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DIMENSION ANALYSIS

(PHYSICS)

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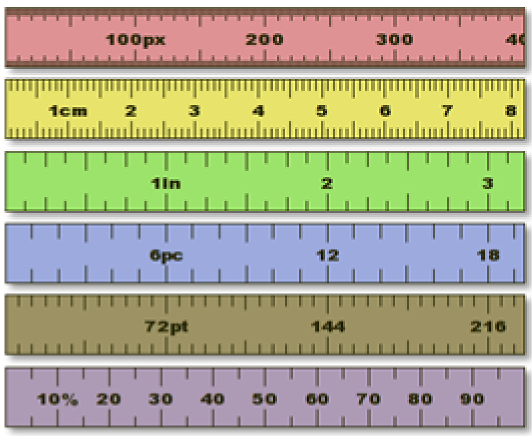
DIMENSION ANALYSIS

The fundamental quantities, irrespective of the system of units used for their measurement and their corresponding quantitative values, characterize different independent groups or classes of basic physical quantities. In other words, a fundamental quantity belongs to a class of physical quantities of its own kind only, each of them having no dependence with other fundamental quantities. The attribute that is common to a class of physical quantities is what is called their dimensionality.



Most physical quantities can be expressed in terms of combinations of five basic dimensions. These are **mass (M), length (L), time (T), electrical current (I), and temperature, represented by the Greek letter theta (θ).** These five dimensions have been chosen as being basic because they are easy to measure in experiments. Dimensions aren't the same as units. For example, the physical quantity, speed, may be measured in units of meters per second, miles per hour etc.; but regardless of the units used, speed is always a length divided a time, so we say that the dimensions of speed are length divided by time, or simply L/T. Similarly, the dimensions of area are L^2 since area can always be calculated as a length times a length. For example, although the area of a circle is conventionally written as πr^2, we could write it as πr (which is a length) × r (another length).

Dimensions of a physical quantity are the powers to which the fundamental units are raised in order to represent that quantity. A dimension deals with the qualitative part of measurement.

By international agreement a small number of physical quantities such as length, time etc. are chosen and assigned standards. These quantities are called 'base quantities' and their units as '**base units**'. All other physical quantities are expressed in terms of these '**base quantities**'. The units of these dependent quantities are called '**derived units**'.

The standard for a unit should have the following characteristics.

(a) It should be well defined.

(b) It should be invariable (should not change with time)

(c) It should be convenient to use

(d) It should be easily accessible

The 14th general conference on weights and measures (in France) picked seven quantities as base quantities, thereby forming the **International System of Units** abbreviated as SI (System de International) system.

Dimensional Formula and Dimensional Equation:-

Dimensional formula of a physical quantity is the formula which tells us how and which of the fundamental units have been used for the measurement of that quantity.

An equation written in the following manner is called dimensional equation.

Area = $[M^0L^2T^0]$

How to Write Dimensions of Physical Quantities:-

Dimensions of a physical quantity can be determined as follows:

(a) Write the formula for that quantity, with the quantity on L.H.S. of the equation.

(b) Convert all the quantities on R.H.S. into the fundamental quantities mass, length and time.

(c) Substitute M,L, and T for mass, length and time respectively.

(d) Collect terms of M,L and T and find their resultant powers (a,b,c) which give the dimensions of the quantity in mass, length and time respectively.

Base quantities and their units:-

The seven base quantities and their units are,

Base quantity	Unit	Symbol
Length	Meter	M
Mass	Kilogram	Kg
Time	Second	Sec
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	Cd
Amount of substance	Mole	Mole

Derived units:-

We can define all the derived units in terms of base units. For example, speed is defined to be the ratio of distance to time.

Unit of Speed = (unit of distance (length))/(unit of time)

= m/s = ms^{-1} (Read as meter per sec.)

SOME DERIVED SI UNITS AND THEIR SYMBOLS:-

Quantity	Unit	Symbol	Express in base units
Force	newton	N	Kg-m/sec^2
Work	joules	J	Kg-m2/sec^2
Power	watt	W	Kg-m2/sec^3
Pressure	Pascal	Pa	Kg m-1/S^2

Note:

The following conventions are adopted while writing a unit.

- Even if a unit is named after a person the unit is not written capital letters. i.e. we write joules not Joules.
- For a unit named after a person the symbol is a capital letter e.g. for joules we write 'J' and the rest of them are in lowercase letters e.g. seconds is written as 's'.
- The symbols of units do not have plural form i.e. 70 m not 70 ms or 10 N not 10Ns.
- Not more than one solid is used i.e. all units of numerator written together before the '/' sign and all in the denominator written after that.

i.e. It is 1 ms^{-2} or 1 m/s^{-2} not 1m/s/s.

- Punctuation marks are not written after the unit

e.g. 1 litre = 1000 cc not 1000 c.c.

It has to be borne in mind that the SI system of units is not the only system of units that is followed all over the world. There are some countries (though they are very few in number) which use different systems of units. For example: the FPS (Foot Pound Second) system or the CGS (Centimeter Gram Second) system.

Dimensions:-

The unit of any derived quantity depends upon one or more fundamental units. This dependence can be expressed with the help of dimensions of that derived quantity. In other words, the dimensions of a physical quantity show how its unit is related to the fundamental units.

To express dimensions, each fundamental unit is represented by a capital letter. Thus the unit of length is denoted by L, unit of mass by M. Unit of time by T, unit of electric current by I, unit of temperature by K and unit of luminous intensity by C.

Remember that speed will always remain distance covered per unit of time, whatever is the system of units, so the complex quantity speed can be expressed in terms of length L and time T. Now, we say that the dimensional formula of speed is LT^{-2}. We can relate the physical quantities to each other (usually we express complex quantities in terms of base quantities) by a system of dimensions.

Dimension of a physical quantity are the powers to which the fundamental quantities must be raised to represent the given physical quantity.

Example:-

Density of a substance is defined to be the mass contained in the unit volume of the substance.

Hence, [density] = ([mass])/([volume]) = $M/L^3 = ML^{-3}$

So, the dimensions of density are 1 in mass, -3 in length and 0 in time.

Hence the dimensional formula of density is written as $[\rho]= ML^{-3}T^0$

It is to be noted that constants such as ½ π, or trigonometric functions such as "sin wt" have no units or dimensions because they are numbers, ratios which are also numbers.

Uses of Dimensional Analysis:-

Dimensional analysis has been put to following three uses:-

- To convert the values of a physical quantity from one system to another.
- To check the correctness of a given relation
- To derive a relation between various physical quantities

Limitations of Dimensional Analysis:-

Owing to the process of its development, the process of dimensional analysis is subjected to the following limitations:

(a) It gives no information regarding the constant of proportionality involved in the equation.

(b) It cannot be used to derive an expression involving trigonometric functions.

(c) It cannot be used to derive an expression involving exponential functions.

(e) It cannot be used to derive an expression for a physical quantity which depends upon factors more than three.