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- Govt. Model Question Paper - 2018 ***[Govt. MQP-2018]***, First Mid-Term Test - 2018 ***[First Mid-2018]***, Quarterly Exam - 2018, 2019, 2023 & 2024 ***[QY-2018, 2019, '23 & '24]***, Half Yearly Exam- 2018, 2019 & 2023 ***[HY-2018, 2019 & '23]***, Public Exam. March - 2019, 2020, May - 2022, March 2023 & 2024 ***[Mar-2019, 2020, May - 2022, Mar-'23 & '24]***, Instant Supplementary Exam June - 2019, August - 2022, June 2023 & July - 2024 ***[June-2019, Aug- '22, June '23 & July '24]***, Govt. Suppl. Exam September - 2020 & 2021 ***[Sep.2020 & Sep.2021]*** and Common Revision Test ***[CRT- '22]*** questions are incorporated in the appropriate sections.
- Half Yearly Exam - December 2024-25 Question Paper is given with answers.

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Our guide encompasses all the requirements of the students to comprehend the text and the evaluation of the textbook.

It will be a teaching companion to teachers and a learning companion to students.

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CONTENTS

SYLLABUS

S.NO	Topic	Month
1	Nature of Physical World and Measurement	June
	Kinematics (2.1 - 2.9)	
2	Kinematics (2.10 - 2.11.6)	July
	Laws of motion (3.1 - 3.4)	
	I MID TERM (June, July)	
3	Laws of motion (3.5 - 3.7.7)	August
	Work, Energy and Power	
4	Motion of System of Particles and Rigid Bodies	September
	Gravitation (6.1 - 6.2.5)	
	QUARTERLY EXAMINATION (June to September)	
5	Gravitation (6.3 - 6.5.5)	October
	Properties of Matter	
	Heat and Thermodynamics (8.1 - 8.6.5)	
6	Heat and Thermodynamics (8.7 - 8.10)	November
	Kinetic Theory of Gases	
	Oscillations (10.1 - 10.3.2)	
	II MID TERM (October, November)	
7	Oscillations (10.4 - 10.6.5)	December
	Waves	
	HALF YEARLY EXAMINATION (Full Portion)	

PHYSICS

VOLUME - I

CONTENTS

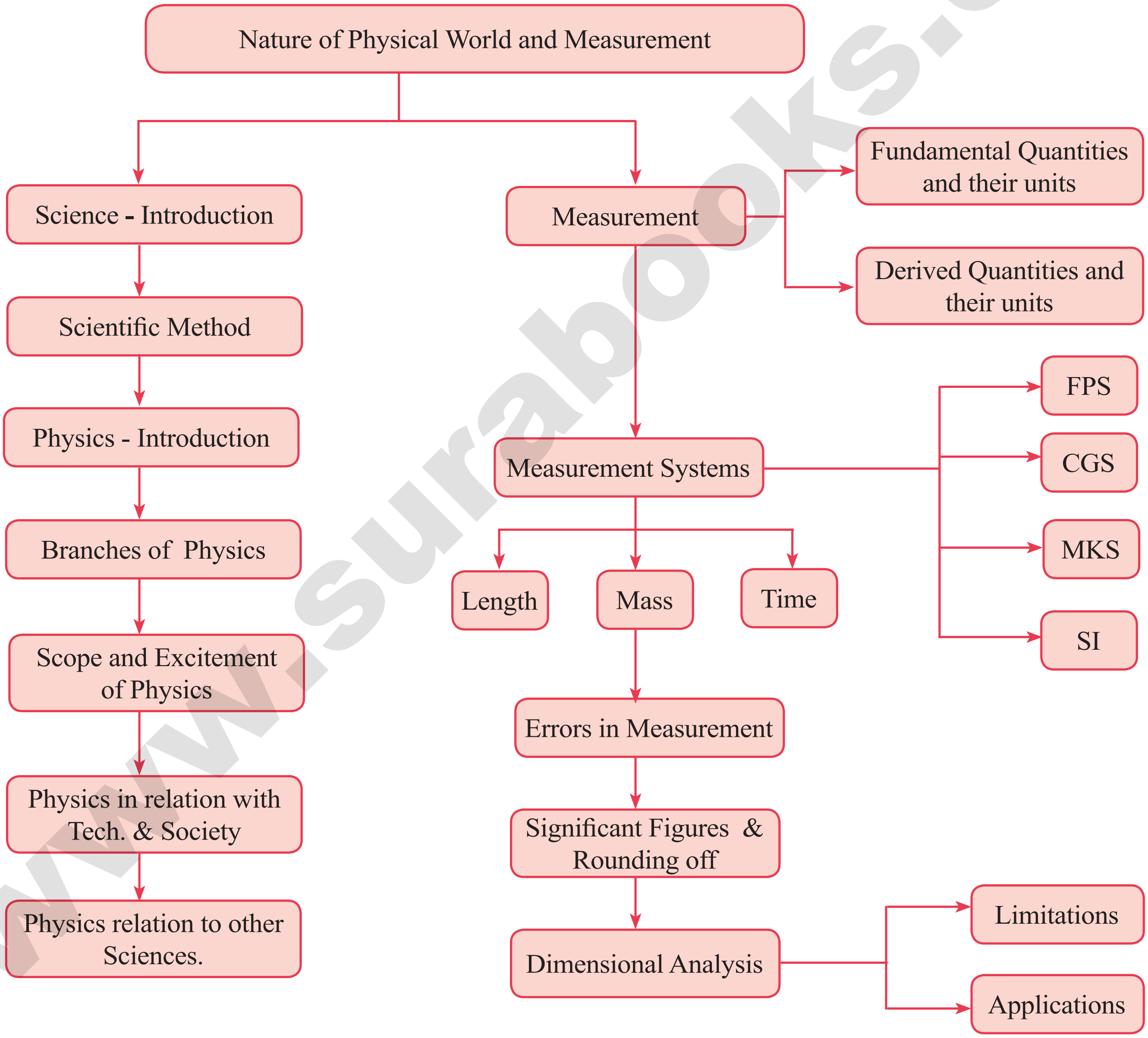
VOLUME - I

UNIT

01

Nature of Physical World and Measurement

Concept Map



FORMULAE TO REMEMBER

(1) Distance travelled by light in one year in vacuum = [velocity of light × 1 year in seconds]
$= 3 \times 10^8 \times 365.25 \times 24 \times 60 \times 60$
$= 9.467 \times 10^{15}$m

(2) π radian = 180°

(3) 1 radian = $\frac{180^\circ}{\pi} = \frac{180^\circ \times 7}{22} = 57.27^\circ$

(4) Also 1° (degree of arc) = 60′ (minute of arc) and 1′ (minute of arc) = 60″ (seconds of arc)

Relations between radian, degree and minutes:

(5) $1^\circ = \frac{\pi}{180}$ rad $= 1.745 \times 10^{-2}$ rad

(6) $1' = \frac{1^\circ}{60} = \frac{1.745 \times 10^{-2}}{60}$ $= 2.908 \times 10^{-4}$ rad
$\approx 2.91 \times 10^{-4}$ rad

(7) $1'' = \frac{1^\circ}{3600} = \frac{1.745 \times 10^{-2}}{3600}$ $= 4.847 \times 10^{-6}$ rad
$\approx 4.85 \times 10^{-6}$ rad

(8) Derived unit:
Example : unit of speed = $\frac{\text{unit of distance}}{\text{unit of time}} = \frac{\text{m}}{\text{s}} = \text{ms}^{-1}$

(9) Absolute error $a_m = \frac{a_1 + a_2 + a_3 + ...+ a_n}{n}$ or $a_m = \frac{1}{n}\sum_{i=1}^{i=n} a_i$; $a_m \rightarrow$ true value of measured quantity, $n \rightarrow$ number of values

(10) Mean Absolute error $\Delta a_m = \frac{1}{n}\sum_{i=1}^{n} |\Delta a_i|$; $\Delta a_m \rightarrow$ Mean absolute error, $n \rightarrow$ number of values

(11) Relative error (or) Fractional error $\Delta a = \frac{\Delta a_m}{a_m}$; $a_m \rightarrow$ Mean value

(12) Percentage error, $\Delta a = \frac{\Delta a_m}{a_m} \times 100\%$

SOME COMMON PRACTICAL UNITS

(1) 1 Fermi, 1 fm = 10^{-15} m
(2) 1 Angstrom, 1Å = 10^{-10} m
(3) 1 nanometer, 1nm = 10^{-9} m
(4) 1 micron (or) micro meter, 1μm = 10^{-6} m
(5) 1 Light year = 9.467×10^{15}m
(6) 1 Astronomical unit, 1 AU = 1.496×10^{11} m
(7) 1 Parallactic second, 1 parsec = 3.08×10^{16} m = 3.26 light year
(8) 1 CSL = 1.4 times, the mass of the sun
(9) 1 shake = 10^{-8} s (or) 10 nanoseconds

Prefixes for Powers of Ten

Multiple	Prefix	Symbol	Sub multiple	Prefix	Symbol
10^1	deca	da	10^{-1}	deci	d
10^2	hecto	h	10^{-2}	centi	c
10^3	kilo	k	10^{-3}	milli	m
10^6	mega	M	10^{-6}	micro	μ
10^9	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

IMPORTANT TERMS & DEFINITIONS

Science : Science is the systematic organization of knowledge gained through observation, experimentation and logical reasoning.

Physics : Physics is most basic science which deals with study of nature and natural phenomena.

Unification : Attempting to explain diverse physical phenomena with a few concepts and laws.

Reductionism : An attempt to explain a macroscopic system in terms of its microscopic constituents.

Technology	:	The application of the principles of physics, i.e. knowledge for practical purposes in various fields to invent and produce useful products or to solve problems.
Classical mechanics	:	The study of forces acting on bodies whether at rest or in motion
Thermodynamics	:	The study of the relationship between heat and other forms of energy
Optics	:	The study of light
Electricity and magnetism	:	The study of electricity and magnetism and their mutual relationship
Acoustics	:	The study of the production and propagation of sound waves
Astrophysics	:	The branch of physics which deals with the study of the physics of astronomical bodies
Relativity	:	One of the branches of theoretical physics which deals with the relationship between space, time and energy particularly with objects moving in different ways .
Quantum mechanics	:	The study of the discrete nature of phenomena at the atomic and subatomic levels
Atomic physics	:	The branch of physics which deals with the structure and properties of the atom
Nuclear physics	:	The branch of physics which deals with the structure, properties and reaction of the nuclei of atoms.
Condensed matter physics	:	The study of the properties of condensed materials (solids, liquids and those intermediate between them and dense gas). It branches into various sub-divisions including developing fields such as nano science, photonics etc. It covers the basics of materials science, which aims at developing new material with better properties for promising applications.
High energy physics	:	The study of the nature of the particles.
Range of time scales	:	Astronomical scales to microscopic scales, 10^{18}s to 10^{-22}s.
Range of masses	:	From heavenly bodies to electron, 10^{55} kg (mass of known observable universe) to 10^{-31} kg (mass of an electron) [the actual mass of an electron is 9.11×10^{-31} Kg].
Measurement	:	The comparison of any physical quantity with its standard unit is known as measurement.
Physical Quantities	:	Quantities that can be measured, and in terms of which, laws of physics are described are called physical quantities.
Fundamental Quantities	:	Fundamental or base quantities are quantities which cannot be expressed in terms of any other physical quantities. These are length, mass, time, electric current, temperature, luminous intensity and amount of substance.
Derived Quantities	:	Quantities that can be expressed in terms of fundamental quantities are called derived quantities. Eg. area, volume, velocity, acceleration, force.
Unit of the quantity	:	An arbitrarily chosen standard of measurement of a quantity, which is accepted internationally is called unit of the quantity.

Fundamental or base units	:	The units in which the fundamental quantities are measured are called fundamental or base units.
Derived Unit	:	The units of measurement of all other physical quantities, which can be obtained by a suitable multiplication or division of powers of fundamental units, are called derived units.
System of units	:	A complete set of units which is used to measure all kinds of fundamental and derived quantities is called a system of units.
Radian (rad)	:	One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.
Steradian (sr)	:	One steradian is the solid angle subtended at the centre of a sphere, by that surface of the sphere, which is equal in area, to the square of radius of the sphere
macrocosm	:	Large objects like the galaxy, stars, Sun, Earth, Moon etc., and their distances constitute a macrocosm. It refers to a large world, in which both objects and distances are large.
Microcosm	:	Objects like molecules, atoms, proton, neutron, electron, bacteria etc., and their distances constitute microcosm, which means a small world in which both objects and distances are small-sized.
Parallax	:	The shift in the position of an object (say, a pen) when viewed with two eyes, keeping one eye closed at a time is known as Parallax.
Accuracy	:	Accuracy refers to how far we are from the true value.
Precision	:	Precision refers to how well we measure.
Systematic errors	:	Systematic errors are reproducible inaccuracies that are consistently in the same direction.
Least count error	:	Least count is the smallest value that can be measured by the measuring instrument, and the error due to this measurement is least count error.
Astronomical unit	:	It is the mean distance of the centre of sun from the centre of earth $1AU = 1.496 \times 10^{11}$m
Light year	:	It is the distance travelled by light in vacuum in one year. 1 light year $= 9.467 \times 10^{15}$ m.
Significant figures	:	The digits which tell us the number of units we are reasonably sure of having counted in making a measurement are called significant figures.
Error measurement	:	The uncertainty in the measurement of a physical quantity is called error. Error = True value – Measured value
Dimensions	:	Dimensions of a physical quantity are the powers to which the fundamental quantities must be raised.
Dimensional constant	:	Physical quantities which possess dimensions and have constant values are called dimensional constants.
Dimensionless constant	:	Quantities which have constant values and also have no dimensions are called dimensionless constants.
Principle of homogeneity of Dimensions	:	The principle of homogeneity of dimensions states that the dimensions of all the terms in a physical expression should be the same.

EVALUATION

I. Multiple Choice Questions:

1. One of the combinations from the fundamental physical constants is $\frac{hc}{G}$. The unit of this expression is *[QY-'24]*

(a) kg^2 (b) m^3 (c) s^{-1} (d) m

[Ans. (a) kg^2]

2. If the error in the measurement of radius is 2%, then the error in the determination of volume of the sphere will be *[Sep. - 2020; QY-'23; Mar-'24]*

(a) 8% (b) 2% (c) 4% (d) 6%

[Ans. (d) 6%]

3. If the length and time period of an oscillating pendulum have errors of 1% and 3% respectively then the error in measurement of acceleration due to gravity is *[July-'24]* *[Related to AMPMT 2008] [HY-2018]*

(a) 4% (b) 5% (c) 6% (d) 7%

[Ans. (d) 7%]

4. The length of a body is measured as 3.51 m, if the accuracy is 0.01m, then the percentage error in the measurement is *(Mar-2020)*

(a) 351% (b) 1%
(c) 0.28% (d) 0.0s35%

[Ans. (c) 0.28%]

5. Which of the following has the highest number of significant figures?

(a) $0.007\ m^2$ (b) 2.64×10^{24} kg
(c) $0.0006032\ m^2$ (d) 6.3200 J

[Ans. (d) 6.3200 J]

6. If $\pi = 3.14$, then the value of π^2 is *[QY. - 2018; Jun.-2019; CRT & May - 2022]*

(a) 9.8596 (b) 9.860
(c) 9.86 (d) 9.9 **[Ans. (c) 9.86]**

7. Round of the following number 19.95 into three significant figures. *[Mar-'23]*

(a) 19.9 (b) 20.0
(c) 20.1 (d) 19.5 **[Ans. (b) 20.0]**

8. Which of the following pairs of physical quantities have same dimension? *[Mar-2019;Aug-'22; June-'23]*

(a) force and power (b) torque and energy
(c) torque and power (d) force and torque

[Ans. (b) torque and energy]

9. The dimensional formula of Planck's constant *h* is *[JEE Main; NEET; Sep-2021; HY-'23]*

(a) $[ML^2T^{-1}]$ (b) $[ML^2T^{-3}]$
(c) $[MLT^{-1}]$ (d) $[ML^3T^{-3}]$

[Ans. (a) $[ML^2T^{-1}]$]

10. The velocity of a particle *v* at an instant t is given by $v = at + bt^2$. The dimensions of *b* is

(a) [L] (b) $[LT^{-1}]$
(c) $[LT^{-2}]$ (d) $[LT^{-3}]$

[Ans. (d) $[LT^{-3}]$]

11. The dimensional formula for gravitational constant G is *[Related to AIPMT 2004]*

(a) $[ML^3T^{-2}]$ (b) $[M^{-1}L^3T^{-2}]$
(c) $[M^{-1}L^{-3}T^{-2}]$ (d) $[ML^{-3}T^2]$

[Ans. (b) $[M^{-1}L^3T^{-2}]$]

12. The density of a material in CGS system of units is $4\ g\ cm^{-3}$. In a system of units in which unit of length is 10 cm and unit of mass is 100 g, then the value of density of material will be

(a) 0.04 (b) 0.4 (c) 40 (d) 400

[Ans. (c) 40]

13. If the force is proportional to square of velocity, then the dimension of proportionality constant is *[JEE–2000] [QY-2019]*

(a) $[MLT^0]$ (b) $[MLT^{-1}]$
(c) $[ML^{-2}T]$ (d) $[ML^{-1}T^0]$

[Ans. (d) $[ML^{-1}T^0]$]

14. The dimension of $(\mu_0\varepsilon_0)^{-\frac{1}{2}}$ is *[HY-2019; CRT-'22]* *[Main AIPMT 2011]*

(a) length (b) time
(c) velocity (d) force

[Ans. (c) velocity]

15. Planck's constant (*h*), speed of light in vacuum (c) and Newton's gravitational constant (G) are taken as three fundamental constants. Which of the following combinations of these has the dimension of length? *[NEET 2016 (phase II)]*

(a) $\frac{\sqrt{hG}}{c^{\frac{3}{2}}}$ (b) $\frac{\sqrt{hG}}{c^{\frac{5}{2}}}$ (c) $\sqrt{\frac{hc}{G}}$ (d) $\sqrt{\frac{Gc}{h^{\frac{3}{2}}}}$

[Ans. (a) $\frac{\sqrt{hG}}{c^{\frac{3}{2}}}$]

II. Short Answer Questions.

1. Briefly explain the types of physical quantities.

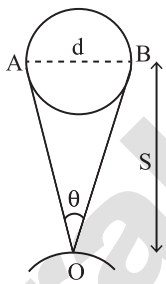
Ans. (i) Physical quantities are classified into two types. There are fundamental and derived quantities.

(ii) Fundamental or base quantities are quantities which cannot be expressed in terms of any other physical quantities. These are length, mass, time, electric current, temperature, luminous intensity and amount of substance.

(iii) Quantities that can be expressed in terms of fundamental quantities are called derived quantities. For example, area, volume, velocity, acceleration, force, etc.

2. How will you measure the diameter of the Moon using parallax method? *[HY-2018 &'19; QY-'19]*

Ans. O - observation point on earth.



(i) In diagram, O is the observation point on the earth and d is the diameter of moon. An astronomical telescope held at O is focussed on moon, the image is observed into moon of a circular disc.

(ii) $\angle AOB = \theta$

S - average distance between moon and the surface of earth.

(iii) As 'S' is very large compared to the diameter, d of the moon, the diameter of the moon is considered as a circular arc of radius, S.

$d = S \times \theta$.

Hence d can be calculated, when 'S' is known and θ is measured.

3. Write the rules for determining significant figures. *[Mar-'23]*

Ans. (i) All non-zero digits are significant

(ii) All zeros between two non-zero digits are significant

(iii) All zeros to the right of a non-zero digit but to the left of a decimal point are significant.

(iv) For the number without a decimal point, the terminal or trailing zero(s) are not significant.

(v) If the number is less than 1, the zero (s) on the right of the decimal point but to left of the first non-zero digit are not significant.

(vi) All zeros to the right of a decimal point and to the right of non-zero digit are significant.

(vii) The number of significant figures does not depend on the system of units used.

4. What are the limitations of dimensional analysis? *[Govt. MQP-2018; HY-2018; Jun.-2019; CRT & Aug-'22; QY-'23; Mar-'24]*

Ans. **Limitations of Dimensional analysis:**

(i) This method gives no information about the dimensionless constants in the formula like 1, 2, ……..π,e, etc.

(ii) This method cannot decide whether the given quantity is a vector or a scalar.

(iii) This method is not suitable to derive relations involving trigonometric, exponential and logarithmic functions.

(iv) It cannot be applied to an equation involving more than three physical quantities.

(v) It can only check on whether a physical relation is dimensionally correct but not the correctness of the relation.

For example using dimensional analysis, $s = ut + 1/3\ at^2$ is dimensionally correct whereas the correct relation is $s = ut + 1/2\ at^2$.

5. Define precision and accuracy. Explain with one example. *[QY-'24]*

Ans. **Precision:** The closeness of two or more measurements to each other is known as precision.

Accuracy: The closeness of a measured value to the actual value of the object being measured is called accuracy.

Example: Suppose a man's true height is exactly 5′9″. When it is measured with a yardstick, the value is 5′0″. Hence measurement is not accurate. When height is measured with a laser yardstick, the value is 5′9″ then measurement is accurate.

If the height is measured consistently as 5′0″ with a yardstick, then measurements are precise.

III. Long Answer Questions

1. (i) Explain the use of screw gauge and vernier caliper in measuring smaller distances.

(ii) Write a note on triangulation method and radar method to measure larger distances.

[Govt. MQP-2018; Aug-'22; QY-'24]

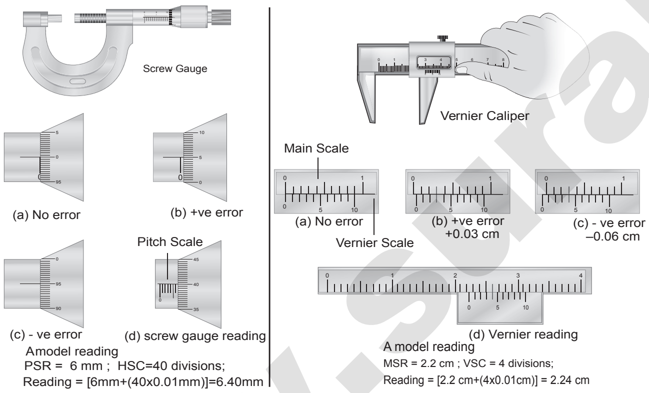
Ans. **Measurement of small distances:**

(i) (1) The **screw gauge** is an instrument used for measuring accurately the dimensions of objects up to a maximum of about 50 mm.

(2) The principle of the instrument is the magnification of linear motion using the circular motion of a screw.

(3) The least count of the screw gauge is 0.01 mm.

(4) A **vernier caliper** is a versatile instrument for measuring the dimensions of an object namely diameter of a hole, or a depth of a hole. The least count of vernier caliper is 0.01 cm.



Screw gauge and vernier caliper with errors

(ii) Triangulation method for the height of an accessible object:

[Mar-2020; CRT-'22; June & QY-'23]

(1) Let AB = h be the height of the tree or tower to be measured. Let C be the point of observation at distance x from B. Place a range finder at C and measure the angle of elevation, $\angle ACB = \theta$ as shown in Figure.

(2) From right-angled triangle ABC, $\tan\theta = \frac{AB}{BC} = \frac{h}{x}$

(or) height $h = x \tan\theta$.

(3) Knowing the distance x, the height h can be determined.

RADAR method *[First Mid-2018; July-'24]*

(1) The word RADAR stands for radio detection and ranging.

(2) A radar can be used to measure accurately the distance of a nearby planet such as Mars. In this method, radio waves are sent from transmitters which, after reflection from the planet, are detected by the receiver.

(3) By measuring, the time interval (t) between the instants the radio waves are sent and received, the distance of the planet can be determined as

Speed = distance travelled / time taken

Distance(d) = Speed of radio waves × time taken

$$d = \frac{v \times t}{2}$$

(4) where v is the speed of the radio wave. As the time taken (t) is for the distance covered during the forward and backward path of the radio waves, it is divided by 2 to get the actual distance of the object.

(5) This method can also be used to determine the height, at which an aeroplane flies from the ground.

2. Explain in detail the various types of errors.

[Mar & QY-2019; June-'23]

Ans. **Types of errors :**

(a) Systematic error (b) Random error

(c) Gross error

(a) Systematic errors : *[June-'23]*

They are reproducible inaccuracies that are consistently in the same direction.

It is classified as follows :

(1) **Instrumental errors :** It arises when an instrument is not calibrated properly at the time of manufacturing. It can be corrected by choosing accurate instruments.

(2) **Imperfections in experimental technique or procedure:** It is due to the limitations in the experimental arrangement. To overcome this, necessary and proper correction is to be applied.

(3) **Personal errors :** These errors are due to individuals performing the experiment, may be due to incorrect initial setting up of the experiment or carelessness of the individual making the observation due to improper precautions.

(4) **Errors due to external causes :** The change in the external conditions during an experiment can cause error in measurement. For example, changes in temperature, humidity, or pressure during measurements may affect the result of the measurement.

(5) **Least count error :** Least count is the smallest value that can be measured by the measuring instrument, and the error due to this measurement is least count error.

(b) **Random error :**

(1) It arises due to random and unpredictable variations in experimental conditions like pressure, temperature, voltage supply, etc.

(2) It also arises due to personal errors by the observer. It is sometimes called 'chance errors'.

(3) It can be minimised by repeating the observations a large number of times and taking the arithmetic mean of all the observations.

(c) **Gross error :**

(1) The error caused due to the shear carelessness of an observer is called gross error.

(2) It can be minimized only when an observer is careful and mentally alert.

3. What do you mean by propagation of errors? Explain the propagation of errors in addition and multiplication. *[Mar-2020]*

Ans. A number of measured quantities may be involved in the final calculation of an experiment. Different types of instruments might have been used for taking readings. Then we may have to look at the errors in measuring various quantities, collectively.

The error in the final result depends on

(i) The errors in the individual measurements

(ii) On the nature of mathematical operations performed to get the final result. So we should know the rules to combine the errors.

The various possibilities of the propagation or combination of errors in different mathematical operations are discussed below:

(i) **Error in the sum of two quantities :**

Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively. Then,

Measured value of A = A ± ΔA

Measured value of B = B ± ΔB

Consider the sum, Z = A + B

The error ΔZ in Z is then given by

$$Z \pm \Delta Z = (A \pm \Delta A) + (B \pm \Delta B)$$
$$= (A + B) \pm (\Delta A + \Delta B)$$
$$= Z \pm (\Delta A + \Delta B)$$
$$\text{(or) } \Delta Z = \Delta A + \Delta B$$

The maximum possible error in the sum of two quantities is equal to the sum of the absolute errors in the individual quantities.

(ii) **Error in the product of two quantities**

Let ΔA and ΔB be the absolute errors in the two quantities, A and B, respectively. Consider the product Z = AB

The error ΔZ in Z is given by

$$Z \pm \Delta Z = (A \pm \Delta A)(B \pm \Delta B)$$
$$= (AB) \pm (A\,\Delta B) \pm (B\,\Delta A) \pm (\Delta A \cdot \Delta B)$$

Dividing L.H.S by Z and R.H.S by AB, we get,

$$1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta B}{B} \pm \frac{\Delta A}{A} \pm \frac{\Delta A}{A} \cdot \frac{\Delta B}{B}$$

As ΔA /A, ΔB / B are both small quantities, their product term $\frac{\Delta A}{A} \cdot \frac{\Delta B}{B}$ can be neglected.

The maximum fractional error in Z is

$$\frac{\Delta Z}{Z} = \pm\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$$

The maximum fractional error in the product of two quantities is equal to the sum of the fractional errors in the individual quantities.

4. Write short notes on the following.

(a) Unit (b) Rounding - off

(c) Dimensionless quantities

Ans. (a) **Unit :** An arbitrarily chosen standard of measurement of a quantity, which is accepted internationally is called unit of the quantity. The units in which the fundamental quantities are measured are called fundamental or base units and the units of measurement of all other physical quantities, which can be obtained by a suitable multiplication or division of powers of fundamental units are called derived units.

(b) **Rounding - off :** The result given by a calculator has too many figures. In no case should the result have more significant figures than the figures involved in the data used for calculation. The result of calculation with numbers containing more than one uncertain digit should be rounded off.

(c) Dimensionless quantities :

There are two types of dimensionless quantities.

(i) Dimensionless Variables:

Physical quantities which have no dimensions, but have variable values are called dimensionless variables. Examples are specific gravity, strain, refractive index etc.

(ii) Dimensionless Constant:

Quantities which have constant values and also have no dimensions are called dimensionless constants. Examples are π, e, numbers, etc.

5. Explain the principle of homogeneity of dimensions. Give example. *[HY-'18 & '19; June-'23; July & QY-'24]*

Ans. **Principle of homogeneity of dimensions :**

The principle of homogeneity of dimensions states that the dimensions of all the terms in a physical expression should be the same. For example, in the physical expression $v^2 = u^2 + 2as$, the dimensions of v^2, u^2 and 2 as are the same and equal to $[L^2T^{-2}]$.

(i) To convert a physical quantity from one system of units to another

(i) This is based on the fact that the product of the numerical values (n) and its corresponding unit (u) is a constant. i.e, $n\ [u]$ = constant (or) $n_1[u_1] = n_2[u_2]$.

(ii) Consider a physical quantity which has dimension 'a' in mass, 'b' in length and 'c' in time. If the fundamental units in one system are M_1, L_1 and T_1 and the other system are M_2, L_2 and T_2 respectively, then we can write, $n_1\ [M_1^a\ L_1^b\ T_1^c] = n_2\ [M_2^a\ L_2^b\ T_2^c]$

Example: Convert 76 cm of mercury pressure into Nm^{-2} using the method of dimensions.

Solution: In *cgs* system 76 cm of mercury pressure = 76 × 13.6 × 980 dyne cm^{-2}

The dimensional formula of pressure P is $[ML^{-1}T^{-2}]$

(ii) To check the dimensional correctness of a given physical equation

Let us take the equation of motion $v=u+at$

Apply dimensional formula on both sides

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

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

Example: Check the correctness of the equation $\frac{1}{2}mv^2 = mgh$ using dimensional analysis method. *[CRT & May-2022]*

Solution: Dimensional formula for

$\frac{1}{2}mv^2 = [M][LT^{-1}]^2 = [ML^2T^{-2}]$

Dimensional formula for

$mgh = [M]\ [LT^{-2}][L] = [ML^2T^{-2}]$

$[ML^2T^{-2}] = [ML^2T^{-2}]$

Both sides are dimensionally the same, hence the equations $\frac{1}{2}mv^2 = mgh$ is dimensionally correct.

(iii) To establish the relation among various physical quantities

If the physical quantity Q depends upon the quantities Q_1, Q_2 and Q_3 ie. Q is proportional to Q_1, Q_2 and Q_3.

Then, $Q \propto Q_1^a\ Q_2^b\ Q_3^c$

$Q = k\ Q_1^a\ Q_2^b\ Q_3^c$

where k is a dimensionless constant. When the dimensional formula of Q, Q_1, Q_2 and Q_3 are substituted, then according to the principle of homogeneity, the powers of M, L, T are made equal on both sides of the equation.

Example: Obtain an expression for the time period T of a simple pendulum. The time period T depends on (i) mass 'm' of the bob (ii) length 'l' of the pendulum and (iii) acceleration due to gravity g at the place where the pendulum is suspended. (Constant k = 2π) i.e

Solution: $T \propto m^a\ l^b\ g^c$; $T = km^a\ l^b\ g^c$

Here k is the dimensionless constant. Rewriting the above equation with dimensions

$[T^1] = [M^a][L^b][LT^{-2}]^c$

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

Comparing the powers of M, L and T on both sides, a=0, b+c=0, –2c = 1

Solving for a,b and c a = 0, b = 1/2, and c = −1/2

From the above equation $T = km^0 \; l^{1/2} g^{-1/2}$

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

Experimentally k = 2π, hence $T = 2\pi\sqrt{\frac{l}{g}}$

IV. Numerical Problems.

1. In a submarine equipped with sonar, the time delay between the generation of a pulse and its echo after reflection from an enemy submarine is observed to be 80 s. If the speed of sound in water is 1460 ms^{-1}. What is the distance of enemy submarine? *[May - 2022]*

Solution:

The speed of sound in water $v = 1460$ ms^{-1}

Time taken by the pulse for to and fro :

$$t = \frac{T}{2} = \frac{80s}{2} = 40s$$

Formula : $v = \frac{d}{t}$

$$\therefore d = v \times \frac{T}{2} = 1460 \times 40$$

$$= 58400 \text{ m or } 58.40 \text{ km.}$$

2. The radius of the circle is 3.12 m. Calculate the area of the circle with regard to significant figures. *[QY-2019]*

Solution:

Radius of the circle r = 3.12 m

Area of the circle A = ?

$A = \pi r^2 = 3.14 \times 3.12 \times 3.12 = 30.566016$

According to the rule of significant fig, A = 30.6 m^2 [Given data has three sig. fig.]

3. Assuming that the frequency γ of a vibrating string may depend upon (i) applied force (F) (ii) length (l) (iii) mass per unit length (m), prove that $\gamma \propto \frac{1}{l}\sqrt{\frac{F}{m}}$ using dimensional analysis. (related to JIPMER 2001; *QY & HY-'23; Mar-'24*)

Solution:

$\gamma \propto l^a F^b m^c$; $\gamma = K\, l^a F^b m^c$ ...(1)

K - dimensionless constant of proportionality

a, b, c - powers of l, F, m

Dimensional Formula of F = $[MLT^{-2}]$

Dimensional Formula of linear density

$$m = \frac{\text{mass}}{\text{length}} = \frac{[M]}{[L]} = [M^1 L^{-1} T^0] = [M^1 L^{-1}]$$

writing dimensions of $\gamma = K\, l^a F^b m^c$

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

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

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

Applying the principle of homogeneity of dimension

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

$a + b - c = 0$ ...(3)

$-2b = -1$ or $\boxed{b = +\frac{1}{2}}$

From (2) $c = -b = -\frac{1}{2}$ $\therefore \boxed{c = -\frac{1}{2}}$

From (3) $a + \frac{1}{2} - (-\frac{1}{2}) = 0 \Rightarrow a + \frac{1}{2} + \frac{1}{2} = 0$

$\therefore \boxed{a = -1}$

Substituting the values a, b, c in (1)

$\gamma = K\, l^{-1} F^{\frac{1}{2}} m^{-\frac{1}{2}}$ $\because K = 1$

$\gamma = \frac{1}{l}\sqrt{\frac{F}{m}}$

Hence proved.

4. Jupiter is at a distance of 824.7 million km from the Earth. Its angular diameter is measured to be 35.72″. Calculate the diameter of Jupiter.

Solution: Distance of Jupiter from the earth,

$D = 824.7 \times 10^6$ km

$D = 824.7 \times 10^9$ m

Angular diameter θ = 35.72"

$= 35.72 \times (4.85 \times 10^{-6}$ rad)

$[\because 1" = 4.85 \times 10^{-6}$ rad]

Diameter of Jupiter, d = ?

$$\theta = \frac{d}{D}$$

$\therefore d = \theta.D$

$= (824.7 \times 10^9) \times 35.72 \times 4.85 \times 10^{-6}$

$= 142872.677 \times 10^3$ m

$= 142872.677 \times 10^3 \times 10^{-3}$ km

$d = 1.428 \times 10^5$ km.

5. The measurement value of length of a simple pendulum is 20 cm known with 2 mm accuracy. The time for 50 oscillations was measured to be 40 s within 1s resolution. Calculate the percentage accuracy in the determination of acceleration due to gravity 'g' from the above measurement.

Solution:

$$T = 2\pi\sqrt{l/g} \Rightarrow T^2 = 4\pi^2 . \, l/g$$

$$\therefore g = 4\pi^2 \, l/T^2$$

The errors in both l & T are least count errors

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$$

Length of simple pendulum l = 20 cm

accuracy Δl = 2mm = 0.2 cm

Time for 50 oscillations T = 40 s

Resolution ΔT = 1 s

$$\therefore \frac{\Delta g}{g} = \left(\frac{0.2}{20}\right) + 2\left(\frac{1}{40}\right) = \frac{0.2}{20} + \frac{2}{40}$$

$$= \frac{0.4+2}{40} = \frac{2.4}{40} = \frac{1.2}{20}$$

Percentage error

$$\frac{\Delta g}{g} \times 100 = \frac{1.2}{20} \times 100 = \pm 6\%$$

% accuracy in g = 6%.

Government Exam Question & Answers

I. Multiple Choice Questions :

1 Mark

1. Which of the following physical quantities have same dimensional formula? *[Govt. M.Q.P - 2018; HY-2018]*

(a) Torque and Work done
(b) Energy and Angular momentum
(c) Force and Torque
(d) Angular momentum and Linear momentum

[Ans. (a) Torque and Work done]

2. A substance whose mass is 4.27 g occupies 1. 3 cm^3. The number of significant figure in density is *[Govt. M.Q.P - 2018]*

(a) 1 (b) 2 (c) 3 (d) 4

[Ans. (d) 4]

3. The maximum value of fractional error in division of two quantities i.e., $x = \frac{A}{B}$ is *[Govt. M.Q.P - 2018]*

(a) $\frac{\Delta x}{x} = \pm\left(\frac{\Delta A}{A} - \frac{\Delta B}{B}\right)$ (b) $\frac{\Delta x}{x} = \left(-\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$

(c) $\frac{\Delta x}{x} = \left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$ (d) $\frac{\Delta x}{x} = \left(\frac{A}{\Delta A} + \frac{B}{\Delta B}\right)$

[Ans. (c) $\frac{\Delta x}{x} = \left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$]

4. The dimensions of physical quantity X in the equation Force = $\frac{X}{\text{Density}}$ is given by *[First Mid - 2018]*

(a) $M^1L^4T^{-2}$ (b) $M^2L^{-2}T^{-1}$
(c) $M^2L^{-2}T^{-2}$ (d) $M^1L^{-2}T^{-1}$

[Ans. (c) $M^2L^{-2}T^{-2}$]

5. Triple point of water is : *[QY. - 2018]*

(a) 273.16 k (b) 237.16 c
(c) 273.16 c (d) 0 k **[Ans.(a) 273.16k]**

6. Mass, temperature, electric current are ______

(a) fundamental quantities *[QY. - 2018]*
(b) scalar quantities (c) vector quantities
(d) both a and b **[Ans. (d) both a and b]**

7. The significant figure of the number 0.003401 is: ________ *[QY. - 2019]*

(a) 6 (b) 3
(c) 5 (d) 4 **[Ans. (d) 4]**

8. The amplitude and time period of a simple pendulum bob are 0.05 m and 2 s respectively. Then the maximum velocity of the bob is : *[Mar-2019]*

a) 0.157 ms^{-1} (b) 0.257 ms^{-1}
c) 0.10 ms^{-1} (d) 0.025 ms^{-1}

[Ans. (a) 0.157 ms^{-1}]

9. The unit of surface energy is : *[Sep-2021]*

(a) Nm^3 (b) Nm^{-2}
(c) Nm (d) Nm^{-1} **[Ans.(d)Nm^{-1}]**

10. Rounding of 231.25 × 10^5 upto 4 digits will give: *[CRT-'22]*

(a) 231.3 (b) 231.3 × 10^5
(c) 231.2 × 10^5 (d) 231.2

[Ans. (c) 231.2 × 10^5]

11. The Dimensional formula for strain: *[May-2022]*

(a) $ML^{-2}T^{-1}$ (b) $M^0L^0T^0$
(c) $ML^{-1}T^{-2}$ (d) M^0LT^0

[Ans. (b) $M^0L^0T^0$]

12. The dimensional formula for coefficient of viscosity is: *[Mar-'23]*

(a) $ML^{-2}T^{-2}$ (b) MLT^{-2}

(c) $ML^{-1}T^{-2}$ (d) $ML^{-1}T^{-1}$

[Ans. (d) $ML^{-1}T^{-1}$]

13. Which of the following is an example of dimensional constant? *[QY-'23]*

(a) Euler's number (b) Relative density

(c) Velocity (d) Plank's constant

[Ans. (d) Plank's constant]

14. If the measurement is made with a meter scale whose end is worn out, the result obtained will have error known as *[QY-'23]*

(a) Least count error (b) Personal error

(c) Instrumental error (d) All the above

[Ans. (c) Instrumental error]

15. In an experiment, four quantities a, b, c and d are measured with percentage error 1%, 2%, 3% and 4% respectively. Quantity P is calculated as follows. $P = \frac{a^3 - b^2}{cd}$ % error in P is *[QY-'24]*

(a) 7 % (b) 4 % (c) 14 % (d) 10 %

[Ans. (c) 14%]

II. Very Short Answer Questions : 2 Marks

1. Check the dimensional correctness for the given equations. *[First Mid-2018]*

(a) V = u + at **(b) $s = ut + \frac{1}{2}at^2$**

Ans. (a) v = u + at

Apply dimensional formula on both sides

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

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

(Quantities of same dimension only can be added)

Since dimensions on both sides are same, the given equation is dimensionally correct.

(b) $[L] = [LT^{-1}][T] + [LT^{-2}][T^2]$

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

$[L] = [LT^0] + [LT^0]$ $[\because T^0 = 1]$

$\therefore [L] = [L] + [L]$

Since dimensions on both sides are same, the given equation is dimensionally correct.

2. Round off to required significant figures *[First Mid-2018]*

(a) 3.1 + 1.780 + 2.046 **(b) 12.637 – 2.42**

(c) 1.21 × 36.72 **(d) 36.72 ÷ 1.2**

Ans. (a) 6.9 (b) 10.22 (c) 44.4 (d) 31

3. What are random errors? How to minimise it? *[First Mid-2018]*

Ans. (i) Random errors may arise due to random and unpredictable variations in experimental conditions like pressure, temperature, voltage supply, etc. Random errors are sometimes called "**chance error**".

(ii) Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.

4. Write down the number of significant figures in the following: (i) 0.007 (ii) 400. *[Govt. MQP-2018]*

Ans. (i) One (ii) One

5. What are the advantages of SI system? *[QY-2018]*

Ans. The advantages of the SI system are,

(i) This system makes use of only one unit for one physical quantity, which means a rational system of units.

(ii) In this system, all the derived units can be easily obtained from basic and supplementary units, which means it is a coherent system of units

(iii) It is a metric system which means that multiples and submultiples can be expressed as powers of 10.

6. What is fractional error? *[QY-2018]*

Ans. The ratio of the mean absolute error to the mean value is called relative error. This is also called as fractional error.

$$\text{Relative error} = \frac{\text{Mean absolute error}}{\text{Mean value}} = \frac{\Delta a_m}{a_m}$$

7. What are Dimensional variables? Give example. *[Sep-2020]*

Ans. Physical quantities, which possess dimensions and have variable values are called dimensional variables. Examples are length, velocity, and acceleration etc.

8. What is meant by Dimensionless variables? Give example. *[Sep-2020]*

Ans. Physical quantities which have no dimensions, but have variable values are called dimensionless variables. Examples are specific gravity, strain, refractive index etc.

9. Check the correctness of the equation $v = u + at$ using dimensional analysis method. *[Sep-2021]*

Ans. Let us take the equation of motion v = u + at

Apply dimensional formula on both side

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

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

(Quantities of same dimension only can be added)

We see that the dimensions of both sides are same. Hence the equation is dimensionally correct.

10. What do you mean by gross error? How shall we minimize it? *[CRT & Aug-'22]*

Ans. (i) The error caused due to the shear carelessness of an observer is called gross error.

(ii) It can be minimized only when an observer is careful and mentally alert.

11. A radar signal is beamed towards a planet and its echo is received 10 minutes later. If the distance between the planet and the earth is 9×10^{10}m, calculate the speed of the signal. *[CRT-'22; QY-'24]*

Solution:

The distance of the planet from the Earth

$d = 9 \times 10^{10}$ m

Time t = 10 minutes = 10 × 60 s.

the speed of signal v = ?

The speed of signal

$$v = \frac{2d}{t} = \frac{2 \times 9 \times 10^{10}}{10 \times 60} \Rightarrow v = 3 \times 10^{8}\ ms^{-1}$$

III. Short Answer Questions : 3 Marks

1. The voltage across a wire is (100 ± 5) v and the current passing through it is (10 ± 0.2) A. Find the resistance of the wire. *[First Mid-2018]*

Ans. Voltage V = (100 ± 5)V

Current I = (10 ± 0.2)A

Resistance R = ?

Then resistance R is given by Ohm's law

$$R = \frac{V}{I} = \frac{100}{10} = 10\ \Omega$$

$$\frac{\Delta R}{R} = \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right)$$

$$\Delta R = \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right) R = \left(\frac{5}{100} + \frac{0.2}{10}\right) \times 10$$

$$= (0.05 + 0.02) \times 10 = 0.07 \times 10 = 0.7$$

The resistance $R = (10 \pm 0.7)\Omega$.

2. Check the correctness of the equation $E = mc^2$ using dimensional analysis method. *[Govt. MQP-2018; Jun.-2019]*

Ans. Consider the equation, $E = mc^2$

Apply dimensional formula on both sides

$ML^2T^{-2} = [M] \cdot [LT^{-1}]^2$

$ML^2T^{-2} = [M] \cdot [L^2T^{-2}]$

The equation is dimensionally correct.

3. Two resistances $R_1 = (100 \pm 3)\Omega$ and $R_2 = (150 \pm 2)\Omega$ are connected in series. What is their equivalent resistance ? *[Govt. MQP-2018; Mar-'24]*

Ans. $R_1 = 100 \pm 3\ \Omega$; $R_2 = 150 \pm 2\Omega$

Equivalent resistance R = ?

Equivalent resistance $R = R_1 + R_2$

$= (100 \pm 3) + (150 \pm 2) = (100 + 150) \pm (3 + 2)$

$R = (250 \pm 5)\ \Omega$

4. Find the dimensional formula of hc/G. *[QY-2018]*

Ans. The dimensional formula for

planck's constant h – $[ML^2T^{-1}]$

c – $[LT^{-1}]$

G – $[M^{-1}L^3T^{-2}]$

$$\frac{hc}{G} = \frac{[ML^2T^{-1}][LT^{-1}]}{[M^{-1}L^3T^{-2}]} = [M^2]$$

5. What are the fundamental quantities and derived quantities? *[Sep-2020; QY-'23; Mar-'24]*

Ans. **Fundamental quantities:** Fundamental quantities are quantities which cannot be expressed in terms of any other physical quantity.

Example: Quantities like length, mass, time, temperature are fundamental quantities.

Derived quantities: Quantities that can be expressed in terms of fundamental quantity are called derived quantities.

Example: Quantities like area, volume, velocity are derived quantities.

6. What are the applications (or) uses of Dimensional Analysis? *[Sep-2021; CRT & May-2022; HY-'23]*

Ans. (i) Convert a physical quantity from one system of units to another.

(ii) Check the dimensional correctness of a given physical equation.

(iii) Establish relations among various physical quantities.

7. What is Gross Error & How can it be minimised? *[Mar-'23]*

Ans. The error caused due to the shear carelessness of an observer is called gross error.

For example

(i) Reading an instrument without setting it properly.

(ii) Taking observations in a wrong manner without bothering about the sources of errors and the precautions.

(iii) Recording wrong observations. These errors can be minimized only when an observer is careful and mentally alert.

IV. Long Answer Questions :

5 Marks

1. The force F acting on a body moving in a circular path depends on mass of the body(m) velocity(v) and radius (r) of the circular path. Obtain the expression for the force by dimensional analysis method. (k = 1). *[First Mid-2018; Mar.-2019]*

Ans. $F \propto m^a v^b r^c$; $F = k\, m^a v^b r^c$

where k is a dimensionless constant of proportionality. Rewriting the above equation in terms of dimensions and taking $k = 1$, we have

$$[MLT^{-2}] = [M]^a [LT^{-1}]^b [L]^c = [M^a L^b T^{-b} L^c]$$

$$[MLT^{-2}] = [M]^a [L^{b+c}] [T^{-b}]$$

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

$a = 1;\ b + c = 1;\ -b = -2;$

$\Rightarrow a = 1;\ b + c = 1;\ \boxed{b = 2}$

$\Rightarrow 2 + c = 1 \Rightarrow \boxed{c = -1}$

$\therefore a = 1;\ b = 2;\ c = -1$

From the above equation we get $F = m^a v^b r^c$

$$F = m^1 v^2 r^{-1} \text{ or } F = \frac{mv^2}{r}$$

2. Obtain an expression for the time period T of a simple pendulum. [The time period T depend upon (i) mass *m* of the bob, (ii) length *l* of the pendulum and (iii) acceleration due to gravity *g* at the place where pendulum is suspended. Assume the constant, $k = 2\pi$].

Ans. *[Govt. MQP-2018; QY, HY-2019; Mar-'23]*

$T \propto m^a l^b g^c$; $T = k.\, m^a l^b g^c$

Here k is the dimensionless constant.

Rewriting the above equation with dimensions.

$$[T^1] = [M]^a [L]^b [LT^{-2}]^c$$

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

Comparing the powers of M, L and T on both sides, $a = 0$, $b + c = 0$, $-2c = 1$

Solving for a, b and c, we get $a = 0$, $b = 1/2$, and $c = -1/2$

From the above equation $T = k.\, m^0 l^{1/2} g^{-1/2}$

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

Experimentally $k = 2\pi$, hence $T = 2\pi\sqrt{l/g}$

3. In a series of successive measurements in an experiment, the readings of the period of oscillation of a simple pendulum were found to be 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s. Calculate (i) the mean value of the period of oscillation (ii) the absolute error in each measurement (iii) the mean absolute error (iv) the relative error (v) the percentage error. Express the results in proper form. *[Govt. MQP-2018]*

Ans. $t_1 = 2.63\text{s}$, $t_2 = 2.56\text{s}$, $t_3 = 2.42$ s, $t_4 = 2.71\text{s}$, $t_5 = 2.80$ s

(i) $$T_m = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5} = \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5}$$

$T_m = \frac{13.12}{5} = 2.624$ s

T_m = 2.62 s (Rounded off to 2nd decimal place)

(ii) Absolute error $\Delta T = T_m - t$

$\Delta T_1 = 2.62 - 2.63 = -0.01$

$\Delta T_2 = 2.62 - 2.56 = +0.06s$

$\Delta T_3 = 2.62 - 2.42 = +0.20s$

$\Delta T_4 = 2.62 - 2.71 = -0.09s$

$\Delta T_5 = 2.62 - 2.80 = -0.18s$

(iii) Mean absolute error = $\frac{\Sigma|\Delta T_t|}{n}$

$$\Delta T_m = \frac{0.01+0.06+0.20+0.09+0.18}{5}$$

$$\Delta T_m = \frac{0.54}{5} = 0.108s = 0.11s$$

(Rounded off to 2nd decimal place)

(iv) Relative error:

$$S_T = \frac{\Delta T_m}{T_m} = \frac{0.11}{2.62} = 0.0419 = 0.04$$

(v) Percentage error in T = 0.04 × 100% = 4%

(vi) Time period of simple pendulum

$$T = (2.62 \pm 0.11)s$$

4. What are the applications of dimensional analysis. Verify $S = ut + 1/2\ at^2$ by dimensional analysis. *[Govt.MQP-2018; QY-2018 ; Sep.-2020]*

***Ans.* Applications:**

(i) To convert a physical quantity from one system of units to another.

(ii) To check the dimensional correctness of a given physical equation.

(iii) To establish the relation among various physical quantities.

Verification :

$$s = ut + \frac{1}{2}at^2$$

Substituting dimensions

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

$$[L] = [L] + [L]$$

The equation is dimensionally correct.

5. Express 76 cm of mercury pressure in terms of Nm^{-2} using the method of dimensions. *[Sep.-2020 & 2021]*

Solution:

In cgs system 76 cm of mercury pressure

= 76 × 13.6 × 980 dyne cm^{-2}

The dimensional formula of pressure P is $[ML^{-1}T^{-2}]$

$$P_1[M_1^a L_1^b T_1^c] = P_2[M_2^a L_2^b T_2^c]$$

We have $P_2 = P_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$

M_1 = 1g, M_2 = 1 kg

L_1 = 1cm, L_2 = 1 m

T_1 = 1s, T_2 = 1 s

As a = 1, b = –1, and c = –2

Then

$$P_2 = 76 \times 13.6 \times 980 \left[\frac{1g}{1kg}\right]^1 \left[\frac{1cm}{1m}\right]^{-1} \left[\frac{1s}{1s}\right]^{-2}$$

$$= 76 \times 13.6 \times 980 \left[\frac{10^{-3}kg}{1kg}\right]^1 \left[\frac{10^{-2}m}{1m}\right]^{-1} \left[\frac{1s}{1s}\right]^{-2}$$

$$= 76 \times 13.6 \times 980 \times 10^{-3} \times 10^2$$

$$= 1012928 \times 10^{-1}$$

$$P_2 = 1.01 \times 10^6 \times 10^{-1} = 1.01 \times 10^5\ Nm^{-2}.$$

6. A RADAR signal is beamed towards a planet and its echo is received 7 minutes later. If the distance between the planet and the Earth is 6.3×10^{10}m, calculate the speed of the signal. *[July-'24]*

Solution:

The distance of the planet from the Earth

$d = 6.3 \times 10^{10}$ m

Time t = 7 minutes = 7 × 60 s.

the speed of signal v = ?

The speed of signal

$$v = \frac{2d}{t} = \frac{2\times6.3\times10^{10}}{7\times60} = 3\times10^8\ ms^{-1}$$

Additional Questions

I. Multiple Choice Questions :

1 Mark

A. Choose the best answer :

1. A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression for l is dimensionally correct? *[JEE (advanced) 2016]*

(a) $l = \sqrt{\dfrac{nq^2}{\varepsilon k_B T}}$ (b) $l = \sqrt{\dfrac{\varepsilon k_B T}{nq^2}}$

(c) $l = \sqrt{\dfrac{q^2}{\varepsilon n^{\frac{2}{3}} k_B T}}$ (d) $l = \sqrt{\dfrac{q^2}{\varepsilon n k_B T}}$

[Ans. (b) $l = \sqrt{\dfrac{\varepsilon k_B T}{nq^2}}$]

2. The word scientia is meaning to ________.

(a) exact (b) to know
(c) control (d) implement

[Ans. (b) to know]

3. Astronomical Scale is dealt with the ________ Physics.

(a) Mesoscopic (b) Microscopic
(c) Macrospic (d) None

[Ans. (c) Macrospic]

4. Microscopic group of Physics dealt with the study of ________.

(a) classical physics (b) statistical mechanics
(c) fluid mechanics (d) quantum physics

[Ans. (d) quantum physics]

5. What is the range of astronomical time scales to microscopic scales?

(a) 10^{15}s to 10^{-15}s (b) 10^{9}s to 10^{-18}s
(c) 10^{18} to 10^{-22}s (d) 10^{11}s to 10^{-16}s

[Ans. (c) 10^{18} to 10^{-22}s]

6. The law of electricity and magnetism is used to

(a) Wireless communication
(b) Nuclear reactor (c) Steam engine
(d) Aeroplane

[Ans. (a) Wireless communication]

7. Match the following.

(1)	Steam engine	(a)	Bernoulli's principle
(2)	Nuclear reactor	(b)	Laws of thermodynamics
(3)	Production of ultra high magnetic fields	(c)	Controlled nuclear fission
(4)	Aeroplane	(d)	Super conductivity

	(1)	(2)	(3)	(4)
(a)	b	c	a	d
(b)	d	a	b	c
(c)	c	d	a	b
(d)	b	c	d	a

[Ans:(d) b c d a]

8. Match the following fundamental forces with respect to relative strengths.

(1)	Gravitational force	(a)	1
(2)	Electromagnetic force	(b)	10^{-38}
(3)	Weak nuclear force	(c)	10^{-2}
(4)	Strong nuclear force	(d)	10^{-13}

	(1)	(2)	(3)	(4)
(a)	a	d	b	c
(b)	b	c	d	a
(c)	c	d	a	b
(d)	c	a	b	d

[Ans: (b) b c d a]

9. How many gram make 1 deca gram?

(a) 10g (b) 100g (c) 1kg (d) 100kg

[Ans. (a) 10g]

10. 1 nano second is equivalent to

(a) 10^{-6}s (b) 10^{-3}s
(c) 10^{-15}s (d) 10^{-9}s [Ans. (d) 10^{-9}s]

11. Which unit is used to measure size of a nucleus?

(a) Angstrom (b) Micron
(c) Nano (d) Fermi

[Ans. (d) Fermi]

12. One parallactic second is,

(a) 3.08×10^{16}m (b) 1.49×10^{11}m
(c) 9.46×10^{15}m (d) 1.66×10^{-27}m

[Ans. (a) 3.08×10^{16}m]

13. How many light years make 1 parsec?

(a) 3.26 (b) 6.67
(c) 1.5 (d) 9.4 **[Ans. (a) 3.26]**

14. How many AU makes one metre?

(a) 3.26×10^{11}AU (b) 1.496×10^{11}AU
(c) 3.08×10^{16}AU (d) 6.684×10^{-12}AU

[Ans. (d) 6.684×10^{-12}AU]

15. The acceleration of 20 m/s^2 in km/h^2 is

(a) 2.59×10^5 km/h^2 (b) 1.29×10^5 km/h^2
(c) 2.0×10^3 km/h^2 (d) 3.5×10^5 km/h^2

[Ans. (a) 2.59×10^5 km/h^2]

16. Which device is used for measuring the mass of atoms?

(a) Spectrograph (b) Fermi
(c) Telescope (d) Microscope

[Ans. (a) Spectrograph]

17. Which of the following statement is wrong?

(a) one fermi = 10^{15}m
(b) All non-zero digits are significant.
(c) 1 AU = 1.496×10^{11}m
(d) Speed is a derived unit.

[Ans. (a) one fermi = 10^{15}m]

18. Which of the following statement is wrong?

(a) Strain is a dimensionless quantity.
(b) Fundamental quantity is also called the base quantity.
(c) force = mass × acceleration
(d) 1 Solar year = 1500 days.

[Ans. (d) 1 Solar year = 1500 days]

19. One lunar month is equal to ___________

(a) 29.5 days (b) 27.3 days
(c) 365 days (d) 31 days

[Ans. (a) 29.5 days]

20. What is the value of one light year in tera metre?

(a) 9.46×10^6Tm (b) 9.46×10^9 Tm
(c) 9.46×10^2Tm (d) 9.46×10^3 Tm

[Ans. (d) 9.46×10^3 Tm]

21. Which of the following statement is true?

(a) Velocity is a fundamental unit.
(b) 1 Solar day = 24 hours. (c) 1 Shake = 10^4s
(d) mass is a derived unit.

[Ans. (b) 1 Solar day = 24 hours]

22. The number of significant figures in 0.0006012 m is

(a) 3 (b) 4 (c) 7 (d) 5

[Ans. (b) 4]

23. The displacement of a particle moving along x-axis with respect to times is given by $x = at + bt^2 - ct^3$. The dimensions of b are

(a) L^0T^{-3} (b) L^0T^{-3}
(c) LT^{-2} (d) LT^{-3}

Hint: **[Ans. (c) LT^{-2}]**

$x = at + bt^2 - ct^3$; $L = aT + bT^2 - cT^3$

$\therefore b = LT^{-2}$

24. If E & B respectively, represent electric field and magnetics induction field, then the ratio E & B has the dimensions of

(a) angle (b) acceleration
(c) velocity (d) displacement

Hint: **[Ans. (c) velocity]**

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$\therefore$ The dimensions of $\vec{E}$ are the same as those of $v\vec{B}$

$\therefore$ The dimensions of E/B = dimension of v.

25. The density of a cube is measured by measuring its mass and length of its side. If the maximum error in the measurement of mass and length are 5% and 3% respectively, the maxmimum error in the measurement of density is

(a) 9% (b) 8%
(c) 14% (d) 2%

Hint: **[Ans. (c) 14%]**

Density $\rho = \frac{M}{V} = \frac{M}{L^3}$ $\Delta M = 5\%$; $\Delta L = 3\%$

$$\frac{\Delta P}{P} = \frac{\Delta M}{M} + \frac{\Delta V}{V} \Rightarrow \frac{\Delta P}{P}\% = \left(\frac{\Delta M}{M} + 3.\frac{\Delta L}{L}\right)\%$$

$$\left(\frac{\Delta P}{P}\right)\% = (5\% + 3.3\%) = (5 + 9) = 14\%$$

26. If force $|F|$, velocity $|v|$ and time $|T|$ are taken as to fundamental units then the dimensions of mass are

(a) $Fv^{-1}T$ (b) $Fv^{-1}T$
(c) FvT^{-1} (d) FvT^{-2}

Hint: **[Ans. (c) FvT^{-1}]**

$F = \frac{mv}{t}$ $[m] = [F\frac{mv}{t}T]$ $\left[\because a = \frac{v}{t}\right]$

27. The dimensions of universal gravitational constant is

(a) $M^{-2}L^3T^{-2}$ (b) $M^{-2}L^2T^{-1}$
(c) $M^{-1}L^3T^{-2}$ (d) ML^2T^{-1}

[Ans. (c) $M^{-1}L^3T^{-2}$]

28. How many light years make 1 par sec?

(a) 3.26 LY (b) 6.67 LY
(c) 1.5 LY (d) 9.4 LY

[Ans. (a) 3.26 LY]

29. Which of the following pairs of physical quantities have same dimension?

(a) Force and Power (b) Stress and Pressure
(c) Momentum and Moment of force
(d) Torque and impulse of force

[Ans. (b) Stress and Pressure]

30. The Dimensional formula for Boltzmann constant is

(a) $[ML^2T^{-1}]$ (b) $[ATmol^{-1}]$
(c) $[ML^2T^{-2}K^{-1}]$ (d) None of the above

[Ans. (c) $[ML^2T^{-2}K^{-1}]$]

31. Specific gravity (Relative Density) is an example for

(a) Dimensional Variables
(b) Dimensionless Variables
(c) Dimensional Constant
(d) Dimension less Constant

[Ans. (b) Dimensionless Variables]

32. 8.250 can be Rounded off to

(a) 8.3 (b) 8.2 (c) 8.25 (d) 8.26

[Ans. (b) 8.2]

33. The number of significant figures in 2.64×10^4 kg is

(a) 2 (b) 4 (c) 5 (d) 3

[Ans. (d) 3]

34. If E and B respectively, represent electric field and magnetic field of Induction, then the ratio of E and B has the dimensional formula of

(a) $[LT^{-2}]$ (b) $[MLT^{-2}]$
(c) $[LT^{-1}]$ (d) $[MLT^{-1}]$

[Ans. (c) $[LT^{-1}]$]

35. Which one has more significant figures

(a) 600800 (b) 5213.0
(c) 2.65×10^{24} (d) 0.0006032

[Ans. (b) 5213.0]

36. Angle of 1 Second of arc is

(a) 48.5×10^{-6} rad (b) 0.485×10^{-5} rad
(c) 4.85×10^{-6} rad (d) 48500×10^{-6} rad

[Ans. (c) 4.85×10^{-6} rad]

37. 1 Yotta = ______.

(a) 10^{21} (b) 10^{-24} (c) 10^{-21} (d) 10^{24}

[Ans. (d) 10^{24}]

38. If mass of an electron is 9.11×10^{-31} Kg, then how many electrons would weight in 1 mg?

(a) 1.68×10^{18} (b) 1.097×10^{24}
(c) 1.45×10^{22} (d) 1.970×10^{23}

[Ans. (b) 1.097×10^{24}]

B. Fill in the Blanks :

1. An attempt to explain a Macroscopic system in terms of its Microscopic constituents is ________.

(a) unification (b) Reductionism
(c) Microphysics (d) Macrophysics

[Ans. (b) Reductionism]

2. The range of masses from heavenly bodies to electro is ___________.

(a) 10^{52} kg to 10^{-28} kg (b) 10^{55} kg to 10^{+28} kg
(c) 10^{55} kg to 10^{-31} kg (d) 10^{-55} kg to 10^{31} kg

[Ans. (c) 10^{55} kg to 10^{-31} kg]

3. The CGS, MKS and SI system of units are _______ system of units.

(a) metric (b) cubic
(c) periodic (d) atomic

[Ans. (a) metric]

4. The temperature at which saturated vapor, pure and melting ice are all in equilibrium is called __________.

(a) Sublimation (b) Melting point
(c) Triple point of water (d) Heat capacity

[Ans. (c) Triple point of water]

5. The expression for Solid Angle is __________.

(a) rod/s (b) surface area / $(radius)^2$
(c) $(radius)^2$ (d) surface area / radius

[Ans. (b) surface Area / $(radius)^2$]

6. J $Kg^{-1}K^{-1}$ is the unit for ________.

(a) Heat capacity (b) Latent heat
(c) Specific heat (d) Energy

[Ans. (c) Specific heat]

7. 1 degree = __________ rad.

(a) 1.754×10^{-2} (b) 1.745×10^{2}
(c) 1.745×10^{-2} (d) 1.547×10^{-2}

[Ans. (c) 1.745×10^{-2}]

8. ________ means a large world in which both objects and distances are large – sized.

(a) Macrocosm (b) Microcosm
(c) Astronomy (d) Universe

[Ans. (a) Macrocosm]

9. The error caused due to the shear carelessness of an observer is called __________.

(a) Absolute Error (b) Gross Error
(c) Instrumental Error (d) Zero Error

[Ans. (b) Gross Error]

10. Quantities which have constant values and also have no dimensions are called _________.

(a) Dimensionless Constants
(b) Dimensional variables
(c) Dimensionless constants
(d) Derived quantities

[Ans. (a) Dimensionless Constants]

11. Dimensional formula for Magnetic Induction is ___________.

(a) MT^2A^{-1} (b) MT^2A
(c) $MT^{-2}A^{-1}$ (d) MA^{-1}

[Ans. (c) $MT^{-2}A^{-1}$]

12. Formula (or) expression for surface energy is __________.

(a) work / length (b) force / length
(c) work / time (d) work / area

[Ans. (d) work / area]

13. Relative error is also called as _________.

(a) Gross Error (b) Percentage Error
(c) Absolute Error (d) Fractional Error

[Ans. (d) Fractional error]

14. The name Physics was introduced by __________ in 350 B.C

(a) Thalus (b) Ptolemy
(c) Aristotle (d) Copernicus

[Ans. (c) Aristotle]

C. Match the following :

1.

	Branch		Major Focus
(1)	Acoustics	(a)	About space, time and energy
(2)	High energy physics	(b)	About sound
(3)	Quantum mechanics	(c)	About nature of particles
(4)	Relativity	(d)	About discrete nature of phenomena at atomic and sub-atomic levels

	(1)	(2)	(3)	(4)
(a)	c	b	d	a
(b)	c	a	d	b
(c)	b	c	d	a
(d)	d	c	b	a

[Ans:(c) b c d a]

2.

	Physical Quantity		Unit
(1)	Force Constant	(a)	Ns
(2)	Boltzmann Constant	(b)	Nm
(3)	Impulse	(c)	JK^{-1}
(4)	Torque	(d)	Nm^{-1}

	(1)	(2)	(3)	(4)
(a)	d	c	a	b
(b)	b	a	c	d
(c)	b	d	a	c
(d)	d	b	a	c

[Ans:(a) d c a b]

3.

	Prefix (Symbol)		Sub-Multiple
(1)	Zepto (z)	(a)	10^{-18}
(2)	Pico (p)	(b)	10^{-1}
(3)	atto (a)	(c)	10^{-12}
(4)	deci (d)	(d)	10^{-21}

	(1)	(2)	(3)	(4)
(a)	b	d	a	c
(b)	d	b	a	c
(c)	c	d	a	b
(d)	d	c	a	b

[Ans:(d) d c a b]

4.

	Devices		Principles
(1)	Steam engine	(a)	Bernollis Principle
(2)	Nuclear Reactor	(b)	Laws of thermodynamics
(3)	Production of ultra high magnetic fields	(c)	Controlled chain reaction
(4)	Aeroplane	(d)	Super conductivity

	(1)	(2)	(3)	(4)
(a)	b	c	a	d
(b)	d	a	b	c
(c)	c	d	a	b
(d)	b	c	d	a

[Ans:(d) b c d a]

5.

	Types of fundamental forces		Strengths
(1)	Gravitational force	(a)	1
(2)	Electro magnetic force	(b)	10^{-39}
(3)	Weak nuclear force	(c)	10^{-2}
(4)	Strong nuclear force	(d)	10^{-13}

	(1)	(2)	(3)	(4)
(a)	a	d	b	c
(b)	b	c	d	a
(c)	c	d	a	b
(d)	c	a	b	d

[Ans: (b) b c d a]

6.

	Classification of quantities		Examples
(1)	Dimensional variables	(a)	Pi (T)
(2)	Dimension less variable	(b)	Planck's Constant
(3)	Dimensional constant	(c)	Velocity
(4)	Dimension less constant	(d)	Strain

	(1)	(2)	(3)	(4)
(a)	b	d	a	c
(b)	b	c	a	d
(c)	c	d	b	a
(d)	a	c	d	b

[Ans: (c) c d b a]

7.

	Physical quantity		Dimensional Formula
(1)	Surface Tension	(a)	$[ML^{-1}T^{-1}]$
(2)	Heat Capacity	(b)	$[ML^2]$
(3)	Moment of Inertia	(c)	$[MT^{-2}]$
(4)	Co-efficient of viscosity	(d)	$[ML^2T^{-2}K^{-1}]$

	(1)	(2)	(3)	(4)
(a)	c	d	b	a
(b)	a	d	c	b
(c)	a	c	d	b
(d)	b	a	c	d

[Ans: (a) c d b a]

8.

	Errors		Cause
(1)	Systematic Errors	(a)	due to shear carelessness
(2)	Random Errors	(b)	Fractional Error
(3)	Gross Errors	(c)	Chance Error
(4)	Relative Errors	(d)	Reproducible inaccuracies

	(1)	(2)	(3)	(4)
(a)	b	c	d	a
(b)	d	c	a	b
(c)	a	c	d	b
(d)	b	a	d	c

[Ans:(b) d c a b]

9.

	Numbers		Significant figures
(1)	40.00	(a)	6
(2)	0.030400	(b)	3
(3)	0.00345	(c)	5
(4)	307000.	(d)	4

	(1)	(2)	(3)	(4)
(a)	b	d	c	a
(b)	b	c	d	a
(c)	c	d	a	b
(d)	d	c	b	a

[Ans:(d) d c b a]

D. Choose the odd one out:

1. (a) Specific gravity (b) Strain
(c) Refractive index (d) Planck's constant
[Ans. (d) Planck's constant]

2. (a) Absolute Error (b) Relative Error
(c) Percentage Error (d) Gross Error
[Ans. (d) Gross Error]

3. (a) Solar clock (b) Electronic Oscillators
(c) Radio active dating (d) Electronic balance
[Ans. (d) Electronic balance]

4. (a) Energy (b) Work
(c) Torque (d) Force **[Ans. (d) Force]**

5. (a) Length (b) Mass
(c) Time (d) Volume **[Ans. (d) Volume]**

6. (a) f.p.s (b) c.g.s
(c) m.k.s (d) r.m.s **[Ans. (d) r.m.s]**

7. (a) Optics (b) Acoustics
(c) Astrophysics (d) Nuclear Physics
[Ans. (d) Nuclear Physics]

8. (a) Force constant (b) Planck's constant
(c) Boltzmann constant (d) Refractive Index
[Ans. (d) Refractive Index]

E. Choose the Incorrect Pair :

1. (a) Work - Energy
(b) Stress - Pressure
(c) Force - Tension
(d) Surface Tension - Force
[Ans. (d) Surface Tension - Force]

2. (a) Velocity - Angular velocity
(b) Force - Torque
(c) Mass - Moment of Inertia
(d) Frequency - Wavelength
[Ans. (d) Frequency - Wavelength]

3. (a) Density - Relative Density
(b) Strain - refractive Index
(c) π - e
(d) Planck's Constant - Stefan's constant
[Ans. (a) Density - Relative Density]

4. (a) Heat - Energy
(b) Mass - Inertia
(c) Charge - Current
(d) Moment of force - Torque
[Ans. (c) Charge - Current]

F. Choose the Correct Pair :

1. (a) 30.00 - 2009 (b) 0.00345 - 2.6
(c) 0.040500 - 20100m (d) 153 - 3072
[Ans. (a) 30.00 - 2009]

2. (a) Telescope - Microscope
(b) Screw gauge - Radar Method
(c) Parallax Method -Vernier Caliper
(d) Spring balance - Common balance
[Ans. (d) Spring balance - Common balance]

3. (a) Torque - Nm
(b) Planck's constant - J / s
(c) Specific heat - J kg k^{-1}
(d) Moment of Inertia - kg/m^2
[Ans. (a) Torque - Nm]

G. Assertion & Reason :

Directions :

(a) Assertion and Reason are correct and Reason is correct explanation of Assertion

(b) Assertion and Reason are true but Reason is the false explanation of the Assertion

(c) Assertion is true but Reason is false

(d) Assertion is false but Reason is true

1. **Assertion:** Quantities that can be expressed in terms of fundamental quantities are derived quantities.
Reason : Examples are Mass, Length, Time etc.,
[Ans. (c) Assertion is true but Reason is false]

2. **Assertion:** Attempting to explain diverse physical phenomena with a few concepts and laws is unification.
Reason : Attempting to explain a macroscopic system in terms of its microscopic constituents is reductionism.
[Ans. (b) Assertion and Reason are true but Reason is the false explanation of the Assertion]

3. **Assertion:** Study of light is called optics.
Reason : Properties of light is studied in optics. They are Reflection, Refraction etc.,
[Ans. (a) Assertion and Reason are correct and Reason is correct explanation of Assertion]

4. **Assertion:** In centimeter, the spelling meter is internationally accepted.
Reason : 'Metre' is internationally used unit whereas 'Meter' is used by Americans.
[Ans. (d) Assertion is false but Reason is true]

5. **Assertion:** Mass due to rotational motion is moment of Inertia.
Reason : Rotational mass explains about radius of Gyration.
[Ans. (a) Assertion and Reason are correct and Reason is correct explanation of Assertion]

6. **Assertion:** Very large distances such as distance of a planet or star can be measured by parallax method.
Reason : For measuring small masses of atomic / sub - atomic particles, mass spectrograph is used.
[Ans. (b) Assertion and Reason are true but Reason is the false explanation of the Assertion]

7. **Assertion:** The least value that can be measured using screw gauges, vernier calipers is called least count.
Reason : The magnitude of difference between the true value and the measured value is called relative error or fractional error.
[Ans. (c) Assertion is true but Reason is false]

8. **Assertion:** The rounding off of 27.653 upto 3 digits is 27.6
Reason : 10200 has three significant figures
[Ans. (d) Assertion is false but Reason is true]

9. **Assertion:** Dimensional analysis method is used to convert a physical quantity from one system of units to another
Reason : $\frac{1}{2}mv^2 = mgh$
[Ans. (b) Assertion and Reason are true but Reason is the false explanation of the Assertion]

H. Choose the Correct or Incorrect Statements :

1. **(I) RADAR method is used for measurement of length in the case of long distances**
(II) The uncertainty in a measurement is called error.
Which statement is correct?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (c) Both are correct]

2. **(I) $G_{CGS} = 6.6 \times 10^{-8}$ dyne $Cm^2\ g^{-2}$**
(II) $T = 2\pi\sqrt{\frac{g}{l}}$
Which statement is correct?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (a) I only]

3. **(I) Expression for charge is current / time**
(II) Expression for Faraday constant is Avagadro constant × elementary charge
Which statement is correct?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (b) II only]

4. **(I) Force constant and Faraday constant are examples for Dimensional constant**
(II) Radius of gyration does not depend on moment of Inertia.
Which statement is incorrect?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (b) II only]

5. **(I) The ratio of mean absolute error to the mean value is called fractional error**
(II) Due to the wrong observations Recording, Random errors occur.
Which statement is correct?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (a) I only]

6. **(I) Distance of moon from earth is 10^{11}m**
(II) Mass of a cell is 10^{-10} kg
Which statement is incorrect?
(a) I only (b) II only
(c) Both are correct (d) None
[Ans. (a) I only]

7. (I) Least count of screw gauge is 0.01mm
(II) Least count of vernier caliper is 0.1mm

Which one is correct?

(a) I only (b) II only
(c) Both are correct (d) None

[Ans. (c) Both are correct]

8. (I) Parallax angle, $\theta = \frac{\text{Unknown distance (x)}}{\text{base (b)}}$
(II) Distance of the planet,
d = Velocity of radio wave (V^e) × time taken (t)

Which statement is incorrect?

(a) I only (b) II only
(c) Both are correct (d) None

[Ans. (a) I only]

9. (I) Frequency and angular velocity has same dimensional formula
(II) Torque is also called as rotational force

Which one is correct?

(a) I only (b) II only
(c) Both are correct (d) None

[Ans. (c) Both are correct]

II. Very Short Answer Questions :

2 Marks

1. What is science?

Ans. (i) The word science comes from a Latin word 'scientia' meaning 'to know'.
(ii) Science is the systematic organization of knowledge gained through observation, experimentation and logical reasoning.

2. What are the steps involved in scientific method? (or) What are the general features of scientific method?

Ans. (i) Systematic observation
(ii) Controlled experimentation
(iii) Qualitative and quantitative reasoning
(iv) Mathematical modelling
(v) Prediction and verification or falsification of theories

3. What is Physics?

Ans. (i) Physics is a branch of science.
(ii) The word comes from a Greek word 'Fusis' meaning 'nature'.
(iii) It deals with the study of nature and natural phenomena.

4. What is mechanics?

Ans. (i) Mechanics is a branch of physics.
(ii) It is divided into statics and Dynamics.
(iii) Mechanics deals with the study of motion of particles, deformable bodies and general system of particles.

5. What is MKS system ?

Ans. The mks system is based on metre, kilogram and second as the fundamental units of length, mass, and time respectively.

6. What is the aim of our Science Education?

Ans. According to part IV Article 51A (h) of Indian Constitution "It shall be the duty of every citizen of India to develop scientific temper, humanism and spirit of inquiry and reform". This is the aim of our Science Education.

7. Name three practical units to measure mass.

Ans. (i) Pound 1*b* = 0.4536 kg
(ii) Quintal 1*q* = 100^{-9} kg
(iii) Atomic mass unit (1amu) = 1.66×10^{-27} kg

8. Name three practical units to measure Area.

Ans. (i) Barn, 1 barn = 10^{-28} m^2
(ii) Acre, 1 acre = 4047 m^2
(iii) Hectare, 1 hectare = 10^4 m^2.

9. What is significant figures?

Ans. The digits that are known reliably plus the first uncertain digit are known as significant figures or significant digits.

10. What is the importance of physical quantity? What are its types?

Ans. (i) Physical quantities are important to understand the properties of materials.
(ii) It is classified into fundamental physical quantity and derived physical quantity.

11. Definition of Physical Quantity.

Ans. Quantities that can be measured, and in terms of which, laws of physics are described are called physical quantities. Examples are length, mass, time, force, energy, etc.

12. What are the things needed to express the measurement of a physical quantity?

Ans. (i) The unit in which the quantity is measured

(ii) The numerical value or the magnitude of the quantity (n), the number of times that unit (u) is contained, in the given physical quantity. Q = *nu*.

13. Name the prefixes for powers of ten with its symbol.

Ans. (i) 10^1 = deca and its symbol is da

(ii) 10^6 = mega and its symbol is M

(iii) 10^{12} = tera and its symbol is T

(iv) 10^{-1} = deci and its symbol is d

(v) 10^{-6} = micro and its symbol is μ

(vi) 10^{-12} = pico and its symbol is *p*

14. Name four units to measure extremely small distances.

Ans. Units used to measure extremely small distances are

(i) 1 micron or micrometer, 1 μm = 10^{-6}m

(ii) 1 nanometer, 1 nm = 10^{-9}m

(iii) 1 Angstrom unit 1Å = 10^{-10}m

(iv) 1 Fermi, 1 Fm = 10^{-15}m.

15. Name three units to measure extremely large distances.

Ans. Units used to measure extremely large distances are,

(i) **Astronomical Unit :** It is the mean distance of the earth from the sun.
1 AU = 1.496 × 10^{11}m.

(ii) **Light year :** It is the distance travelled by light in vacuum in one year.
1 ly = 9.467 × 10^{15}m

(iii) **Parallactic second :** It is the distance at which an arc of length 1 astronomical unit subtends an angle of 1 second of arc.
1 par sec = 3.08 × 10^{16}m = 3.26 ly.

16. What is an error? Name the three Errors in Measurement.

Ans. The uncertainty in a measurement is called an error.

The three possible errors are

(i) Systematic errors

(ii) Random errors

(iii) Gross errors

17. What is Absolute Error.

Ans. The magnitude of difference between the true value and the measured value of a quantity is called absolute error.

$\Delta a_n = a_m - a_n$

18. What is Mean Absolute error?

Ans. The arithmetic mean of absolute errors in all the measurements is called the mean absolute error. If a_m is the true value and Δa_m is the mean absolute error, then the magnitude of the quantity may lie between $a_m + \Delta a_m$ and $a_m - \Delta a_m$.

19. What is Percentage error?

Ans. The relative error expressed as a percentage is called Percentage error.

$$\text{Percentage error} = \frac{\Delta a_m}{a_m} \times 100\%$$

20. What is meant by the dimensions of a physical quantity?

Ans. The dimensions of a physical quantity are the powers to which the units of base quantities are raised to represent a derived unit of that quantity.

21. What is meant by Scientific method?

Ans. The scientific method is a step-by-step approach in studying natural phenomena and establishing laws which govern these phenomena.

22. What do you mean by unification and reductionism?

Ans. **Unification:** Attempting to explain diverse physical phenomena with a few concepts and laws is unification.

Reductionism: An attempt to explain a macroscopic system in terms of its microscopic constituents is reductionism.

23. What is Classical mechanics?

Ans. The study of forces acting on bodies whether at rest or in motion.

24. What is Thermodynamics?

Ans. The study of the relationship between heat and other forms of energy.

25. What is the meaning of Acoustics?

Ans. The study of the production and propagation of sound waves.

26. What is Astrophysics?

Ans. The branch of physics which deals with the study of the physics of astronomical bodies.

27. Which branches of physics deal at the level of atom & nucleus?

Ans. Atom : Atomic physics.
Nucleus : Nuclear physics.

28. What is meant by Range of masses?

Ans. Range of masses: from heavenly bodies to electron, 10^{55} kg (mass of known observable universe) to 10^{-31} kg (mass of an electron) [the actual mass of an electron is 9.11×10^{-31} kg].

29. What are types of discoveries in physics?

Ans. Discoveries in physics are of two types.

(i) **Accidental discoveries** and **well-analysed research outcome** in the laboratory based on intuitive thinking and prediction.

(ii) For example, **magnetism was accidentally observed** but the reason for this strange behavior of magnets was later analysed theoretically.

(iii) This analysis revealed the underlying phenomena of magnetism. **With this knowledge, artificial magnets were prepared in the laboratories.**

30. How Physics is related to technology and define technology with respect to Physics.

Ans. Technology is the application of the principles of physics for practical purposes. The application of knowledge for practical purposes in various fields to invent and produce useful products or to solve problems is known as technology.

31. What is meant by Quantum mechanics?

Ans. The study of the discrete nature of phenomena at the atomic and subatomic levels.

32. In what ways physics is in relation to astronomy?

Ans. Astronomical telescopes are used to study the motion of planets and other heavenly bodies in the sky. Radio telescopes have enabled the astronomers to observe distant points of the universe. Studies of the universe are done using physical principles.

33. Define the SI unit of length.

Ans. Metre is the SI unit of length. One metre is the length of the path travelled by light in vacuum in $\frac{1}{299,792,458}$ of a second.

34. What is the SI unit of temperature and define it? What is one kelvin in SI system of units?

Ans. Kelvin is the SI unit of temperature. One kelvin is the fraction of $\left(\frac{1}{273.16}\right)$ of the thermodynamic temperature of the triple point of the water.

35. What is the SI unit of amount of substance? (or) What is one mole in SI system of units? (or) Define one mole (S.I standard for amount of substance)

Ans. Mole is the SI unit of amount of substance. One mole is the amount of substance which contains as many elementary entities as there are atoms in 0.012 kg of pure carbon-12.

36. What is meant by one candela? and which base quantity is measured by this unit? (or) Define one candela (S.I standard for Luminous intensity)

Ans. One candela is the luminous intensity in a given direction, of a source that emits monochromatic radiation of frequency 5.4×10^{14} Hz and that has a radiant intensity of $\frac{1}{683}$ watt/steradian in that direction.

37. What is meant by the triple point of water?

Ans. Triple point of water is the temperature at which saturated vapour, pure water and melting ice are all in equilibrium. The triple point temperature of water is 273.16K.

38. What is meant by Range of time scales?

Ans. Range of time scales: astronomical scales to microscopic scales, 10^{18}s to 10^{-22}s.

39. What is meant by Parallax?

Ans. Parallax is the name given to the apparent change in the position of an object with respect to the background, when the object is seen from two different positions.

40. Write the largest and the smallest practical unit of mass and time respectively. (or) Define Chandrasekar Limit (CSL)

Ans. Chandrasekhar Limit (CSL) is the largest practical unit of mass.1 CSL = 1.4 times the mass of the Sun. The smallest practical unit of time is Shake. 1 Shake = 10^{-8} s.

41. Write the masses of tiny as well as huge matter?

Ans. A tiny mass of electron (9.11×10^{-31}kg). The huge mass is of the known universe (10^{55} kg).

42. Define mass of a body.

Ans. Mass of a body is defined as the quantity of matter contained in a body. The SI unit of mass is kilogram (kg).

43. Why is the cylinder used in defining kilogram made up of platinum-iridium alloy?

Ans. This is because the platinum-iridium alloy is least affected by environment and time.

44. What is clock? Write the principle and its types.

Ans. A clock is used to measure the time interval. An atomic standard of time, is based on the periodic vibration produced in a Cesium atom. Some of the clocks developed later are electric oscillators, electronic oscillators, solar clock, quartz crystal clock, atomic clock, decay of elementary particles, radioactive dating.

45. Is it possible to have length and velocity both as fundamental quantities? Why?

Ans. No, length is fundamental quantity whereas velocity is the derived quantity.

46. Which of these unit is largest: AU, light year and parsec. Express the average distance of earth from the sun in (i) light year (ii) per sec.

Ans. Parsec is the largest unit.

parsec > light year > AU

Average distance of earth from the sun is (d) (astronomical unit).

(i) $d = 1 \text{ AU} = 1.496 \times 10^{11}$ m

$= \dfrac{1.496\times10^{11}}{9.46\times10^{15}} = 1.58\times10^{-5}$ light year.

(ii) $d = \dfrac{1.496\times10^{11}}{3.08\times10^{16}}$ par sec.

$= 4.86 \times 10^{-6}$ par sec.

47. The radius of gold nucleus is 41.3 Fermi. Express its volume in m^3.

Ans. Radius of gold nucleus = 41.3×10^{-15} m

$$\text{Volume (V)} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times (41.3 \times 10^{-15})^3$$

$$V = 2.95 \times 10^{-40} \text{ m.}$$

48. Describe the relation of Physics with mathematics.

Ans. (i) Physics is a quantitative science.

(ii) Physics is closely related to mathematics as a tool for its development.

49. Describe the errors due to external causes.

Ans. These errors are due to external conditions like change in temperature, humidity or pressure during an experiment.

50. What is the difference between Accuracy and Precision?

Ans.

S.No.	Accuracy	Precision
1.	Measurements close to true value.	Measurements close to each other.
2.	All the accuracy values are precised.	All the precised values are not accurate.

51. Describe the Personal errors.

Ans. These errors are due to individuals performing the experiment, may be due to incorrect initial setting up of the experiment or carelessness of the individual making the observation due to improper precautions.

52. What is dimensional equation? Give an example.

Ans. When the dimensional formula of a physical quantity is expressed in the form of an equation, such equation is known as the dimensional equation.
Ex: acceleration = $[M^0LT^{-2}]$

53. Define FPS system of units.

Ans. It is the British Engineering system of units, which uses **foot, pound** and **second** as the basic units for measuring length, mass and time respectively.

54. Define CGS system of units.

Ans. It is the Gaussian system of units, which uses **centimeter, gram** and **second** as the basic units for measuring length, mass and time respectively.

55. Define MKS system of units.

Ans. It is the Metric system of units, which uses **metre, kilogram** and **second** as the basic units for measuring length, mass and time respectively.

56. Define one radian (S.I standard for plane angle)

Ans. One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.

$$1 \text{ rad} = \frac{180^\circ}{\pi} = 57.27^\circ.$$

57. Define one steradian (S.I standard for solid angle)

Ans. It is the solid angle subtended at the centre of a sphere, by that surface of the sphere, which is equal in area, to the square of radius of the sphere.

III. Short Answer Questions : 3 Marks

1. Give any three applications of physics in our society.

Ans. (i) Basic laws of electricity and magnetism led to the discovery of wireless communication technology which has shrunk the world with effective communication over large distances.

(ii) The launching of satellite into space has revolutionized the concept of communication.

(iii) Microelectronics, lasers, computers, superconductivity and nuclear energy have comprehensively changed the thinking and living style of human beings.

2. Give any three practical units of time.

Ans. (i) **Solar year :** It is the time taken by the earth to complete one revolution around the sun in its orbit.

1 solar year = 365.25 average solar days.

(ii) **Leap year:** The year which is divisible by 4 and in which the month of February has 29 days is called leap year.

(iii) **Lunar month :** It is the time taken by the moon to complete one revolution around the earth in its orbit.

1 lunar month = 27.3 days.

3. Give the values for the following units with prefixes.

(i) 1 Mega ohm (ii) 1 milliampere
(iii) 1 deca gram (iv) 1 nano second
(v) 1 micro volt (vi) 1 centimetre

Ans.

(i) 1 Mega ohm (MΩ) $= 10^6\,\Omega$

(ii) 1 milliampere (mA) $= 10^{-3}$A

(iii) 1 daca gram (da g) = 10g

(iv) 1 nano second (ns) $= 10^{-9}$s

(v) 1 microvolt (μV) $= 10^{-6}$V

(vi) 1 centimetre (cm) $= 10^{-2}$m

4. Distinguish between fundamental and derived units.

Ans.

	Fundamental Units	Derived Units
1.	Using fundamental units fundamental quantities are measured	Using derived units, derived quantities are measured
2.	These units cannot be expressed in terms of other fundamental units	These units can be expressed in terms of all fundamental units.
3.	**Examples :** metre, kilogram, second (m, s, kg. A. mol)	**Examples:** area, volume, velocity, acceleration, force, etc.

5. Name the SI unit for electric current and give a definition for it.

Ans. The SI unit for electric current is ampere (A)

Definition:

One ampere is the constant current, which when maintained in each of the two straight parallel conductors of infinite length and negligible cross section, held one metre apart in vacuum shall produce a force per unit length of 2×10^{-7} N/m between them.

6. Name the SI unit for Luminous intensity and give a definition for it.

Ans. The SI unit for Luminous intensity is candela. Its symbol is cd.

Definition:

One candela is the luminous intensity in a given direction, of a source that emits monochromatic radiation of frequency 5.4×10^{14} Hz and that has a radiant intensity of $\frac{1}{638}$ watt/steradian in that direction.

7. Explain Random errors.

Ans. **Random errors**

(i) Random errors may arise due to random and unpredictable variations in experimental conditions like pressure, temperature, voltage supply etc.

(ii) Errors may also be due to personal errors by the observer who performs the experiment. Random errors are sometimes called "chance error".

(iii) When different readings are obtained by a person every time he repeats the experiment, personal error occurs.

(iv) For example, consider the case of the thickness of a wire measured using a screw gauge.

(v) The readings taken may be different for different trials. In this case, a large number of measurements are made and then the arithmetic mean is taken.

(vi) If n number of trial readings are taken in an experiment, and the readings are a_1, a_2, a_3,................ a_n. The arithmetic mean is

$$a_m = \frac{a_1 + a_2 + a_3 + ...a_n}{n}$$

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

Usually this arithmetic mean is taken as the best possible true value of the quantity.

8. Explain unification with example.

Ans. (i) Attempting to explain diverse physical phenomena with a few concepts and laws is unification.

(ii) For example, Newton's universal law of gravitation explains the motion of freely falling bodies towards the Earth, motion of planets around the Sun, motion of the Moon around the Earth, thus unifying the fundamental forces of nature.

9. Explain reductionism with example.

Ans. (i) An attempt to explain a macroscopic system in terms of its microscopic constituents is reductionism.

(ii) For example, thermodynamics was developed to explain macroscopic properties like temperature, entropy, etc., of bulk systems.

(iii) The above properties have been interpreted in terms of the molecular constituents (microscopic) of the bulk system by kinetic theory and statistical mechanics.

10. How are theoretical predictions useful?

Ans. (i) Theoretical predictions aided with recent simulation and computation procedures are widely used to identify the most suited materials for robust applications.

(ii) The pharmaceutical industry uses this technique very effectively to design new drugs. Bio compatible materials for organ replacement are predicted using quantum prescriptions of physics before fabrication.

(iii) Thus, experiments and theory work, hand in hand, complimenting one another.

11. In what way physics is exciting us?

Ans. A small number of basic concepts and laws can explain diverse physical phenomena.

(i) The most interesting part is the designing of useful devices based on the physical laws.

For example i) use of robotics ii) journey to Moon and to nearby planets with controls from the ground iii) technological advances in health sciences etc.

(ii) Carrying out new challenging experiments to unfold the secrets of nature and in verifying or falsifying the existing theories.

(iii) Probing and understanding the science behind natural phenomena like the eclipse, and why one feels the heat when there is a fire? (or) What causes the wind, etc.

12. In what way Physics is in relation to Chemistry?

Ans. (i) In physics, we study the structure of atom, radioactivity, X-ray diffraction etc.

(ii) Such studies have enabled researchers in chemistry to arrange elements in the periodic table on the basis of their atomic numbers.

(iii) This has further helped to know the nature of valency chemical bonding and to understand the complex chemical structures. Inter-disciplinary branches like Physical chemistry and Quantum chemistry play important roles here.

13. What are systematic errors? (or) What are the Classifications of Systematic errors?

Ans. Systematic error is reproducible inaccuracies that are consistently in the same direction. They can be classified as

(i) Instrumental errors,
(ii) Imperfections in experimental technique or procedure
(iii) Personal errors.
(iv) Errors due to external causes
(v) Least count error.

14. What is the relation of Physics to Biology?

Ans. (i) Biological studies are impossible without a microscope designed using physics principles.

(ii) The invention of the electron microscope has made it possible to see even the structure of a cell.

(iii) X-ray and neutron diffraction techniques have helped us to understand the structure of nucleic acids, which help to control vital life processes.

(iv) X-rays are used for diagnostic purposes.

(v) Radio-isotopes are used in radiotherapy for the cure of cancer and other diseases. In recent years, biological processes are being studied from the physics point of view.

15. How is physics useful in geology and oceanography?(or) Describe the relation of Physics with Geology.

Ans. (i) Diffraction techniques helps to study the crystal structure of various rocks.

(ii) Radioactivity is used to estimate the age of rocks, fossils and the age of the Earth.

(iii) Oceanographers seek to understand the physical and chemical processes of the oceans. They measure parameters such as temperature, salinity, current speed, gas fluxes, chemical components.

16. How can the systematic errors be minimised?

Ans. (i) By choosing the instrument carefully.

(ii) Necessary correction is to be made.

(iii) High precision instrument is to be used.

(iv) Proper setting up of experiments is to be done.

(v) Taking proper precautions is a must, while making observations.

17. Describe the relation of Physics with Psychology.

Ans. (i) All psychological interactions can be derived from a physical process.

(ii) The movements of neurotransmitters are governed by the physical properties of diffusion and molecular motion.

(iii) The function of our brain is related to our underlying dualism (wave -particle nature).

18. Write a note on parallax method.

Ans. (i) Parallax is the name given to the object with respect to the background, when the object is seen from two different positions.

(ii) The distance between the two positions is called basis (b).

(iii) This method is used for measuring very large distance such as distance of a planet or star.

IV. Long Answer Questions :

5 Marks

1. Discuss the relation of physics with other branches of science

Ans. Physics is the most fundamental branch of science. It has played a key role in the development of all branches of sciences.

Physics in relation to mathematics

- Physics is a quantitative science. Mathematics provides the necessary signs and tools which the physicist use.

- It has played an important role in the development of theoretical physics.
- Had newton not invented calculus, he would not have been able to discover the universal law of gravitation.

Physics in relation to chemistry:

- In physics, we study the structure of atom, radio activity, X-ray diffraction, etc.
- Such studies have enabled chemists to arrange elements in the periodic table on the basis of their atomic numbers.
- This has further helped to know the nature of valency, chemical bonding and to understand the complex chmical structures.

Physics in relation to biology:

- The developments in life sciences a great deal to physics.
- Optical microscopes are extensively used in the study of biology.
- With the help of an electron microscope, one can study the structure of cell.
- The X-rays and neutron diffraction techniques have helped in understanding the structure of nucleic acids, which helped to control vital life process.
- Radio isotopes are used in radiation therapy for the cure of deadly diseases like cancer.

2. Write the rules for rounding off. (or) Explain the rules framed for rounding off the numbers with the examples.

Ans.

	Rule		Example
i)	If the digit to be dropped is smaller than 5, then the preceding digit should be left unchanged.	i) ii)	7.32 is rounded off to 7.3 8.94 is rounded off to 8.9
ii)	If the digit to be dropped is greater than 5, the preceding digit should be increased by 1	i) ii)	17.26 is rounded off to 17.3 11.89 is rounded off to 11.9
iii)	If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit should be raised by 1	i) ii)	7.352, on being rounded off to first decimal becomes 7.4 18.159 on being rounded off to first decimal, become 18.2.
iv)	If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is not changed if it is even	i) ii)	3.45 is rounded off to 3.4 8.250 is rounded off to 8.2.
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	i) ii)	3.35 is rounded off to 3.4 8.350 is rounded off to 8.4

3. Explain propagation of errors in the difference of two quantities and also in the division of two quantities.

Ans. **Errors in the difference of two quantities :**

Let ΔA and ΔB be the absolute errors in the two quantities, A and B, respectively. Then,

Measured value of A = $A \pm \Delta A$

Measured value of B = $B \pm \Delta B$

Consider the difference, $Z = A - B$

The error ΔZ in Z is then given by

$$Z \pm \Delta Z = (A \pm \Delta A) - (B \pm \Delta B)$$
$$= (A - B) \pm (\Delta A + \Delta B)$$
$$= Z \pm (\Delta A + \Delta B)$$

(or) $\Delta Z = \Delta A + \Delta B$

The maximum error in difference of two quantities is equal to the sum of the absolute errors in the individual quantities.

Error in the division or quotient of two quantities

Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.

Consider the quotient, $Z = \frac{A}{B}$

The error ΔZ in Z is given by

$$Z \pm \Delta Z = \frac{A \pm \Delta A}{B \pm \Delta B} = \frac{A\left(1 \pm \frac{\Delta A}{A}\right)}{B\left(1 \pm \frac{\Delta B}{B}\right)}$$

$$= \frac{A}{B}\left(1 \pm \frac{\Delta A}{A}\right)\left(1 \mp \frac{\Delta B}{B}\right)^{-1}$$

$$\text{or } Z \pm \Delta Z = Z\left(1 \pm \frac{\Delta A}{A}\right)\left(1 \pm \frac{\Delta B}{B}\right)$$

[using $(1+x)^n \approx 1 + nx$, when $x<<1$]

Dividing both sides by Z, we get,

$$1 \pm \frac{\Delta Z}{Z} = \left(1 \pm \frac{\Delta A}{A}\right)\left(1 \mp \frac{\Delta B}{B}\right)$$

$$= 1 \pm \frac{\Delta A}{A} \mp \frac{\Delta B}{B} \pm \frac{\Delta A}{A} \cdot \frac{\Delta B}{B}$$

As the terms ΔA/A and ΔB/B are small, their product term can be neglected.

The maximum fractional error in Z is given by

$$\frac{\Delta Z}{Z} = \left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$$

The maximum fractional error in the quotient of two quantities is equal to the sum of their individual fractional errors.

4. Explain the rules framed to counting significant figures with the examples.

Ans.

	Rule	Example
1.	All non-zero digits are significant	1342 has four significant figures
2.	All zeros between two non-zero digits are significant	2008 has four significant figures
3.	All zeros to the right of a to non-zero digit but to the left of a decimal point are significant.	30700. has five significant figures
4.	The terminal or trailing zeros in the number without decimal point are not significant.	30700 has three significant figures
5.	If the number is less than 1, the zero(s) on the right of the decimal point but to the left of the first non zero digit are significant.	0.00345 has three significant figures.
6.	All zeros to the right of a decimal point and to the right of non-zero digit are significant.	40.00 has four significant figures and 0.030400 has five significant figures.
7.	The number of significant figures does not depend on the system of units used	1.53 cm, 0.0153 m, 0.0000153 km all have three significant figures.

Numerical Problems

1 Mark

1. Find the value of one AU in 1000 km

(a) 1.5×10^5m (b) 2.5×10^6m

(c) 1.5×10^{11}m (d) 2.5×10^{10}m

[Ans. (a) 1.5×10^5m]

Hint:

1 AU = 1.5×10^{11}m.

$$1 \text{ AU in } 1000 \text{ km} = \frac{1.5 \times 10^{11} \text{m}}{10^6 \text{m}}$$

[∵ 1000km = 10^6m]

$= 1.5 \times 10^5$m

2. How many AU present in one light year?

(a) 6.30×10^4m (b) 9.46×10^{15}m

(c) 6.2×10^2m (d) 9.4×10^{16}m

[Ans. (a) 6.30×10^4m]

Hint:

1 light year = 9.45×10^{15}m.

∴No. of AU in 1 light year

$$= \frac{9.45 \times 10^{15} \text{m}}{1.5 \times 10^{11} \text{m}} = 6.30 \times 10^4 \text{m}$$

3. How many μm present in one metre?

(a) 10^{-6}μm (b) 10^6μm

(c) 10^{-3}μm (d) 10^{-2}μm **[Ans. (b) 10^6μm]**

Hint:

$1\ \mu m = 10^{-6}$ m.

No. of μm in 1m $= \frac{1}{10^{-6}} = 10^6\ \mu m$

4. The speed of an object v = 40ms^{-1}. The same quantity of speed in kmh^{-1} is,

(a) 60 (b) 160 (c) 40 (d) 144

[Ans. (d) 144]

Hint:

Quantity of speed in m/s = 40

Quantity of speed in km/h $= 40 \times \frac{18}{5}$

$= 144$ kmh^{-1}.

5. The speed of an object v = 90km/h. The same quantity of speed in m/s is,

(a) 90 (b) 25 (c) 45 (d) 180

[Ans. (b) 25]

Hint:

Quantity of speed in km/h = 90

Quantity of speed in m/s $= 90 \times \frac{5}{18} = 25$ m/s.

6. 3.5kg mass of a metal plate has the volume of 1.5m^3. Find the density of metal plate.

(a) 1.5 kg/m^3 (b) 2.3 kg/m^3

(c) 3.4 kg/m^3 (d) 4.8 kg/m^3

[Ans. (b) 2.3 kg/m^3]

Hint:

Density is a derived unit.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{3.5\text{kg}}{1.5\text{m}^3} = 2.3\ \text{kg/m}^3$$

7. The value of 1° is,

(a) 1.745×10^{-2} rad (b) 1.946×10^{-11} rad

(c) 3.6 rad (d) 3600 rad

[Ans. (a) 1.745×10^{-2} rad]

Hint:

$$1° = \frac{2\pi}{360} = \frac{\pi}{180} = \frac{22}{7\times180} = 1.745 \times 10^{-2}\ \text{rad}$$

8. How many parsec are there in one kilometer?

(a) 3.084×10^{-16} (b) 3.08×10^{8}

(c) 3.24×10^{-14} (d) None

Hint: **[Ans. (c) 3.24×10^{-14}]**

3.086×10^{16}m = 1 parsec

$\Rightarrow 3.086 \times 10^{13}$ km = 1 parsec

$$1\text{km} = \frac{1}{3.086\times10^{13}}\ \text{parsec} = 3.24 \times 10^{-14}\ \text{parsec}$$

9. The angle of an object is 18.2°. What is the angular diameter of the object in radians?

(a) 36.4 rad (b) 3.64×10^{-2}rad

(c) 31.74×10^{-2}rad (d) 3.17 rad

Hint: **[Ans. (c) 31.74×10^{-2}rad]**

$$\theta = 18.2° = 18.2 \times \frac{\pi}{180} = 18.2 \times \frac{3.14}{180}$$

$$= 31.74\times10^{-2}\text{rad}$$

10. If a circle with 10 m radius and angle 60° at centre, then what will be the length of arc?

(a) 5.24m (b) 6.21m

(c) 7.1 mm (d) 10.46m **[Ans. (d) 10.46m]**

Hint:

Radius r = 10m, angle $\theta = \frac{\pi}{3}$ (60°)

Length of the arc $(l) = r\theta = 10 \times \frac{\pi}{3}$

$$= 10 \times \frac{22}{7}\times\frac{1}{3} = 10.46\text{m}$$

11. The mass of an iron sheet is 0.250 kg and volume of the sheet is 1.5m^3. Then what is the density of the iron sheet? Express the result in SI unit system.

(a) 0.267kg m^{-3} (b) 0.167 kg m^{-3}

(c) 0.255 kg m^{-3} (d) 0.285 kg m^{-3}

[Ans. (b) 0.167 kg m^{-3}]

Hint: Mass of the iron sheet = 0.250 kg

Volume of the iron sheet = 1.5 m^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{0.250}{1.5} = 0.167\ \text{kg m}^{-3}$$

12. What is the SI unit of linear momentum?

(a) ms^{-1} (b) ms^{-2}

(c) kg ms^{-1} (d) kg m^{2}s^{-1}

[Ans. (c) kg ms^{-1}]

Hint:

Linear momentum = mass × velocity

SI unit of mass = kg

SI unit of velocity $= \frac{\text{distance}}{\text{time}} = \frac{\text{m}}{\text{s}} = \text{ms}^{-1}$

Linear momentum = kg ms^{-1}.

13. What is the SI unit of Area?

(a) m (b) m^2 (c) Nm^{-1} (d) cm^{-1}

[Ans. (b) m^2]

Hint:

Area = length × breadth

SI unit of length = m

SI unit of breadth ⇒ (length) = m

Area = length × breadth

$= \text{m} \times \text{m} = \text{m}^2$.

14. SI unit of the universal constant of gravitation (G) is,

(a) $\text{kg}^{-2}\ \text{m}^{-2}$ (b) kg ms^{-1}

(c) $\text{Nm}^2\ \text{kg}^{-2}$ (d) Nm^{-1}

[Ans. (c) $\text{Nm}^2\ \text{kg}^{-2}$]

Hint: Universal constant of gravitation (G) is,

$$= \frac{\text{Fr}^2}{\text{m}_1\text{m}_2} \qquad [\because \text{F} = \text{G}.\frac{m_1 m_2}{r^2}]$$

SI unit of force = N

SI unit of distance $(r) = \text{m} \Rightarrow r^2 = \text{m}^2$

SI unit of masses m_1 and $\text{m}_2 = \text{kg}^2$

$$\Rightarrow \frac{\text{Fr}^2}{\text{m}_1\text{m}_2} = \frac{\text{Nm}^2}{\text{kg}^2} = \text{Nm}^2\ \text{kg}^{-2}.$$

2 Marks

1. Express the derived unit of pressure.

Solution:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{\text{unit of force}}{\text{unit of Area}} = \frac{\text{N}}{\text{m}^2} = \text{Nm}^{-2}$$

2. What is the formula representation of Mean Absolute error?

Solution:

Mean Absolute error, $\Delta a_m = \frac{1}{n}\sum_{i=1}^{n}|\Delta a_i|$

3. Using a screw gauge the thickness of a wire was measured as 5mm. Calculate (i) the fractional error (ii) the percentage error.

Given data:

Thickness of the wire (t) = 5mm

Accurancy $\Delta t = 0.01$mm

Solution:

(i) Fractional error, $\delta_t = \frac{\Delta \text{t}}{\text{t}} = \frac{0.01}{5} = 0.002.$

(ii) Percentage error, $\delta_t = \frac{\Delta \text{t}}{\text{t}} \times 100\%$

$= 0.002 \times 100\% = 0.2\%$

4. If a mass of a proton is 1.67×10^{-27}kg, how many protons will be present in 1kg?

Given data:

Mass of a proton $= 1.67 \times 10^{-27}$ kg

⇒ 1.67×10^{-27} kg is mass of 1 proton.

Solution:

1 kg is the mass of $\frac{1}{1.67 \times 10^{-27}}$ protons

$= 0.5988 \times 10^{27}$ protons

$= 5.988 \times 10^{26}$ protons

5.988×10^{26} protons will be present in 1 kg.

5. Calculate angle of 1 second of arc.

Solution:

1 second of arc $= 1'' = \frac{1^\circ}{60 \times 60}$

$$= \frac{1}{60 \times 60} \times \frac{\pi}{180} = \left(\frac{1}{3600} \times \frac{3.14}{180}\right) \left[\because 1^\circ = \frac{\pi}{180}\right]$$

1 second of arc $= 4.85 \times 10^{-6}$ rad.

6. 5.64kg mass of a object is moving uniformly. The radius of gyration is measured as 30cm of an object. Then what is the moment of Inertia and the SI unit of moment of inertia.

Solution:

Moment of inertia = MR^2

SI unit of Mass = kg

SI unit of the radius (gyration) = m

SI unit of moment of inertia = kg × m × m = kg m^2

Moment of inertia = 5.64 × (0.3)2
= 5.64 × 0.09
= 0.5076 kg m^2

7. The radius of a nucleus is 1.5×10^{-15}m of the order fermi. Find the volume of the nucleus.

Solution:

Radius of a nucleus r = 1.5×10^{-15}m.

Volume of the nucleus $V = \frac{4}{3}\pi r^3$.

$$= \frac{4}{3} \times 3.14 \times (1.5 \times 10^{-15})^3 = \frac{4}{3} \times 3.14 \times (3.375 \times 10^{-45})$$

$= 14.13 \times 10^{-45} m^3$

Volume of the nucleus is $V = 14.13 \times 10^{-45} m^3$

8. A beam of metal has length, breadth and height as 4m, 3m and 5m respectively. Then what will be the volume of the metal beam? Express the result in SI unit system.

Solution:

Volume = length × breadth × height
SI unit of volume (v) = m × m × m = m^3
SI unit of length (l) = 4m
SI unit of breadth (b)= 3m
SI unit of height (h) = 5m
Volume (v) = $l \times b \times h$ = 4 × 3 × 5 = 60m^3

9. The ratio of stress and strain of a wire is 3 : 2. Find the co-efficient of elasticity. Express the result in SI unit system.

Solution:

The ratio of stress and strain of a wire is 3 : 2

SI unit of stress = $\frac{\text{Force}}{\text{Area}} = \frac{N}{m^2} = Nm^{-2}$

Strain is dimensionless variable.

So, co-efficient of elasticity of a wire is = $\frac{\text{Stress}}{\text{Strain}}$

$$= \frac{3\ Nm^{-2}}{2\ (\text{No unit})} = 1.5\ Nm^{-2}.$$

3 Marks

1. In a following physical units, how many units are there in 1 metre?

(i) 1 Astronomical unit AU = 1.496×10^{11}m

(ii) 1 light year = 9.467×10^{15}m

(iii) 1 micron (μ) = 10^{-6}m

(iv) 1 parallactic second (parsec) = 3.08×10^{16}m

Given data:

1 AU = 1.496×10^{11}m
1 light year = 9.467×10^{15}m
1 μm = 10^{-6}m
1 parsec = 3.08×10^{16}m

Solution:

(i) 1.496×10^{11}m is equivalent to 1 AU.

1 metre is equivalent to $\frac{1}{1.496 \times 10^{11}}$

$= 0.6684 \times 10^{-11} = 6.68 \times 10^{-12}$ AU

In one metre, 6.68×10^{-12} astronomical units are present

(ii) 9.467×10^{15}m is equivalent to 1 light year.

1 metre is equivalent to $\frac{1}{9.467 \times 10^{15}}$

$= 0.1056 \times 10^{-15} = 1.05 \times 10^{-16}$ light year

In one metre, 1.05×10^{-16} light years are present.

(iii) 10^{-6}m equivalent of 1μm

1 metre is equivalent to $\frac{1}{10^{-6}} = 10^6$μm

In one metre 10^6 microns are present

(iv) 3.08×10^{16} m equivalent to 1 parsec.

1metre is equivalent to $\frac{1}{3.08 \times 10^{16}}$

$= 0.324 \times 10^{-16} = 3.24 \times 10^{-17}$m

In one metre 3.24×10^{-17} parsec are present.

2. How many parallactic second are there in one Astronomical unit?

Given data:

1 parallactic second = 3.08×10^{16} m

1 Astronomical unit = 1.496×10^{11} m

Solution:

$$\frac{1\text{ AU}}{1\text{ parsec}} = \frac{1.496\times10^{11}}{3.08\times10^{16}} = \frac{1.496\times10^{11}\times10^{-16}}{3.08}$$

$$= \frac{1.496\times10^{-5}}{3.08} = 0.485 \times 10^{-5}$$

$$= 4.85 \times 10^{-6} \text{ par sec.}$$

4.85×10^{-6} parsec present in one astronomical unit.

3. The unit of length convenient on the atomic scale is known as angstrom and is denoted by Å. The size of a helium atom is about 30 pico meter. What is the total atomic volume in metre^3 of one mole of helium atom?

Solution:

1Å = 100 pm ⇒ 30pm = 0.3Å

pm → picometer (10^{-12}m)

Å → Angstrom (10^{-10})m

Radius of the helium atom (r) = 30pm = 0.3Å $= 0.3 \times 10^{-10}$m

Volume of helium nucleus

$$V = \frac{4}{3} \times 3.14 \times (0.3 \times 10^{-10})^3 m^3 = 1.256 \times 10^{-30} m^3$$

Number of atoms in 1 mole of helium atom

= Avogadro's number(N) = 6.023×10^{23}

Atomic volume of 1 mole of helium atoms (v')

$$V' = V \times N$$
$$= 1.256 \times 10^{-30} \times 6.023 \times 10^{23}$$
$$= 7.564 \times 10^{-7}\text{m.}$$

4. The radius of the platinum atom in a nucleus is 60.2 fermi. Find the volume of the nucleus. Why fermi is used to measure size of a nucleus?

Solution:

The radius of the nucleus = 60.2 fermi $= 60.2 \times 10^{-15}$m

Volume of the platinum nucleus

$$= \frac{4}{3}\pi r^3 m^3 = \frac{4}{3} \times 3.14 \times (60.2 \times 10^{-15})^3 m^3$$

$$= \frac{4}{3} \times 3.14 \times (218167 \times 10^{-45})$$

$$= \frac{4}{3} \times 3.14 \times (2.18167 \times 10^{-40})$$

$$= 9.133 \times 10^{-40} m^3$$

Volume of the platinum nucleus is $9.133 \times 10^{-40}m^3$.

Fermi is used to measure very small distance so it is used to measure the nuclear size of an atom. It is denoted as 1 Fermi = 10^{-15}m.

VALUE BASED QUESTIONS

1. (i) Monica was watching the night sky. She saw a star, moving towards her, with increase in brightness. After some few minutes when she watched closely, she found it was the light from a flight in the sky. She was surprised, but initially the flight looked stationary, after some time it was glowing brightly moving towards her. So she went and asked her father. Why this effect occurred?

(ii) Is RADAR used in launching a missile from the ground to hit the target (i.e. fight air craft)?

Ans. (i) Any moving object, which is perpendicular to our eye sight will look like a stationary thing for a while. But as the moving object changes its angle of vision, its movement will be known.

(ii) Yes, RADAR is used in launching missile from the ground.

Creative Questions (HOTS)

1. Why has 'second' been defined is terms of periods of radiations from cesium-133?

Ans. Second has been defined is terms of periods of radiations because

(i) This period is accurately defined

(ii) This period is not affected by change of physical conditions like temperature. Pressure and volume etc.

(iii) The unit is easily reproducible in any good laboratory.

2. How many Astronomical units are there in one light year?

Given data:

1 Astronomical unit = 1.496×10^{11}m

1 light year = 9.46×10^{15}m

Solution:

$$\frac{1\text{ ly}}{1\text{ AU}} = \frac{9.46\times10^{15}}{1.496\times10^{11}} = \frac{9.46\times10^{15}\times10^{-11}}{1.496}$$

$$= \frac{9.46\times10^{4}}{1.496} = 6.32\times10^{4}\text{AU}$$

In 6.32×10^4AU are present in one light year.

3. When the planet Jupiter is at a distance of 824.7 million kilometers from the earth, its angular diameter is measured to be 35.72 of arc. Calculate the diameter of Jupiter.

Solution:

Distance, D = 824.7×10^6 km

$$\theta = 35.72'' = \frac{35.72}{60\times60}\times\frac{\pi}{180}\text{ rad}$$

$\theta \rightarrow$ is angular diameter

Diameter, d = ? ; $d = D \times \theta$

$$= 824.7\times10^{6}\times\frac{35.72}{60\times60}\times\frac{\pi}{180}\text{ km}$$

$$= 824.7\times10^{6}\times\frac{35.72}{3600}\times\frac{\pi}{180}\text{ km}$$

$$= 824.7\times10^{6}\times\frac{35.72\times3.14}{3600\times180}\text{ km}$$

Diameter of Jupiter = 1.427×10^5 km

4. In a submarine fitted with a SONAR, the time delay between generation of a signal and reception of its echo from an enemy ship is 110.3 seconds. If speed of sound in water is 1450 ms^{-1} then calculate the distance of the enemy ship from the submarine.

Solution:

Speed of a sound in water 1450 ms^{-1}

Time delay T = 110.3s

Distance of the enemy ship, $D = \frac{vT}{2}$

$$= \frac{1450\times110.3}{2} = \frac{159935}{2} = 79967\text{ m}$$

Distance of enemy ship = 79.96 km

5. In an ocean surveillance system of ship fitted with a (RADAR), the time delay between generation of a radio waves reflected from an enemy ship is observed to be 5.6s. Calculate the distance of the enemy ship from the surveillance ship.

Solution:

Time delay T = 5.6s

$$t = \frac{T}{2} = \frac{5.6}{2} = 2.8$$

Speed of radiowaves = speed of light (v)

$= 3 \times 10^8$ms^{-1}

Distance from the surveillance ship to enemy ship $D = v \times t = 3 \times 10^8 \times 2.8 = 8.4 \times 10^8$m

Distance (D) = 8.4×10^8 km.

Conceptual Questions

1. Why is it convenient to express the distance of stars in terms of light year (or) parsec rather than in km?

Ans. The distances of astronomical objects like stars, planets etc from the earth are huge. The distance on the earth are relatively small so it can be measured in km.

For Example :

The distance to be next nearest big galaxy Andromeda is 21,000,000,000,000,000,000 km.

i.e. 21×10^{18} km.

This number is so large that it becomes hard to write and to interpret.

So astronomical units like light year, parsec A.U are used for large distances.

2. Having all units in atomic standards is more useful. Explain.

Ans. All units in atomic standards are more useful because they never change with time.

3. Why dimensional methods are applicable only up to three quantities?

Ans. If a quantity depends on more than three factors than dimensional formula cannot be derived.

Because on equating the powers of M, L & T on either side of the dimensional equation, three equations can be obtained, from which only three unknown dimensions can be calculated.

4. Show that a screw gauge of pitch 1 mm and 100 divisions is more precise than a vernier caliper with 20 divisions on the sliding scale.

Ans. Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{No. of divisions}} = \frac{1}{100} = 0.01 \text{ mm (or) } 0.001\text{cm} \text{ on the Head scale.}$$

Least count of vernier calipers

$$= 1\text{MSD} - 1\text{VSD} = (1 - {}^{19}\!/_{20}) \text{ MSD} = \frac{1}{20} = 0.05\text{cm}.$$

So screw gauge is more precise than vernier.

5. If humans were to settle on other planets, which of the fundamental quantities will be in trouble? Why?

Ans. Time will be in trouble. Time becomes irrelevant. Because day and year based on spinning and revolution of the planet. So each planet has its own year length.

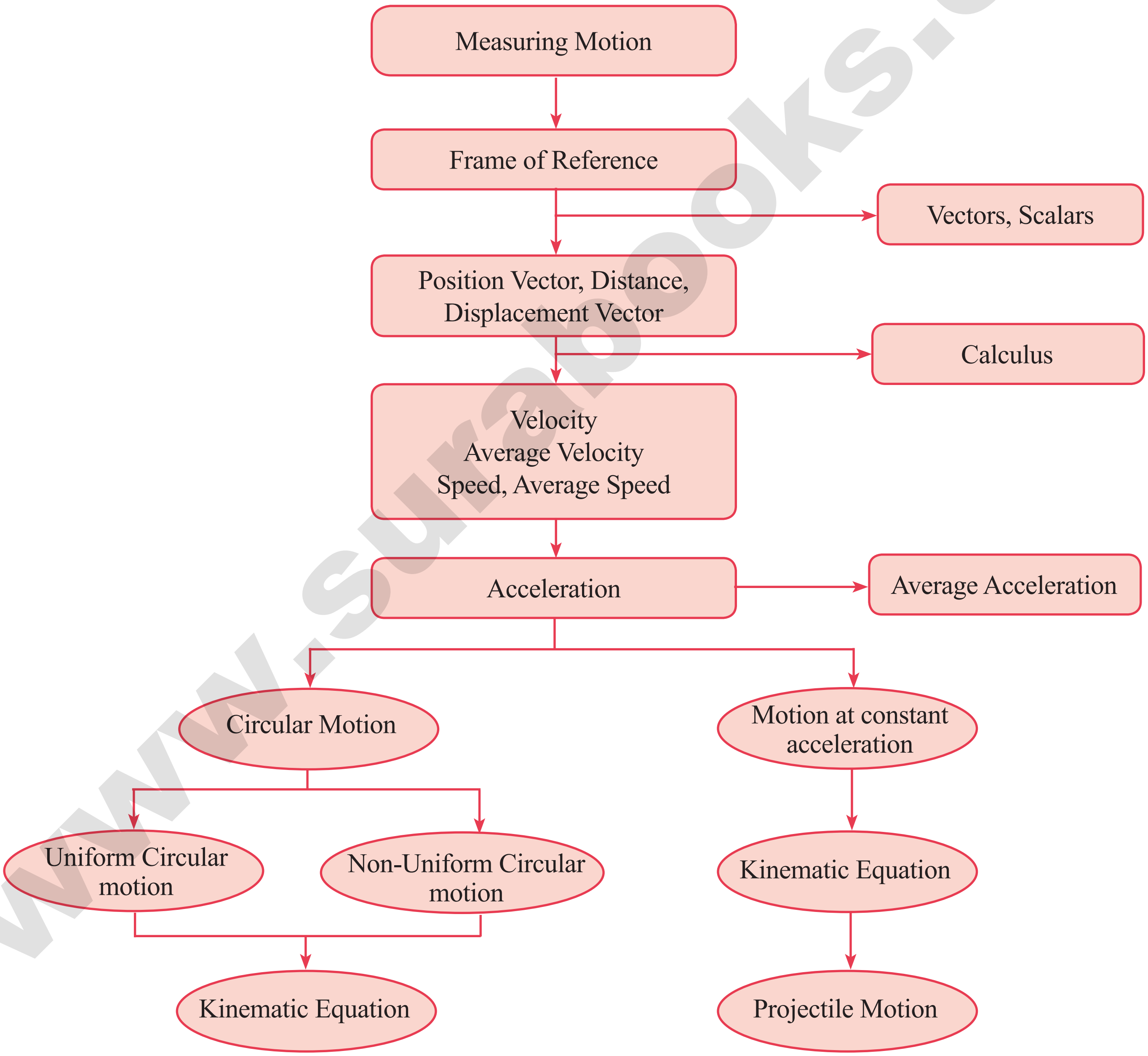
Eg. : Uranus and Neptune move too slow.

★ ★ ★ ★ ★

UNIT

02 KINEMATICS

CONCEPT MAP



FORMULAE TO REMEMBER

(1) Path length of distance, D = speed × time.

(2) Displacement = velocity × time.

(3) $\text{Speed} = \dfrac{\text{Distance}}{\text{Time}}$

(4) $\text{Velocity} = \dfrac{\text{Displacement}}{\text{Time}}$

(5) Relative velocity

(i) $\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ (ii) $\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$

(6) The equations of motion for accelerated body are:

(i) $v = u + at$ (ii) $S = ut + \frac{1}{2}at^2$ (iii) $v^2 = u^2 + 2as$ (iv) $S_n = u + \frac{a}{2}(2n-1)$

(7) The equations of motion for retarded body. Here a is negative.

(i) $v = u - at$ (ii) $S = ut - \frac{1}{2}at^2$ (iii) $v^2 = u^2 - 2as$ (iv) $S_n = u - \frac{a}{2}(2n-1)$

(8) The equations of motion for a body falling down under gravity. Here $a = +g$

(i) $v = u + gt$ (ii) $S = ut + \frac{1}{2}gt^2$ (iii) $v^2 = u^2 + 2gs$ (iv) $S_n = u + \frac{g}{2}(2n-1)$

(9) The equations of motion for a body going up against gravity. Here $a = -g$

(i) $v = u - gt$ (ii) $S = ut - \frac{1}{2}gt^2$ (iii) $v^2 = u^2 - 2gs$ (iv) $S_n = u - \frac{g}{2}(2n-1)$

(10) The maximum height attained by a body thrown vertically upwards with initial velocity u is, $S_{max} = \dfrac{u^2}{2g}$

(11) Total time taken by body in going up and coming down. $T = at = \dfrac{2u}{g}$

(12) The initial velocity of body in order to attain height h is, $u = \sqrt{2gh}$

(13) Unit vector $(\hat{A}); \hat{A} = \dfrac{\vec{A}}{A} = \dfrac{A_x\hat{i} + A_y\hat{j} + A_z\hat{k}}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$

(14) Area of parallelogram = $|\vec{A} \times \vec{B}|$

(15) Velocity of projectile at an instant of its flight is $v = \sqrt{v_x^2 + v_y^2}$

(16) Angular projection of projectile:

(i) Time of flight, $T_f = \dfrac{2u\sin\theta}{g}$

(ii) Maximum height, $h = \frac{u^2 \sin^2 \theta}{2g}$

(iii) Horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$

(iv) Maximum horizontal range $R_{max} = \frac{u^2}{g}$

(17) Centripetal acceleration $a_c = \omega^2 r$

(18) For motion along x axis, $v_x = u_x + a_x t$ and $x = x_0 + u_x t + \frac{1}{2} a_x t^2$

(19) For motion along y axis, $v_y = u_y + a_y t$ and $y = y_0 + u_y t + \frac{1}{2} a_y t^2$

IMPORTANT TERMS & DEFINITIONS

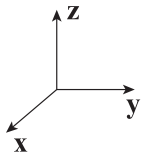
Rest	:	An object or a particle is said to be in the state of rest when it does not change its position with time with respect to its surroundings. Depending upon the position of observer, the state of rest (i) Absolute state of rest (ii) Relative state of rest
Motion	:	An object or a particle is said to be in the state of motion when it changes its position with time with respect to its surroundings. The motion of an object can be linear or curvilinear, circular or in a plane or in a space.
Motion in 1 - Dimensional	:	Motion of a body in a straight line is called one dimensional motion.
Motion in 2 – Dimensional	:	Motion of body in a plane is called two dimensional motion.
Motion in 3 – Dimensional	:	Motion of body in a space is called three dimensional motion.
Distance	:	It is the actual length of the path covered by a moving particle in a given interval of time, SI unit : metre(m).
Displacement	:	Displacement is the difference between the final and initial positions of the object in a given interval of time. It can also be defined as the shortest distance between these two positions of the object and its direction is from the initial to final position of the object, during the given interval of time. It is a vector quantity.
Speed	:	The rate of the path length (or) the distance covered by an object to the time taken. Its SI unit is m/s.
Uniform Speed	:	When a particle covers equal distances in equal intervals of time, then it is said to be moving with uniform speed.

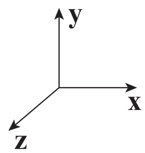
Non-uniform Speed	:	In non-uniform speed, particle covers unequal distances in equal intervals of time.
Average Speed	:	The average speed of a particle for a given "Interval of time" is defined as the ratio of distance travelled to the time taken. $\text{Average Speed} = \dfrac{\text{Total path length}}{\text{Total time period}}$
Instantaneous Speed	:	It is the speed of a particle at particular instant. When we say "speed" it usually means instantaneous speed. The instantaneous speed is average speed for infinitesimally small time interval (i.e. $\Delta t \to 0$). $\text{Instantaneous Speed } v = \lim_{\Delta t \to 0} \dfrac{\Delta s}{\Delta t} = \dfrac{ds}{dt}.$
Velocity	:	The rate of change of position (or) displacement of an object with respect to time. Its SI unit is m/s.
Uniform velocity	:	A particle is said to have uniform velocity, if magnitude as well as direction of its velocity remains same and this is possible only when the particles move in the same straight line without reversing its direction.
Non-uniform velocity	:	A particle is said to have non-uniform velocity, if either of magnitude or direction of velocity changes or both changes.
Average velocity	:	It is defined as the ratio of displacement to time taken by the body. $\text{Average Velocity} = \dfrac{\text{Total path length}}{\text{Total time}}; \quad \vec{v}_{avg} = \dfrac{\Delta \vec{r}}{\Delta t}$
Instantaneous velocity	:	It is defined as rate of change of position vector of particles with time. $\text{Instantaneous velocity } \vec{v} = \lim_{\Delta t \to 0} \dfrac{\Delta \vec{r}}{\Delta t} = \dfrac{d\vec{r}}{dt}.$
Acceleration	:	The rate of change of velocity of an object with time. Its SI unit is ms^{-2}.
Uniform acceleration	:	A body is said to have uniform acceleration if magnitude and direction of the acceleration remains constant during particle motion.
Non-uniform acceleration	:	A body is said to have non-uniform acceleration if magnitude or direction or both, change during motion.
Average acceleration	:	$\vec{a}_{avg} = \dfrac{\Delta \vec{v}}{\Delta t} = \dfrac{v_2 - v_1}{\Delta t}$, the direction of average acceleration vector is the direction of the change in velocity vectors as $\vec{a} = \dfrac{\Delta \vec{v}}{\Delta t}$.
Instantaneous acceleration	:	$\vec{a} = \lim_{\Delta t \to 0} \dfrac{\Delta \vec{v}}{\Delta t} = \dfrac{d\vec{v}}{dt}$ For a moving body, there is no relation between the direction of instantaneous velocity and direction of acceleration.
Projectile	:	A body which is thrown with an Initial horizontal velocity and at angle less than 90°, under the action of gravity is called Projectile.

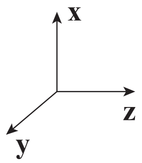
EVALUATION

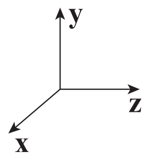
I. Multiple Choice Questions:

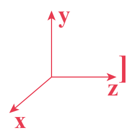
1. Which one of the following Cartesian coordinate systems is not followed in physics?

(a) 

(b) 

(c) 

(d) 

[Ans. (d) 

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2. Identify the unit vector in the following. *[Mar-2020]*

(a) $\hat{i}+\hat{j}$ (b) $\frac{\hat{i}}{\sqrt{2}}$

(c) $\hat{k}-\frac{\hat{j}}{\sqrt{2}}$ (d) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

[Ans. (d) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$]

3. Which one of the following physical quantities cannot be represented by a scalar? *[Mar-'23]*

(a) Mass (b) length

(c) momentum

(d) magnitude of acceleration

[Ans. (c) momentum]

4. Two objects of masses m_1 and m_2 fall from the heights h_1 and h_2 respectively. The ratio of the magnitude of their momenta when they hit the ground is *(AIPMT 2012) [July-'24]*

(a) $\sqrt{\frac{h_1}{h_2}}$ (b) $\sqrt{\frac{m_1h_1}{m_2h_2}}$

(c) $\frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$ (d) $\frac{m_1}{m_2}$

[Ans. (c) $\frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$]

5. If a particle has negative velocity and negative acceleration, its speed *[First Mid. - 2018; July-'24 HY-2018; QY-2019]*

(a) increases (b) decreases

(c) remains same (d) zero

[Ans. (a) increases]

6. If the velocity is $\vec{v}=2\hat{i}+t^2\hat{j}-9\vec{k}$, then the magnitude of acceleration at t = 0.5 s is *[QY. - 2018; June-'23]*

(a) 1 ms^{-2} (b) 2 ms^{-2}

(c) zero (d) –1 ms^{-2}

[Ans. (a) 1 ms^{-2}]

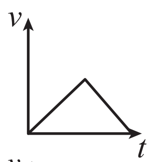
7. If an object is dropped from the top of a building and it reaches the ground at t = 4 s, then the height of the building is (ignoring air resistance) (g = 9.8 ms^{-2}) *[Aug-'22; QY-'24]*

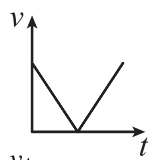
(a) 77.3 m (b) 78.4 m

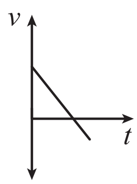
(c) 80.5 m (d) 79.2 m

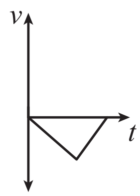
[Ans. (b) 78.4 m]

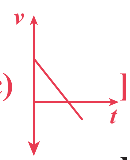
8. A ball is projected vertically upwards with a velocity *v*. It comes back to ground in time *t*. Which *v-t* graph shows the motion correctly? *(NSEP 00-01) [First Mid. - 2018; QY-'23; Mar-'24]*

(a) 

(b) 

(c) 

(d) 

[Ans. (c) 

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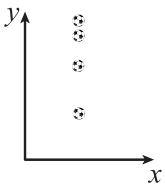
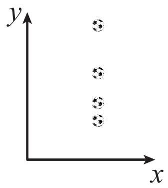
9. If one object is dropped vertically downward and another object is thrown horizontally from the same height, then the ratio of vertical distance covered by both objects at any instant t is

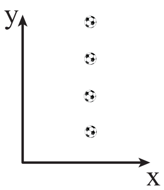
(a) 1 (b) 2 (c) 4 (d) 0.5

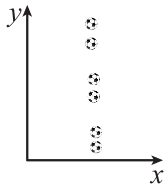
[Ans. (a) 1]

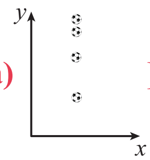
10. A ball is dropped from some height towards the ground. Which one of the following represents the correct motion of the ball?

(a) 

(b) 

(c) 

(d) 

[Ans. (a)  **]**

11. If a particle executes uniform circular motion in the *xy* plane in clock wise direction, then the angular velocity is in *[Sep-2020; Sep-2021; CRT & May 2022; HY-'23]*

(a) $+y$ direction (b) $+z$ direction

(c) $-z$ direction (d) $-x$ direction

[Ans. (c) $-z$ direction]

12. If a particle executes uniform circular motion, choose the correct statement *[July-'24]* *(NEET 2016; Aug-'22)*

(a) The velocity and speed are constant

(b) The acceleration and speed are constant.

(c) The velocity and acceleration are constant.

(d) The speed and magnitude of acceleration are constant. **[Ans. (d) The speed and magnitude of acceleration are constant.]**

13. If an object is thrown vertically up with the initial speed *u* from the ground, then the time taken by the object to return back to ground is *[Jun-2019 & -'23; Sep-2021; CRT-'22]*

(a) $\frac{u^2}{2g}$ (b) $\frac{u^2}{g}$

(c) $\frac{u}{2g}$ (d) $\frac{2u}{g}$ **[Ans. (d) $\frac{2u}{g}$]**

14. Two objects are projected at angles 30° and 60° respectively with respect to the horizontal direction. The range of two objects are denoted as $R_{30°}$ and $R_{60°}$. Choose the correct relation from the following. *[May-2022]*

(a) $R_{30°} = R_{60°}$ (b) $R_{30°} = 4R_{60°}$

(c) $R_{30°} = \frac{R_{60^0}}{2}$ (d) $R_{30°} = 2 R_{60°}$

[Ans. (a) $R_{30°} = R_{60°}$]

15. An object is dropped in an unknown planet from height 50 m, it reaches the ground in 2s . The acceleration due to gravity in this unknown planet is *[HY-2018]*

(a) $g = 20 \text{ m s}^{-2}$ (b) $g = 25 \text{ m s}^{-2}$

(c) $g = 15 \text{ m s}^{-2}$ (d) $g = 30 \text{ m s}^{-2}$

[Ans. (b) $g = 25 \text{ m s}^{-2}$]

II. Short Answer Questions.

1. Explain what is meant by Cartesian coordinate system?

Ans. At any given instant of time, the frame of reference with respect to which the position of the object is described in terms of position coordinates (x, y, z) is called **"Cartesian coordinate system"**.

2. Define a vector. Give examples. *[Mar-'24]*

Ans. Vector is a quantity which can be described by both magnitude and direction.

Examples:

Force, velocity, displacement, acceleration, etc.

3. Define a scalar. Give examples. *[QY. - 2019; Mar-'23]*

Ans. Scalar is a property which can be described only by magnitude.

Examples :

Distance, mass, temperature, speed and energy.

4. Write a short note on the scalar product between two vectors.

Ans. (i) The scalar product (or dot product) of two vectors is defined as the product of the magnitudes of both the vectors and the cosine of the angle between them.

(ii) Thus if there are two vectors $\vec{A}$ and $\vec{B}$ having an angle θ between them, then their scalar product is defined as $\vec{A} \cdot \vec{B} = AB \cos \theta$. Here, A and B are magnitudes of $\vec{A}$ and $\vec{B}$.

5. Write a short note on vector product between two vectors. *[HY-2018]*

Ans. (i) The vector product or cross product of two vectors is defined as another vector having a magnitude equal to the product of the magnitudes of two vectors and the sine of the angle between them.

(ii) The direction of the product vector is perpendicular to the plane containing the two vectors, in accordance with the right hand screw rule or right hand thumb rule.

(iii) Thus, if $\vec{A}$ and $\vec{B}$ are two vectors, then their vector product is written as $\vec{A} \times \vec{B}$ which is a vector $\vec{C}$ defined by

$$\vec{C} = \vec{A} \times \vec{B} = (AB \sin\theta)\hat{n}.$$

6. How do you deduce that two vectors are perpendicular?

Ans. If two vectors $\vec{A}$ and $\vec{B}$ are perpendicular to each other then their scalar product $\vec{A}\cdot\vec{B} = 0$, because cos 90°=0. Then the vectors $\vec{A}$ and $\vec{B}$ are said to be mutually orthogonal.

7. Define displacement and distance.

Ans. (i) **Displacement** is the difference between the final and initial positions of the object in a given interval of time. It is a vector quantity.

(ii) **Distance** is the actual path length travelled by an object in the given interval of time during the motion. It is a positive scalar quantity.

8. Define velocity and speed. *[First Mid-2018]*

Ans. Velocity :

Velocity is equal to rate of change of position vector with respect to time. Velocity is a vector quantity.

Speed :

It is the distance travelled in unit time. It is a scalar quantity.

9. Define acceleration. *[Mar. & QY-'24]*

Ans. It is the rate of change of velocity with time. Its SI unit is m s^{-2}.

10. What is the difference between velocity and average velocity? *[June-'23]*

Ans.

Velocity	Average Velocity
Velocity is equal to rate of change of position vector with respect to time.	Average velocity is the ratio of the displacement vector to the corresponding time interal.
$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$	$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t}$

11. Define a radian.

Ans. One radian is the angle subtended at the center of a circle by an arc that is equal in length to the radius of the circle.

12. Define angular displacement and angular velocity. *[Sep-2021; QY-'23]*

Ans. (i) **Angular displacement:** The angle described by the particle about the axis of rotation (or center O) in a given time is called angular displacement. Its unit is radian.

(ii) **Angular velocity:** The rate of change of angular displacement is called **angular velocity**. Its unit is rad s^{-1}.

13. What is non uniform circular motion? *[CRT-'22]*

Ans. (i) When an object is moving on a circular path with change in speed and direction, it is called non-uniform circular motion.

(ii) For example, when the bob attached to a string moves in vertical circle, the speed of the bob is not the same at all time.

14. Write down the Kinematic equations for angular motion. *[CRT-'22; QY-'23]*

Ans. Kinematic equations for Angular motion

$$\omega = \omega_0 + \alpha t$$

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

$$\theta = \frac{(\omega_0 + \omega)t}{2}$$

where θ = angular displacement

ω = angular velocity

ω_0 = initial angular velocity

α = angular acceleration

t = time.

15. Write down the expression for angle made by resultant acceleration and radius vector in the non uniform circular motion.

Ans. (i) The resultant acceleration is obtained by vector sum of centripetal and tangential acceleration.

(ii) The magnitude of this resultant acceleration is given by $a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}$

(iii) This resultant acceleration makes an angle θ with the radius vector.

This angle is given by $\tan\theta = \frac{a_t}{\left(\frac{v^2}{r}\right)}$

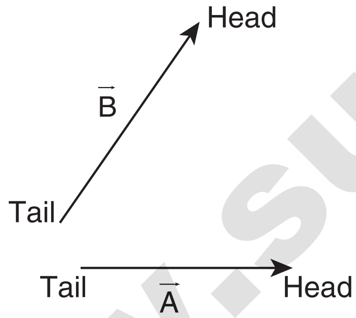
III. Long Answer Questions

1. Explain in detail the triangle law of addition. [OR] Explain triangular law of addition method

[First Mid-2018, QY-2018, '19 & 24; Jun.-2019; CRT & Aug-'22; Mar-'23]

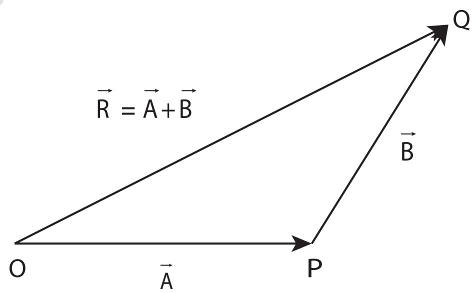
Ans. (i) **Triangular Law of addition method**

Let us consider two vectors $\vec{A}$ and $\vec{B}$ as shown in Figure.



Head and tail of vectors

(ii) Represent the vectors $\vec{A}$ and $\vec{B}$ and by the two adjacent sides of a triangle taken in the same order.



Triangle law of addition

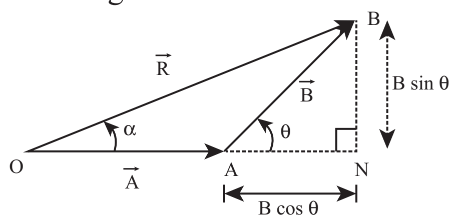
(iii) To explain further, the head of the first vector $\vec{A}$ is connected to the tail of the second vector $\vec{B}$. Let θ be the angle between $\vec{A}$ and $\vec{B}$. Then $\vec{R}$ is the resultant vector connecting the tail of the first vector $\vec{A}$ to the head of the second vector $\vec{B}$. The magnitude of $\vec{R}$ (resultant) is given geometrically by the length of $\vec{R}$ (OQ) and the direction of the resultant vector is the angle between $\vec{R}$ and $\vec{A}$.

(iv) Thus we write, $\vec{R} = \vec{A} + \vec{B}$

$$\overrightarrow{OQ} = \overrightarrow{OP} + \overrightarrow{PQ}$$

a) **Magnitude of resultant vector**

(i) The magnitude and angle of the resultant vector are determined as follows. Consider the triangle ABN, which is obtained by extending the side OA to ON. ABN is a right angled triangle.



Resultant vector and its direction by triangle law of addition.

$$\cos\theta = \frac{AN}{B} \quad \therefore AN = B\cos\theta \text{ and}$$

$$\sin\theta = \frac{BN}{B} \quad \therefore BN = B\sin\theta$$

(ii) From ΔOBN, we have

$$OB^2 = ON^2 + BN^2$$

$$\Rightarrow R^2 = (A + B\cos\theta)^2 + (B\sin\theta)^2$$

$$\Rightarrow R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$$

$$\Rightarrow R^2 = A^2 + B^2(\cos^2\theta + \sin^2\theta) + 2AB\cos\theta$$

$$\Rightarrow R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

which is the magnitude of the resultant of $\vec{A}$ and $\vec{B}$

b) Direction of resultant vectors:

If θ is the angle between $\vec{A}$ and $\vec{B}$, then

$$|\vec{A}+\vec{B}| = \sqrt{A^2+B^2+2AB\cos\theta}$$

If $\vec{R}$ makes an angle α with $\vec{A}$, then in ΔOBN,

$$\tan\alpha = \frac{BN}{ON} = \frac{BN}{OA+AN}$$

$$\tan\alpha = \frac{B\sin\theta}{A+B\cos\theta}$$

$$\Rightarrow \quad \alpha = \tan^{-1}\left(\frac{B\sin\theta}{A+B\cos\theta}\right)$$

2. Discuss the properties of Scalar and Vector products. *[HY-2018 & 19; QY-'23; July-'24]*

Ans. **Properties of Scalar Products:** *[Mar-'23]*

(i) The product quantity $\vec{A}\cdot\vec{B}$ is always a scalar. It is positive if the angle between the vectors is acute (i.e. < 90º) and negative if the angle between them is obtuse (i.e. 90º < θ < 180º).

(ii) The scalar product is commutative,

i.e. $\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$

(iii) The vectors obey distributive law i.e.

$\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$

(iv) The angle between the vectors

$$\theta = \cos^{-1}\left[\frac{\vec{A}\cdot\vec{B}}{AB}\right]$$

(v) The scalar product of two vectors will be maximum when cos θ = 1, i.e. θ = 0°, i.e., when the vectors are parallel;

$$(\vec{A}\cdot\vec{B})_{max} = AB$$

(vi) The scalar product of two vectors will be minimum, when cos θ = –1, i.e. θ = 180°

$(\vec{A}\cdot\vec{B})_{min} = -AB$ when the vectors are anti-parallel.

(vii) If two vectors $\vec{A}$ and $\vec{B}$ are perpendicular to each other then their scalar product $\vec{A}\cdot\vec{B}$ = 0, because cos 90°=0. Then the vectors $\vec{A}$ and $\vec{B}$ are said to be mutually orthogonal.

(viii) The scalar product of a vector with itself is termed as self–dot product and is given by $(\vec{A})^2 = \vec{A}\cdot\vec{A} = AA\cos\theta = A^2$. Here angle θ = 0º

The magnitude or norm of the vector $\vec{A}$ is $|\vec{A}| = A = \sqrt{\vec{A}\cdot\vec{A}}$

(ix) In case of a unit vector $\hat{n}$

$\hat{n}\cdot\hat{n} = 1 \times 1 \times \cos 0 = 1$. For example, $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$.

(x) In the case of orthogonal unit vectors $\hat{i}$, $\hat{j}$ and $\hat{k}$,

$\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 1\cdot1\cos 90º = 0$

(xi) In terms of components the scalar product of $\vec{A}$ and $\vec{B}$ can be written as

$\vec{A}\cdot\vec{B} = (A_x\hat{i}+A_y\hat{j}+A_z\hat{k})\cdot(B_x\hat{i}+B_y\hat{j}+B_z\hat{k})$

$= A_xB_x + A_yB_y + A_zB_z$, with all other terms zero.

The magnitude of vector $|\vec{A}|$ is given by

$$|\vec{A}| = A = \sqrt{A_x^2+A_y^2+A_z^2}$$

Properties of Vector Products: *[CRT-'22]*

(i) The vector product of any two vectors is always another vector whose direction is perpendicular to the plane containing these two vectors, i.e., orthogonal to both the vectors $\vec{A}$ and $\vec{B}$ even though the vectors $\vec{A}$ and $\vec{B}$ may or may not be mutually orthogonal.

(ii) The vector product of two vectors is not commutative, $\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$ But, $\vec{A}\times\vec{B} = -[\vec{B}\times\vec{A}]$. Here it is worthwhile to note that $|\vec{A}\times\vec{B}| = |\vec{B}\times\vec{A}| = AB\sin\theta$ i.e. in the case of the product vectors $\vec{A}\times\vec{B}$ and $\vec{B}\times\vec{A}$, the magnitudes are equal but directions are opposite to each other.

(iii) The vector product of two vectors will have maximum magnitude when sin θ = 1, i.e., $\theta = 90°$ i.e., when the vectors $\vec{A}$ and $\vec{B}$ are orthogonal to each other.

$$\left(\vec{A}\times\vec{B}\right)_{max} = AB\hat{n}$$

(iv) The vector product of two non-zero vectors will be minimum when $|\sin\theta| = 0$,
i.e. $\theta = 0°$ or $180°$.

$$\left[\vec{A}\times\vec{B}\right]_{min} = 0$$

i.e., the vector product of two non–zero vectors vanishes, if the vectors are either parallel or antiparallel.

(v) The self–cross product, i.e., product of a vector with itself is the null vector

$$\vec{A}\times\vec{A} = AA\sin 0°\,\hat{n} = \vec{0}$$

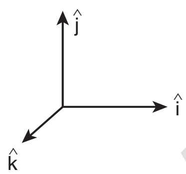
In physics the null vector $\vec{0}$ is simply denoted as zero.

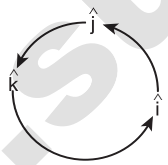
(vi) The self–vector products of unit vectors are thus zero.

$$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}\times\hat{k} = \vec{0}$$

(vii) In the case of orthogonal unit vectors, $\hat{i},\hat{j},\hat{k}$ in accordance with the right hand screw rule:

$$\hat{i}\times\hat{j} = \hat{k},\ \hat{j}\times\hat{k} = \hat{i} \text{ and } \hat{k}\times\hat{i} = \hat{j}$$





Also, since the cross product is not commutative,

$$\hat{j}\times\hat{i} = -\hat{k},\ \hat{k}\times\hat{j} = -\hat{i} \text{ and } \hat{i}\times\hat{k} = -\hat{j}$$

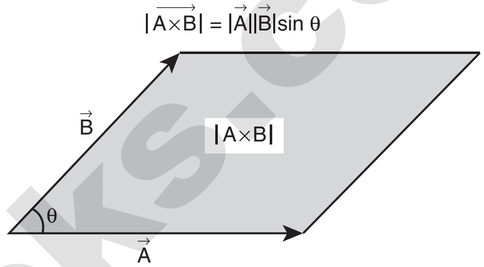
(viii) In terms of components, the vector product of two vectors $\vec{A}$ and $\vec{B}$ is

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$= \hat{i}\,(A_yB_z - A_zB_y) + \hat{j}\,(A_zB_x - A_xB_z) + \hat{k}\,(A_xB_y - A_yB_x)$$

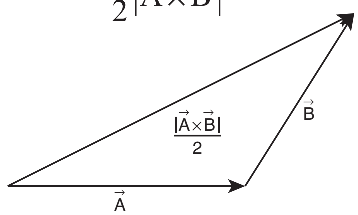
Note that in the $\hat{j}^{th}$ component the order of multiplication is different than $\hat{i}^{th}$ and $\hat{k}^{th}$ components.

(ix) If two vectors $\vec{A}$ and $\vec{B}$ form adjacent sides in a parallelogram, then the magnitude of $\vec{A}\times\vec{B}$ will give the area of the parallelogram as represented graphically.



Area of parallelogram

(x) Divide a parallelogram into two equal triangles the area of a triangle with $\vec{A}$ and $\vec{B}$ as sides is $\frac{1}{2}\left|\vec{A}\times\vec{B}\right|$.



Area of triangle

A number of quantities used in Physics are defined through vector products. Particularly physical quantities representing rotational effects like torque, angular momentum, are defined through vector products.

3. Derive the kinematic equations of motion for constant acceleration.

[Sep-2021; May-2022; June & HY-'23; Mar-'24]

[OR]

Derive equations of uniformly accelerated motion by calculus method. *[Govt. M.Q.P. -2018, QY-2018 & '19]*

Ans. **(i)** Consider an object moving in a straight line with uniform or constant acceleration 'a'.

(ii) Let 'u' be the initial velocity at time $t = 0$ and 'v' be the final velocity at time t.

(a) Velocity - time relation:

(i) Acceleration, $a = \frac{dv}{dt}$ or $dv = a\,dt$

(ii) By integrating both sides, we get,

$$\int_u^v dv = \int_0^t a\,dt = a\int_0^t dt = a[t]_0^t$$

$v - u = at$

$$\boxed{v = u + at}$$

(b) Displacement – time relation:

(i) Velocity, $v = \frac{ds}{dt}$ or $ds = v\,dt$

and since $v = (u + at)$, we get,

$ds = (u + at)\,dt$

Assume that initially at time t = 0, the particle started from the origin.

Further assuming that acceleration is time-independent, we have

$$\int_0^s ds = \int_0^t u dt + \int_0^t at\,dt \quad \text{(or)}$$

$$s = ut + \frac{1}{2}at^2 \quad ...(1)$$

(c) Velocity – displacement relation

(i) Acceleration $a = \frac{dv}{dt} = \frac{dv}{ds}\frac{ds}{dt} = \frac{dv}{ds}v$

[since $ds / dt = v$] where s is displacement traversed.

This is rewritten as a $\frac{1}{2}\frac{d}{ds}(v^2)$

or $ds = \frac{1}{2a}d(v^2)$

(ii) Integrating the above equation, using the fact when the velocity changes from u to v, displacement changes from 0 to s, we get,

$$\int_0^s ds = \int_u^v \frac{1}{2a}d(v^2)$$

$$\therefore s = \frac{1}{2a}(v^2 - u^2)$$

$$\therefore v^2 = u^2 + 2as \quad ...(2)$$

We can also derive the displacement s in terms of initial velocity u and final velocity v.

From the equation we can write,

$at = v - u$

Substituting equation (1) , we get,

$$s = ut + \frac{1}{2}(v - u)\,t$$

$$s = \frac{(u+v)t}{2}$$

4. Derive the equations of motion for a particle (a) falling vertically (b) projected vertically. *[QY-'24]*

Ans. **Case (a):** A body falling from a height (h)

(i) Consider an object of mass 'm' falling from a height 'h'.

(ii) Assume that there is no air resistance and acceleration due to gravity is constant near the surface of the Earth.

(iii) If the object is thrown with an initial velocity u along the Y-axis, then its final velocity and displacement at any time 't' is v and y respectively. Further acceleration a is equal to g.

(iv) Therefore equations of motion are,

$$v = u + gt\ ;\ y = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gy$$

(v) Suppose initial velocity $u = 0$, then

$$v = gt;\ y = \frac{1}{2}gt^2\ ;\ v^2 = 2gy$$

(vi) Time taken by the object to reach the ground(T), If $t = T$ and $y = h$, then,

$$h = \frac{1}{2}gT^2$$

$$T = \sqrt{\frac{2h}{g}}$$

(vii) The Speed of the object when it reaches the ground,

$$v^2_{ground} = 2gh$$

$$v_{ground} = \sqrt{2gh}$$

Case (b): A body thrown vertically upward.

(i) Consider an object of mass '*m*' thrown vertically upward with an initial velocity u.

(ii) Assume that there is no air resistance and acceleration due to gravity is constant near surface of the Earth.

(iii) The final velocity and displacement at any time 't' is v and y respectively. Further acceleration a is equal to –g.

(iv) Therefore equations of motion are,

$$v = u - gt$$
$$y = ut - \frac{1}{2}gt^2$$
$$v^2 = u^2 - 2gy$$

5. Derive the equation of motion, range and maximum height reached by the particle thrown at an oblique angle θ with respect to the horizontal direction.

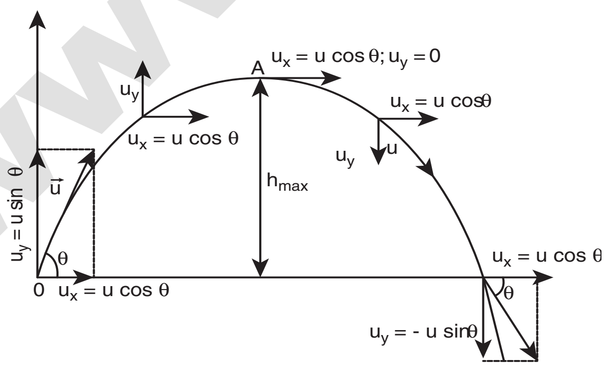
[Govt. MQP-2018; QY-2018. '23 & '24 ; HY-2018]

Ans. **(i)** Consider an object thrown with initial velocity $\vec{u}$ at an angle θ with the horizontal.

Then, $\vec{u} = u_x\hat{i} + u_y\hat{i}$

Where $u_x = u\cos\theta$ is the horizontal component and $u_y = u\sin\theta$ the vertical component of velocity.

(ii) Since acceleration due to gravity acts vertically downwards, velocity along the horizontal x-direction u_x doesn't change throught the motion. Whereas velocity along the y-direction u_y is changed.



Graphical representation of angular projection

The path of the projectile:

(a) Motion along *x*-direction:

(i) The horizontal distance travelled by the projectile at a point P after a time t can be written as,

$$s_x = u_x t + \frac{1}{2}a_x t^2$$

(ii) Here, $s_x = x$, $u_x = u\cos\theta$, and $a_x = 0$, Therefore,

$$x = u\cos\theta . t$$
$$t = \frac{x}{u\cos\theta} \quad ...(1)$$

(b) Motion along *y*-direction:

(i) The downward distance travelled by the projectile at a point P after a time t can be written as,

$$s_y = u_y t + \frac{1}{2}a_y t^2$$

(ii) Here, $s_y = y$, $u_y = u\sin\theta$, and $a_y = -g$

Therefore, $y = u\sin\theta\, t - \frac{1}{2}gt^2$

(iii) Substituting equation (1), we get,

$$y = u\sin\theta \frac{x}{u\cos\theta} - \frac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2$$

$$y = x\tan\theta - \frac{1}{2}g\frac{x^2}{u^2\cos^2\theta}$$

(iv) Thus, the path travelled by the projectile is an inverted parabola.

Maximum Height: (h_{max})

(i) The maximum vertical distance travelled by the projectile during its journey is called maximum height.

(ii) For the vertical part of the motion,

$$v_y^2 = u_y^2 + 2a_y s$$

(iii) Here, $v_y = 0$, $s_y = h_{max}$, $u_y = u\sin\theta$ and $a_y = -g$ Therefore.

$$0 = u^2\sin^2\theta - 2gh_{max}$$

$$\boxed{h_{max} = \frac{u^2\sin^2\theta}{2g}}$$

Time of flight: (T_f)

(i) The time of flight(T_f) is the total time taken by the projectile to hit the ground after thrown.

(ii) The downward distance travelled by the projectile at a time t can be written as,

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

(iii) Here substituting the values $S_y = 0$, $t = T_f$, $u_y = u \sin\theta$, and $a_y = -g$ we get,

$$0 = u \sin\theta\, T_f - \frac{1}{2} g T_f^2$$

Therefore, $\boxed{T_f = \frac{2u\sin\theta}{g}}$

Horizontal range : (R)

(i) The horizontal range (R) is the maximum horizontal distance distance between the point of projection and the point where the projectile hits the ground.

(ii) The horizontal distance travelled by the projectile at a time t can be written as,

$$s_x = u_x t + \frac{1}{2} a_x t^2$$

(iii) Here, $S_x = R$, $u_x = u \cos\theta$, $a_x = 0$ and $t = T_f$

$R = u \cos\theta \cdot T_f$

$$R = u \cos\theta \cdot \left(\frac{2u\sin\theta}{g}\right) = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$\left[\because T_f = \frac{2u\sin\theta}{g}\right]$$

(iv) Therefore, $\boxed{R = \frac{u^2 \sin 2\theta}{g}}$

$[\because \sin 2\theta = 2\sin\theta \,.\, \cos\theta]$

(v) For maximum range, $\sin 2\theta = 1$

$$2\theta = \frac{\pi}{2}$$

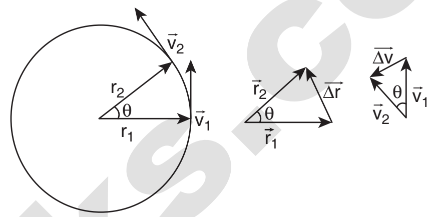
$$\theta = \frac{\pi}{4}$$

The maximum range is, $\boxed{R = \frac{u^2}{g}}$

6. Derive the expression for centripetal acceleration. (OR) Derive an expression for the centripetal acceleration of a body moving in a circular path of radius 'r' with uniform speed.

[Mar-2020; July-'24]

***Ans.* (i)** Consider the position vectors and velocity vectors shift through the some angle θ in a small interval of time Δt as shown in Figure



(ii) In uniform circular motion,

$$r = \left|\vec{r}_1\right| = \left|\vec{r}_2\right| \text{ and } v = \left|\vec{v}_1\right| = \left|\vec{v}_2\right|$$

(iii) From Figure, the geometrical relationship between the magnitude of position and velocity vectors is given by,

$$\frac{\Delta r}{r} = -\frac{\Delta v}{v} = \theta$$

(iv) Here the negative sign implies that Δv points radially inward, towards the center of the circle.

$$\Delta v = -v\left(\frac{\Delta r}{r}\right)$$

(v) Dividing both sides by Δt, we get,

$$a = \frac{\Delta v}{\Delta t} = -\frac{v}{r}\left(\frac{\Delta r}{\Delta t}\right)$$

(vi) Applying the limit $\Delta t \to 0$, We get,

$$\frac{dv}{dt} = -\frac{v}{r}\left(\frac{dr}{dt}\right)$$

(vii) Since $a_c = \frac{dv}{dt}$ and $v = \frac{dr}{dt}$, we can write,

$$\boxed{a_c = -\frac{v^2}{r}} = \frac{v^2}{r} \quad v = \omega r$$

where a_c is the centripetal acceleration.

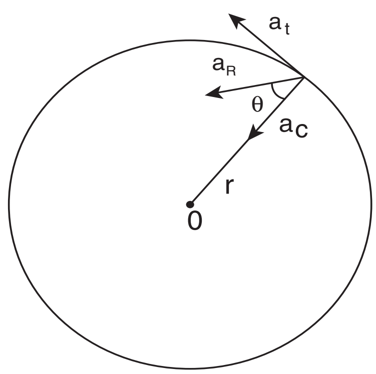
$$\boxed{a = -\omega^2 r}$$

7. Derive the expression for total acceleration in the non-uniform circular motion.

Ans. **(i)** If the speed of the object in circular motion is not constant, then we have non-uniform circular motion.

(ii) For example, when the bob attached to a string moves in vertical circle, the speed of the bob is not the same at all time.

(iii) Whenever the speed is not same in circular motion, the particle will have both centripetal and tangential acceleration as shown in the Figure.



Resultant acceleration (a_R) in non uniform circular motion

(iv) The resultant acceleration is obtained by vector sum of centripetal and tangential acceleration.

(v) Since centripetal acceleration is $\frac{v_2}{r}$, the magnitude of this resultant acceleration is given by $a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}$

(vi) This resultant acceleration makes an angle θ with the radius vector as shown in Figure.

This angle is given by $\tan\theta = \frac{a_t}{\left(v^2/r\right)}$

IV. Exercises

1. The position vectors particle has length 1m and makes 30° with the *x*-axis. What are the lengths of the *x* and *y* components of the position vector? *[Govt. MQP-2018; First Mid-2018; Jun.-2019]*

Solution:

Length of position vector = OA = 1 m = l

x = component of length l_x = ?

y = component of length l_y = ?

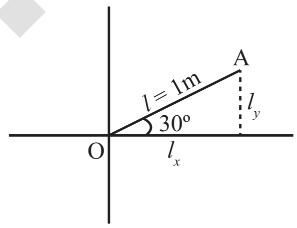
$$\cos 30° = \frac{l_x}{l} = \frac{l_x}{1} = l_x$$

$$\therefore l_x = \cos 30° = \frac{\sqrt{3}}{2}$$

$$\sin 30° = \frac{l_y}{l} = \frac{l_y}{1} = l_y$$

$$\therefore l_y = \sin 30° = \frac{1}{2}$$

$$l_x = \frac{\sqrt{3}}{2};\ l_y = \frac{1}{2} = 0.5$$



2. A particle has its position moved from $\vec{r}_1 = 3\hat{i} + 4\hat{j}$ to $\vec{r}_2 = \hat{i} + 2\hat{j}$. Calculate the displacement vector ($\Delta\vec{r}$) and draw the $\vec{r}_1$, $\vec{r}_2$ and $\Delta\vec{r}$ vector in a two dimensional Cartesian coordinate system.

Solution:

The position vector $P_1 = \vec{r}_1 = 3\hat{i} + 4\hat{j}$

The position vector $P_2 = \vec{r}_2 = \hat{i} + 2\hat{j}$

The displacement vector $\Delta\vec{r}$ = ?

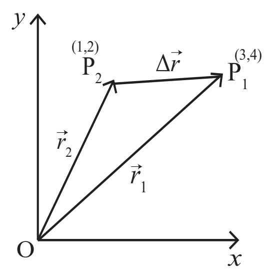
$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$$

$$= (\hat{i} + 2\hat{j}) - (3\hat{i} + 4\hat{j})$$

$$= (1-3)\hat{i} + (2-4)\hat{j}$$

$$\Delta\vec{r} = -2\hat{i} - 2\hat{j}$$

$$\Delta\vec{r} = -2(\hat{i} + \hat{j})$$



3. Calculate the average velocity of the particle whose position vector changes from $\vec{r}_1 = 5\hat{i} + 6\hat{j}$ to $\vec{r}_2 = 2\hat{i} + 3\hat{j}$ in a time 5 second.

Solution:

Initial velocity $\vec{v}_1 = 5\hat{i} + 6\hat{j}$

Final velocity $\vec{v}_2 = 2\hat{i} + 3\hat{j}$

Time = 5s

Average Velocity = ?

$$V_{average} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{(2\hat{i}+3\hat{j})-(5\hat{i}+6\hat{j})}{5}$$

$$= \frac{(2-5)\hat{i} + (3-6)\hat{j}}{5} = \frac{-3\hat{i} - 3\hat{j}}{5}$$

$$V_{average} = \frac{-3}{5}(\hat{i} + \hat{j})$$

4. Convert the vector $\vec{r} = 3\hat{i} + 2\hat{j}$ into a unit vector.

Solution:

Given vector $\vec{r} = 3\hat{i} + 2\hat{j}$

Unit vector $\hat{r} = ?$

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{3\hat{i}+2\hat{j}}{\sqrt{3^2+2^2}} = \frac{3\hat{i}+2\hat{j}}{\sqrt{13}}$$

5. What are the resultants of the vector product of two given vectors given by $\vec{A} = 4\hat{i} - 2\hat{j} + \hat{k}$ and $\vec{B} = 5\hat{i} + 3\hat{j} - 4\hat{k}$? *[May-2022]*

Solution:

Given : $\vec{A} = 4\hat{i} - 2\hat{j} + \hat{k}$

$\vec{B} = 5\hat{i} + 3\hat{j} - 4\hat{k}$

$$\text{Resultant vector} = \vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 4 & -2 & 1 \\ 5 & 3 & -4 \end{vmatrix}$$

$$= [(8-3)\hat{i} - (-16-5)\hat{j} + (12+10)\hat{k}]$$

$$\text{Resultant vector} = 5\hat{i} + 21\hat{j} + 22\hat{k}$$

6. An object at an angle such that the horizontal range is 4 times of the maximum height. What is the angle of projection of the object?

Solution: Given :

Horizontal range = 4 (maximum height)

(i.e) $R = 4\,h_{maximum}$

Angle of projection θ = ?

Formula :

$$\text{Range } R = \frac{u^2 \sin 2\theta}{g}$$

$$h_{maximum} = \frac{u^2 \sin^2\theta}{2g}$$

$$R = 4\,h_{maximum}$$

$$\frac{u^2 \sin 2\theta}{g} = 4 \times \frac{u^2 \sin^2\theta}{2g}$$

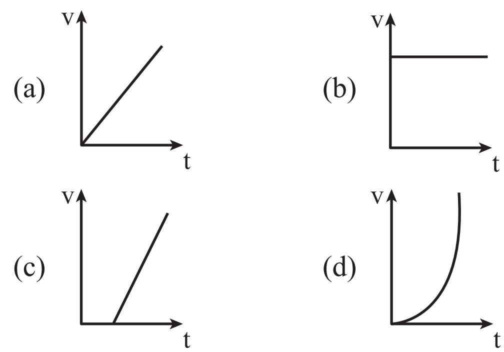
$$\sin 2\theta = 2\sin^2\theta$$

$$2\sin\theta\cos\theta = 2\sin^2\theta$$

$$\Rightarrow \cos\theta = \sin\theta \Rightarrow \frac{\sin\theta}{\cos\theta} = 1$$

$$\therefore \tan\theta = 1 \Rightarrow \boxed{\theta = 45^\circ}$$

7. The following graphs represent velocity – time graph. Identify what kind of motion a particle undergoes in each graph.



Ans. (a) (i) It represents the uniform acceleration. Body starts from rest and move with constant velocity (i.e $\vec{a}$ = constant, $\vec{v}$ = constant)

(ii) Greater is the slope, greater will be the acceleration.

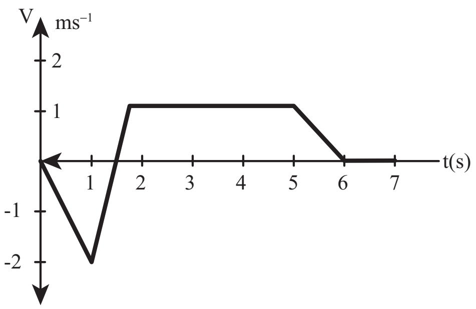
(b) Body moving with uniform velocity. zero slope indicates zero acceleration.

(i.e $\vec{v}$ = constant)

(c) Straight line $v - t$ graph does not pass the origin. After some time it moves with a uniform acceleration. [acceleration is constant but greater than first graph]

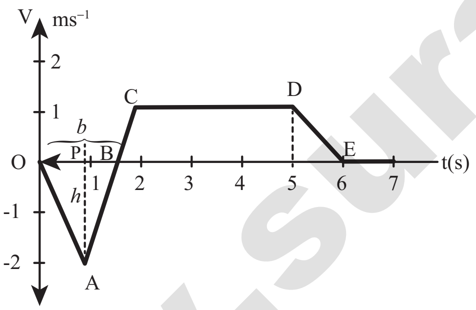
(d) Greater changes in velocity are taking place in equal intervals of time. It represents an increasing acceleration ie. acceleration is variable.

8. The following velocity–time graph represents a particle moving in the positive x–direction. Analyse its motion from 0 to 7 s. Calculate the displacement covered and distance travelled by the particle from 0 to 2 s.



Solution:

It is a uniform motion



a) **As per graph :-**

(i) From 0 to 1.5s the particle moving in a opposite direction.

(ii) From 1.5s to 2s the particle is moving with increasing velocity.

(iii) From 2s to 5s velocity of the particle is constant of magnitude $1ms^{-1}$.

(iv) From 5s to 6s velocity of the particle is decreasing

(v) From 6s to 7s the particle is at rest.

b) **Distance covered by the particle :-**

$$= \frac{1}{2} \times 2 \times 1.5 + \frac{1}{2} \times 1 \times 0.5$$
$$= 1.5 \text{ m} + 0.25\text{m}$$
$$= 1.75\text{m}$$

c) **Displacement of the particle :-**

$$= -\frac{1}{2} \times 2 \times 1.5 + \frac{1}{2} \times 1 \times 0.5$$
$$= -1.5\text{m} + 0.25\text{m}$$
$$= -1.25\text{m}$$

A particle moves with $-ve$ velocity along OA, then moves with uniform velocity and retards uniformly then it comes to rest at E.

9. A particle is projected at an angle of θ with respect to the horizontal direction. Match the following for the above motion.

(a) v_x – decreases and increases

(b) v_y – remains constant

(c) Acceleration – varies

(d) Position vector – remains downward

Ans. (a) v_x – remains constant

(b) v_y – decreases and increases

(c) Acceleration – remains downward

(d) Position vector – varies

10. A water fountain on the ground sprinkles water all around it. If the speed of the water coming out of the fountain is v, calculate the total area around the fountain that gets wet.

Solution:

Speed of the water coming out of the fountain = v

The maximum distance the water wets = R_{max}

Total area around the fountain that gets wet = A = ?

Water that comes from a fountain can be taken as a projectile and the distance covered is the maximum range of the projectile (i.e) θ= 45°

$$A = \pi R^2_{max.}$$

$$R_{max} = \frac{v^2 \sin 2\theta}{g} = \frac{v^2 \sin 90^o}{g} = \frac{v^2}{g}$$

$$\therefore A = \pi\left(\frac{v^2}{g}\right)^2 = \frac{\pi v^4}{g^2}$$

11. The following table gives the range of a particle when thrown on different planets. All the particles are thrown at the same angle with the horizontal and with the same initial speed. Arrange the planets in ascending order according to their acceleration due to gravity, (g value).