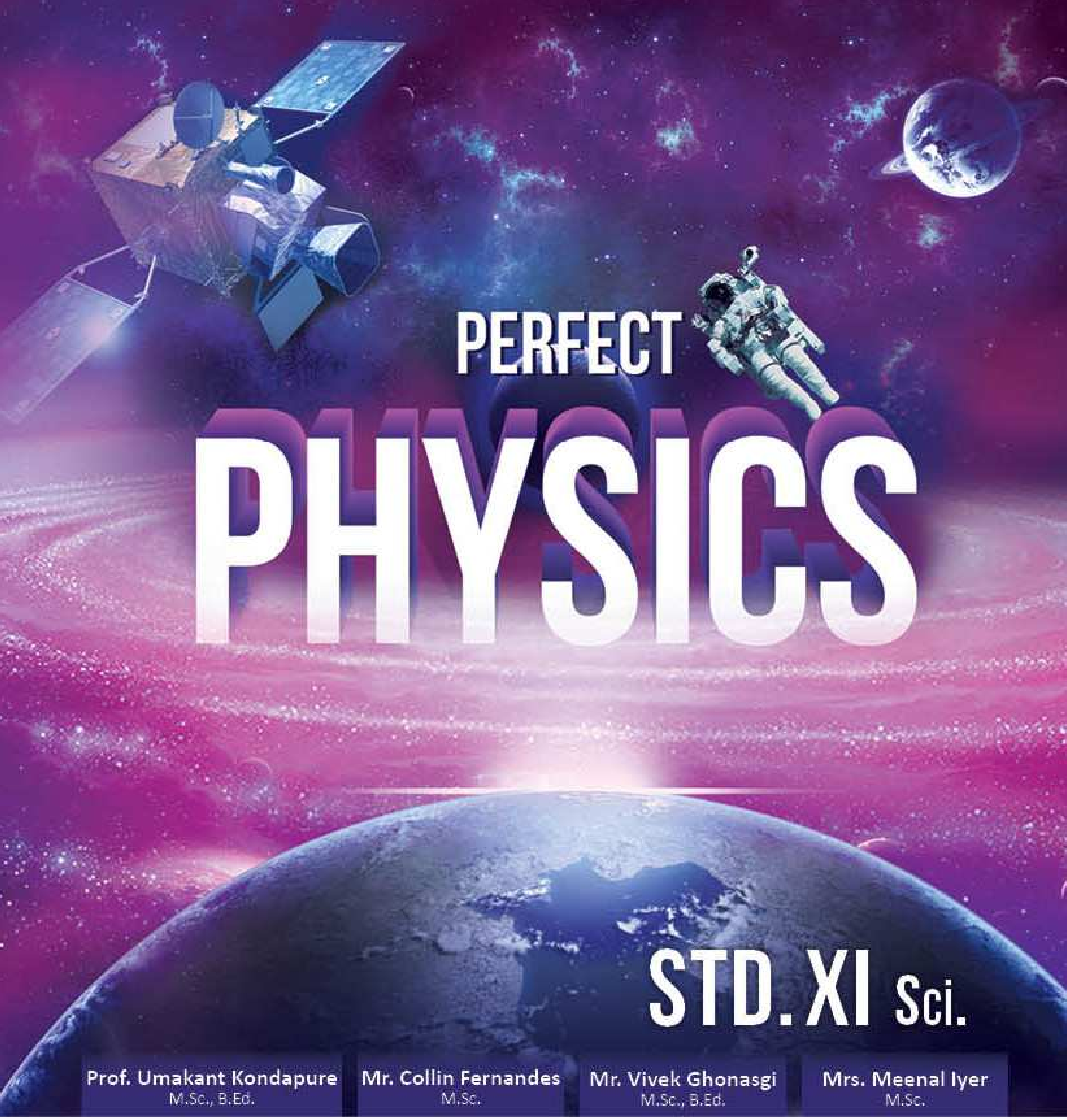

PERFECT PHYSICS

STD. XI Sci.

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Target Publications Pvt. Ltd.

Written as per the revised syllabus prescribed by the Maharashtra State Board
of Secondary and Higher Secondary Education, Pune.

STD. XI Sci.
Perfect Physics

Fifth Edition: June 2015

Salient Features

- Exhaustive coverage of syllabus in Question Answer Format.
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Printed at: **Dainik Saamana,** Navi Mumbai

TEID : 925

Preface

In the case of good books, the point is not how many of them you can get through, but rather how many can get through to you.

"Std. XI Sci. : PERFECT PHYSICS" is a complete and thorough guide critically analysed and extensively drafted to boost the students confidence. The book is prepared as per the Maharashtra State board syllabus and provides answers to all **textual and intext questions**. Sub-topic wise classified 'question and answer format' of this book helps the student to understand each and every concept thoroughly. Neatly labelled diagrams have been provided wherever required.

National Council Of Educational Research And Training (NCERT) questions and problems based on Maharashtra board syllabus have been provided along with solutions for a better grasp of the concept and preparing the students on a competitive level.

Definitions, statements and laws are specified with italic representation. **Formulae** are provided in every chapter which are the main tools to tackle difficult problems. To develop better understanding of concepts, relevant points and questions are discussed in the form of **Additional Information**. **Brain Teasers** are theory questions and numericals build within the frame-work of State Board syllabus to develop higher order thinking among students. **Solved problems** are provided to understand the application of different concepts and formulae. **Additional theory questions** have been provided to help the student gain insight on the various levels of theory-based questions.

Practice Problems and **Multiple Choice Questions** help the students to test their range of preparation and the amount of knowledge of each topic. Hints have been provided for selected multiple choice questions to help the students overcome conceptual or mathematical hinderances.

A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

Contents

Note: All the Textual questions are represented by * mark
All the Intext questions are represented by # mark

01 Measurements

Syllabus

1.0 Introduction

Physics is the branch of science which deals with the study of nature and natural phenomena.

There are two domains in the scope of physics:

i. **Macroscopic domain:**
The macroscopic domain includes phenomena at the laboratory, terrestrial and astronomical scales.

ii. **Microscopic domain:**
The microscopic domain includes atomic, molecular and nuclear phenomena.

Q.1. What are physical quantities?

Ans: *Those quantities which can be measured i.e., subjected equally to all three elements of scientific study, namely : detailed analysis, precise measurement and mathematical treatment, are called physical quantities.*

Example: Mass, length, time, volume, pressure, force, etc.

1.1 Need for Measurement

***Q.2. What is the need for measurement of a physical quantity?**

Ans:
i. To study phenomena in physics, scientists have performed different experiments.
ii. These experiments require measurement of physical quantities such as mass, length, time, volume, etc.
iii. Based on the observations of these experiments, scientists have developed various laws and theories.
iv. For the experimental verification of various theories, each physical quantity should be measured precisely.
v. Therefore, accurate measurement of physical quantities with appropriate instruments is necessary.
vi. Example: Consider the statement "The water boiled after some time." In the given statement, the physical quantity time is not defined precisely. A numerical value for time, which is measured on a watch is necessary.

1.2 Unit for Measurement

The magnitude of a physical quantity 'x' is expressed in the following way:

Magnitude of physical quantity = Numerical value of physical quantity × Size of its unit.

i.e., $x = \text{nu}$

where, n = number of times the unit is taken.

u = size of unit of physical quantity.

Example:

If the length of a rod is 5 metre it means that the rod is 5 times as long as the standard unit of length (i.e., metre).

***Q.3. What is meant by unit of a physical quantity?**

Ans: i. *The reference standard used for the measurement of a physical quantity is called the unit of that physical quantity.*

ii. Example:

Physical Quantity	Standard (unit)
Length	metre, centimetre, inch, feet, etc.
Mass	kilogram, gram, pound etc.

Q.4. State the essential characteristics of a good unit.

Ans: Characteristics of a good unit:

i. It should be well-defined.
ii. It should be easily available and reproducible at all places.
iii. It should not be perishable.
iv. It should be invariable.
v. It should be universally accepted.
vi. It should be comparable to the size of the measured physical quantity.
vii. It must be easy to form multiples or sub multiples of the unit.

Note: Choice of unit depends upon its suitability for measuring the magnitude of a physical quantity under consideration. Hence, we choose different scales for same physical quantity.

Various units to express a physical quantity:

Prefix	Symbol	Power of 10	Prefix	Symbol	Power of 10
Exa	E	10^{18}	deci	d	10^{-1}
Peta	P	10^{15}	centi	c	10^{-2}
Tera	T	10^{12}	milli	m	10^{-3}
Giga	G	10^{9}	micro	μ	10^{-6}
Mega	M	10^{6}	nano	n	10^{-9}
Kilo	k	10^{3}	angstrom	Å	10^{-10}
Hecto	h	10^{2}	pico	p	10^{-12}
Deca	da	10^{1}	femto	f	10^{-15}
			atto	a	10^{-18}

1.3 System of Units

Units are classified as fundamental units and derived units. In 1832, Gauss had suggested to select any three physical quantities as fundamental quantities. Accordingly, many systems of units came into existence.

Q.5. A. What is a system of units?
***B. Briefly describe different types of systems of units.**

Ans: *The whole set of units i.e., all the basic and derived units taken together forms a system of units.*

System of units are classified mainly into four types:

i. C.G.S. system:

It stands for Centimetre-Gram-Second system. In this system, fundamental quantities i.e., length, mass and time are measured in centimeter, gram and second respectively. It is a French metric system of unit.

ii. M.K.S. system:

It stands for Metre-Kilogram-Second system. In this system, fundamental quantities i.e. length, mass and time are measured in metre, kilogram and second respectively. It is a French metric system of unit.

iii. F.P.S. system:

It stands for Foot-Pound-Second system. In this system, length, mass and time are measured in foot, pound and second respectively. It is a British imperial system.

iv. **S.I. system:**
It stands for Standard International system. This system has replaced all other systems mentioned above. It has been internationally accepted and is being used all over world.

#Q.6. Can you call a physical quantity large or small without specifying a standard for comparison?

Ans: No, we cannot call a physical quantity large or small without specifying a standard for comparison.

1.4 S.I. units

Q.7. *What is S.I. system of units? Explain its need. OR Write a short note on S.I. units.

Ans: S.I. system of units:

i. Use of different systems of units became very inconvenient for exchanging scientific information between different parts of the world.

ii. To overcome this difficulty, it became necessary to develop a common system of units.

iii. In October 1960, at the Eleventh International General Conference of weights and measures in Paris, a common system of units was accepted. This system of units called "Systeme Internationale d′Units" is the modern metric system of unit measurement. It is abbreviated as S.I. units.

iv. S.I. units consist of seven fundamental units, two supplementary units and a large number of derived units.

v. Nowadays, S.I. system has replaced all the other systems of units and is greatly used to exchange scientific data between different parts of the world.

1.5 Fundamental and derived units

***Q.8. What are fundamental quantities? State two examples of fundamental quantities. Write their S.I. and C.G.S. units.**

Ans: Fundamental quantities:
The physical quantities which do not depend on any other physical quantity for their measurements i.e., they can be directly measured are called fundamental quantities.
Examples: mass, length etc.

Fundamental quantities	S.I. unit	C.G.S. unit
Mass	kilogram (kg)	gram (g)
Length	metre (m)	centimetre (cm)

Q.9. *A. What are fundamental units?
B. State the S.I. units of seven basic fundamental quantities.

Ans: A. Fundamental units:
The units used to measure fundamental quantities are called fundamental units.

B. Units of fundamental quantities:

i. There are seven fundamental quantities accepted in S.I. system.

ii. Fundamental quantities with their corresponding units are given in following table.

Fundamental quantity	S. I. unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units		
Plane angle	radian	rad
Solid angle	steradian	sr

Q.10. *A. What are derived quantities and derived units? State two examples.
B. State the corresponding S.I. and C.G.S. units of the examples.

Ans: A.

i. Derived quantities:
Physical quantities other than fundamental quantities which depend on one or more fundamental quantities for their measurements are called derived quantities.
Examples: speed, acceleration, momentum, force, etc.

ii. Derived units:
The units of derived quantities which depend on fundamental units for their measurements are called derived units.

B. Examples and units:

Derived quantity	S.I. unit	C.G.S. unit
Speed	m/s	cm/s
Force	N	dyne
Density	kg/m^3	g/cm^3
Acceleration	m/s^2	cm/s^2

Some practical units in term of S.I. unit

Practical units	Abbreviation	S.I. unit
1 Angstrom	Å	10^{-10} m
1 Micron	μm	10^{-6} m
1 Nanometer	nm	10^{-9} m
1 Light year	*l*y	9.46×10^{15} m
1 Astronomical unit	AU	1.496×10^{11} m
1 Atomic mass unit	amu	1.66×10^{-27} kg
1 Torr	T	1 mm of Hg

Additional Information

Following conventions should be followed while writing S.I. units of physical quantities:

i. For a unit derived from the name of a person, the symbol or first letter of the symbol is a capital letter.
For example, N for newton, J for joule, W for watt, Hz for hertz. Symbols of the other units are not written with capital initial letter.

ii. Unit names, including units named after a person are written in lower – case. Example: unit of force is written as newton and not as Newton; unit of power is written as watt and not as Watt, symbol for metre is 'm', for second is 's', for kilogram is 'kg'

iii. Symbols of units are not to be expressed in plural form. For example, 10 metres is written as 10 m and not as 10 ms. This is because, 10 ms, means 10 millisecond.

iv. Full stop and any other punctuation mark should not be written after the symbol. e.g. kg and not kg., or N and not N.

v. Multiplication of unit symbols must be indicated by a space or half-high (centred) dot (·), since otherwise some prefixes could be misinterpreted as a unit symbol.
Example: N·m for newton-metre; ms for millisecond but m·s for metre times second.

vi. Division of unit symbol is indicated by a horizontal line or by a solidus (/) or by negative exponents. When several unit symbols are combined, care should be taken to avoid ambiguities, for example by using brackets or negative exponents.
A solidus is not used more than once in a given expression without brackets to remove ambiguities.
Examples: $\frac{\text{m}}{\text{s}}$ or m/s or m·s^{-1}, for the metre per second; m·s^{-1} is the symbol for the metre per second while ms^{-1} is the symbol for the reciprocal of millisecond (10^3 s^{-1}); m·kg/(s^3·A) or m·kg·s^{-3}·A^{-1} but not mkg/s^3/A nor mkg/s^3 A.

vii. Unit symbols and unit names are not to be used together. Example: C/kg, C·kg^{-1} or coulomb per kilogram but not coulomb/kg nor coulomb per kg nor C/kilogram nor coulomb. kg^{-1} nor C per kg nor coulomb/kilogram.

viii. Abbreviations for the unit symbols or names are not allowed. Example: sec (for either s or second), sq. mm (for either mm^2 or square millimetre), cc (for either cm^3 or cubic centimetre), mins (for either min or minutes), hrs (for either h or hours), lit (for either L or litre), amps (for either A or amperes), AMU (for either u or unified atomic mass unit), or mps (for either m/s or metre per second).

Q.11. Explain the advantages of S.I. system of units.

Ans: The advantages of S.I. system of unit are as follows:

i. It is comprehensive, i.e. its small set of seven fundamental units cover the needs of all other physical quantities.

ii. It is coherent, i.e., its units are mutually related by rules of multiplication and division with no numerical factor other than 1.
For example, 1 ohm = 1 volt / 1 ampere.

iii. S.I. system being a decimal or metric system, writing of very large or very small numerical value is simplified by using prefixes to denote decimal multiples and submultiples of the S.I. units.
Example: 1 μm (micrometre) = 10^{-6} m.

iv. The joule is the unit of all forms of energy. Hence, the joule provides a link between mechanical and electrical units.

Q.12. Classify the following quantities into fundamental and derived quantities:
Length, Velocity, Area, Electric current, Acceleration, Time, Force, Momentum, Energy, Temperature, Mass, Pressure, Magnetic induction, Density.

Ans: Fundamental Quantities: Time, Temperature, Mass, Length, Electric current

Derived Quantities: Velocity, Area, Acceleration, Force, Momentum, Energy, Pressure, Magnetic induction, Density

Q.13. Classify the following units into fundamental, supplementary and derived units:
newton, metre, candela, radian, hertz, square metre, tesla, ampere, kelvin, volt, mol, coulomb, farad, steradian.

Ans:

Fundamental units	Supplementary units	Derived units
metre candela ampere kelvin mol	radian steradian	newton hertz square metre tesla volt coulomb farad

***Q.14. Explain the methods to measure length.**

Ans: Methods for measurement of length

There are broadly two methods for measurement of length:

i. Direct methods:

a. A metre scale is used for measurement of length from 10^{-3} m to 10^{2} m using different instruments.

b. A Vernier callipers is used for the measurement of length upto the accuracy of 10^{-4} m.

c. Further accuracy can be attained by using spherometer and screw gauge. The accuracy achieved by using these instruments is upto 10^{-5} m for smaller lengths.

d. Hence, direct measurement of length using various measuring devices is possible for length from about 10^{2} m to 10^{-5} m.

ii. Indirect methods:

a. It includes measurement of large distances such as distance between two planets, diameter of sun, distance of stars from the earth etc.

b. For such measurements, trigonometric parallax method is used.

***Q.15. Explain the method to measure mass.**

Ans: Method for measurement of mass:

i. Mass is fundamental property of matter. It does not depend on the temperature, pressure or location of the object in space. The S.I. unit of mass is kilogram (kg).

ii. Mass of an object can be measured directly by comparison with multiples and submultiples of the kilogram using a beam balance.

iii. For atomic levels, instead of kilogram, unified atomic mass unit is used.
1 unified atomic mass unit = 1 u = $\left(\frac{1}{12}\right)^{\text{th}}$ of the mass of an isolated atom of the isotope Carbon-12 in kg.

iv. For measurement of small masses of atomic or subatomic particles, mass spectrography is used. This method uses the property that mass of the charged particle is proportional to radius of the trajectory when particle is moving in uniform electric and magnetic field.

v. Large masses in the universe like planets, stars etc. can be measured by using Newton's law of gravitation.

***Q.16. Explain the method for measurement of time.**

Ans: Method for measurement of time:

i. A clock is needed to measure any time interval.

ii. The unit of time, the second, is considered to be $\frac{1}{86400}$ of the mean solar day.

iii. However, this definition proved to be unsatisfactory to define the unit of time more precisely. Thus, the definition of second was replaced by one based on atomic standard of time.

iv. Atomic standard of time is now used for the measurement of time. In atomic standard of time, periodic vibrations of cesium atom is used.

v. One second is time required for $9{,}192{,}631{,}770$ vibrations of the radiation corresponding to transition between two hyperfine energy states of cesium-133 atom.

vi. The cesium atomic clocks are very accurate.

vii. The national standard of time interval 'second' as well as the frequency is maintained through four cesium atomic clocks.

Q.17. Define parallactic angle.

Ans: i. *Angle between the two directions along which a star or planet is viewed at the two points of observation is called parallax angle (Parallactic angle).*

ii. It is given by $\theta = \frac{b}{D}$

where, b = separation between two points of observation,

D = Distance of source from any point of observation.

#Q.18. How to determine the distance of different stars from the Earth? OR

Explain the method to determine the distance of a planet from the earth and the diameter of the planet.

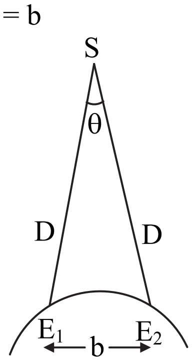
Ans: i. Parallax method is used to determine distance of different stars from the earth.

ii. To measure the distance 'D' of a far distant star or planet S, select two different observatories (E_1 and E_2).

iii. The star or planet should be visible from E_1 and E_2 observatories simultaneously i.e. at the same time.

iv. E_1 and E_2 are separated by distance 'b' as shown in figure.

$\therefore$ $E_1E_2 = b$



Earth

v. The angle between the two directions along which the star or planet is viewed, can be measured. It is θ and is called parallax angle or parallactic angle.

$\therefore$ $\angle E_1SE_2 = \theta$

vi. The star or planet is far away from the (earth) observers, hence

$b << D$

$\therefore$ $\frac{b}{D} << 1$ and 'θ' is also very small.

Hence, E_1 E_2 can be considered as arc of length b of circle with S as centre and D as radius.

$\therefore$ $E_1S = E_2S = D$ $\therefore$ $\theta = \frac{b}{D}$

$\therefore$ $b = \theta D$ ….(θ is taken in radians)

vii. From the above equation, on rearranging, we get $D = \frac{b}{\theta}$

Hence, the distance 'D' of a far away planet 'S' can be determined using the parallax method.

viii. To determine the diameter of a planet, two diametrically opposite points of the planet are viewed from the same observatory.

The angle α between these two directions gives the angular size of the planet, i.e., the angle subtended by the planet. If d is the diameter of the planet, then $d = \alpha D$. Hence, having determined D and measuring α, we can determine the diameter d of the planet.

1.6 Dimensional Analysis

***Q.19. A. Define dimensions and dimensional equation of physical quantities. Give two examples of each.**

Ans: A.

i. Dimensions:

The dimensions of a physical quantity are the powers to which the fundamental units must be raised in order to obtain the unit of a given physical quantity.

ii. Dimensional equation:

An expression which gives the relation between the derived units and fundamental units in terms of dimensions is called a dimensional equation.

B. Examples of dimensions:

i. Dimensions of speed are [0,1,-1] in the order of mass, length and time respectively.

ii. Dimensions of force are $[1,1,-2]$ in the order of mass, length and time respectively.

Examples of dimensional equation:

i. Speed = $[M^0 L^1 T^{-1}]$

$\therefore$ Speed = $\frac{\text{Distance}}{\text{time}}$

ii. Force = $[M^1 L^1 T^{-2}]$

$\therefore$ Force = Mass × acceleration

= Mass × $\frac{\text{Distance}}{(\text{time})^2}$

iii. Temperature gradient = $[M^0L^{-1}T^0K^1]$

$\therefore$ Temperature gradient = $\dfrac{\text{Temperature}}{\text{Distance}}$

Some derived quantities with dimensions are as follows:

Physical Quantities	Formula	Dimensions
Speed	$\dfrac{\text{Distance}}{\text{Time}}$	$[M^0L^1T^{-1}]$
Acceleration	$\dfrac{\text{Change in velocity}}{\text{Time}}$	$[M^0L^1T^{-2}]$
Force	Mass × Acceleration	$[M^1L^1T^{-2}]$
Pressure	$\dfrac{\text{Force}}{\text{Area}}$	$[M^1L^{-1}T^{-2}]$
Density	$\dfrac{\text{Mass}}{\text{Volume}}$	$[M^1L^{-3}T^0]$
Work	Force × distance	$[M^1L^1T^{-2}]\ [L^1] = [M^1L^2T^{-2}]$
Energy	Force × distance	$[M^1L^1T^{-2}]\ [L^1] = [M^1L^2T^{-2}]$
Power	$\dfrac{\text{Work}}{\text{Time}}$	$[M^1L^2T^{-3}]$
Momentum	Mass × Velocity	$[M^1L^1T^{-1}]$
Impulse	Force × Time	$[M^1L^1T^{-1}]$
Torque	$\vec{\tau} = \vec{r} \times \vec{F}$	$[M^1L^1T^{-2}][L] = [M^1L^2T^{-2}]$
Charge	Current × Time	$[A^1T^1]$
Coefficient of viscosity	$\eta = -\dfrac{F\ dx}{A\ dv}$	$[M^1L^{-1}T^{-1}]$
Resistance	$\dfrac{\text{Potential difference}}{\text{Current}}$	$[M^1L^2T^{-3}A^{-2}]$
Planck's constant	$\dfrac{\text{Energy of Photon}}{\text{Frequency}}$	$[M^1L^2T^{-1}]$
Electric potential	$V = \dfrac{W}{q}$	$[M^1L^2T^{-3}A^{-1}]$
Electric permittivity	$\varepsilon_0 = \dfrac{q^2}{4\pi r^2 F}$	$[M^{-1}L^{-3}T^4A^2]$
Electric capacity	$C = \dfrac{q}{V}$	$[M^{-1}L^{-2}T^4A^2]$
Magnetic flux	$\phi = B.A$	$[M^1L^2T^{-2}A^{-1}]$
Pole strength	$m = \dfrac{F}{B}$	$[M^0L^1T^0A^1]$
Magnetic permeability	$\mu = \dfrac{B}{H}$	$[M^1L^1T^{-2}A^{-2}]$

Following table helps to write S.I. units / common names and dimensions of various derived quantities:

Derived quantity	Formula	S.I. unit	Dimensions
Area	$A = L^2$	m^2	$[M^0L^2T^0]$
Volume	$V = L^3$	m^3	$[M^0L^3T^0]$
Density	$\rho = M/V$	kg/m^3	$[M^1L^{-3}T^0]$
Velocity or speed	$v = s/t$	m/s	$[M^0L^1T^{-1}]$
Acceleration	$a = v/t$	m/s^2	$[M^0L^1T^{-2}]$
Momentum	$P = mv$	kg m/s	$[M^1L^1T^{-1}]$
Force	$F = ma$	kg m/s^2 or N	$[M^1L^1T^{-2}]$
Impulse	$J = F.t$	Ns	$[M^1L^1T^{-1}]$
Work	$W = F.s$	N m or J	$[M^1L^2T^{-2}]$
Kinetic energy	$K.E. = \dfrac{1}{2}mv^2$	kg $\dfrac{m^2}{s^2}$ or J	$[M^1L^2T^{-2}]$
Potential Energy	$P.E. = mgh$		$[M^1L^2T^{-2}]$
Power	$P = \dfrac{W}{t}$	J/s or W	$[M^1L^2T^{-3}]$
Pressure	$P = \dfrac{F}{A}$	N/m^2 or Pa	$[M^1L^{-1}T^{-2}]$

Note:
Students can write θ for temperature, I for current, C for luminous intensity and mol for mole.

Q.20. A book with many printing errors contains four different formulae for the displacement y of a particle undergoing a certain periodic function:

i. $y = a \sin \dfrac{2\pi t}{T}$ **ii.** $y = a \sin v t$

iii. $y = \dfrac{a}{T} \sin \dfrac{t}{a}$

iv. $y = \dfrac{a}{\sqrt{2}}\left[\sin \dfrac{2\pi t}{T} + \cos \dfrac{2\pi t}{T}\right]$

Here, a is maximum displacement of particle, v is speed of particle, T is time period of motion. Rule out the wrong formulae on dimensional grounds. (NCERT)

Ans: The argument of trigonometrical function, i.e., angle is dimentionless. Now,

i. The argument,

$$\left[\dfrac{2\pi t}{T}\right] = \dfrac{[T]}{[T]} = 1 = [M^0L^0T^0]$$

which is a dimensionless quantity.

ii. The argument,
$[v\,t] = [LT^{-1}]\,[T] = [L] = [M^0L^1T^0]$
which is not a dimensionless quantity.

iii. The argument,
$\left[\frac{t}{a}\right] = \frac{[T]}{[L]} = [M^0L^{-1}T^1]$
which is not a dimensionless quantity.

iv. The argument,
$\left[\frac{2\pi t}{T}\right] = \frac{[T]}{[T]} = 1 = [M^0L^0T^0]$
which is a dimensionless quantity.
Hence, formulae (i) and (iv) are incorrect.

Q.21. State principle of homogeneity. Use this principle and find conversion factor between the units of the same physical quantity in two different systems of units.

OR

Explain how the principle of homogeneity can be used to find the conversion factor between the units of the same physical quantity in two different systems of units.

Ans: A. Principle of homogeneity:
The dimensions of all the terms on the two sides of a physical equation must be same. This is called the principle of homogeneity of dimensions.

B. To find the conversion factor between the units of the same physical quantity in two different systems of units:

i. This principle is based on the fact that two physical quantities can be added together or subtracted from one another only if they have same dimensions.

ii. Consider dimensions of a physical quantity in two systems of units: $\left[M_1^aL_1^bT_1^c\right]$ and $\left[M_2^aL_2^bT_2^c\right]$.

iii. If 'n' is the conversion factor in two systems, then applying principle of homogeneity, we have,
$\left[M_1^aL_1^bT_1^c\right] = n\left[M_2^aL_2^bT_2^c\right]$

iv. $\therefore \quad n = \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$

Q.22. Explain the use of dimensional analysis to check the correctness of a physical equation.

Ans: Correctness of a physical equation by dimensional analysis:

i. A physical equation is correct only if the dimensions of all the terms on both sides of that equations are the same.

ii. For example, consider the equation of motion.
$v = u + at$ ….(1)

iii. Writing the dimensional equation of every term, we get
$v = [M^0L^1T^{-1}]$ $u = [M^0L^1T^{-1}]$
$a = [M^0L^1T^{-2}]$ $t = [M^0L^0T^1]$

iv. Now, at $= [M^0L^1T^{-2}] \times [M^0L^0T^1] = [M^0L^1T^{-1}]$
As dimensions of both side of equation is same, physical equation is dimensionally correct.

Q.23. Explain the use of dimensional analysis to find the conversion factor between units of same physical quantity into different systems of units.

OR

Find the conversion factor between the S.I. and the C.G.S. units of force using dimensional analysis.

Ans: Conversion factor between units of same physical quantity:

i. Suppose we have to find the conversion factor between the units of force i.e. newton in S.I. system to dyne in C.G.S. system.

ii. Let 'n' be the conversion factor between the units of force.

iii. Dimensions of force in S.I. system are $[M_1^1L_1^1T_1^{-2}]$ and in CGS system are $[M_2^1L_2^1T_2^{-2}]$

iv. Suppose, 1 newton = n dyne ....(1)
$\therefore \quad 1[M_1^1L_1^1T_1^{-2}] = n\,[M_2^1L_2^1T_2^{-2}]$
$\therefore \quad n = \left[\frac{M_1^1L_1^1T_1^{-2}}{M_2^1L_2^1T_2^{-2}}\right]$
$= \left[\frac{M_1}{M_2}\right]^1 \left[\frac{L_1}{L_2}\right]^1 \left[\frac{T_1}{T_2}\right]^{-2}$ ....(2)

v. By expressing L, M and T into its corresponding unit we have,
$n = \left[\frac{kg}{g}\right]^1 \left[\frac{m}{cm}\right]^1 \left[\frac{second}{second}\right]^{-2}$ ….(3)

vi. Since, 1 m = 100 cm and 1 kg = 1000g, we have,

$$n = \left(\frac{1000\,g}{g}\right)\left(\frac{100\,cm}{cm}\right)(1)^{-2}$$

$n = 10^3 \times 10^2 \times 1 = 10^5$

Hence, the conversion factor, $n = 10^5$

Therefore, from equation (1), we have,

$\therefore$ 1 newton = 10^5 dyne.

Q.24. Time period of a simple pendulum depends upon the length of pendulum (l) and acceleration due to gravity (g). Using dimensional analysis, obtain an expression for time period of simple pendulum.

Ans: Expression for time period of a simple pendulum by dimensional analysis:

i. Time period (T) of a simple pendulum depends upon length (l) and acceleration due to gravity (g) as follows:

$T \propto l^a g^b$

i.e., $T = k\, l^a g^b$ ....(1)

where k = proportionality constant which is dimensionless.

ii. The dimensions of T = $[M^0L^0T^1]$

The dimensions of l = $[M^0L^1T^0]$

The dimensions of g = $[M^0L^1T^{-2}]$

Taking dimensions on both sides of equation (1),

$[M^0L^0T^1] = [M^0L^1T^0]^a\ [M^0L^1T^{-2}]^b$

$[M^0L^0T^1] = [M^0L^{a+b}T^{-2b}]$

iii. Equating corresponding power of L, M and T on both sides, we get

$a + b = 0$ ....(2)

and $-2b = 1$

$\therefore\ b = -\dfrac{1}{2}$

iv. Substituting 'b' in equation (2), we get

$a = \dfrac{1}{2}$

v. Substituting values of a and b in equation (1), we have,

$T = k\ l^{\frac{1}{2}} g^{-\frac{1}{2}}$

$$\therefore\ T = k\ \frac{l^{\frac{1}{2}}}{g^{\frac{1}{2}}} = k\left(\frac{l}{g}\right)^{\frac{1}{2}} = k\sqrt{\frac{l}{g}}$$

vi. Experimentally, it is found that $k = 2\pi$

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

This is the required expression for time period of simple pendulum.

***Q.25. State the uses of dimensional analysis. Explain each use with the help of an example.**

Ans: Uses of dimensional analysis:

i. To check the correctness of a physical equation.

ii. To derive the relationship between different physical quantities.

iii. To find the conversion factor between the units of the same physical quantity in two different systems of units.

iv. To derive the formula of a physical quantity, provided we know the factors on which the physical quantity depends.

(For explanation of uses refer Q.22, Q.23, Q.24).

Q.26. State the drawbacks of dimensional analysis.

Ans: Drawbacks of dimensional analysis:

i. While deriving a formula, the proportionality constant cannot be found.

ii. The formula for a physical quantity depending on more than three other physical quantities cannot be derived. It can only be verified. Example: The equations of the type v = u + at cannot be derived. It can only be checked.

iii. The equations containing trigonometric functions (sin θ, cos θ, etc), logarithmic functions (log x, log x^3, etc) and exponential functions (e^x, e^{x^2} etc) can neither be derived nor be checked because they are independent of L, M and T.

iv. To derive the formula for a physical quantity, we must know all the physical quantities on which it depends.

#Q.27. A. If two quantities have same dimensions, do they represent the same physical content?

B. A dimensionally correct equation need not actually be a correct equation but dimensionally incorrect equation is necessarily wrong. Justify.

Ans: A. When dimensions of two quantities are same, they do not represent the same physical content.

Example:

Modulus of rigidity, pressure, Young's modulus and longitudinal stress.

B. i. To justify the statement, let us take an example of a simple pendulum, having the bob attached to a string. It oscillates under the action of gravity. The period of oscillation of simple pendulum depends upon its length (l), mass of the bob (m) and acceleration due to gravity (g).

ii. An expression for its time period by the method of dimensions can be found out as follows:

$T = k\, l^x\, g^y\, m^z$ ….(1)

where, k is dimensionless constant and x, y, z are exponents.

iii. By taking dimensions on both sides of equation (1), we have,

$[M^0L^0T^1] = [M^0L^1T^0]^x\,[M^0L^1T^{-2}]^y\,[M^1L^0T^0]^z$

$\therefore$ $[M^0L^0T^1] = [M^zL^{x+y}T^{-2y}]$ ….(2)

iv. Equating dimensions of equation (2) on both sides we have,

$x + y = 0$, $z = 0$, $-2y = 1$

$\therefore$ $x = -y$ $\therefore$ $y = -\frac{1}{2}$

$\therefore$ $x = \frac{1}{2}$ $z = 0$

Then equation (1) becomes,

$T = k\, l^{\frac{1}{2}}\, g^{-\frac{1}{2}} = k\sqrt{\frac{l}{g}}$

$\therefore$ $T = k\sqrt{\frac{l}{g}}$ ….(3)

v. The value of constant k cannot be obtained by the method of dimensions. It does not matter if some number multiplies the right hand side of formula given by equation (3) because that does not affect dimensions.

$T = k\sqrt{\frac{l}{g}}$ is not correct formula unless we put value of $k = 2\pi$

Hence, dimensionally correct equation need not actually be correct equation.

vi. Now, Let us consider the formula,

$\frac{1}{2}mv = mgh$ ….(4)

We have to check whether it is correct or not.

vii. For that write the dimensions of L.H.S. and R.H.S.

L.H.S. = $[M^1L^1T^{-1}]$

R.H.S. = $[M^1L^2T^{-2}]$

Since the dimensions of R.H.S. and L.H.S. are not correct, the formula given by equation (4) is incorrect. Here, $\frac{1}{2}$ which is dimensionless constant does not play any role. Thus, dimensionally incorrect equation is necessarily wrong.

#Q.28. Whether all constants are dimensionless or unitless?

Ans: All constants need not be dimensionless or unitless.

Example – Non-dimensional constants are pure numbers. i.e. π, e, trigonometric functions, etc. whereas quantities like Planck's constant, gravitational constant etc., possess dimensions and also have a constant value. They are dimensional constants.

1.7 Order of magnitude and significant figures

Q.29. *Explain with example the term 'order of magnitude of a physical quantity'.

OR

What is order of magnitude? Explain with suitable examples.

Ans: A. Order of magnitude:

The order of magnitude of a physical quantity is defined as the value of its magnitude rounded-off to the nearest integral power of 10.

B. Explanation:

i. To find the order of magnitude of a physical quantity, it is first expressed in the form: $P \times 10^Q$ where, P is a number between one and ten and Q is an integer (positive or negative).

ii. If P is 5 or less than 5, the power of 10 (i.e., 10^Q) gives the order of magnitude.

iii. If P is greater than 5, add 1 to the power of 10 to get the order of magnitude.

iv. Examples:

a. Speed of light in air = 3×10^8 m/s

$\therefore$ Order of magnitude = 10^8 m/s

($\because 3 < 5$)

b. Mass of an electron = 9.1×10^{-31} kg

$\therefore$ Order of magnitude = 10^{-30} kg

($\because$ 9.1 > 5)

Q.30. Determine the order of magnitude of the following physical quantities.

i. Radius of the earth

ii. Mass of the earth

iii. Charge on electron

iv. One year

v. Universal gravitational constant

Ans:

Physical Quantity		Order of magnitude
i.	Radius of the earth (R)	$R = 6400 \times 10^3$ m $= 6.4 \times 10^6$ m The number 6.4 is more than 5 $\therefore$ Order of magnitude = 10^7 m
ii.	Mass of the earth (M)	$M = 5.98 \times 10^{24}$ kg, Since 5.98 is greater than 5, $\therefore$ Order of magnitude = 10^{25} kg
iii.	Charge on electron (e^-)	$e = 1.6 \times 10^{-19}$ C. $\therefore$ Order of magnitude = 10^{-19} C
iv.	One year	One year = 365 × 24 × 3600 second = 31536000 second = 3.1536×10^7 second $\therefore$ Order of magnitude = 10^7 second
v.	Universal gravitational constant	$G = 6.67 \times 10^{-11}$ Nm^2/kg^2 $\therefore$ Order of magnitude = 10^{-10}Nm^2/kg^2

Note:

Order of magnitude of some other physical quantities:

No.	Physical quantities	Order of magnitude
i.	Mass of the sun	10^{30} kg
ii.	Mass of an electron	10^{-30} kg
iii.	Distance of the sun from earth	10^{11} m
iv.	Distance of the moon from earth	10^8 m
v.	Diameter of proton	10^{-15} m
vi.	Life time of an excited atom	10^{-8} s
vii.	Size of atom	10^{-10} m
viii.	Size of nucleus	10^{-15} m
ix.	Size of our galaxy	10^{21} m
x.	Mass of atom	10^{-26} kg

Q.31. A. Define significant figures.

***B. State the rules for determining significant figures.**

Ans: A. Significant figures:

A figure which is of some significance but it does not necessarily denote a certainty is called a significant figure.

B. Rules for determining significant figures:

i. One and only one uncertain (doubtful) figure is retained in a measurement. In a reading of 2.64 cm, only the figure 4 is uncertain.

ii. When a number is to be rounded-off to a specific number of significant figures, then

a. If the figure to be rounded-off is five or greater than five, then the last digit retained is increased by one. e.g. 12.46 should be written as 12.5.

b. If the figure to be rounded-off is less than 5, then the last digit retained is left unchanged. e.g. 12.43 should be written as 12.4.

iii. The zeros on the left side of the number are not significant. eg. the number 0.0034 has only two significant figures.

iv. The zeros on the right side of number are significant because they indicate the accuracy of the instrument used for measurement. Eg. 2.40 and 2.400 represent the same number but they are not equivalent. In 2.40 there are three significant figures and 2.400 has four significant figures.

v. If the number of digits is more than the number of significant figures, the number should be expressed in the power of ten. Thus, the mass of the earth is written as 5.98×10^{24} kg, as it is known only upto 3 significant figures.

Q.32. Find the number of significant figures in the following numbers.

i. 25.42 ii. 0.004567

iii. 35.320 iv. 4.56×10^8

v. 1.609×10^{19} vi. 91.000

Ans:

No.	Number	No. of significant figures
i.	25.42	4
ii.	0.004567	4
iii.	35.320	5

iv.	4.56×10^{8}	3
v.	1.609×10^{19}	4
vi.	91.000	5

Q.33. Explain the rules for rounding-off the number of the significant figures with examples.

Ans: Rules for rounding-off the numbers:

While rounding-off numbers in measurement, following rules are applied.

i. If the digit to be dropped is smaller than 5, then the preceding digit should be left unchanged. eg. 7.34 is rounded-off to 7.3.

ii. If the digit to be dropped is greater than 5, then the preceding digit should be raised by 1.
eg. 17.26 is rounded-off to 17.3

iii. If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit should be raised by 1.
eg. 7.351, on being rounded-off to first decimal becomes 7.4.

iv. If the digit to be dropped is 5 or 5 followed by zero, then the preceding digit is not changed if it is even.
eg. 3.45, on being rounded-off becomes 3.4.

v. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by 1 if it is odd. eg. 3.35, on being rounded-off becomes 3.4.

1.8 Accuracy and errors in measurements

***Q.34. Explain in brief, accuracy in measurements.**

OR

A. Define accuracy.

B. Explain accuracy in measurement giving suitable examples.

Ans: A. Accuracy:

Accuracy is the closeness of the measurement to the true or known value.

B. Explanation:

i. Accuracy of the measurement depends upon the accuracy of the instrument used for measurement.

ii. Defect in measurement of physical quantities can lead to errors and mistakes.

iii. Lesser the error, more is the accuracy in the measurement of a physical quantity.

iv. For example, when we measure volume of a bar, the length is measured with a metre scale whose least count is 1 mm. The breadth is measured with a vernier calliper whose least count is 0.1 mm. Thickness of the bar can be measured with a micrometer screw gauge whose least count is 0.01 mm.

v. Thus, the smaller the magnitude of a quantity, the greater is the need for measuring it accurately.

Q.35. A. What is an error? Classify errors into different categories.

Ans: A. Error:

i. *The difference between measured value and true value of a physical quantity is called error.*

ii. It is the uncertainty in measurement of a physical quantity.
Error = Measured value – True value

B. Classification of errors:

Errors are classified into following four groups:

i. Instrumental error (Constant error)
ii. Systematic error (Persistent error)
iii. Personal error (Human error)
iv. Random error (accidental error)

Q.36. A. What is instrumental (constant) error?

B. Explain the cause and remedies of instrumental errors.

Ans: A. Instrumental (constant) error:

If the same error is repeated every time in a series of observations, the error is said to be constant error.

B. i. Cause:

a. Constant error is caused due to faulty construction of measuring instruments.

b. Example: If a thermometer is not graduated properly, i.e. one degree on the thermometer actually corresponds to 0.99°, the temperature measured by such a thermometer will differ from its value by a constant amount.

ii. Remedies:

In order to minimise constant error, measurements are made with different accurate instruments.

Q.37. A. What is systematic error?
B. Write down the cause and minimisation of systematic error.

Ans: A. Systematic errors:
Those errors which occur due to defective setting of an instrument is called systematic error.

B. i. Causes:
a. These errors are due to known reasons, i.e. fault in instrument, improper attention, change in condition, etc.
b. Example: If the pointer of an ammeter is not pivoted exactly at the zero of the scale, it will not point to zero when no current is passing through it.

ii. Minimization:
These errors can be minimized by detecting the sources of errors.

Q.38. A. What is personal error?
B. Give its remedies.

Ans: A. Personal error (Human error):
i. *The errors introduced due to fault of an observer taking readings are called personal errors.*
ii. Example: Error due to non-removal of parallax between pointer and its image in case of a magnetic compass needle, errors made in counting number of oscillations while measuring the period of simple pendulum.

B. Remedies:
They vary from person to person.
These errors can be reduced to some extent by asking different observers to take the measurement.

Q.39. A. What is random error (accidental)?
B. How can it be minimized?

Ans: A. Random error (accidental):
The errors which are caused due to minute change in experimental conditions like temperature, pressure or fluctuation in voltage, while the experiment is being performed are called random errors.
Example: Mechanical vibrations, variations in Earth's magnetic field.

B. Minimization:
Random error cannot be eliminated completely but can be minimized to a large extent.

***Q.40. Explain different types of errors in measurements with remedies.**

Ans: *Refer Q.36, Q.37, Q.38, Q.39.*

Q.41. State general methods to minimise effect of errors.

Ans: Methods to minimise effect of errors:
i. Taking a large magnitude of the quantity to be measured.
ii. Taking large number of readings and calculating their mean value.
iii. Using an instrument whose least count is as small as possible.
iv. Experimental conditions such as temperature, pressure etc. should remain constant within tolerable limit.

Q.42. A. What are mistakes?
B. Explain causes of mistakes and their remedies.

Ans: A. Mistakes:
The faults caused by the carelessness of an untrained experimenter are called mistakes.

B. i. Causes:
Mistakes are commited due to lack of skill, faulty observation and wrong readings

ii. Remedies:
Mistakes can be avoided by careful and properly trained experimenter.

Q.43. Distinguish between Mistakes and Errors in measurements.

Ans:

No.	Mistakes	Errors
i.	Mistake is a fault on the part of the observer.	Error is a fault due to other reasons such as limitations of human senses, instruments etc.
ii.	Mistakes can be totally avoided by taking proper care.	Errors cannot be eliminated; they can be reduced.
iii.	Mistakes are caused due to lack of taking precautions, carelessness in taking and recording readings, carelessness in calculations etc.	Errors are caused due to limitations of instruments used for measurement, personal error due to limitations of senses etc.

Q.44. Define the terms:

***i. Most probable value (mean value)**

***ii. Absolute error**

iii. Mean absolute error

***iv. Relative error**

***v. Percentage error**

Ans: i. Most probable value (mean value):

a. *The mean value i.e., the arithmetic average value of a large number of readings of a quantity is called the most probable value of that quantity.* This value can be considered to be true value of the quantity.

b. If $a_1, a_2, a_3, \ldots\ldots\ldots a_n$ are 'n' number of readings taken for measurement of a quantity, then their mean value is given by,

$$a_{mean} = \frac{a_1 + a_2 + \ldots\ldots + a_n}{n}$$

$$\therefore \quad \bar{a}_m = \frac{1}{n}\sum_{i=1}^{n} a_i$$

ii. Absolute error:

a. *For a given set of measurements of a quantity, the magnitude of the difference between mean value (Most probable value) and each individual value is called absolute error (Δa) in the measurement of that quantity.*

b. absolute error = |mean value–measured value|

$|\Delta a_1| = |a_m - a_1|$

Similarly, $|\Delta a_2| = |\bar{a}_m - a_2|$,

. . .

. . .

. . .

. . .

$|\Delta a_n| = |\bar{a}_m - a_n|$

iii. Mean absolute error:

For a given set of measurements of a same quantity, the arithmetic mean of all the absolute errors is called mean absolute error in the measurement of that physical quantity.

$$|\Delta \bar{a}_m| = \frac{|\Delta a_1| + |\Delta a_2| + \ldots\ldots + |\Delta a_n|}{n}$$

$$= \frac{1}{n}\sum_{i=1}^{n}|\Delta a_i|$$

iv. Relative error:

The ratio of the mean absolute error in the measurement of a physical quantity to its most probable value is called relative error.

$$\text{Relative error} = \frac{|\Delta \bar{a}_m|}{\bar{a}_m}$$

v. Percentage error:

The relative error multiplied by 100 is called the percentage error.

$$\text{Percentage error} = \frac{|\Delta \bar{a}_m|}{\bar{a}_m} \times 100\%$$

Q.45. If the error in 'a' is Δa then find the percentage error in:

i. a^n ii. a·b iii. $\frac{a}{b}$

Ans: If the error in 'a' is Δa, then the percentage error is $\frac{\Delta a}{a} \times 100$

i. If the error in 'a' is Δa, then the percentage error in a^n is given as,

$$a^n = n\left(\frac{\Delta a}{a}\right) \times 100\%$$

ii. If the error in measurement of a is Δa and the error in measurement of 'b' is Δb, then the percentage error in 'ab' is given as,

$$ab = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times 100$$

iii. If the error in measurement of 'a' is Δa and the error in measurement of 'b' is Δb then the percentage error in $\frac{a}{b}$ is given as,

$$\frac{a}{b} = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times 100$$

Formulae

1. **Measure of physical quantity:**
   M = nu
   where, n = numerical value, u = size of unit

2. **Relation between numerical value and size of unit:**
   $n_1u_1 = n_2u_2$

3. **Conversion factor of a unit in two system of units**:

$$n = \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$$

4. **Average value or mean value**:
$$\bar{a}_m = \frac{a_1 + a_2 + a_3 + .. + a_n}{n} = \frac{1}{n}\sum_{i=1}^{n} a_i$$

5. If $x = x_1 \pm x_2$, then maximum error:
$\Delta x = \Delta x_1 + \Delta x_2$

6. If $x = x_1^m \times x_2^n$, then error in measurement:
$$\frac{\Delta x}{x} = \frac{m\Delta x_1}{x_1} + \frac{n\Delta x_2}{x_2}$$

7. **Absolute error =** $|$Average value – Measured value$|$
$|\Delta a_n| = |a_m - a_n|$

8. **Mean absolute error:**
$$|\Delta \bar{a}_m| = \frac{|\Delta a_1| + |\Delta a_2| + ... + |\Delta a_n|}{n} = \frac{1}{n}\sum_{i=1}^{n} \Delta a_i$$

9. **Relative (fractional) error =** $\dfrac{|\Delta \bar{a}_m|}{\bar{a}_m}$

10. **Percentage error =** $\dfrac{|\Delta \bar{a}_m|}{\bar{a}_m} \times 100\,\%$

Solved Examples

Type I : Problems based on dimensional analysis

***Example 1**
Find the dimensions of the following
i. Power ii. Force
iii. Electric Permittivity
Solution:

i.	Power	$\frac{\text{Work}}{\text{Time}}$	$[M^1L^2T^{-3}]$
ii.	Force	Mass × Acceleration	$[M^1L^1T^{-2}]$
iii.	Electric permittivity	$\varepsilon_0 = \frac{q^2}{4\pi r^2 F}$	$[M^{-1}L^{-3}T^4A^2]$

Example 2
Check the correctness of formula $v^2 = u^2 + 2as$ by using dimensional analysis.
Solution:

Dimensions of v^2 = $[M^0L^1T^{-1}]^2$
= $[M^0L^2T^{-2}]$
Dimensions of u^2 = $[M^0L^1T^{-1}]^2$
= $[M^0L^2T^{-2}]$
Dimensions of a = $[M^0L^1T^{-2}]$
Dimensions of s = $[M^0L^1T^0]$
2 is dimensionless quantity.
Substitute dimensions in L.H.S. of equation

∴ L. H. S. = $v^2 = [M^0L^2T^{-2}]$ ….(1)
Substitute dimensions in R.H.S. equation
R.H.S. = $u^2 + 2$ as
$= [M^0L^2T^{-2}] + \{[M^0L^1T^{-2}] \times [M^0L^1T^0]\}$
R.H.S.= $[M^0L^2T^{-2}] + [M^0L^2T^{-2}]$ ….(2)
From the equations (1) and (2), it is found that each term in the formula has same dimensions.

***Example 3**
If length 'L', force 'F' and time 'T' are taken as fundamental quantities, what would be the dimensional equation of mass and density?
Solution:

i. Force = Mass × Acceleration

∴ Mass = $\dfrac{\text{Force}}{\text{Acceleration}}$

∴ Dimensional equation of mass
$$\frac{\text{Dimensions of force}}{\text{Dimensions of acceleration}} = \frac{[F^1]}{[L^1T^{-2}]}$$
$= [F^1L^{-1}T^2]$

∴ Dimensional equation of mass = $\mathbf{[F^1L^{-1}T^2]}$

ii. Density = $\dfrac{\text{Mass}}{\text{Volume}}$

Dimensional equation of density
$$= \frac{\text{Dimensions of mass}}{\text{Dimensions of volume}}$$
$$= \frac{[F^1L^{-1}T^2]}{[L^3]}$$
$= \mathbf{[F^1L^{-4}T^2]}$

Ans: i. The dimensional equation of mass is $\mathbf{[F^1L^{-1}T^2]}$.
ii. The dimensional equation of density is $\mathbf{[F^1L^{-4}T^2]}$.

***Example 4**
Derive an expression of kinetic energy of a body of mass 'm' and moving with velocity 'v', using dimensional analysis.
Solution:

Kinetic energy of a body depends upon mass (m) and velocity (v) of the body.
Let K.E. $\propto m^x v^y$

∴ K.E. = km^xv^y ….(1)

where k = dimensionless constant of proportionality.
Taking dimensions on both sides of equation (1),

$[M^1L^2T^{-2}] = [M^1L^0T^0]^x [M^0L^1T^{-1}]^y$
$= [M^xL^0T^0] [M^0L^yT^{-y}]$
$= [M^{x+0} L^{0+y} T^{0-y}]$
$[M^1L^2T^{-2}] = [M^xL^yT^{-y}]$ ….(2)

Equating dimensions of L, M, T on both sides of equation (2)

y = 2 and x = 1 also –y = –2

$\therefore$ y = 2

Substituting x, y in equation (1), we have

K.E. = kmv²

Example 5

A calorie is a unit of heat or energy and it is equal to about 4.2 J where 1 J = 1 kg m² s⁻². Suppose, we employ a system of units in which unit of mass equals α kg, the unit of length equals β m, and the unit of time is γ s. Show that a calorie has a magnitude of 4.2 β⁻²α⁻¹ γ² in terms of the new units. (NCERT)

Solution: 1 cal. = 4.2 kg m²s⁻²

S.I. system	New system
L_1 = 1 m	$L_2 = \beta$ m
M_1 = 1 kg	$M_2 = \alpha$ kg
T_1 = 1 second	$T_2 = \gamma$ second

Dimensional formula of energy is $[M^1L^2T^{-2}]$

According to the question,

$$4.2[M_1^1 L_1^2 T_1^{-2}] = n \times [M_2^1 L_2^2 T_2^{-2}]$$

Hence, magnitude of calorie in the new system is given by conversion factor, 'n'.

$$\therefore \quad n = 4.2\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-2}$$

$$= 4.2\left[\frac{1\text{ kg}}{\alpha\text{ kg}}\right]^1\left[\frac{1\text{ m}}{\beta\text{ m}}\right]^2\left[\frac{1\text{ s}}{\gamma\text{ s}}\right]^{-2}$$

$\therefore$ n = $\mathbf{4.2\ \beta^{-2}\alpha^{-1}\gamma^2}$

Ans: The magnitude of a calorie in terms of the new units is $\mathbf{4.2\ \alpha^{-1}\beta^{-2}\gamma^2}$.

Example 6

Density of oil is 0.8 g cm⁻³ in C.G.S. unit. Find its value in S.I. units.

Solution:

Dimensions of density is $[M^1L^{-3}T^0]$

C.G.S unit	S.I unit
Dimension= $[M_1^1 L_1^{-3} T_1^0]$	Dimension = $[M_2^1 L_2^{-3} T_2^0]$
L_1 = 1 cm M_1 = 1 g T_1 = 1 s	L_2 = 1 m = 100 cm M_2 = 1 kg = 1000 g T_2 = 1 s

0.8 g cm⁻³ = conversion factor (n) × kg m⁻³ ….(1)

$0.8\ [M_1^1 L_1^{-3} T_1^0] = n \times [M_2^1 L_2^{-3} T_2^0]$

$$\therefore \quad n = \frac{0.8[M_1^1 L_1^{-3} T_1^0]}{[M_2^1 L_2^{-3} T_2^0]}$$

$$n = 0.8\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^{-3}\left[\frac{T_1}{T_2}\right]^0$$

$$= 0.8\left[\frac{1\text{ g}}{1000\text{ g}}\right]^1\left[\frac{1\text{ cm}}{100\text{ cm}}\right]^{-3}\left[\frac{1\text{s}}{1\text{s}}\right]^0$$

$= 0.8\ [10^{-3}]^1\ [10^{-2}]^{-3}$
$= 0.8\ [10^{-3}]\ [10]^6$
$n = 0.8 \times 10^3$

Substituting the value of 'n' in equation (1), we get, 0.8 g cm⁻³ = 0.8 × 10³ kg m⁻³.

Ans: Density of oil in S.I unit is **0.8 × 10³ kg m⁻³**.

Example 7

Assume that the speed (v) of sound in air depends upon the pressure (P) and density (ρ) of air, then use dimensional analysis to obtain an expression for the speed of sound.

Solution:

It is given that speed (v) of sound in air depends upon the pressure (P) and density (ρ) of the air.

So we can write, $v = k\,P^a \rho^b$ …(1)

where k is a dimensionless constant and a and b are powers to be determined.

Dimensions of v = $[M^0L^1T^{-1}]$
Dimensions of P = $[M^1L^{-1}T^{-2}]$
Dimensions of ρ = $[M^1L^{-3}T^0]$

Substitute the dimensions of the quantities on both sides of equation (1),

$\therefore \quad [M^0L^1T^{-1}] = [M^1L^{-1}T^{-2}]^a [M^1L^{-3}T^0]^b$
$\therefore \quad [M^0L^1T^{-1}] = [M^aL^{-a}T^{-2a}] [M^bL^{-3b}T^0]$
$\therefore \quad [M^0L^1T^{-1}] = [M^{a+b}L^{-a-3b}T^{-2a}]$

Comparing the powers of L, M and T on both sides, we get,

$-2a = -1 \qquad \therefore \quad a = \frac{1}{2}$

Also, a + b = 0

$\therefore \quad \frac{1}{2} + b = 0 \qquad \therefore \quad b = -\frac{1}{2}$

Substituting values of a and b in equation (1), we get

$v = k\ P^{1/2} \cdot \rho^{-1/2}$

Example 8

The hydrostatic pressure 'P' of a liquid column depends upon the density 'ρ', height 'h' of liquid column and also an acceleration 'g' due to gravity. Using dimensional analysis, derive a formula for pressure P.

Solution:

Let $P \propto h^x \rho^y g^z$

$\therefore \quad P = k\, h^x \rho^y g^z \quad \ldots (1)$

Where k is the constant of proportionality.

Dimensionally,

$[M^1L^{-1}T^{-2}] = [M^0L^1T^0]^x \times [M^1L^{-3}T^0]^y \times [M^0L^1T^{-2}]^z$

$\therefore \quad [M^1L^{-1}T^{-2}] = [M^y L^{x-3y+z} T^{-2z}]$

Comparing the powers of L, M and T on the both sides, we get

y = 1, x – 3y + z = – 1 and – 2z = – 2

Solving we get, x = 1, y = 1 and z = 1

Substituting the values of x, y, z in equation (i) we get, P = k hρg

Assuming k = 1, we get

The formula for the hydrostatic pressure of a liquid column is, **P = hρg.**

Example 9

The value of G in C.G.S system is 6.67×10^{-8} dyne cm^2 g^{-2}. Calculate its value in S.I. system.

Solution:

Dimensional formula of gravitational constant = $[M^{-1}L^3T^{-2}]$

C.G.S system	S.I. system
Dimension= $[M_1^{-1}L_1^3T_1^{-2}]$	Dimension= $[M_2^{-1}L_2^3T_2^{-2}]$
L_1 = 1 cm	L_2 = 1 m = 100 cm
M_1 = 1 g	M_2 = 1 kg = 1000 g
T_1 = 1 s	T_2 = 1 s

6.67×10^{-8} dyne cm^2 g^{-2} = Conversion factor (n) × Nm^2 kg^{-2} ....(1)

$\therefore \quad 6.67 \times 10^{-8} [M_1^{-1}L_1^3T_1^{-2}] = n \times [M_2^{-1}L_2^3T_2^{-2}]$

$\therefore \quad n = 6.67 \times 10^{-8} \left[\frac{M_1}{M_2}\right]^{-1}\left[\frac{L_1}{L_2}\right]^{3}\left[\frac{T_1}{T_2}\right]^{-2}$

$n = 6.67 \times 10^{-8} \left[\frac{1\text{ g}}{1000\text{ g}}\right]^{-1}\left[\frac{1\text{ cm}}{100\text{ cm}}\right]^{3}\left[\frac{1\text{ s}}{1\text{ s}}\right]^{-2}$

$n = 6.67 \times 10^{-8} \times 10^{-6} \times 10^{3}$

$n = 6.67 \times 10^{-11}$

From equation (1),

6.67×10^{-8} dyne cm^2 g^{-2} = 6.67×10^{-11} Nm^2 kg^{-2}

Ans: Value of G in S.I. system is **6.67×10^{-11} Nm^2 kg^{-2}**.

Example 10

Using the method of dimension, show that 1 joule = 10^7 erg.

Solution:

Dimensions of work = $[M^1L^2T^{-2}]$ ….(1)

S.I. systems	C.G.S system
Dimensions= $[M_1^1L_1^2T_1^{-2}]$	Dimensions= $[M_2^1L_2^2T_2^{-2}]$
L_1 = 1 m = 100 cm	L_2 = 1 cm
M_1 = 1 kg = 1000 g	M_2 = 1 g
T_1 = 1 s	T_2 = 1 s

To show that: 1 J = 10^7 erg

Let 1 J = n × erg ....(2)

Conversion factor, n, is given by,

$1 \times [M_1^1L_1^2T_1^{-2}] = n \times [M_2^1L_2^2T_2^{-2}]$

$\therefore \quad n = \left[\frac{M_1}{M_2}\right]^{1}\left[\frac{L_1}{L_2}\right]^{2}\left[\frac{T_1}{T_2}\right]^{-2}$

$= \left[\frac{1000\text{ g}}{\text{g}}\right]^{1}\left[\frac{100\text{ cm}}{\text{cm}}\right]^{2}\left[\frac{1\text{ s}}{1\text{ s}}\right]^{-2}$

$= 10^3 \times 10^4$

$\therefore \quad n = 10^7$

Substituting the value of 'n' in equation (2), we have,

1 J = 10^7 erg.

Type II: Problems based on order of magnitude and significant figures

Example 11

Add 7.21, 12.141 and 0.0028 and express the result to an appropriate number of significant figures.

Solution:

$$\begin{array}{r} 7.21 \\ +12.141 \\ +0.0028 \\ \hline \text{Sum} = 19.3538 \end{array}$$

In the given problem, minimum number of digits after decimal is 2.

$\therefore$ Result will be rounded off upto two places of decimal.

Ans: Corrected rounded off sum is **19.35.**

Example 12

State the order of magnitude of the following:

i. Acceleration due to gravity g = 9.81 m/s^2

ii. The gravitation constant G = 6.67×10^{-11} Nm^2/kg^2

iii. The period of rotation of the earth about its own axis.

Solution:

i. Acceleration due to gravity, $g = 9.81\ ms^2$
$= 9.81 \times 10^0\ m/s^2 \quad \because \quad 9.81 > 5$

$\therefore$ Order of magnitude of acceleration due to gravity $= 10^{0+1}$ $= \mathbf{10^1\ ms^{-2}}$

ii. The gravitational constant,
$G = 6.67 \times 10^{-11}\ Nm^2 / kg^2 \ \because\ 6.67 > 5$

$\therefore$ Order of magnitude of gravitational constant
$= 10^{-11+1} = \mathbf{10^{-10}\ Nm^2/kg^2}$

iii. The period of rotation of the earth about its own axis,
$T = 8.64 \times 10^4\ s \quad \because \quad 8.64 > 5$

$\therefore$ Order of magnitude of period of rotation $=10^{4+1}$
$= \mathbf{10^5\ s}$

Ans: i. The order of magnitude of acceleration due to gravity is $\mathbf{10^1\ m/s^2}$.

ii. The order of magnitude of gravitational constant is $\mathbf{10^{-10}\ Nm^2/kg^2}$.

iii. The order of magnitude of period of revolution of earth about its own axis is $\mathbf{10^5}$ **s**.

***Example 13**

Determine the number of significant figures in the following measurements.

i. 0.05718 **ii. 93.26**

iii. $\mathbf{2.35 \times 10^{-19}}$ **iv. $\mathbf{1.3725 \times 10^9}$**

Solution:

i. 0.05718 significant figures are 5, 7, 1, 8 (Zero of left side of number is not significant)

$\therefore$ Number of significant figures = **4**

ii. 93.26
Significant figures = 9, 3, 2, 6

$\therefore$ Number of significant figures = **4**

iii. 2.35×10^{-19}
Significant figures = 2, 3, 5

$\therefore$ Number of significant figures = **3**

iv. 1.3725×10^9
Significant figures = 1, 3, 7, 2, 5

$\therefore$ Number of significant figures = **5**

Example 14

The length, breadth and thickness of a rectangular sheet of metal are 4.234 m, 1.005 m and 2.01 cm respectively. Give the area and volume of the sheet to correct significant figures. (NCERT)

Solution:

Given: $l = 4.234$ m, b = 1.005 m,
t = 2.01 cm = 2.01×10^{-2} m

To find: i. Area of sheet to correct significant figures (A)
ii. Volume of sheet to correct significant figures (V)

Formulae: i. $A = l \times b$ ii. $V = l \times b \times t$

Calculation: From formula (i),
$A = 4.234 \times 1.005 = 4.255$

As the rectangular sheet has two surfaces, we multiply the above answer by 2.

$\therefore$ total area of rectangular sheet $= 4.255 \times 2$
$= 8.510\ m^2$

In correct significant figure, A = $\mathbf{8.510\ m^2}$

From formula (ii),
$V = 4.234 \times 1.005 \times 2.01 \times 10^{-2}$
$= 0.0855289\ m^3$

In correct significant figure, V = $\mathbf{0.085\ m^3}$

Ans: i. Area of sheet to correct significant figures is $\mathbf{8.510\ m^2}$.

ii. Volume of sheet to correct significant figures is $\mathbf{0.085\ m^3}$.

Example 15

The mass of a box measured by a grocer's balance is 2.3 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is (i) the total mass of the box? (ii) the difference in the masses of the pieces to correct significant figures? (NCERT)

Solution:

i. Total mass of the box
= (2.3 + 0.02017 + 0.02015) kg
= 2.34032 kg

Since, the last number of significant figure is 2, therefore, the total mass of the box = **2.3 kg**

ii. Difference of mass = (20.17 – 20.15) = 0.02 g

Since, there are two significant figures so the difference in masses to the correct significant figures is **0.02 g**.

Ans: i. The total mass of the box to correct significant figures is **2.3 kg.**

ii. The difference in the masses to correct significant figures is **0.02 g**.

Example 16

**Find the order of magnitude of force exerted by the sun on the earth. Mass of the sun = $\mathbf{1.99 \times 10^{30}}$ kg, Mass of earth = $\mathbf{5.97 \times 10^{24}}$ kg, Distance between Earth and the Sun = $\mathbf{1.49 \times 10^{11}}$ m,
G = $\mathbf{6.67 \times 10^{-11}\ Nm^2/kg^2}$**

Solution:

Given: $M_S = 1.99 \times 10^{30}$ kg, $M_E = 5.97 \times 10^{24}$kg,
$R = 1.49 \times 10^{11}$m, $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

To find: Order of magnitude of force

Formula: $F = G.\dfrac{M_S.M_E}{R^2}$

Calculation: From formula,

$$F = \frac{6.67\times10^{-11}\times1.99\times10^{30}\times5.97\times10^{24}}{\left(1.49\times10^{11}\right)^2}$$

$= 35.69 \times 10^{21}$ N

$= 3.569 \times 10^{22}$ N

$\because$ 3.569 < 5

$\therefore$ Order of magnitude = $\mathbf{10^{22}}$ **N**

Ans: The order of magnitude of the force exerted by the sun on the earth is $\mathbf{10^{22}}$ **N**.

Type III: Problems based on errors in measurement

Example 17

In an experiment to find the density of a solid, the mass and volume of the solid were found to be 400.3 ± 0.02 g and 75.6 ± 0.01 cm^3 respectively. Find the percentage error in the determination of its density.

Solution:

Given: M = 400.3 g, ΔM = 0.02 g,
V = 75.6 cm^3, ΔV= 0.01 cm^3

To find: Percentage error in ρ

Formula: $\dfrac{\Delta\rho}{\rho}\times 100\%$

Calculation: From formula,

$$\frac{\Delta M}{M} = \frac{0.02}{400.3} = 0.00005$$

and $\dfrac{\Delta V}{V} = \dfrac{0.01}{75.6} = 0.00013$

Relation between mass, volume and density is

ρ = M/V

$\therefore \quad \dfrac{\Delta\rho}{\rho} = \dfrac{\Delta M}{M} + \dfrac{\Delta V}{V}$ (neglecting sign)

$\therefore \quad \dfrac{\Delta\rho}{\rho} = 0.00005 + 0.00013 = 0.00018$

Hence, the percentage error in the determination of the density of the solid is

$\dfrac{\Delta\rho}{\rho}\times 100\% = (0.00018 \times 100)\% = \mathbf{0.018\%}$

Ans: The percentage error in the determination of density is **0.018%**.

Example 18

Find the percentage error in energy E = $\mathbf{\frac{1}{2}mv^2}$, where m = (52.4 ± 0.2) kg and v = (25.6 ± 0.1) m/s.

Solution:

Given: m = 52.4 kg, v = 25.6 m/s, Δm = 0.2 kg, Δv = 0.1 m/s

To find: Percentage error in E

Formula:

$$\text{Percentage error in E} = \left(\frac{\Delta m}{m} + 2\frac{\Delta v}{v}\right)\times 100\%$$

Calculation:

From formula,

$$\text{Percentage error in E} = \left(\frac{0.2}{52.4} + 2\times\frac{0.1}{25.6}\right)\times 100\%$$

$= \mathbf{1.16\%}$

Ans: The percentage error in energy is **1.16%**.

Type IV: Miscellaneous

Example 19

In an experiment, width of given object was found to be 1.55 cm, 1.54 cm, 1.53 cm, 1.52 cm, 1.49 cm in successive trials. Calculate mean absolute error, relative error and percentage error.

Solution:

Given: a_1 = 1.55 cm, a_2 = 1.54 cm, a_3 = 1.53 cm, a_4 = 1.52 cm, a_5 = 1.49 cm, n = 5

To find:
i. Mean absolute error
ii. Relative error
iii. Percentage error

Formula:

i. Mean absolute error = $\dfrac{|\Delta a_1| + |\Delta a_2| + ... + |\Delta a_n|}{n}$

ii. Relative error = $\dfrac{|\Delta \bar{a}_m|}{\bar{a}_m}$

iii. Percentage error = $\dfrac{|\Delta \bar{a}_m|}{\bar{a}_m}\times 100\%$

Calculation:

i. Mean of readings, $\bar{a}_m = \dfrac{a_1 + a_2 + a_3 + a_4 + a_5}{5}$

$= \dfrac{1.55+1.54+1.53+1.52+1.49}{5}$

$\therefore \quad \bar{a}_m = \dfrac{7.63}{5} = 1.526$ cm

$|\Delta a_1| = |1.526 - 1.55| = |-0.024| = 0.024$

$|\Delta a_2| = |1.526 - 1.54| = |-0.014| = 0.014$

$|\Delta a_3| = |1.526 - 1.53| = |-0.004| = 0.004$

$|\Delta a_4| = |1.526 - 1.52| = |0.006| = 0.006$

$|\Delta a_5| = |1.526 - 1.49| = |0.036| = 0.036$

From formula (i),

$$|\Delta \bar{a}_m| = \frac{|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + |\Delta a_4| + |\Delta a_5|}{5}$$

$$= \frac{0.024 + 0.014 + 0.004 + 0.006 + 0.036}{5}$$

$$= \frac{0.084}{5} = 0.0168$$

∴ $|\Delta \bar{a}_m|$ = **0.0168 cm**

ii. From formula (ii),

Relative error = $\frac{0.0168}{1.526}$ = 0.011

∴ Relative error = **0.011 cm**

iii. From formula (iii),

Percentage error = 0.011 × 100 = 1.1

∴ Percentage error = **1.1%**

Ans: i. The mean absolute error is **0.0168 cm**.
ii. The relative error is **0.011 cm**.
iii. The percentage error is **1.1%**.

Example 20

An object was weighed by a physical balance and following readings were obtained:
5.04 g, 5.06 g, 4.97 g, 5.00 g, 4.93 g.
Find i. Mean value
ii. Mean absolute error
iii. Percentage error

Solution:

Given: a_1 = 5.04 g, a_2 = 5.06 g, a_3 = 4.97 g
a_4 = 5.00 g, a_5 = 4.93 g, n = 5

To find: i. Mean value
ii. Mean absolute error
iii. Percentage error

Formula:

i. Mean value = $\bar{a}_m = \frac{a_1 + a_2 + a_3 + a_4 + a_5}{5}$

ii. Mean absolute error = $\frac{|\Delta a_1| + |\Delta a_2| + ... + |\Delta a_n|}{n}$

iii. Percentage error = $\frac{|\Delta \bar{a}_m|}{\bar{a}_m} \times 100\%$

Calculation:

i. From formula (i),

$$\bar{a}_m = \frac{5.04 + 5.06 + 4.97 + 5.00 + 4.93}{5}$$

$$= \frac{25.00}{5} = 5.00 \text{ g}$$

∴ $\bar{a}_m$ = **5.00 g**

ii. Absolute errors:

$|\Delta a_1| = |a_m - a_1| = |5.00 - 5.04| = |-0.04| = 0.04$

$|\Delta a_2| = |a_m - a_2| = |5.00 - 5.06| = |-0.06| = 0.06$

$|\Delta a_3| = |a_m - a_3| = |5.00 - 4.97| = |0.03| = 0.03$

$|\Delta a_4| = |a_m - a_4| = |5.00 - 5.00| = 0.00$

$|\Delta a_5| = |a_m - a_5| = |5.00 - 4.93| = |0.07| = 0.07$

From formula (ii),

$$|\Delta \bar{a}_m| = \frac{|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + |\Delta a_4| + |\Delta a_5|}{5}$$

$$= \frac{0.04 + 0.06 + 0.03 + 0.00 + 0.07}{5}$$

$$= \frac{0.20}{5} = 0.04$$

∴ $|\Delta \bar{a}_m|$ = **0.04 g**

iii. From formula (iii),

Percentage error = $\frac{0.04}{5.00} \times 100\% = \frac{4}{5} = 0.8$

∴ Percentage error = **0.8%**

Ans: i. The mean value is **5.00 g**.
ii. The mean absolute error is **0.04 g**.
iii. The percentage error is **0.8%**.

Practice Problems

Type I : Problem based on Dimensional analysis

1. The acceleration due to gravity of a place is 9.8 ms^{-2}. Find its value in km h^{-2}.

2. If the value of atmospheric pressure is 10^6 dyne cm^{-2} in CGS system, find its value in S.I. system.

3. Check the correctness of the relation τ = Iα, where τ is the torque acting on a body, I is the moment of inertia and α is angular acceleration.

4. Check the correctness of $T = 2\pi\sqrt{\frac{l}{g}}$

5. Assuming that the mass M of the largest stone that can be moved by a flowing river depends upon 'v' the velocity, 'ρ' the density of water and on 'g' the acceleration due to gravity. Show that M varies with sixth power of the velocity of flow.

6. Assuming that the critical velocity v_c of a viscous liquid flowing through a capillary tube depends only upon the radius r of the tube, density ρ and the coefficient of viscosity η of the liquid, find the expression for critical velocity.

Type II: Order of magnitude and significant figures

7. Find the order of magnitude of following data.
   i. height of a tower 4325 m
   ii. weight of a car 789 kg
   iii. Charge on electron 1.6×10^{-19} C
8. Round off the following numbers as indicated
   i. 15.654 upto 3 digits
   ii. 1426 upto 5 digits
   iii. 5.996×10^5 upto 3 digits
9. Add 3.8×10^{-6} and 4.2×10^{-5} with due regards to significant figures.
10. The diameter of a sphere is 2.78 m. Calculate its volume with due regards to significant figures.

Type III: Errors in measurement

11. Two different masses are determined as (23.7 ± 0.5) g and (17.6 ± 0.3) g. What is the sum of their masses?
12. The lengths of two rods are recorded as $l_1 = (25.2 \pm 0.1)$ cm and $l_2 = (16.8 \pm 0.1)$ cm. Find their combined length.

Type IV : Miscellaneous

13. The length of a rod as measured in an experiment was found to be 2.48 m, 2.46 m, 2.49 m, 2.50 m and 2.48 m. Find the mean absolute error, relative error and percentage error.

Multiple Choice Questions

1. Which of the following is the fundamental unit?
   (A) Length, force, time
   (B) Length, mass, time
   (C) Mass, volume, height
   (D) Mass, velocity, pressure
2. S.I. unit of energy is joule and it is equivalent to
   (A) 10^6 erg (B) 10^{-7} erg
   (C) 10^7 erg (D) 10^5 erg
3. Which of the following pairs are similar?
   (A) work and power
   (B) momentum and energy
   (C) force and power
   (D) work and energy
4. Which of the following is the moment of a force?
   (A) $[M^1L^1T^{-2}]$ (B) $[M^1L^2T^{-2}]$
   (C) $[M^1L^{-1}T^{-2}]$ (D) $[M^1L^1T^{-1}]$
5. The dimension of elastic constant is
   (A) $[M^1L^2T^{-2}]$ (B) $[M^1L^{-1}T^{-2}]$
   (C) $[M^{-1}L^2T^{-2}]$ (D) $[M^{-1}L^{-1}T^{-1}]$
6. The dimension of angular velocity is
   (A) $[M^1L^1T^{-1}]$ (B) $[M^1L^3T^{-1}]$
   (C) $[M^0L^0T^{-1}]$ (D) $[M^1L^{-1}T^{-1}]$
7. The dimension of power is
   (A) $[M^1L^2T^{-3}]$ (B) $[M^1L^3T^{-1}]$
   (C) $[M^1L^2T^{-1}]$ (D) $[M^1L^{-2}T^{-3}]$
8. Which of the following is the proper combination for force?
   (A) kg (B) metre/s^2
   (C) kg × m × m/s^2 (D) kg × m/s^2
9. A physical quantity may be defined as
   (A) the one having dimension.
   (B) that which is immeasurable.
   (C) that which has weight.
   (D) that which has mass.
10. $[M^1L^1T^{-1}]$ is an expression for _______.
    (A) force (B) energy
    (C) pressure (D) momentum
11. Dimensions of sin θ is
    (A) $[L^2]$ (B) $[M]$
    (C) $[ML]$ (D) $[M^0L^0T^0]$
12. Dimensions of surface tension is
    (A) $[M^1L^{-1}T^{-1}]$ (B) $[M^1L^0T^{-2}]$
    (C) $[M^1LT^{-1}]$ (D) $[M^2L^2T^{-1}]$
13. Dimensions of frequency is
    (A) $[M^{-1}L^3T^{-2}]$ (B) $[M^1L^1T^{-1}]$
    (C) $[M^0L^0T^{-1}]$ (D) $[M^1L^{-2}T^{-2}]$
14. The unit of energy is same as the unit of
    (A) power (B) momentum
    (C) work (D) force
15. Dyne-second stands for the unit of
    (A) force (B) momentum
    (C) energy (D) power
16. Which of the following quantities can be written as kg m^2 A^{-2} s^{-3} in S.I. units?
    (A) resistance (B) inductance
    (C) capacitance (D) magnetic flux
17. Error in the measurement of radius of a sphere is 1%. Then error in the measurement of volume is
    (A) 1% (B) 5%
    (C) 3% (D) 8%

18. Three measurements are made as 18.425 cm, 7.21 cm and 5.0 cm. The addition should be written as
(A) 30.635 cm (B) 30.64 cm
(C) 30.63 cm (D) 30.6 cm

19. Subtract 0.2 J from 7.26 J and express the result with correct number of significant figures
(A) 7.1 J (B) 7.06 J
(C) 7 .0 J (D) 7 J

20. The number of significant figure in 11.118×10^{-6} is
(A) 3 (B) 4
(C) 5 (D) 6

21. Zero error of an instrument introduces _______.
(A) systematic error (B) random error
(C) personal error (D) decimal error

22. Accuracy of measurement is determined by
(A) absolute error (B) percentage error
(C) human error (D) personal error

23. What is the % error in measurement of time period of a pendulum, if maximum errors in measurements of length and 'g' are 2% and 4% respectively?
(A) 6% (B) 3%
(C) 4% (D) 5%

24. When a current of (2.5 ± 0.5) A flows through a wire, it develops a potential difference of (20 ± 1) V. The resistance of wire is
(A) (8 ± 2) ohm (B) (8 ± 1.5) ohm
(C) (8 ± 0.5) ohm (D) (8 ± 3) ohm

25. A distance of about 50 cm is measured using a metre stick having mm division. The percentage error is
(A) 0.2 % (B) 0.4%
(C) 0.02% (D) 0.002%

26. The distance of the planet from the earth is measured by _______.
(A) direct method
(B) directly by metre scale
(C) spherometer method
(D) parallax method

27. The diameter of the paper pin is measured accurately by using _______.
(A) vernier callipers
(B) micrometer screw gauge
(C) metre scale
(D) a measuring tape

28. For measurement of mass of subatomic particles, which of the following method is suitable?
(A) Parallax method
(B) Mass spectro graph
(C) Method based on Newton's law of gravitation
(D) Lever balance

29. An atomic clock makes use of _______.
(A) cesium-133 atom (B) cesium-132 atom
(C) cesium-123 atom (D) cesium-131 atom

30. Dimensional equation for temperature gradient is
(A) $[M^1L^0T^1K^0]$ (B) $[M^0L^1T^0K^1]$
(C) $[M^0L^{-1}T^0K^{-1}]$ (D) $[M^0L^{-1}T^0K^1]$

31. The two stars S_1 and S_2 are located at distances d_1 and d_2 respectively. Also if $d_1 > d_2$ then following statement is true.
(A) The parallax of S_1 and S_2 are same.
(B) The parallax of S_1 is twice as that of S_2
(C) The parallax of S_1 is greater than parallax of S_2
(D) The parallax of S_2 is greater than parallax of S_1

32. 0.00849 contains ______ significant figures.
(A) 6 (B) 5
(C) 3 (D) 2

33. 50.000 contains ______ significant figures.
(A) 5 (B) 3
(C) 2 (D) 1

34. 3.310×10^2 has ______ significant figures.
(A) 6 (B) 4
(C) 2 (D) 1

35. Which of the following is NOT a fundamental quantity?
(A) Temperature (B) Electric charge
(C) Mass (D) Electric current

36. Which of the following is NOT a unit of time?
(A) Hour (B) Nano second
(C) Microsecond (D) Light year

37. Identify the pair, whose dimensions are equal
(A) Torque and work (B) Stress and energy
(C) Force and stress (D) Force and work

38. The Earth's radius is 6371 km. The order of magnitude of the Earth's radius is
(A) 10^3 m (B) 10^9 m
(C) 10^7 m (D) 10^2 m

Answers to Practice Problems

1. $127008\ \text{km h}^{-2}$
2. $10^5\ \text{Nm}^{-2}$
6. $\left(v_c = \frac{K\eta}{r\rho}\right)$
7. i. 10^3 m ii. 10^3 kg iii. 10^{-19} C
8. i 15.7 ii. 14260 iii. 6.00×10^5
9. 4.6×10^{-5}
10. $11.25\ \text{m}^3$
11. 41.3 ± 0.8 g
12. 42.0 ± 0.2 cm
13. 0.01 m, 0.004 m, 0.4%

Answers to Multiple Choice Questions

1.	(B)	2.	(C)	3.	(D)	4.	(B)
5.	(B)	6.	(C)	7.	(A)	8.	(D)
9.	(A)	10.	(D)	11.	(D)	12.	(B)
13.	(C)	14.	(C)	15.	(B)	16.	(A)
17.	(C)	18.	(D)	19.	(A)	20.	(C)
21.	(A)	22.	(B)	23.	(B)	24.	(A)
25.	(A)	26.	(D)	27.	(B)	28.	(B)
29.	(A)	30.	(D)	31.	(D)	32.	(C)
33.	(A)	34.	(B)	35.	(B)	36.	(D)
37.	(A)	38.	(C)				

Hints to Multiple Choice Questions

3. $[\text{Work}] = [\text{Force}] \cdot [\text{Displacement}]$
$= [M^1L^1T^{-2}] \cdot [L^1]$
$= [M^1L^2T^{-2}]$
$[\text{Energy}] = [\text{Mass}]\,[\text{Velocity}]^2$
$= [M^1]\,[L^1T^{-1}]^2 = [M^1L^2T^{-2}]$
Hence, [Work] = [Energy]

5. $$[\text{Elastic constant}] = \frac{[\text{stress}]}{[\text{strain}]}$$
$$= \frac{[\text{Force / Area}]}{[\text{Ratio of same physical quantities}]}$$
$$= \frac{[\text{Force}]}{[\text{Area}]} = \frac{[M^1L^1T^{-2}]}{[L^2]} = [M^1L^{-1}T^{-2}]$$

8. $[\text{Force}] = [\text{Mass}] \cdot [\text{Acceleration}]$
$$= [\text{Mass}] \cdot \left[\frac{\text{Velocity}}{\text{Time}}\right]$$
$$= \frac{[\text{Mass}] \cdot \left[\frac{\text{Distance}}{\text{Time}}\right]}{[\text{Time}]}$$
$$= \frac{[\text{Mass}][\text{Distance}]}{[\text{Time}]^2}$$
$$= \frac{[M^1][L^1]}{[T^2]} = [M^1L^1T^{-2}]$$
which is the correct option.
For option (C): $[\text{kg} \times \text{m} \times \text{m/sec}^2]$
$$= \left[M^1 \times L^1 \times \frac{L^1}{T^2}\right]$$
$= [M^1L^2T^{-2}]$.
which is incorrect.
For option (B): $[\text{metre/sec}^2]$
$$= \frac{[L^1]}{[T^2]} = [M^0L^1T^{-2}]$$
which is incorrect.
For option (A): $[\text{kg}] = [M^1\ L^0\ T^0]$
which is incorrect.

13. $$[\text{Frequency}] = \frac{[\text{Number of oscillations}]}{[\text{Time}]}$$
$$= \frac{[M^0L^0T^0]}{[T^1]} = [M^0L^0T^{-1}]$$

17. $V = \frac{4}{3}\pi r^3$
$\therefore$ % error in V = 3 × % error in r = 3 × 1% = 3%

18. 18.425 cm + 7.21 cm + 5.0 cm = 30.635 cm.
Performing addition, the number of significant figures in the sum must be equal to those in the number having the smallest number of decimal places. Such a number in the given example is 5.0 carrying only one decimal place. Hence the sum, 30.635 must be rounded to one decimal place yielding 30.6 cm.

25. Here, the Least count of the stick = 1 mm
= 0.1 cm.
Magnitude of the distance to be measured using the stick = 50 cm.
$\therefore$ % error = $\frac{0.1 \times 100}{50}$% = 0.2%.