solid angle is unit less, but for practical reasons, the steradian is assigned.)

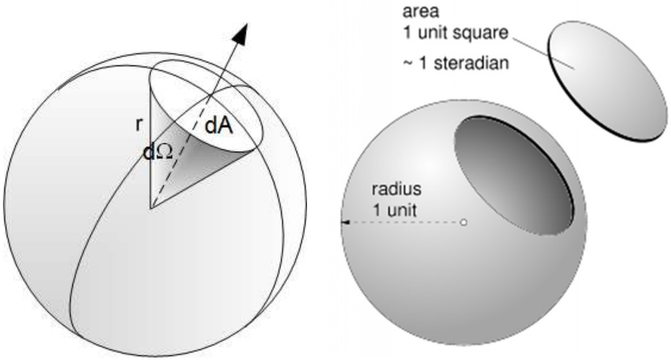


Figure 3 Steradian Defined

MEASUREMENT OF LENGTH AND THE LEAST COUNT

- A meter scale is used for lengths from 10^{-3} m to 10^{2} m.
- Vernier calipers are used for lengths to an accuracy of 10^{-4} m.
- A screw gauge and a spherometer can be used to measure lengths as less as to 10^{-5} m.

- **Least count** is the minimum distance which can be measured by any instrument.

For example for a meter scale it is 1milimeter = 10^{-3} meter

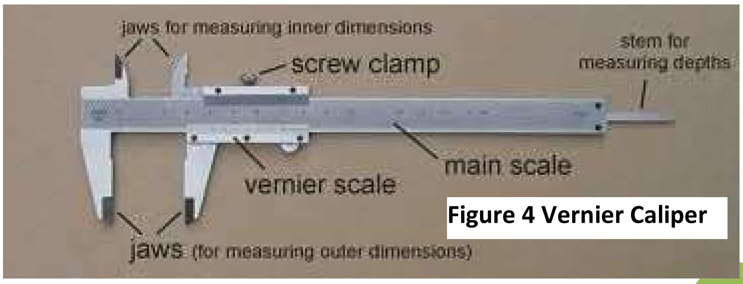


Figure 4 Vernier Caliper

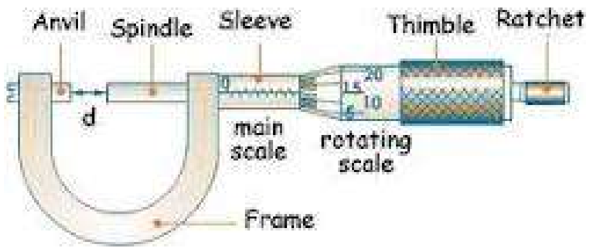


Figure 5 Screw Gauge

Spherometer

Some Practical Units

1. 1 fermi $=10^{-15}$ m
2. 1 X-ray unit = 10^{-13} m
3. 1 astronomical unit = 1.49×10^{11} m (average distance between sun and earth)
4. 1 light year = 9.46×10^{15} m
5. 1 parsec = 3.08×10^{16} m = 3.26 light year

Significant Figures: In the measured value of a physical quantity, the number of digits about the correctness of which we are sure plus the next doubtful digit, are called the significant figures.

Rules for Finding Significant Figures

1. All non-zeros digits are significant figures, e.g., 4362 m has 4 significant figures.
2. All zeros occurring between non-zero digits are significant figures, e.g., 1005 has 4 significant figures.
3. All zeros to the right of the last non-zero digit are not significant, e.g., 6250 has only 3 significant figures.
4. In a digit less than one, all zeros to the right of the decimal point and to the left of a non-zero digit are not significant, e.g., 0.00325 has only 3 significant figures.
5. All zeros to the right of a non-zero digit in the decimal part are significant, e.g., 1.4750 has 5 significant figures.

Significant Figures in Algebric Operations

(i) In Addition, or Subtraction In addition or subtraction of the numerical values the final result should retain the least decimal place as in the various numerical values. e.g., If l1= 4.326 m and l2 = 1.50 m. Then, l1 + l2 = (4.326 + 1.50) m = 5.826 m

As l2 has measured upto two decimal places, therefore l1 + l2 = 5.83 m

(ii) In Multiplication or Division In multiplication or division of the numerical values, the final result should retain the least significant figures as the various numerical values. e.g., If length l= 12.5 m and breadth b = 4.125 m.

Then, area A = l x b = 12.5 x 4.125 = 51.5625 m^2

As l has only 3 significant figures, therefore A= 51.6 m^2

Rules of Rounding Off Significant Figures

1. If the digit to be dropped is less than 5, then the preceding digit is left unchanged. e.g., 1.54 is rounded off to 1.5.
2. If the digit to be dropped is greater than 5, then the preceding digit is raised by one. e.g., 2.49 is rounded off to 2.5.
3. If the digit to be dropped is 5 followed by digit other than zero, then the preceding digit is raised by one. e.g., 3.55 is rounded off to 3.6.
4. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd and left unchanged if it is even. e.g., 3.750 is rounded off to 3.8 and 4.650 is rounded off to 4.6.

Dimensional Formula

The dimensional formula of any physical quantity is the formula that tells which of the fundamental units have been used for the measurement of that physical quantity.

How dimensional formula is written for a physical quantity

(1) The formula of the physical quantity must be written. The quantity must be on the left-hand side of the equation.

(2) All the quantities on the right-hand side of the formula must be written in

terms of fundamental quantities like mass, length and time.

(3) Replace mass, length and time with M, L and T.

(4) Write the powers of the terms.

Characteristics of Dimensions

(1) Dimensions do not depend on the system of units.

(2) Quantities with similar dimensions can be added or subtracted from each other.

(3) Dimensions can be obtained from the units of the physical quantities and vice versa.

(4) Two different quantities can have the same dimension.

(5) When two dimensions are multiplied or divided it will form the dimension of the third quantity.

Dimensional Analysis

The dimensional formula can be used to

(1) To check the correctness of the equation.

(2) Convert the unit of the physical quantity from one system to another.

(3) Deduce the relation connecting the physical quantities.

Deducing relation among physical quantities

To deduce relation among physical quantities, we should know the dependence of one quantity over others (or independent variables) and consider it as product type of dependence.

Dimensionless constants cannot be obtained using this method.
Example, $T = k\, l^x g^y m^z$

Or $[L^0M^0T^1] = [L1]^x\ [L1T^{-2}]^y\ [M1]^z = [L^{x+y}T^{-2y}M^z]$

Means, x+y = 0, -2y = 1 and z = 0. So, x = ½, y = -½ and z = 0

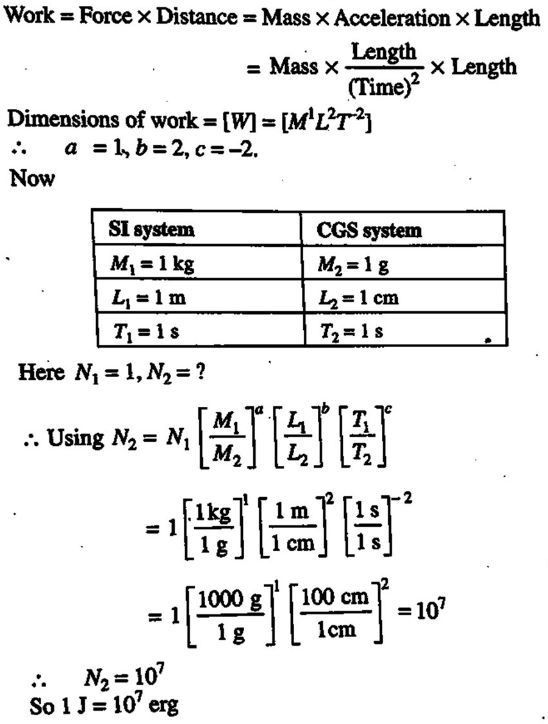
So the original equation reduces to

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

Unit Conversion: Example

Convert 1 Joule to erg.

1 Joule-SI Unit, Erg-cgs unit



$$\text{Work} = \text{Force} \times \text{Distance} = \text{Mass} \times \text{Acceleration} \times \text{Length}$$

$$= \text{Mass} \times \frac{\text{Length}}{(\text{Time})^2} \times \text{Length}$$

Dimensions of work = $[W] = [M^1L^2T^{-2}]$

$\therefore \quad a = 1, b = 2, c = -2.$

Now

SI system	CGS system
$M_1 = 1$ kg	$M_2 = 1$ g
$L_1 = 1$ m	$L_2 = 1$ cm
$T_1 = 1$ s	$T_2 = 1$ s

Here $N_1 = 1, N_2 = ?$

$$\therefore \text{ Using } N_2 = N_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$$

$$= 1\left[\frac{1\text{kg}}{1\text{ g}}\right]^1 \left[\frac{1\text{ m}}{1\text{ cm}}\right]^2 \left[\frac{1\text{ s}}{1\text{ s}}\right]^{-2}$$

$$= 1\left[\frac{1000\text{ g}}{1\text{ g}}\right]^1 \left[\frac{100\text{ cm}}{1\text{cm}}\right]^2 = 10^7$$

$\therefore \quad N_2 = 10^7$

So 1 J = 10^7 erg