Government of Tamilnadu

Department of Employment and Training

Course : TNPSC Group II Exam

Subject : Physics

Topic : **Physical quantities, Standards & Units**

PHYSICAL QUANTITIES, STANDARDS & UNITS

Units and Dimension & Errors

1. Review of Basic Concepts :

- ❖ Physics is the branch of Science which deals with observation, measurement and description of natural phenomena related to Matter and Energy 'Physics' is also defined as the study of nature and its law.
- ❖ Mechanics is one of the branches of Physics which deals with the studies of forces acting on the bodies.
- ❖ Physical Quantities are the quantities which can be able to describe the Laws of physics Physical quantities may be divided into fundamental and derived quantities.
- ❖ Fundamental quantities can be classified into 7 Quantities . Namely :
    - Mass
    - Length
    - Time
    - Temperature
    - Electric current
    - Luminous Intensity
    - Amount of substance
- ❖ In addition to these seven basic units there are two supplementary units – 'radian' and 'steradian'. The units of Fundamental quantities are called 'fundamental units'
- ❖ In 1960, to measure the physical quantities, International System of Units abbreviated as 'SI' in all languages was introduced.

<u>Supplementary units</u>

Name of Quantity	Name of Unit
Plane angle	Radian
Solid angle	Steradian

Fundamental Quantities can be defined as follows :

- ❖ The fundamental quantities should be independent to one another.
- ❖ All other quantities may be expressed in terms of fundamental quantities.

Derived Quantities and their units :

PHYSICAL QUANTITY	EXPRESSION	UNIT
Area	Length x breadth	m^2
Volume	area x height	m^3
Velocity	Displacement / time	ms^{-1}
Acceleration	Velocity / time	ms^{-2}
Angular velocity	Angular displacement/time	rad s^{-1}
Angular acceleration	Angular velocity/time	rad s^{-2}
Density	Mass/ volume	Kg m^{-3}
Momentum	Mass x velocity	Kg m s^{-1}
Moment of Inertia	Mass x (distance) ^{2}	Kg m^2
Force	Mass x acceleration	$Kgms^{-2}$ or N
Pressure	Force x area	Nm^{-2} or Pa
Energy (work)	Force x distance	Nm or J
Impulse	Force x time	Ns
Surface tension	Force / length	Nm^{-1}
Moment of force (torque)	Force x distance	Nm
Electric change	Current x time	As
Current density	Current / area	Am^{-2}
Magnetic induction	Force/ [current x length]	NA^{-1} m^{-1}

Fundamental or Basic Quantities:

Quantity	Unit	Symbol	Dimension
Length	Metre	M	L
Mass	Kilogram	Kg	M
Time	Second	S	T
Electric current	Ampere	A	A
Temperature	Kelvin	K	K
Luminous Intensity	Candela	Cd	Cd
Amount of substance	Mole	Mol	Mol

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

Derived Quantities :

- The quantities derived from the fundamental quantities are called derived quantities.

  Eg. Area, Volume, Density

Derived Units :

- The units of derived quantities are called derived units.

Rules and conventions for writing SI Units and their Symbols :

1. The units named after scientists are not written with a capital initial latter.

   E.g: Newton, Henry, watt.
2. The symbols of the units named after scientists should be written by a capital letter.

   E.g : N for Newton, H for Henry, W for watt
3. Small letters are used as symbols for units not derived from a proper name.

   E.g : m for metre, kg for kilogram
4. No full stop or other punctuation marks should be used within or at the end of symbols.

   E.g: 50 m and not as 50m
5. The symbols of the units do not take plural form.

   E.g: 10kg not as 10kgs
6. When temperature is expressed in Kelvin, the degree sign is omitted.

   E.g: 273 K not as 273°K
7. If expressed in Celsius scale, degree sign to be included.

   E.g: 100 °C not 100°C
8. Use of solidus is recommended only for indicating a division of one letter units symbol by another unit symbol. Not more than one solidus is used.

E.g: ms^{-1} or m/s J/K or JK^{-1} mol^{-1} but not J /K /mol

9. Some space is always to be left between the number and the symbol of the unit and also between the symbols for compound units such as force, momentum etc.

Nano second means one billionth of a second

10. Only accepted symbols should be used.

E.g: ampere is represented as A not as amp. (or) am; second is represented as 's' and not as sec.

11. Numerical value of any physical quantity should be expressed of mercury is 1.36 x 104kg m^{-3} and not as 13600kg m^{-3}

E.g: density of mercury is 1.36 x 10 4 kg m^{-3} and not as 13600kg m^{-3}

Light Year:

In order to measure very large distance, the following units are used.

1. Light year
2. Astronomical Unit

Light year is the distance travelled by light in one year in vacuum.

Distance travelled = velocity of light x 1 year

$\therefore$ 1 light year = 3×10^8 m x 1 year (In seconds)

$= 3 \times 10^8 \times 365.25 \times 24 \times 60 \times 60$

$= 9.467 \times 10^{15}$m

1 light year = 9.467×10^{15} m.

Greatest Units

- 1 light year = 9.46×10^{15} m
- 1 parsec = 3.84×10^{16} m
- 1 AU = 1.5×10^{11} m
- 1 metric ton = 10^3 kg
- 1 Quintal = 10^2 kg

Astronomical unit :

- ❖ Astronomical unit is the mean distance of the centre of the Sun from the centre of the earth. 1 Astronomical unit = 1.496×10^{11}m

Expressing Larger and smaller Quantities :

- ❖ The fundamental units are defined.
- ❖ Now it is easier to express larger and smaller units of the same physical quantity.
- ❖ The table lists the standard SI prefixes, their meanings and abbreviation.

Power of Ten	Prefix	Abbreviation
10^{-15}	femto	f
10^{-12}	Pico	p
10^{-9}	Nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centime	c

10^{-1}	deci	d
10^{1}	deca	da
10^{2}	Hecto	h
10^{3}	Kilo	k
10^{6}	Mega	M
10^{9}	Giga	G
10^{12}	Tera	T
10^{15}	Peta	P

Scalar Quantities

- Physical quantities which have magnitude only and no direction

  E.g : Mass, Speed, Volume, Work, Time, Power Energy

Vector Quantities

- Physical quantities which have magnitude and direction both and which obey triangle law.

  Eg : Displacement, Velocity, acceleration, force, Momentum

Dimensional Quantities :

- Constant which possess dimensions are called Dimensionless are called 'Dimensionless quantities'

  E.g : Strain, Specific Gravity etc.

Uses of Dimensional Analysis :

- The method of dimensional analysis is used in four important ways :

1. It is used to check the dimensional correctness of a given physical equation.
2. To the physical equation
3. Finding the dimensions of constants (or) variables in an equation.
4. Conversion of one unit from one system to another.

Limitation of Dimensional Analysis :

1. If a physical quantity depends more than 3 quantities, the dimensions cannot be applied
2. The dimensional method cannot be applied to equations involving exponential and trigonometric functions.
3. The value of dimensionless constants be determined by this method.

Dry ice is solid carbon dioxide

Dimensional Formulae of some derived quantities

PHYSICAL QUANTITY	EXPRESSION	DIMENSIONAL FORMULA
Area	length x breadth	$[L^2]$
Density	mass / volume	$[ML^{-3}]$
Acceleration	velocity / time	$[LT^{-2}]$
Momentum	mass x velocity	$[MLT^{-1-}]$
Force	mass x acceleration	$[MLT^2]$
Work	force x distance	$[ML^2T^{-2}]$
Power	work / time	$[ML^2T^{-3}]$
Energy	Work	$[ML^2T^{-2}]$
Impulse	force x time	$[MLT^{-1}]$
Radius of Gyration	distance	$[L]$
Pressure	force / area	$[ML^{-1}T^{-2}]$
Surface tension	force / length	$[MT^{-2}]$
Frequency	1 / time period	$[T^{-1}]$
Tension	force	$[MLT^{-2}]$
Moment of force (or torque]	force x distance	$[ML^2T^{-2}]$
Angular velocity	angular displacement / time	$[T^{-1}]$
Stress	force / area	$[ML^{-1}T^{-2}]$
Heat	energy	$[ML^2T^2]$
Heat capacity	heat energy / temperature	$[ML^2T^2K^{-1}]$
Charge	current x time	$[AT]$
Faraday constant	Avogadro constant x elementary charge	$[AT\ mol^{-1}]$
Magnetic induction	force / (current x length)	$[MT^2\ A^{-1}]$

Dimensional quantities

- Constants which possess dimensions are called dimensional constants. Planck's constant, universal gravitational constant are dimensional constants.
- Dimensional variables are those physical quantities which possess dimensions but do not have a fixed value. Example – velocity, force, etc.

Dimensionless quantities

- There are certain quantities which do not possess dimensions. They are called dimensionless quantities. Examples are strain, angle, specific gravity, etc. They are dimensionless as they are the ratio of two quantities having the same dimensional formula.

Fundamental Physical Constants	
Avagadro's number	N = 6.022045 X 10^{23} molecules/mol
Boltzmann's constant	k = R/N = 1.380662 x 10^{-23}J/K
Electric permittivity of evacuated free space	ε_0 = 8.85418782 x 10^{-12} F /m or C^2 J^{-1} m^{-1}
Electron charge mass ratio	e/m_e = 1.7588047 x 10^{11} C/kg
Elementary charge	e = 1.6021892 x 10^{-19} C
Faraday constant	F = Ne = 9.648456 x 10^4 C/mole
Gravitational constant,	G = 6.672 X 10^{-11} N.m²/kg²
Magnetic permeability	μ_0 = 4π X 10^{-7} H/m -12.5663706 x 10^{-7} Wb/ A.m.
Normal acceleration due to gravity	g = 9.80665 m/s² = 9.81 m/s²
Normal atmospheric pressure	P = 1.0129 X 10^5 N/m²
One Atomic mass unit	1 a.m.u. = 1.6605655 x 10^{-27} kg
Planck's constant	h = 6.622176 X 10^{-34} j.s.
Rest mass of electron	m_e = 9.109534 x 10^{-31} kg

Rest mass of neutron	M_n = 1.6749543 x 10^{-27} kg
Rest mass of proton	m_p = 1.6726485 x 10^{-27} kg
Rydberg constant	$R_\propto$ = 1.094 x $10^7 10^{-1}$
Solar constant	= 1.388 x 10^3 Wm^2
Stefan- Boltzmann constant	σ = 5.67032 X 10^{-8} Wm^{-2}. k^{-4}
Universal gas constant	R = 8.31 J/mole/K
Velocity of light in vacuum	C = 2.9979258 X 10^8 m/s = 3 x10^8 m/s
Volume of one mole of ideal gas at NTP	V = 22.41383 X 10^{-3} m^3/mole
Volume of one mole of ideal gas at NTP	= 0.00289782 m.k.

Least count of a venier callipers is 0.1 mm (or) 0.01 cm