Physical Quantity

- Physical Quantity: A quantity which can be measured and expressed in form of laws is called a physical quantity.
- Physical quantity (Q) = n × u , Where n represents the numerical value and u represents the unit.
- As the unit(u) changes, the magnitude (n) will also change but product nu will remain same. i.e. n u = constant, or n1u1 = n2u2 = constant;

Fundamental and Derived Units

- Fundamental and Derived Units:
- Any unit of mass, length and time in mechanics is called a fundamental, absolute or base unit.
- Other units which can be expressed in terms of fundamental units, are called derived units

System of units

- System of units : A complete set of units, both fundamental and derived for all kinds of physical quantities is called system of units. (1) CGS system, (2) MKS system, (3) FPS system. (4) S.I. system : It is known as International system of units.
- There are seven fundamental quantities in this system. These quantities and their units are given in the following table.

SI UNITS

Quantity	Name of Units	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere	A
Temperature	Kelvin	K
Amount of Substance	Mole	Mol
Luminous Intensity	Candela	Cd

- Besides the above seven fundamental units two supplementary units are also defined - Radian (rad) for plane angle and Steradian (sr) for solid angle

Dimensions of a Physical Quantity

- Dimensions of a Physical Quantity: When a derived quantity is expressed in terms of fundamental quantities, it is written as a product of different powers of the fundamental quantities.
- The powers to which fundamental quantities must be raised in order to express the given physical quantity are called its dimensions.

Important Dimensions

- S.NO Quantity Dimension

1. Velocity or speed (v)
2. Acceleration
3. Distance
4. Force
5. Pressure
6. Stress
7. Strain
8. Angle
9. Gravitational constant
10. Acceleration due to gravity

- (1) To find the unit of a physical quantity in a given system of units.
- (2) To find dimensions of physical constant or coefficients.
- (3) To convert a physical quantity from one system to the other.
- (4) To check the dimensional correctness of a given physical relation: This is based on the ‘principle of homogeneity’. According to this principle the dimensions of each term on both sides of an equation must be the same.
- (5) To derive new relations.

Limitations of Dimensional Analysis

- (1) If dimensions are given, physical quantity may not be unique.
- (2) Numerical constant having no dimensions cannot be deduced by the methods of dimensions.
- (3) The method of dimensions can not be used to derive relations other than product of power functions. For example, s = u t + (1/2) at2 or y = a sin w t
- (4) The method of dimensions cannot be applied to derive formula consist of more than 3 physical quantities.

Significant Figures

- Significant Figures in the measured value of a physical quantity tell the number of digits in which we have confidence.
- Larger the number of significant figures obtained in a measurement, greater is the accuracy of the measurement. The reverse is also true.

- (1) All non-zero digits are significant.
- (2) A zero becomes significant figure if it appears between two non-zero digits.
- (3) Leading zeros or the zeros placed to the left of the number are never significant. Example : 0.543 has three significant figures. 0.006 has one significant figures.

Significant Figures-RULES

- (4) Trailing zeros or the zeros placed to the right of the number are significant, if they come after a decimal point. Example : 4.330 has four significant figures. 343.000 has six significant figures.
- (5) In exponential notation, the numerical portion gives the number of significant figures. Example : 1.32 x102 has three signifi cant fi gures.

Rounding Off

- (1) If the digit to be dropped is less than 5, then the preceding digit is left unchanged. Example : x = 7.82 is rounded off to 7.8, again x = 3.94 rounded off to 3.9.
- (2) If the digit to be dropped is more than 5, then the preceding digit is raised by one. Example : x = 6.87 is rounded off to 6.9, again x = 12.78 is rounded off to 12.8.
- (3) If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is raised by one. Example : x = 16.351 is rounded off to 16.4, again x = 6.758 is rounded off to 6.8

Rounding Off

- (4) If digit to be dropped is 5 or 5 followed by zeros, then preceding digit is left unchanged, if it is even. Example : x = 3.250 becomes 3.2 on rounding off, again x = 12.650 becomes 12.6 on rounding off.
- (5) If digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd. Example : x = 3.750 is rounded off to 3.8, again x = 16.150 is rounded off to 16.2.

- The following two rules should be followed to obtain the proper number of significant figures in any calculation.
- (1) The result of an addition or subtraction in the number having different precisions should be reported to the same number of decimal places as are present in the number having the least number of decimal places.
- (2) The answer to a multiplication or division is rounded off to the same number of significant figures as is possessed by the least precise term used in the calculation

- Accuracy of a measurement is how close the measured value is to the true value.
- Precision is the resolution or closeness of a series of measurements of a same quantity under similar conditions.
- For example : If the true value of a certain length is 3.678 cm and two instruments with different resolutions, up to 1 (less precise) and 2 (more precise) decimal places respectively, are used. If first measures the length as 3.5 and the second as 3.38 then the first has more accuracy but less precision while the second has less accuracy and more precision.

Order of Magnitude

- Order of magnitude of quantity is the power of 10 required to represent the quantity.
- For determining this power, the value of the quantity has to be rounded off. While rounding off, we ignore the last digit which is less than 5. If the last digit is 5 or more than five, the preceding digit is increased by one. For example, (1) Speed of light in vacuum = 3 $X10^8$ m/s
- $= 10^8$ m/s (ignoring $3 < 5$)
- (2) Mass of electron = = $9.1X\ 10^{-31}$ kg= 10^{-30} kg (as $9.1 > 5$).

Errors of Measurement.

- Errors of Measurement. The measured value of a quantity is always somewhat different from its actual value, or true value.
- **This difference in the true value of a quantity is called error of measurement.**

- **GROSS ERRORS** :This category basically takes into account human oversight and other mistakes while reading, recording and the readings. The most common of errors, the human error in the measurement fall under this category of errors in measurement.
- For example the person taking the reading from the meter of the instrument he may read 23 as 28. Gross errors can be avoided by using two suitable measures and they are written below:
- A proper care should be taken in reading, recording the data. Also, calculation of error should be done accurately.
- By increasing the number of experimenters we can reduce the gross errors. If each experimenter takes different reading at different points, then by taking average of more readings we can reduce the gross errors

- **Systematic Errors:** Systematic errors can be better understood if we divide it into subgroups;
  - **Instrumental Errors:** These errors arise due to faulty construction and calibration of the measuring instruments. Such errors arise due to the hysteresis of the equipment or due to friction.
  - Lots of the time, the equipment being used is faulty due to misuse or neglect which changes the reading of the equipment. The zero error is a very common type of error. This error is common in devices like vernier calipers and screw gauge. The zero error can be either positive or negative.
  - Sometimes the readings of the scale are worn off and this can also lead to a bad reading.

- SYSTEMATIC ERRORS
- **Environmental Errors:** This type of error arises in the measurement due the effect of the external conditions on the measurement. The external condition includes temperature, pressure, and humidity and can also include external magnetic field. If you measure your temperature under the armpits and during the measurement if the electricity goes out and the room gets hot, it will affect your body temperature thereby affecting the reading.
- **Observational Errors:** These are the errors that arise due to an individual's bias, lack of proper setting of the apparatus or individual's carelessness in taking observations. The measurement errors also include wrong readings due to Parallax errors.

- **Random Error:** The random errors are those errors, which occur irregularly and hence are random.
- These can arise due to random and unpredictable fluctuations in experimental conditions (e.g. unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc, errors by the observer taking readings, etc.
- For example, when the same person repeats the same observation, it is very likely that he may get different readings every time.

Errors of Measurement.

- **Absolute error**—Absolute error in the measurement of a physical quantity is the magnitude of the difference between the true value and the measured value of the quantity.
- $\Delta a = a_m - a$
- Let a physical quantity be measured n times. Let the measured value be a1, a2, a3, . . . an. The arithmetic mean of these value is Usually, a_m is taken as the true value of the quantity, if the same is unknown otherwise.
- The absolute errors may be positive in certain cases and negative in certain other cases.

Errors of Measurement.

- **<u>Mean absolute error</u>**—It is the arithmetic mean of the magnitudes of absolute errors in all the measurements of the quantity. It is represented by $\overline{\Delta a}$.
- Hence the final result of measurement may be written as ....

This implies that any measurement of the quantity is likely to lie between(a_m - $\overline{\Delta a}$) and (a_m + $\overline{\Delta a}$).

error or Fractional error is

- = mean absolute error/ mean value
- $= \overline{\Delta a} / \overline{a}$
- Percentage error :
- $= (\overline{\Delta a} / \overline{a}) \times 100\%$

Propagation of Errors

- **<u>Error in sum of the quantities</u>** :
- Suppose $x = a + b$
- Let Δa = absolute error in measurement of a Δb = absolute error in measurement of b
- Δx = absolute error in calculation of x i.e. sum of a and b.
- The maximum absolute error in x is
- $\Delta x = (\Delta a + \Delta b)$

Propagation of Errors

- **Error in difference of the quantities—Suppose** $x = a - b$
- The maximum absolute error in x is
- $\Delta x = (\Delta a + \Delta b)$

Propagation of Errors

- **<u>Error in product of quantities</u>**—
- Suppose $x = a \times b$
- The maximum fractional error in x is :
- $\Delta x / x = \Delta a/a + \Delta b/b$

Propagation of Errors

- **Error in division of quantities—**
- **Suppose** $x = a/b$
- The maximum fractional error in x is :
- $\Delta x / x = \Delta a/a + \Delta b/b$

Propagation of Errors

- Error in quantity raised to some power—Suppose $x = (a)^m / (b)^n$
- The maximum fractional error in x is :
- $\Delta x / x = m (\Delta a/a) + n (\Delta b/ b)$