Chapter # 1 (Measurements)
Important Short Questions

1. What are the main frontiers of the fundamental sciences?

Ans: There are three main frontiers of fundamental science.

- The world of extremely large. i.e. universe, stars etc
- The world of the extremely small (i.e. particles such as electrons, protons and neutrons)
- The world of middle sized things (from molecule to Earth). It is the world of complex matter.

2. What are the steps involving in measuring of base quantities?

Ans: The measurement of base quantities involves two steps: -

- The choice of standard.
- The procedure for comparing the quantity to be measured with the standard.

Properties of an Ideal Standard:

An ideal standard has two principle characteristics:

- It is easily accessible
- It is invariable

3. Differentiate between radian and steradian.

Ans:

Radian	Steradian
• It is plane angle (two dimensional angle) • It is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius of the circle. • **Diagram from book**	• It is solid angle (three dimensional angle) • It is the solid angle subtended at the center of sphere by an area of surface equal to square the radius of the sphere. • **Diagram from book**

4. Define scientific notation. Give one example.

Ans: Scientific Notation:

"Numbers are expressed in standard form is called scientific Notation, which employ power of ten. In scientific notation a number is expressed as some power of ten multiplied by a number of between 1 and 10."

Example:

A number 62750 can be expressed as $\mathbf{6.275 \times 10^4}$ and a number **0.000572** can be written as $\mathbf{5.72 \times 10^{-4}}$.

5. Differentiate between random and systematic error.

Ans: Random error:

"Random error is said to be occur when repeated measurements of the quantity, gives **different values** under the same condition."

Cause:

It is due to **unknown** reason.

Reduction of random error:

The random error can be reduced by taking several readings of same quantity and then take their mean or average.

Systematic error:

Systematic error is said to be occur when all the measurements of a particular quantity are affected equally, these gives **consistent difference** in readings.

Cause:

The systematic error occurs due to following reasons: -

- Zero error in measuring instruments.
- Poor calibration of instrument.
- Incorrect calibration on the measuring instrument.

Reduction of systematic error:

- Systematic error can be reduced by **replacing the instrument**.
- Systematic error can be reduced by applying the **correction factor**.

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6. Define significant figures. Write two rules with examples.

Ans: Significant Figures: -

"In any measurement, the accurately known digits and first doubtful digit are called significant figures."

We can increase the number of significant figures in a measurement by improving the **quality** of our instrument.

Rules for finding the significant figures: -

(i) All non-zero digits are significant.

- In 12.70 cm, there are four significant figures.
- In 8.70×10^4 kg has three significant figures.

(ii) Zeros between two significant digits are also significant.

- In 202 cm, there are three significant figures.
- In 2005 years, there are four significant figures.

(iii) Zeros on left side are not significant, they are just place holders.

- In 0.003 cm, there are one significant figures.
- In 0.00056 g, there are two significant figures.

(iv) Zero on right sides after decimal are also significant.

- In 2.00 cm, there are three significant figures.
- In 5.0 kg, there are two significant figures.

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7. How can you assess the total uncertainty in the final result in case of addition or subtraction?

Ans: In Case of Addition or Subtraction:

"Absolute uncertainties are added"

For Example:

The distance 'X' found by the difference between two separate position measurements.

$X_1 = 10.5 \pm 0.1$ cm

$X_2 = 26.8 \pm 0.1$ cm

$\mathbf{X = X_2 - X_1}$

$X = (26.8 \pm 0.1) - (10.5 \pm 0.1)$

$\mathbf{X = 16.3 \pm 0.2}$ **cm**

8. How can you assess the total uncertainty in the final result in case of multiplication or division?

Ans: In Case of Multiplication or Division:

"Percentage uncertainties are added"

For Example:

$V = 5.2 \pm 0.1$ V

$I = 0.8 \pm 0.05$ A

$R = ?$

$$\%\text{ age Uncertainity for V} = \frac{0.1}{5.2} \times 100 = 1.9\ \% = \text{About } 2\%$$

$$\%\text{ age Uncertainity for I} = \frac{0.05}{0.84} \times 100 = 0.59\ \% = \text{About } 6\%$$

Total % age uncertainty in R = 2 + 6 % = 8 %

$$R = \frac{V}{I} = \frac{5.2}{0.84} = 6.19 \text{ ohms with 8 \% uncertainty}$$

$$\mathbf{R = 6.2 \pm 0.5\ \Omega}$$

9. How can you assess the total uncertainty in the final result in case of power factor?

Ans: In Case of Power Factor:

"Multiply the percentage uncertainties with power"

For Example:

$r = 2.25 \pm 0.01$ cm

Volume of sphere = V = ?

$$\%\text{ age Uncertainity for r} = \frac{0.01}{2.25} \times 100 = 0.4\ \%$$

Total % age uncertainty in V = 3 × 0.4 % = 1.2 %

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(2.25)^2 = 47.689 \text{ cm}^3 \text{ with 1.2 \% uncertainty}$$

$$\mathbf{V = 47.7 \pm 0.6\ cm^3}$$

10. How can you assess the total uncertainty in the final result in case of average of many measurement?

Ans: In Case of Average of many measurement:

- Find the average value of measured values.
- Find deviation of each measured value from the average value.
- The mean deviation is the uncertainty in the average value.

For Example:

The six reading of micrometre screw gauge to measure the diameter of wire in mm are; 1.20, 1.22, 1.23, 1.19, 1.22, 1.21

$$\text{Average} = \frac{1.20 + 1.22 + 1.23 + 1.19 + 1.22 + 1.21}{6} = 1.21 \text{ mm}$$

The deviation of readings, which are the differences between each reading and average values are; 0.01, 0.01, 0.02, 0.02, 0.01, 0

$$\text{Mean of deviation} = \frac{0.01 + 0.01 + 0.02 + 0.02 + 0.01 + 0}{6} = 0.01 \text{ mm}$$

Average value = 1.21 ± 0.01 mm

11. How can you assess the total uncertainty in the final result in case of timing experiment?

Ans: In Case of timing experiment:

"The uncertainty in the time period is found by dividing the least count with the number of observations**"**

For Example:

Time for 30 vibrations = 54.6 sec

Least Count of the stop watch = 0.01 s

Time Period = ?

$$T = \frac{54.6}{30} = 1.82 \text{ sec}$$

$$\text{Uncertainty} = \frac{0.01}{30} = 0.003 \text{ sec}$$

T = 1.82 ± 0.003 sec

12. What is the difference between precision and accuracy?

Ans:

Precision	Accuracy
• The precision means how measure values are close to each other.	• Accuracy means how close a measure value (result) is to the actual value.
• Precision is defined in terms of random error.	• Accuracy is defined in terms of systematic error.
• The precision of a measurement depends upon absolute uncertainty.	• Accuracy depends upon the fractional or percentage uncertainty in that measurement.

13. Define dimensional analysis. Write its uses.

Ans: Dimensional Analysis:

"Each basic physical quantity represented by a specific symbol with in the square brackets."

- The dimensions of physical quantities represent nature of that physical quantities.
- The dimension of length, mass and time is [L], [M] and [T].

Uses of Dimensional Analysis:

There are following two uses of dimensional analysis:

- Checking the homogeneity of the physical equation.
- Deriving the possible formula.

14. What are the dimension of force and work?

Ans: Dimension of Force:

Force = mass × acceleration

[F] = [m][a]

$[F] = [M][LT^{-2}]$

$\mathbf{[F] = [MLT^{-2}]}$

Dimension of Work:

Work = force × displacement

$[w] = [F][d]$
$[w] = [MLT^{-2}][L]$
$\mathbf{[w] = [ML^2T^{-2}]}$

15. Describe the principle of homogeneity of dimensional analysis.

Ans: Principle of homogeneity:

In order to check the correctness of an equation, we are to show that dimension of the quantities on both sides if the equation is the same, irrespective of the form of the formulas. This is called the principle of homogeneity of dimensions.

16. Check the correctness of the relation $v = \sqrt{\frac{F \times l}{m}}$, where v is the speed of transverse wave on stretched string of tension F, length l and mass in m

Ans:

Equation $v = \sqrt{\frac{F \times l}{m}}$

Dimension of L.H.S = $[v] = [LT^{-1}]$ ------------------ (i)

Dimension of L.H.S = $[v] = \sqrt{\frac{F \times l}{m}}$

Dimension of R.H.S = $\sqrt{\frac{[MLT^{-2}][L]}{[M]}} = \left(\frac{[MLT^{-2}][L]}{[M]}\right)^{\frac{1}{2}} = [L^2T^{-2}]^{\frac{1}{2}}$

Dimension of R.H.S = $[LT^{-1}]$ ------------------ (ii)

From equation (i) and (ii),

L.H.S = R.H.S

17. Find the dimension and hence, the SI units of coefficient of viscosity η in the relation of Stoke's law for the drag force F for the spherical object of radius r moving with velocity v given as F = 6 πηrv.

Given:

$F = 6\pi\eta rv$
Where F = drag force
r = radius
η = co-efficient of viscosity

To find:

(i) Dimension of co-efficient of viscosity = η = ?
(ii) SI unit of co-efficient of viscosity = η = ?

Calculations:

(i) F = 6πηrv

6π is a number having no dimension, so it is not taken in dimensional analysis.

$$[F] = [\eta rv]$$

$$[\eta] = \frac{[F]}{[r][v]} = \frac{[MLT^{-2}]}{[L][LT^{-1}]}$$

$$[\eta] = [ML^{-1}T^{-1}]$$

(ii) This SI unit of co-efficient of viscosity is $kgm^{-1}s^{-1}$ or Nsm^{-2}

Exercise Short Questions

1. Name several repetitive phenomena occurring in nature which could serve as responsible time standards.

Ans: The phenomenon that repeats itself after certain intervals of time is called **repetitive phenomenon.** Which can be serve as time standard.

Examples:

- Lattice vibrations in a crystal.
- The rotation of moon around earth.
- The rotation of earth around sun.
- The rotation of earth its own axis.
- Changes of weathers.

2. Give the draw backs to use the period of pendulum as a time standard?

Ans: As the time period of the simple pendulum can be expressed as:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

But this time period cannot serve as time standard due to several reasons.

Reason:

Time period of pendulum varies with length and length varies with temperature due to **thermal expansion.**

Time period of the simple pendulum varies with g and g varies with altitude.

Frictional Force of air may affect the time period of the pendulum.

3. Why do we find it useful to have two units for amount of substance, the kilogram and mole?

Ans: Mole:

When we concerned **number of particles** then we use mole as the unit of amount of substance because one mole of the substance contains equal number of particles i.e. $\left(N_A = 6.022\times10^{23}\right)$.

Kilogram:

But when we are not concerned with particles (Atoms or molecules) then the amount of substance is measured in kilogram.

4. Three students measured the length of a needle with a scale on which minimum division is 1 mm and recorded as (a) 0.2145m (b) 0.21m (c) 0.214 m. Which record is correct?

Ans: 0.214 is correct record.

Reason:

It is because **the least count of the scale is 1mm or 0.001m.** So, length can be measure accurately up to three decimals. Hence 0.214 is correct record.

5. An old saying is "A chain is only as strong as its weakest link. "What analogous statement that can you make regarding experimental data used in computation?

Ans: Its analogous statement is

"A result of experimental data is only as much as accurate as its least count reading in the experiment.**"**

6. The period of a simple pendulum is measured by a stop watch. What types of error are possible?

Ans: Possible Errors:

There are types of the error are possible errors:

(i) Systematic Error:

Stop watch may be faulty:

- Zero error may occur.
- Poor calibration on the stop watch. Or incorrect calibration.

(ii) Random Error:

Random error occurs due to:

- Negligence and inexperience of the person at the time to start or stop the stopwatch.

7. Does dimensional analysis give any information about a constant of proportionality that may appear in an algebraic expression?

Ans: Dimensional analysis does not give any information about the value of constant proportionality; it can be determined by experiment.

Example:

For Time period of the simple pendulum

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Where dimensional analysis does not give may information about the constant 2π .

But dimension analysis provides the information about the dimensions of constants like "g" (Gravitational acceleration). G (Universal gravitational constant), K (spring constant). Because they have units.

8. Write the dimension of (a) Pressure (b) density

Ans: Dimension of pressure:

$$\text{Pressure}=p=\frac{F}{A}=\frac{ma}{A}=\frac{[M][LT^{-2}]}{[L^2]}=[ML^{-1}T^{-2}]$$

Dimension of Density:

$$\text{Density} = \rho = \frac{m}{V} = \frac{[M]}{[L^3]} = [ML^{-3}]$$

9- The wavelength depends upon speed "v" of wave and its frequency "f", knowing that $[\lambda]=[L]$ and $[v]=[LT^{-1}]$ and $[f]=[T^{-1}]$. Decide which one id correct.

(a) $f=v\lambda$ **(b) $f=\frac{v}{\lambda}$**

(a) For $f=v\lambda$

$$[T^{-1}] = [LT^{-1}][T^{-1}]$$

$$[T^{-1}] = [LT^{-2}]$$

Which is not correct.

(b) For $f=\frac{v}{\lambda}$

$$[T^{-1}] = \frac{[LT^{-1}]}{[L]}$$

$$[T^{-1}] = [T^{-1}]$$

Which is correct

Numerical Problems

1. A light year is the distance light travels in one year. How many meters are there?

Given:

Time = t = 1 year

t = 365 days

t = 365 × 24 hours

t = 365 × 24 × 60 min

t = 365 × 24 × 60 × 60 sec

t = 31536000 sec

t = 3.1536×10^7 sec

Speed of light = v = c = 3.0×10^8 ms^{-1}

To find:

Distance = S = ?

Calculations:

S = vt = ct

$S = 3.0 \times 10^8 \times 3.1536 \times 10^7$

$\mathbf{S = 9.5 \times 10^{15}\ m}$

2. (a) How many seconds are there in 1 year?
(b) How many nano seconds in 1 year?
(c) How many year in 1 second?

Given:

1 year = 365 days

To find:

(a) Seconds in 1 year = ?

(b) Nano seconds in 1 year = ?

(c) Years in 1 seconds = ?

Calculation:

(a) As 1 year = 365 days

1 year = 365 × 24 hours

1 year = 365 × 24 × 60 min

1 year = 365 × 24 × 60 × 60 sec

1 year = 31536000 sec

1 year = 3.1536 × 10^7 sec

(b) As 1 year = 3.1536 × 10^7 sec

1 year = 3.1536 × 10^7 × 10^9 × 10^{-9} sec

1 year = 3.1536 × 10^{16} ns

(c) 1 year = 3.1536 × 10^7 sec

$$1 \text{ sec} = \frac{1}{3.1536 \times 10^7}$$

1 sec = 3.17 × 10^{-8} years

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4. What are the dimensions and units of gravitational constant G in the formula $F = G\frac{m_1m_2}{r^2}$

Given:

$$\text{Gravitational force} = F = G\frac{m_1m_2}{r^2}$$

To find:

(i) Dimension of G = ?

(ii) SI unit of G = ?

Calculations:

(i) $F = G\frac{m_1m_2}{r^2}$

$$G = \frac{Fr^2}{m_1m_2}$$

$$[G] = \frac{[MLT^{-2}][L^2]}{[M][M]} = \frac{[ML^2T^{-2}]}{[M^2]}$$

$[G] = [M^{-1}L^2T^{-2}]$

(ii) This SI unit of Gravitational Constant G is Nm^2kg^{-2}

5. Show that the expression $V_f = V_i + at$ is dimensionally correct, where V_i is the velocity at t = 0, a is the acceleration and V_f is the velocity at time t.

Ans:

Equation $V_f = V_i + at$

Dimension of L.H.S = $[V_f] = [LT^{-1}]$ -------- (i)

Dimension of R.H.S = $[V_i] + [at]$

$= [LT^{-1}] + [LT^{-2}][L]$

$= [LT^{-1}] + [LT^{-1}]$

$= 2[LT^{-1}]$

As 2 has no dimension because it is a constant.

Dimension of R.H.S = $[LT^{-1}]$ ---------------- (ii)

From equation (i) and (ii),

L.H.S = R.H.S

6. Show that the famous formula "Einstein equation" $E = mc^2$ is dimensionally correct.

Ans:

Einstein Equation $E = mc^2$

Dimension of L.H.S = $[E] = [W] = [F.d] = [MLT^{-2}][L]$

Dimension of L.H.S = $[ML^2T^{-2}]$ ------------------ (i)

Dimension of R.H.S = $[mc^2] = [M][LT^{-1}]^2$

Dimension of R.H.S = $[ML^2T^{-2}]$ ------------------ (ii)

From equation (i) and (ii),

L.H.S = R.H.S

Important Dimensions

Physical Quantities	Symbol or Formula	Unit	Dimension
Mass	m	kilogram	$[ML^oT^o] = [M]$
Length	l	meter	$[M^oLT^o] = [L]$
Time	t	second	$[M^oL^oT] = [T]$
Velocity or Speed	v	ms^{-1}	$[M^oLT^{-1}] = [LT^{-1}]$
Acceleration	a	ms^{-2}	$[M^oLT^{-2}] = [LT^{-2}]$
Area	A	m^2	$[M^oL^2T^o] = [L^2]$
Volume	V	m^3	$[M^oL^3T^o] = [L^3]$
Density	$\rho = m/v$	Kg/m^3	$[ML^3T^o] = [ML^3]$
Force	F = ma	$N = kgms^{-2}$	$[MLT^{-2}]$
Pressure	P = F/A	$Pa = Nm^{-2}$	$[ML^{-1}T^{-2}]$
Momentum or Impulse	$P = mv$, $I = \Delta P$	$Ns = kgms^{-1}$	$[MLT^{-1}]$
Torque, Work and Energy	$\tau = l \times F$ W = Fd	J = Nm = Kgm^2s^{-2}	$[ML^2T^{-2}]$
Power	P = w/t	W = J/s	$[ML^2T^{-3}]$
Angular displacement	θ	Radian	None
Angular Velocity	$\omega = \Delta\theta/\Delta t$	Rad/s	$[T^{-1}]$
Angular Acceleration	$\alpha = \Delta\omega/\Delta t$	Rad/s^2	$[T^{-2}]$
Angular Momentum	L = mvr	$Js = Kgm^2s^{-2}$	$[ML^2T^{-1}]$
Moment of Inertia	$I = mr^2$	Kgm^2	$[ML^2]$
Gravitational Constant	$G = \frac{Fr^2}{m_1m_2}$	Nm^2/kg^2	$[M^{-2}L^3T^{-2}]$
Acceleration due to gravity	g = w/m	ms^{-2}	$[LT^{-2}]$
Time period	T	sec	[T]
Frequency or angular frequency	f = 1/f $\omega = 2\pi f$	Hz = cycle/sec	$[T^{-1}]$
Coefficient of viscosity	$\eta = \frac{F}{6\pi rv}$	Ns/m^2 = $kgm^{-1}s^{-1}$	$[ML^{-1}T^{-1}]$
Wavelength	$\lambda = \frac{v}{f}$	m	[L]
Stress	$\sigma = \frac{F}{A}$	$Pa = Nm^{-2}$	$[ML^{-1}T^{-2}]$
Strain	$\varepsilon = \frac{\Delta V}{V} = \frac{\Delta l}{l}$	none	none
Elastic Modulus	$E = \frac{\sigma}{\varepsilon}$	$Pa = Nm^{-2}$	$[ML^{-1}T^{-2}]$
Focal Length	F	m	[L]

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