UNIT: 01
MEASUREMENT

Date 12th August, 2022

1.1
'Physics and its scope'

→ PHYSICS:

→ Physics is a branch of science that involves the study of the physical world in specific and physical universe in general: energy, matter, and how they are related.

→ HOW EVERYTHING INVOLVES PHYSICS:

→ From walking to driving a car
→ From cooking to using a gadget
→ From cutting a tree to building a house
→ Even as we read this sentence, physics is at work.

→ ALL NATURAL SCIENCES STEM FROM PHYSICS:

→ So many pivotal discoveries of the 20th century - including

- laser
- radio
- DNA
- Internet
- television
- computer technology
- Nuclear weapons

are all credited to advancement in physics.

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SYSTEM INTERNATIONAL (SI)

→ Definition:

→ The International System of Units is a scientific method of expressing the magnitudes or quantities of natural phenomenon.

→ PHYSICAL QUANTITIES:

→ Quantities like length, time, density, temperature can be measured therefore they are called physical quantities.

→ System of Units:

→ A complete set of units for all physical quantities is called system of units. (SI unit system)

→ For e.g: the MKS: metre, kg, second
(Gaussian) CGS: cm, g, second
(British) FPS: foot, pound, second

→ A single system:

→ In 1960, an international comittee agreed on a single system for whole world. In science we always uses
∴ Official name: **Système International**

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Basic units: mass, length, time.

→ **Definition:**

→ There are seven base quantities and their units are defined and standardized and are called base units.

→ **SI BASE QUANTITIES AND BASE UNITS:**

Name	Symbol	Name	Symbol
Length	l, x, r	meter	m
Mass	m	Kilogram	kg
Time, duration	t	second	s
Electric current	I	ampere	A
Thermodynamic temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

Derived Units:

→ **Definition:**

→ A quantity and its unit obtained and developed from base quantities and their respective units without giving any consideration to the directional properties are called derived quantities and its units

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→ **TABLE:**

Name	Symbol	Name	Base terms
→ Area	A	square meter	m^2
→ Volume	V	cubic meter	m^3
→ speed, velocity	$v, \vec{v}$	meter per second	ms^{-1}
→ Acceleration	a	meter per second squared	ms^{-2}

→ **Supplementary Units:** radian, steradian

→ **Definition:**

→ Pure geomatrical units (radian and the steradian) were classified by the system International (SI) as supplementary units.

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→ Scientific Notation:

→ Definition:

→ scientific notation is an easy way of writing numbers that are too big to be written in decimal form.

→ number = mantissa $\times 10^{exponent}$

→ Scientific notation makes it easy to add, subtract, multiply and divide large numbers.

→ For e.g, $= (7 \times 10^{27})(7 \times 10^{27})$

$= 49 \times 10^{27+27}$

$= 49 \times 10^{54}$

$= 4.9 \times 10^{55}$

→ Prefixes to the power of TEN:

→ Definition:

→ 'A mechanism through which a term in scientific notation is expressed by giving a proper name to its power of ten is called prefix to the power of ten.

→ Advantage:

→ Prefixes make standard form to be written even more easily.

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→ **EXAMPLE:**

→ 5×10^{-3} m is equivalent to 5 mm (millimeters).

→ 8.25×10^{5} m is equivalent to 825 kilometers (km).

→ **Names of some:**

deca	10^{1}	da
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m

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→ ERRORS

→ definition:

→ Error is the doubt that exists about the result of any measurement. For every measurement (even the most careful) there is always a margin of doubt which is called error

→ types of errors:

I. Systematic errors — Instrumental errors / Personal errors

II. Random errors

I. Systematic Error:

→ tend to be in one direction, either +ve or -ve.

→ sources:

a) Instrumental errors:

→ causes:

1. due to imperfect design of instrument
2. due to calibration of measuring instrument.
3. due to zero error in the instrument.

b) Personal errors:

→ causes:

1. due to an individual's bias.
2. due to lack of proper setting of apparatus
3. due to carelessness in taking observations

→ **Systematic errors reduced by:**

1. By improving experimental techniques
2. By selecting better instruments.
3. By removing personal bias.

ii. Random Errors:

→ The random errors are those errors, which occur irregularly and are random with respect to sign and size

→ **Sources:** (random, unpredictable fluctuations in experiments)

1. changes in external environment
2. Personal (unbiased) errors by observer
3.

→ LEAST COUNT ERROR:

→ **Least Count:**

→ The smallest value that can be measured by the measuring instrument is called its least count.

→ **Least Count Error:**

→ The least count error is the error associated with the resolution of the instrument

→ It occurs in both random and systematic errors

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→ Can be reduced by:

1. By using instruments with higher resolution.
2. By improving experimental techniques

→ Example:

→ Vernier callipers has least count as **0.01cm**.
→ A spherometer has least count as **0.001cm**.

→ UNCERTAINTIES:

→ definition:

→ The quantification or magnitude of error or doubt in measurement is called uncertainty. Uncertainty estimate how small or large the error is.

→ **measurement = best estimate ± uncertainty**
value   magnitude of error

→ Example:

→ A measurement **(5.07 ± 0.02)g** means that the actual value lies between **5.05g** i-e (5.07 − 0.02)g and **5.09g** i-e (5.07 + 0.02)g.

→ Types of Uncertainties:

1. Absolute uncertainty
2. Fractional/Relative uncertainty
3. Percentage uncertainty

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→ The Ladder of Uncertainty:

Percentage Uncertainty

$$\%\text{ uncertainty} = \frac{\text{Ab·uncertainty}}{\text{measurement}} \times 100$$

Fractional or Relative uncertainty

$$\text{Fractional Uncertainty} = \frac{\text{Ab·uncertainty}}{\text{measurement}}$$

1. Denoted by ε
2. It has no unit

Absolute Uncertainty

1. Least count of measuring instrument
2. Denoted by Δ
3. Has the same unit as the quantity.

→ Purpose of uncertainty:

1. It estimates how small or large the error is.
2. It is present in every measurement upto some extent.

→ Causes of uncertainty:

1. Limitation of instrument
2. Natural variation in object
3. Imperfection of person's sense

→ Confidence and uncertainty are inversely proportional.

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→ Uncertainties are usually expressed by using statistical methods.

A. Sum or difference

B. Product or quotient

C. Power

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→ SIGNIFICANT FIGURES:

→ definition:

→ A significant figure is one that is reliably known. In any measurement the accurately known digits and the first doubtful digit are collectively called significant figures

→ General Rules:

1. All Non-Zero digits are significant
   e.g 47.872 has 5 sig digs
2. Captive Zeroes are significant
   e.g 301.5007 has 7 sig digs.
3. Trailing Zeroes are only significant if there is a decimal point
   e.g 5.200 has 4 sig digs
4. Leading Zeroes are never significant
   e.g 0.000538 has 3 sig digs.
5. Exact numbers have an infinite amount significant digits
   e.g 5000 has 4 sig digs.

→ Significant figures in Calculation:

a) Addition and Subtraction
b) Multiplication and Division

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a) Addition and Subtraction

→ When two or more quantities are added or subtracted, the result is as precise as the least precise of the quantities

For e.g.,

$44.56005 + 0.0698 + 1103.2 = 1147.8298$

(rounding off) $= 1147.8$

b) Multiplication and Division

→ When quantities are multiplied or divided, the result has the same number of significant figures as the quantity with the smallest number of significant figures

For e.g.,

$45.26 \times 2.41 = 109$

$= 1.09 \times 10^2$

→ PRECISION AND ACCURACY:

→ When a value is measured, precision and accuracy affect measurement.

→ Precision:

→ definition:

→ Precision describes the degree of exactness with which a measurement is made and stated (i-e position of last significant figures)

→ precision is defined as "the quality of being exact"

→ Precision depends on:

→ Precision depends on the instrument and technique used to make the measurement.

→ The device that has the finest division on its scale produces the most precise measurement.

→ Precision therefore refers to closeness of the set of measurements of the same quantity made in the same way.

→ Example:

the precision of 2624 m is 1 m.

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→ Accuracy:

definition:

→ In measurement, the accuracy is the closeness of a measured value to the actual value of the measured quantity.

→ Accuracy depends on:

→ The accuracy of a measurement depends on the number of significant digits.

→ The greater the significant digs, the better the accuracy.

→ Example:

→ For e.g, the accuracy of the measure-ment 0·025 m is indicated by 2 sig digs

→ Conclusion:

→ All in all, accuracy shows how well the results of a measured value agree with the actual value. (i-e the accepted value as measured by competent experimenters)

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→ DIMENSIONS OF PHYSICAL QUANTITIES:

→ definition:

→ Dimensions describe the physical nature of quantity.

→ Each basic measurable physical quantity is represented by specific symbol and written within square bracket is called dimension of physical quantity.

→ Each 7 base quantities used in SI has its own dimension. $L = [L]$ etc

→ The dimensions of the derived quantities are the product of the dimensions of the base quantities of which the quantity is derived.

for e.g area = (Length x length)

$= [L]^2$

→ Dimensional Exponents:

→ In general, the dimension of any quantity Q is written in the form of **dimensional product**.

$$\dim Q = L^{\alpha} M^{\beta} T^{\gamma} I^{\delta} \Theta^{\varepsilon} N^{\zeta} J^{\eta}$$

→ where the exponents $\alpha, \beta, \gamma, \delta, \varepsilon, \zeta$ and η are **dimensional exponents**.

→ Some derived quantities:

Quantity	Dimension
Velocity	$[LT^{-1}]$
Acceleration	$[LT^{-2}]$
Volume	$[L^3]$
Power	$[ML^2T^{-3}]$

→ Some terms used with dimensions:

a) Dimensional variables:

→ The physical quantities having the dimensions of variable magnitude.

e.g: force, energy, acceleration etc.

b) Dimensional constants:

→ The physical quantities having dimensions but are constant in magnitude.

e.g: speed of light, gravitational constant etc.

c) Dimensionless variables:

→ The physical quantities having no ~~magnit~~ dimensions but changing magnitude.

e.g: plane angle, solid angle etc.

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d) Dimensionless constants:

→ The physical quantities having no dimension but constant magnitude.
e.g: pure number, π etc

→ Dimensional Formula:

→ The expression which shows how and which of the base quantities represent the dimensions of a physical quantity.
for e.g: formula of volume = $[M^0L^3T^0]$
formula of acceleration $[M^0LT^{-2}]$

→ Dimensional Equation:

→ An equation obtained by equating a physical quantity with its dimensional formula.
for e.g:
dimensional eq. of volume;
$[V] = [M^0L^3T^0]$
dimensional eq. of force;
$[F] = [MLT^{-2}]$

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→ **Advantages of Dimensional Analysis:**

A→ Checking the correctness of a physical equation:

→ In order to show the rightness of the physical equation we have to show that the dimensions on both sides of the equation are same without any regard of the formula aka the principle of the ~~homogeniti~~ dimensional homogenity of a physical equation

→ **Limitation:**

→ Even if a physical relation is dimensionally correct, it doesn't prove the relation is physically correct

B→ Deriving a possible formula:

→ Dimensional analysis can be used to derive a possible formula, but the success of this method depends upon the correct guessing of various factors on which physical quantity depend,

→ **Limitation:**

→ Dimension-less constants cannot be obtained by this method

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→ UNIT SYMBOLS:

1. Printing:

→ Unit symbols are printed in roman (upright) type.
e.g: s for second, Pa for pascal

2. Compound Prefixes:

→ Compound prefixes are never used
e.g not mμm(milli micro meter); it is nm.

3. Multiplication and Division:

→ To multiply or divide the two units, the normal rules of algebraic (multiplication or division) apply
For e.g: Nm or N·m, for a newton metre and m/s or ms^{-1} for metre per second.

4. No Abbreviation:

→ It is not allowed to use abbreviation for unit symbols or unit names
e.g: sec for either (second or s)

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5. Power

→ When multiple of unit is raised to the power, the power applies to the whole multiple not just unit.

→ UNIT NAMES:

1. Capital Letter:

→ Full name of the unit does not begin with a capital letter even if named after scientist
e.g, newton

2. Initial capital:

→ The symbol of the unit ~~does not begin with a capital~~ named after a scientist has initial capital such as N for newton.

3. Multiple and sub-multiple prefix:

→ A multiple or sub-multiple prefix is part of the unit and is written before the unit symbol without any space

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→ **Radian :**

→ Radian is the unit of plane angle.

→ **definition:**

→ One radian (1 rad) is the angle subtended at the center of a circle by an arc with a length equal to the radius of the circle

→ **Formula:**

Mathematically,

$$\text{Name of radian}(\theta) = \frac{\text{Arc length}}{\text{radius of same circle}} = \frac{S}{r}$$

→ **Relation radian measurement and degree measurement:**

Number of degrees in 1 revolution $= 360°$ — ①

∴ Where as the number of radians ~~rot~~ in one revolution

$$= \frac{\text{circumference of Circle}}{\text{Radius of same circle}}$$

Number of radians in 1 revolution $= \frac{2\pi r}{r}$

$= 2\pi$ radians — ②

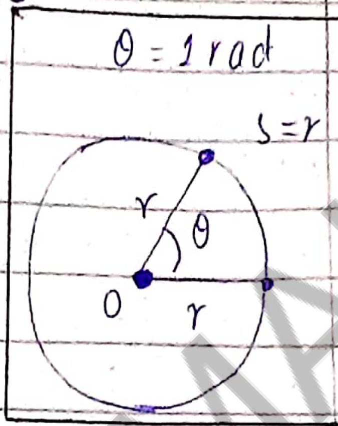
comparing eq ① and eq ②

$$2\pi \text{ rad} = 360^\circ$$

or $$1 \text{ rad} = \frac{360^\circ}{2\pi}$$

$$= \frac{360^\circ}{2 \times 3.14}$$

$$\boxed{1 \text{ rad} = 57.3^\circ}$$



→ Steradian:

→ steradian is the unit for solid angle

→ **definition:**

→ "steradian is defined as the solid angle subtended at the center of sphere by an area of its surface equal to the square of radius of that sphere"

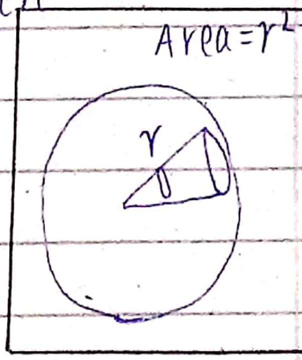
→ **formula:**

Mathemetrically,

$$\text{No. of steradians in sphere} = \frac{\text{Area of sphere}}{r^2}$$

There fore,

$$\text{No. of steradians in sphere} = \frac{4\pi r^2}{r^2}$$



→ sphere (or any closed surface) subtends 4π (12.56sr)