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EC PHYSICS

11

Volume - I & II

This special guide is prepared
on the basis of New Syllabus and Govt. Key

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PREFACE

Student with average IQ always struggle to cope up studies. They always seek for the best, sources to learn and score high marks.

The pattern of the question being asked in the exams has changed dramatically and the difficulty level has also increased considerably. To succeed in board exams and to actualise your dream, you are required to prepare strategically and study in a focussed manner.

LOYOLA serves the above cited purpose in perfect manner.

Specially designed for coaching students of different levels. (Slow learners, average and above average students)

- Simplified text matter.
- Focussed on coverage of text book
- MCQ's are framed based on new pattern.
- Comprehensive questions are designed for average and above average students based on key points
- **Included Govt. question paper with their keys.**

Best wishes

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CONTENTS

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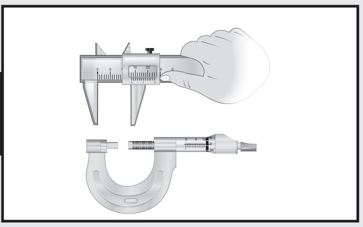
UNIT -1



NATURE OF PHYSICAL WORLD AND MEASUREMENT

PART - I - TEXT BOOK 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

a) kg^2 b) m^3
c) s^{-1} d) m **Ans: a) kg^2**

Solution: Hint : Dimension for $h = ML^2T^{-1}$

$c = LT^{-1}$

$G = M^{-1}L^3T^{-2}$

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

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

a) 8% b) 2%
c) 4% d) 6% **Ans: d) 6%**

Solution: volume = $\frac{4}{3}\pi r^3$

%of error = 3 x 2% = 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 HY - 2018

a) 4% b) 5%
c) 6% d) 7% **Ans: d) 7%**

Solution: $T = 2\pi\sqrt{l/g}$ $\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$

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

$g = 4\pi^2 \, l/T^2 \left[\frac{\Delta l}{l} = 1\%, \; \frac{\Delta T}{T} = 3\%\right]$

$\therefore \frac{\Delta g}{g} = 1 \times 1 + 2 \times 3 = 1 + 6 = 7\%$

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

a) 351% b) 1%
c) 0.28% d) 0.035%

Ans: c) 0.28%

Solution: % error = $\frac{\Delta l}{l} \times 100\%$

% error = $\frac{0.01}{3.51}$ = 100%

$= \frac{1}{3.51} = 0.28\%$

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

a) 0.007 m^2 b) 2.64 x 10^{24} kg
c) 0.0006032 m^2 d) 6.3200 J

Ans: d) 6.3200 J

Solution: 0.007 → 1

2.64×10^{24} → 3

0.0006032 → 4

6.3200 → 5

6. If π = 3.14, then the value of π^2 is QY - 2018 Jun - 2019 May-2022

a) 9.8596 b) 9.860
c) 9.86 d) 9.9 **Ans: c) 9.86**

Solution: π^2 = 3.14 x 3.14 =9.8596

Rounded to 3 significant fig. **= 9.86**

7. Round of the following number 19.95 into three significant figures. Mar - 2023

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? HY - 2018 Mar - 2019 Aug-2022

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

Ans: b) torque and energy

Solution: Force $= MLT^{-2}$

Torque $= ML^2T^{-2}$

Energy $= ML^2T^{-2}$

Power $= ML^2T^{-3}$

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9. **The dimensional formula of Planck's constant h is** Aug-2022 AMU JEE Main ; NEET

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

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

Solution: $E = h\gamma$

$$h = E/\gamma = \frac{ML^2T^2}{T^{-1}}$$

$$= ML^2T^{-1}$$

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) $[LT^{-3}]$

Solution: $v = bt^2$

$$b = v/t^2 = \frac{LT^{-1}}{T^2}$$

$$= [LT^{-3}]$$

11. **The dimensional formula for gravitational constant G is** 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) $[M^{-1}L^3T^{-2}]$

Solution: $F = \frac{Gm_1 m_2}{r^2}$

$$G = \frac{Fr^2}{m_1 m_2}$$

$$= \frac{MLT^{-2}\times L^2}{M^2}$$

$$G = [M^{-1}L^3T^{-2}]$$

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

a) 0.04 b) 0.4
c) 40 d) 400 **Ans: c) 40**

Solution: $n_1u_1 = n_2u_2$

$$4\frac{g}{cm^2} = n_2\frac{100}{(10)^3}$$

$$n_2 = \frac{4\times 10^3}{100} = \frac{4000}{100} = 40$$

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

a) $[MLT^0]$ b) $[MLT^{-1}]$
c) $[ML^{-2}T]$ d) $[ML^{-1}T^0]$ QY - 2019

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

Solution: $F \alpha v^2$

$F = K v^2$

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

$$= [ML^{-1}T^0]$$

14. **The dimension of $(\mu_0\varepsilon_0)^{-1/2}$ is** HY - 2019

a) length b) time
c) velocity d) force Main AIPMT-2011

Ans: c) velocity

Solution: $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

$c = [\mu_0\varepsilon_0]^{-1/2}$

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) $\frac{\sqrt{hG}}{c^{3/2}}$ b) $\frac{\sqrt{hG}}{c^{5/2}}$

c) $\frac{\sqrt{hc}}{G}$ d) $\frac{\sqrt{Gc}}{h^{3/2}}$

Ans: a) $\frac{\sqrt{hG}}{C^{3/2}}$

Solution: $L \alpha h^x c^y G^z$

$L = (ML^2T^{-1})^x (LT^{-1})^y (M^{-1}L^3T^{-2})^z$

$L = M^{x-z}L^{2x+y+3z}T^{-x-y-2z}$

$x - z = 0$

$2x + y + 3z = 1$

$-x - y - 2z = 0$

On solving $x = 1/2$

$y = -3/2$

$z = 1/2$

$$L \alpha h^{1/2} c^{-3/2} G^{1/2}$$

$$L = \frac{h^{1/2}G^{1/2}}{c^{3/2}}$$

$$L = \frac{\sqrt{hG}}{C^{3/2}}$$

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II. Short Answer Questions

1. Briefly explain the types of Physical quantities.

Physical quantities are classified into two types 1. Fundamental Quantities

2. Derived Quantities

Fundamental quantities : Sep-2020

Fundamental or base quantities are 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.

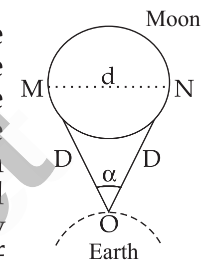
Derived Quantities :

Quantities that can be expressed in terms of fundamental quantities are called derived quantities. 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 - 2019

➢ Once the distance 'D' of a planet is determined the diameter 'd' angular size of the moon can be estimated by parallax method.

➢ Two diametrically opposite points M and N of moon are viewed through telescope from a point A on the earth. The angle α between the two directions viewed is measured. Then by considering MN as arc of length d of a circle with centre at A and distance D as radius, we can write.



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

(or) $d = \alpha D$

3. Write the rules for determining significant figures. QY - 2018 Mar - 2023

Rules for counting significant figures :

	Rule	Example
i	All non-zero digits are significant	1342 has **four** significant figures
ii	All zeros between two non zero digits are significant	2008 has **four** significant figures
iii	All zeros to the right of a non-zero digit but to the left of a decimal point are significant.	30700. has **five** significant figures
iv	For the number without a decimal point, the terminal or trailing zero (s) are not significant.	30700 has **three** significant figures
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.	0.00345 has **three** significant figures
vi	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
vii	The number of significant figures does not depend on the system of units used.	1.53 cm, 0.0153m, 0.0000153 km. all have **three** significant figures.

4. What are the Limitations of dimensional analysis? GMQ-2018, HY-2018, June-2019, Sep-2020, Aug-2022

Limitations of Dimensional analysis :

1. This method gives no information about the dimensionless constants in the formula like 1, 2 .... π, e, etc.
2. This method cannot decide whether the given quantity is a vector or a scalar.
3. This method is not suitable to derive relations involving trigonmetric, exponential and logarithmic functions.
4. It cannot be applied to an equation involving more than three physical quantities.

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5. It can only check on whether a physical relation is dimensionally correct but not the correctness of the relation. For example using dimensional analysis, $s = ut + \frac{1}{3}at^2$ is dimensionally correct whereas the correct relation is $s = ut + \frac{1}{2}at^2$

5. Define Precision and accuracy. Explain with one example.

Accuracy is a measure of the closeness of the measured value to the true value.

Precision : The precision of an instrument gives the minimum value that can be measured by it.If a measurement is precise, that does not necessarily mean that it is accurate. However, if the measurement is consistently accurate, it is also precise.

Example : Let the temperature of a refrigerator repeatedly measured by a thermometer be given as 10.4^0C, 10.2^0C, 10.3^0C, 10.1^0C, 10.2^0C, 10.1^0C, 10.1^0C, 10.1^0C However, if the real temperature inside the refrigerator is 9^0C, we say that the thermometer is not accurate but since all the measured value are close to 10^0C, hence it is 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.

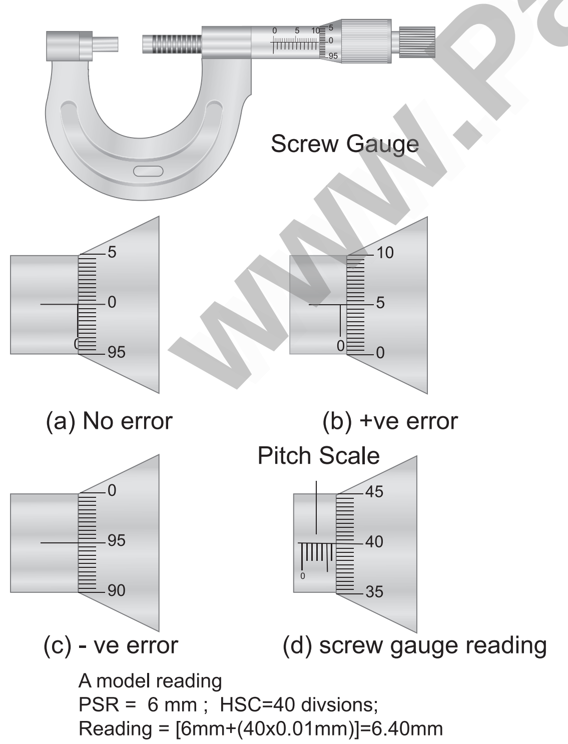
QY - 2018 Aug - 2022

i) Measurement of small distances :

Screw gauge and Vernier caliper:

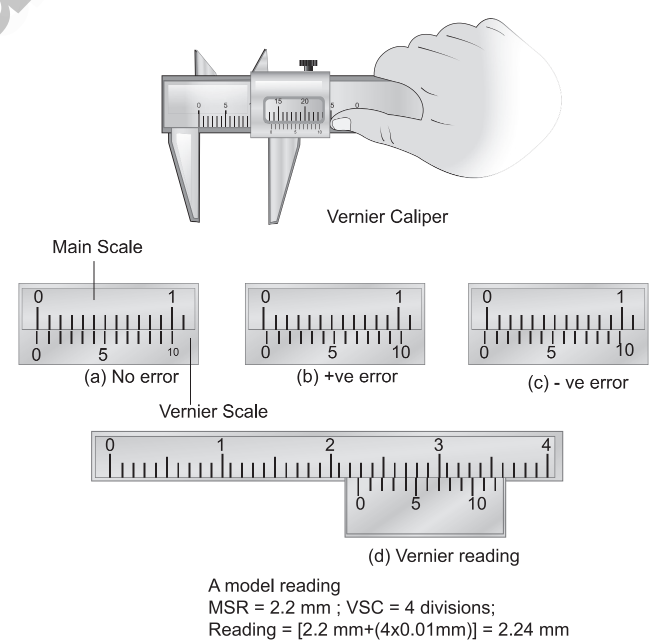
Screw gauge:

- ➢ The screw gauge is an instrument used for measuring accurately the dimensions of objects up to a maximum of about 50 mm.
- ➢ The principle of the instrument is the magnification of linear motion using the circular motion of a screw.
- ➢ The least count of the screw gauge is 0.01 mm.



Vernier caliper:

- ➢ 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 the vernier caliper is 0.1 mm.



ii) Triangulation method for the height of an accessible object Mar-20

- ➢ Let AB=h be the height of the tree or tower to be measured. Let C be the point of

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observation at distance x from B. Place a range finder at C and measure the angle of elevation. ∠ACB = θ as shown in Figure.

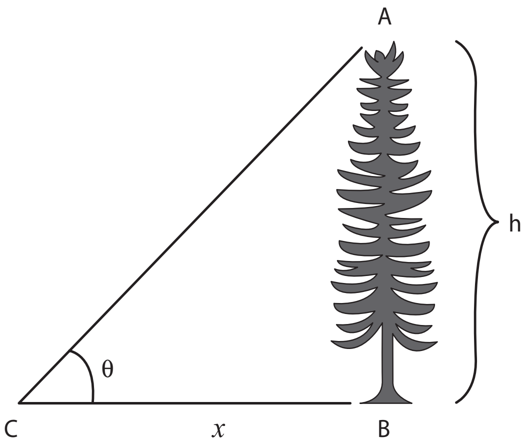
➢ From right angled triangle ABC.

$$\tan\theta = \frac{AB}{BC} = \frac{h}{x}$$

(or)

$$\text{height } h = x \tan\theta$$

Knowing its distance x,
the height h can be determined.



Radar method Mar-2020

➢ The word RADAR stands for Radio Detection and Ranging. 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, after reflection from the planet, are detected by the receiver.

➢ 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

$$\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

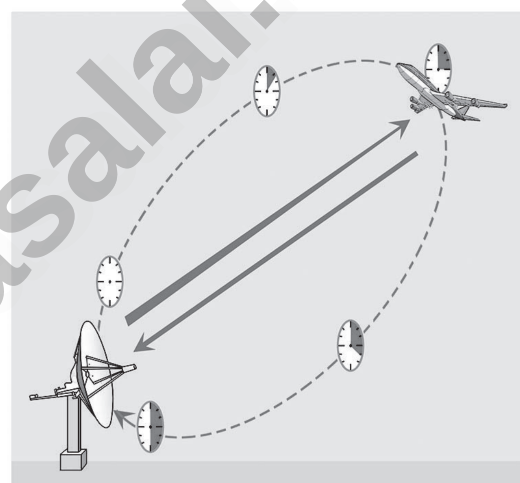
Distance(d) = Speed of radio waves x time taken

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

v = Speed of the radio wave

t = distance covered during the forward and backward path of radio wave.

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. QY - 2019

The uncertainty in a measurement is called an error. Random error, systematic error and gross error are the three possible errors.

i) Systematic errors Mar-2019

➢ Systematic errors are reproducible inaccuracies that are consistently in the same direction. These occur often due to a problem that persists throughout the experiment. Systematic errors can be classified as follows.

1) Instrumental errors

➢ When an instrument is not calibrated properly at the time of manufacture, instrumental errors may arise.

➢ If a measurement is made with a meter scale whose end is worn out, the result obtained will have errors.

➢ These errors can be corrected by choosing the instrument carefully.

2) Imperfections in experimental technique or procedure

➢ These errors arise due to the limitation in the experimental arrangement.

➢ As an example while performing experiments with a calorimeter, if there is no proper insulation, there will be radiation losses.

➢ This results in errors and to overcome these, necessary correction has to be applied.

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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. Least count error can be reduced by using a high precision instrument for the measurement.

ii) **Random errors:**

- Random errors may arise due to random and unpredictable variations in experimental conditions like pressure, temperature, voltage supply etc.
- Errors may also be due to personal errors by the observer who performs the experiment. Random errors are sometimes called "chance error".
- When different readings are obtained by a person every time he repeats the experiment, personal error occurs.
- If n number of trial readings are taken in an experiment,
- The readings are $a_1, a_2, a_2, ... a_n$.

The arithmetic mean is

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

(or)

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

iii) **Gross errors:** Aug - 2022 Mar - 2023

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

Ex:
- Taking reading without setting instrument properly.
- Taking observation in wrong manner
- Recording wrong observation.
- Using wrong values in calculation

These errors 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-20

Propagation of errors

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:

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(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 = $A \pm \Delta A$

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

Consider the sum, $Z = A + B$

The error ΔZ in Z is then given by

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

(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 Δ A 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 $Z \pm \Delta Z = (A \pm \Delta A)(B \pm \Delta B)$

$= (AB) \pm (A\Delta B) \pm (B\Delta A) \pm (\Delta A . \Delta B)$

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

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

As $\Delta A / A$, $\Delta B / B$ are both small quantities, their product term $\frac{\Delta A}{A}\frac{\Delta B}{B}$ 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

a) Unit: An arbitrarily chosen standard of measurement of a quantity, which is accepted internationally is called unit of the quantity.

b) Rounding off : Calculators are widely used now-a-days to do calculations. 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.

Examples :

- 7.32 is rounded off to 7.3
- 8.94 is rounded off to 8.9
- 17.26 is rounded off to 17.3

c) 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.

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5. **Explain the principle of homogeneity of dimensions. Give example.**

Principle of homogeneity of dimensions: QY - 2018 HY- 2018 Mar-2019 May-2022

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 2as are the same and equal to $[L^2T^{-2}]$

Uses : This method is used to Sep - 2020

(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.

(i) To Convert a physical quantity from one system of units to another. QY - 2018 HY - 2018

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) $n_1[u_1] = n_2[u_2]$

Consider a physical quantity which has dimension 'a' in mass, 'b' in length an 'c' in time. If the fundamental units in one system are M_1, L_1 and T_1 and the other system are T_2, M_2, L_2 and T_2 respectively, then we can write, $n_1 [M_1^aL_1^bT_1^c] = n_2 [M_2^aL_2^bT_2^c]$

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

Solution : In cgs system 76cm of mercury pressure = 76 x 13.6 x 980 dyne cm^{-2} Sep - 2020 Aug-2021

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

$P_1 [M_1^aL_1^bT_1^c] = P_2 [M_2^aL_2^bT_2^c]$

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

$M_1 = 1g,\ M_2 = 1kg$

$L_1 = 1cm,\ L_2 = 1m$

$T_1 = 1s,\quad T_2 = 1s$

So a = 1, b = -1, and c = -2

Then

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

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

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

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

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

Let us take the equation of motion, v = u + at GMQ-2018, QY-2018, Aug-2021

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)

The dimensions of both sides are same. Hence the equation is dimensionally correct.

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Example : Check the correctness of the equation $\frac{1}{2}mv^2 = mgh$ using dimensional analysis method. **Mar - 2020** **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.

$Q \alpha Q_1^a Q_2^b Q_3^c, Q = KQ_1^a Q_2^b Q_3^c$

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: $T \alpha m^a l^b g^c$

$T = k. m^a l^b g^c$ **Mar - 2023**

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

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

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

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 $T = k. m^0 l^{1/2} g^{-1/2}$

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

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

IV. Exercises

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 80s. If the speed of sound in water is 1460 ms^{-1}. What is the distance of enemy submarine? **May - 2022**

Solution: Time t = 80 s

Speed of sound v = 1460 ms^{-1}

distance of submarine = d

The speed of sound

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

distance of submarine

$d = \frac{vt}{2} = \frac{1460 \times 80}{2} = 58400m$

= 58.40km

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

Solution: Area $A = \pi r^2$

$= 3.14 \times 3.12 \times 3.12$

$= 30.566016$

Here the least number of significant figure is three. Hence the result when rounded off to three significant digits is

A = 30.6m^2

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

$\gamma \alpha \frac{1}{l}\sqrt{\frac{F}{m}}$ **using dimensional analysis** **related to JIPMER 2001**

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Solution: $\gamma \propto F^a l^b m^c$

Rewriting the above equation with dimensions

$T^{-1} \propto [MLT^{-2}]^a [L]^b [ML^{-1}]^c$

$M^0L^0T^{-1} \propto M^{a+c} L^{a+b-c} T^{-2a}$

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

$a + c = 0$

$a + b - c = 0$

$-2a = -1$

Solving for a ,b and c,

$a = \frac{1}{2}$, $b = -1$ and $c = -\frac{1}{2}$

From the above equation

$$\gamma \propto F^{\frac{1}{2}} l^{-1} m^{-\frac{1}{2}}$$

$$\gamma \propto \frac{1}{l} \left(\frac{F}{m}\right)^{\frac{1}{2}}$$

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

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.

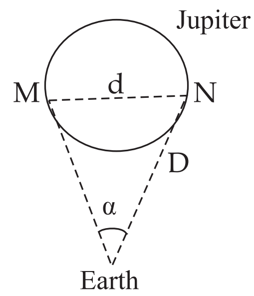
Solution: $\alpha = \frac{d}{D}$

$d = \alpha . D$

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

$= 142\,872.67 \times 10^{3}$ m

$\mathbf{= 1.428 \times 10^5}$ **km**



[∵ 1″ = 4.85×10^{-6} rad]

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

Solution:

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

$$g = 4\pi^2 \frac{l}{T^2}$$

Percentage accuracy :

$$\frac{\Delta g}{g} \times 100 = \frac{\Delta l}{l} \times 100 + 2\frac{\Delta T}{T} \times 100$$

$$= \frac{0.2}{20} \times 100 + 2 \times \frac{1}{40} \times 100$$

$= 1\% + 5\%$

$= 6\%$

The percentage of accuracy in **g = 6%**

PART - II - GMQ, GOVT. EXAM QUESTIONS & ANSWERS

I. Choose the best answer

1. A substance whose mass is 4.27 kg occupies 1.3cm³. The number of significant figure in density is GMQ - 2018

a) 1 b) 2
c) 3 d) 4 **Ans: d) 4**

2. Triple point of water is : QY - 2018

a) 273.16 k b) 237.16°c
c) 273.16° c d) 0 k

Ans: a) 273.16 K

3. Mass, temperature, electric current are ______ QY - 2018

a) fundamental quantities
b) scalar quantities
c) vector quantities
d) both a and b **Ans: d) both a and b**

4. The significant figure of the number 0.003401 is : ________ QY - 2019

a) 6 b) 3
c) 5 d) 4 **Ans: d) 4**

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5. **The amplitude and time period of a simple pendulum bob are 0.05 m and 2s 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) $0.157\ ms^{-1}$

6. **The dimensional formula for coefficient of viscosity is :** MAR- 2023

a) $ML^{-2}T^{-2}$ b) MLT^{-2}
c) $ML^{-1}T^{-2}$ d) $ML^{-1}T^{-1}$

Ans: d) $ML^{-1}T^{-1}$

II. Short Answer Questions

1. **Check the correctness of the equation $E = mc^2$ using dimensional analysis method.** GMQ - 2018 JUNE - 2019

➢ Consider the equation, $E = mc^2$
Apply dimensional formula on both sides
$ML^2T^{-2} = [M][LT^{-1}]^2$
$ML^2T^{-2} = [M][L^2T^{-2}]$
The equation is dimensionally correct.

2. **Write down the number of significant figures in the following :** GMQ - 2018

i) 0.007 **ii) 400**

Ans : (i) One (ii) One

3. **Find the dimensional formula of hc/G.** QY - 2018

The dimensional formula for planck's constant $h = [ML^2T^{-1}]$

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

$G = [M^{-1}L^3T^{-2}]$

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

4. **What is fractional error ?** QY - 2018

Ratio of mean absolute error to the mean value (or) relative error or fractional error = mean absolute error / mean value.

5. **Verify $S = ut + 1/2\ at^2$ by dimensional analysis.** QY - 2018

$[L] = [LT^{-1}][T] + [LT^{-2}][T^2]$
$[L] = [LT^{-1+1}] + [LT^{-2+2}]$
$[L] = [LT^0] + [LT^0]$
$\therefore [L] = [L] + [L]$
Since dimensions on both sides are same, the given equation is dimensionally correct.

6. **What are the advantages of SI system ?** QY - 2018

(i) It is a rational system, in which only one unit is used for one physical quantity.
(ii) It is a coherent system, which means all the derived units can be easily obtained form basic and supplementary units.
(iii) It is a metric system which means that multiples and submultiples can be expressed as powers of 10.

7. **Write about dimensional variables and dimensionless variables with an example.** SEP - 2020

(i) **Dimensional variables :** Physical quantities, which possess dimensions and have variable values are called dimensional variables. Examples are length, velocity, and acceleration etc.
(ii) **Dimensionless variables :** Physical quantities which have no dimensions, but have variable values are called dimensionless variables. Exmaples are specific gravity, strain, refractive index etc.

III. Problems

1. **Two resistances $R_1 = (100 \pm 3)\Omega$ and $R_2 = (150 \pm 2)\Omega$ are connected in series. What is their equivalent resistance ?**

Solution : GMQ - 2018

$R_1 = 100 \pm 3\Omega$; $R_2 = 150 \pm 2\Omega$
Equivalent resistance R = ?
Equivalent resistance $R = R_1 + R_2$
$= (100 \pm 3) + (150 \pm 2) = (100 + 150) \pm (3 + 2)$
$R = (250 \pm 5)\ \Omega$

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2. 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. **GMQ - 2018**

Solution :

$t_1 = 2.63s$, $t_2 = 2.56s$, $t_3 = 2.42s$,

$t_4 = 2.71s$, $t_5 = 2.80s$

(i) $T_m = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5}$

$= \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5}$

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

$\mathbf{T_m = 2.62\ s}$ (Rounded off to 2nd decimal place)

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

$\Delta T_1 = |\mathbf{2.62 - 2.63}| = \mathbf{+\ 0.01s}$

$\Delta T_2 = |\mathbf{2.62 - 2.56}| = \mathbf{+\ 0.06s}$

$\Delta T_3 = |\mathbf{2.62 - 2.42}| = \mathbf{+\ 0.20s}$

$\Delta T_4 = |\mathbf{2.62 - 2.71}| = \mathbf{+\ 0.09s}$

$\Delta T_5 = |\mathbf{2.62 - 2.80}| = \mathbf{+\ 0.18s}$

(iii) Mean absolute error $= \frac{\sum |\Delta T_i|}{n}$

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

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

(Rounded off to 2nd decimal place)

(iv) Relative error :

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

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

(vi) Time period of simple pendulum

$\mathbf{T = (2.62 \pm 0.11)\ s}$

3. 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) **MAR - 2019**

Solution :

$F \alpha m^a v^b r^c$; $F = k m^a v^b r^c$

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

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

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

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

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

$c = 1 - 2$, $c = -1$

$a = 1$, $b = 2$ and $c = -1$

From the above equation we get $F = m^av^br^c$

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

4. Explain propagation of errors in division of two quantities. **MAR - 2020**

Solution :

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

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

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

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

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

Dividing both sides by Z, we get,

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

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

As the terms $\Delta A/A$ and $\Delta B/B$ 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.

5. From a point on the ground, the top of tree is seen to have an angle of elevation 60º. The distance between the tree and a point is 50m. Calculate the height of the tree. **MAR - 2020**

Solution :

Angle = 60º

The distance between the tree and a point x = 50m

Height of the tree (h) = ?

For traingulation method $\tan\theta = \frac{h}{x}$

h = $x \tan\theta$

= 50 × tan 60º

= 50 × 1.732

h = 86.6 m

The height of the tree is 86.6m

PART III - ADDITIONAL QUESTIONS

I. Match the following

1.

	Classification of Physical quantities		Examples
1	Dimensional constant	a	Velocity
2	Dimensionless constant	b	Strain
3	Dimensional variables	c	Planck's constant
4	Dimensionless variables	d	Pi(π)

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

Ans: (c) c d a b

2.

	Physical Quantity		Dimensional formula
1	Heat capacity	a	$[ML^{-1}T^{-1}]$
2	Surface Tension	b	$[ML^2T^{-2}K^{-1}]$
3	Co-efficient of viscosity	c	$[ML^2]$
4	Moment of Inertia	d	$[ML^{-2}]$

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

Ans: d) b d a c

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II. Statement type questions

1. **(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 correct?
a) II only b) None
c) I only d) Both are correct
Ans: a) II only

2. **(I) Least count of screw gauge is 0.01mm**
(II) Least count of varnier caliper is 0.1mm
Which statement is correct?
a) both are correct b) none
c) both are correct d) II only
Ans: a) Both are correct

III. Assertion and Reason

Direction:
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 : Very large distance 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.

2. **Assertion : Study of light is called optics**
Reason : Properties of light is studied in optics. They are Reflection, Retraction etc.,
Ans: a) Assertion and reason are correct and Reason is correct explanation of Assertion.

IV. Choose the odd one out

1. a) Electronic Oscillator
b) Solar clock
c) Electronic balance
d) Radio active dating
Ans: c) Electronic balance

2. a) Acoustics b) Optics
c) Nuclear Physics d) Astrophysics
Ans: c) Nuclear Physics

V. Choose the incorrect pair

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

2. a) Strain - Refractive Index
b) Density - Relative Density
c) Planck's Constant - Stefan's constant
d) π - e
Ans: b) Density - Relative Density

VI. Choose the correct pair

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

2. a) 0.040500 - 20100m
d) 153 - 3072
c) 0.00345 - 2.6
d) 30.00 - 2009
Ans: d) 30.00 - 2009

VII. Fill in the blanks

1. The name Physics was introduced by ______ in 350 B.C
Ans: Aristotle

2. Dimensional formula for Magnetic Induction is _________
Ans: $MT^{-2}A^{-1}$

3. The largest practical unit of mass is _____
Ans: Chandrasekhar Limit (CSL)

4. 1 degree = ________ rad.
Ans: 1.745×10^{-2}

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VIII. Multiple choice questions

1. A physical quantity of dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi t_0}$ is 0 c is velocity of light, G is universal constant of gravitation and e is

a) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ b) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

a) $\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{1/2}$ b) $\frac{1}{c}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

Ans: a) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

Solution: $l = (c)^x (G)^y (\frac{e^2}{4\pi\varepsilon_o})$

$L = [LT^{-1}]^x [M^{-1}L^3T^{-2}]^y$

$[ML^3T^{-2}]^z$

Solving we get $x = -2$;

$y = z = 1/2$

$L = c^{-2} G^{1/2} \left[\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

2. Which one of the following is not a branch of Modern Physics.

a) Quantum Physics
b) Astrophysics
c) Nuclear Physics
d) Condensed Matter Physics

Ans: b) Astrophysics

Solution: Astrophysics is branch of classical physics

3. Solid angle subtended by the periphery of an area 1cm² at a point situated symmetrically at a distance of 5cm. from the are is

a) 2×10^{-2} steradian b) 4×10^{-2} steradian
c) 6×10^{-2} steradian d) 8×10^{-2} steradian

Ans: b) 4×10^{-2} steradian

Solution: Solid angle $d\Omega \frac{dA}{r^2} = \frac{1}{5}$

$= \frac{1}{5} = 0.04$

$= 4 \times 10^{-2}$ steradian

4. The vernier scale of a travelling microscope has 50 divisions which coincide with 49 main scale divisions. If each main scale division is 0.5mm, then the least count of the microscope is

a) 0.01cm b) 0.5 mm
c) 0.01mm d) 0.5mm

Ans: c) 0.01mm

Solution: Least count = 1MSD - 1VWSI

$= 1\text{ MSD} - \frac{49}{50}\text{ MSD}$

$= (1-\frac{49}{50})\text{ MSD} = \frac{1}{50} \times 0.05$

= 0.01mm steradian

5. A new unit of length is chosen such that the speed of light in vacuum is unity. What is the distance between the sun and the earth in terms of the new unit, if light takes 8 min and 20s to cover this distance ?

a) 300 b) 400
c) 500 d) 600

Ans: c) 500

Solution: Speed of light = c

time = 8 x 60 + 20 = 500

Distance = ct

= 1 x 500

= 500 new unit

6. A student measured the diameter of a small steel ball using a screw gauge of least count 0.001cm. The main scale reading is 5mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of 0.004 cm, the correct diameter of f the ball is

a) 0.521cm b) 0.525cm
c) 0.053cm d) 0.529cm

Ans: d) 0.529cm

Solution: Reading of screw gauge

= MSR +(VSR x LC) + ZEC

= 0.5cm+(25x0.001)cm+0.004cm

= 0.529 cm.

7. If the size of bacteria is 1 micron, what will be the number of it in 1m length ?

a) one hundred b) one crore
c) one thousand d) one million

Ans: d) one million

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Solution:
1 micron = 10^{-6}m
10^{-6}m space occupied by 1 bacteria
1 m space occupied by 10^6m bacteria
= 1 million

8. If the unit of force is 100N, unit of length is 10m and unit of time is 100s, what is the unit of mass in this system of units?

a) 10^3kg b) 10^4kg
c) 10^5kg d) 10^6kg

Ans: c) 10^5kg

Solution: Dimensional formula for force
F = $[MLT^{-2}]$

$$M = \frac{[F]}{[LT^{-2}]} = \frac{100}{10 \times (100)^{-2}}$$
$= 10^5$ kg

9. Boltzmann constant and Planck's constant differ in the dimensions of

a) Mass and Time
b) Length and Time
c) Length and Mass
d) Time and Temperature

Ans: d) Time and Temperature

Solution: Boltzmann const : $[ML^2T^{-2}K^{-1}]$
Planck's const : $[ML^2T^{-1}]$

10. $\frac{X^2}{mass}$ has the dimensions of kinetic energy. Then x has the dimension of

a) Pressure
b) Torque
c) Moment of Inertia
d) Impulse

Ans: d) Impulse

Solution: $\frac{X^2}{mass} = E$
$X^2 = E.$ mass
$= [ML^2T^{-2}][M]$
$X^2 = [M^2L^2T^{-2}]$ $\therefore X = [MLT^{-1}]$

11. If R is the Rydberg. constant, C is velocity and h is planck's constant, then Rch has the dimension of

a) Power b) Angular frequency
c) Wave length d) Energy

Ans: d) Energy

Solution: $Rch = [L^{-1}][LT^{-1}][ML^2T^{-1}]$
$= [ML^2T^{-2}] \Rightarrow$ Energy

12. If x times momentum is work, then the dimensions of x is

a) $[LT^{-1}]$ b) $[L^{-1}T]$
b) $[ML^{-1}T^{-1}]$ c) $[MLT]$ **Ans: $[LT^{-1}]$**

Solution: $x\,p = W$

$$x = \frac{W}{p} = \frac{[ML^2T^2]}{[MLT^{-1}]}\ E$$
$= [LT^{-1}]$

13. The time period of a seconds pendulum is measured Solution : (a) respected by for three times by two stop watches, A, B. If the readings are as follows

S.No.	A	B
1	2.01s	2.56s
2	2.10s	2.55s
3	1.98s	2.57s

a) A is more accurate but B is more precise
b) B is more accurate but A is more precise
c) A, B are equally precise
d) A, B are equally accurate

Ans: a) A is more accurate but B is more precise

14. A. The value of dimensionless constant or proportionality constants cannot be found by dimensional methods.
B. The equations containing trigometrical, exponential and logarithmic functions can not be analysed by dimensional methods.

a) Both A & B are true
b) Both A & B are false
c) Only A is true
d) Only B is true

Ans: a) Both A & B are true

15. When 5728 is reduced to 2 significant figures its value is

a) 573 b) 57
c) 5730 d) 5700

Ans: d) 5700

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16. The position of a particle at a time 't' is given by the equation :

$x(t) = \frac{v_o}{A}(1 - e^{AT})$

v_o is constant and A > O. Dimensions of v_o and A respectively are

a) $[M^0L^0T^0$ and $T^{-1}]$ b) $[M^0LT^{-1}$ and $LT^{-2}]$

c) $[M^0LT^{-1}$ and T] d) $[M^0LT^{-1}$ and $T^{-1}]$

Ans: d) $[M^0LT^{-1}]$ and $[T^{-1}]$

Solution :

$$X = \frac{V_o}{A}$$

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

17. When 10 observations are taken the random error is x, when 100 observations are taken the random error is

a) $\frac{x}{10}$ b) x^2

c) $10x$ d) $\sqrt{x}$ **Ans: a) $\frac{x}{10}$**

18. A physical quantity is represented by X = $M^aL^bT^{-c}$. If the percentage error in the measurement of M, L and T are 2α%, β%, 3γ % respectively then maximum percentage error in x is

a) (aα + bβ - cγ) % b) (2aα +bβ + 3cγ)%

c) (aα + bβ + cγ) % d)(aα - bβ - cγ) %

Ans: b) (2aα + bβ + 3cγ)%

19. The density of a material in CGS system of units is 4 g cm . In a system of units is which unit of length is 10cm and unit of mass is 100g. The value of density of material will be

a) $0.04g\ cm^{-3}$ b) $0.4g\ cm^{-3}$

c) $40g\ cm^{-3}$ d) $400g\ cm^{-3}$

Ans: c) $40g\ cm^{-3}$

Solution: $n_1u_1 = u_2u_2$

$$n_2 = n_1 \frac{u_1}{u_2}$$

$$= 4 \times \frac{1}{100} \times \frac{1}{10^{-3}}$$

$$= 40\ g\ cm^{-3}$$

IX. Very Short answer questions (2 Marks)

1. What are the steps involved in scientific method ?

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

Any scientific method involves the following general features.

i) systematic observation
ii) controlled experimentation
iii) Qualitative and quantitative reasoning
iv) Mathematical modeling
v) Prediction and verification or falsification of theories

2. Define significant figures. State the numbers of significant figures in the following :

i. 600800 iii. 400
ii. 5213.0 iv. 2.67 × 10^{24}

The number of meaningful digits which contain numbers that are known reliably and first uncertain numbers.

i. 600800 - Four iii. 400 - one
ii. 5213.0- Five iv. 2.67 × 10^{24} - Three

3. What is dimension of physical quantity? Write the dimensional formula for (i) velocity (ii) Acceleration (iii) force (iv) force constant.

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.

Dimensional formula

(i) velocity = $[M^0LT^{-1}]$
(ii) Acceleration = $[M^0,LT^{-2}]$
(iii) Force = $[MLT^{-2}]$
(iv) Force constant = $[ML^0T^{-2}]$

4. What is the principle of screw gauge ? Write its least count.

The principle of the screw gauge is the magnification of linear motion using the circular motion of a screw. Least count is 0.01 mm.

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5. **What is parallax method ?**
Parallax is the name given to the apparent change in the position of an object with respect to the back ground, when the object is seen from two different positions.

6. **Define : Parsec.**
1 parsec (Parallactic second) is the distance at which an arc of length 1 AU subtends an angle of 1 second of arc.
1 parsec = 3.08×10^{16} m = 3.26 light year.

7. **What are Gross errors ? How is it minimized ?**
1. The error caused due to the shear carelessness of an observer.
e.g : Reading an instrument without setting it properly.
2. It can be minimized only when an observer is careful and mentally alert.

X. Short answer questions (3 Marks)

1. **What are the two basic quest in physics ?**
There are two main quests in physics.
(i) Unification and
(ii) Reductionism.
i) **Unification:**
- Attempting to explain diverse physical phenomena with a few concepts and laws.
- Attempts are being made to unify fundamental forces of nature in the persuit of unification.

ii) **Reductionism :**
- An attempt to explain macroscopic system in terms of its microscopic constituents.
- Thermodynamics was developed to explain macroscopic properties like temperature, entropy, etc., of bulk systems.
- The above properties have been interpreted in terms of the molecular constituents (microscopic) of the bulk system by kinetic theory and statistical mechanics.

2. **Write a short note on measurement of Mass.**
Mass is a property of matter. It does not depend on temperature, pressure and location of the body in space.
- Mass of a body is defined as the quantity of matter contained in a body.
- The SI unit of mass is kilogram (kg).
- The mass of an object is determined in kilograms using a common balance like the one used in grocery shop. For measuring larger masses like that of planets, stars etc., we make use of gravitational methods. For measurement of small masses of atomic/ subatomic particles etc., we make use of a mass spectrograph.
- Some of the weighing balances commonly used are common balance, spring balance, electronic balance, etc.

3. **Write a note on (i) Random Error and (ii) Systematic error with an example. How will you minimize it ?**
(i) Random Error : Random errors may arise due to random and unpredictable variation in experimental conditions like pressure, temperature, voltage supply etc. Errors may also be due to personal errors by the observer who performs the experiment.
Example : Measurement of mass of a ring three times using same balance and get slightly different values. 15.46g, 15.42g, 15.44g.
Minimizing : Take more data, Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.
(ii) Systematic errors: Systematic errors are reproducible inaccuracies that are consistently in the same direction. These occur often due to a problem that persists throughout the experiment.
Example: Suppose, the cloth tap that you use to measure the length of an object has been stretched out from years to use.
Minimizing : Systematic errors are difficult to detect and can not be analysed statistically, because all of the data is in the same direction.

4. **What are the types of Errors and Explain :**
There are four types of errors. They are
i) Absolute Error
ii) Mean absolute Error
iii) Relative Error
iv) Percentage Error.

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(i) Absolute Error : The difference between the true value and the measured value of a quantity is called absolute error.

(ii) Mean Absolute Error : The arithmetic mean of the absolute errors in all the measurements is called the mean absolute error.

(iii) Relative Error : The ratio of the mean absolute error to the mean value is called relative error. This is also called as fractional error.

(iv) Percentage Error: The relative error expressed as a percentage is called percentage error.

5. **Write a note on i) Dimensional constant ii) Dimensionless constant with an example.**

(i) Dimensional constant

Physical quantities which posses dimensions and have constant values are called dimensional cosntants. Examples are Gravitational constant, Planck's constant etc.

(ii) Dimensionless Constant

Quantities which have constant values and also have no dimensions are called dimensionless constnats. Examples are π, e (Euler's number), numbers etc.

XI. Long answer questions

1. **Explain the Determination of distance of Moon from Earth.**

In Figure C is the centre of the Earth. A and B are two diametrically opposite places on the surface of the Earth. From A and B, the parallexes θ_1 and θ_2 respectively of Moon M with respect to some distant star are determined with the help of an astronomical telescope. Thus, the total parallax of the Moon subtended on Earth $\angle AMB = \theta_1+\theta_2 = \theta$.

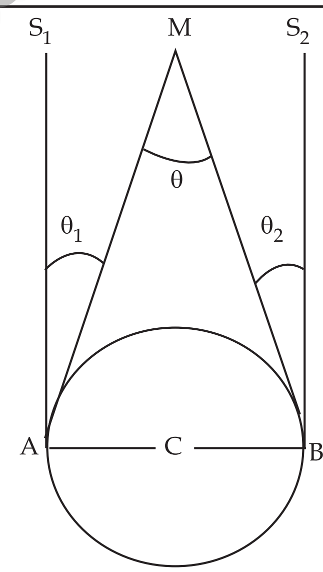
If θ is measured in radians, then

$$\theta = \frac{AB}{AM} \; ; AM \approx MC$$

(AM is approximately equal to MC)

$$\theta = \frac{AB}{MC} \text{ or } MC = \frac{AB}{\theta};$$

Knowing the values of AB and θ, we can calculate the distance MC of Moon from the Earth.



Parallax method : determination of distance of Moon from Earth

2. **Explain the different types of measurement systems.**

(a) **the f.p.s. system** is the British Engineering system of units, which uses **foot, pound** and **second** as the three basic units for measuring length, mass and time respectively.

(b) **The c.g.s system** is the Gaussian system, which uses **centimeter, gram** and **second** as the three basic units for measuring length, mass and time respectively.

(c) **The m.k.s system** is based on **metre, kilogram** and **second** as the three basic units for measuring length, mass and time respectively.

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

Rules for Rounding off :

	Rule	Example
i	If the digit to be dropped is smaller than 5, then the preceding digit should be left unchanged.	i) 7.32 is rounded off to 7.3 ii) 8.94 is rounded off to 8.9
ii	If the digit to be dropped is greater than 5, then the preceding digit should be increased by 1	i) 17.26 is rounded off to 17.3 ii) 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) 7.352, on being rounded off to first decimal becomes 7.4 ii) 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) 3.45 is rounded off to 3.4 ii) 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) 3.35 is rounded off to 3.4 ii) 8.350 is rounded off to 8.4

4. Explain the propogation of errors in multiplication and power of a two quantities.

i) 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 of ΔZ in Z is given by

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

$= (AB) \pm (A\Delta B) \pm (B\Delta A) \pm (\Delta A \,.\, \Delta B)$

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

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

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

The maximum fractional error in Z is

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

iii) Error in the power of a quantity

Consider the n^{th} power of A, $Z = A^n$

The error ΔZ in Z is given by

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

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

We get $[(1+x)^n \approx 1+nx$, when $x<<1]$ neglecting remaining terms, Dividing both sides by Z.

$$1 \pm \frac{\Delta Z}{Z} = 1 \pm n\frac{\Delta A}{A} \text{ (or) } \frac{\Delta Z}{Z} = n.\frac{\Delta A}{A}$$

The fractional error in the n^{th} power of a quantity is n times the fractional error in that quantity.

General rule. If $Z = \frac{A^p B^q}{C^r}$ then,

maximum fractional error in Z is given by $\frac{\Delta Z}{Z} = p\frac{\Delta A}{A} + q\frac{\Delta B}{B} + r\frac{\Delta C}{C}$

The percentage err in Z is given by

$$\frac{\Delta Z}{Z} \times 100 = p\frac{\Delta A}{A} \times 100 + q\frac{\Delta B}{B} \times 100 + r\frac{\Delta C}{C} \times 100$$

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XII. Additional Problems

1. How many parsec are there in 1 light year ?

Solution:

1 parsec = 3.26 light year

1 light year = $\frac{1}{3.26}$ parsec

= 0.3067 parsec

2. The Sun's angular diameter θ is measured to be 1920″. The distance D of the sun from the Earth is 1 AU. What is the diameter of the Sun ?

Solution:

Sun's angular diameter θ = 1920″

= 1920 x 4.85 x 10^{-6} rad.

= 9.31 x 10^{-3} rad

Sun - Earth distance D,

1 AU = 1.496 x 10^{11} m

Sun's diameter d = θ D

d = 9.31 x 10^{-3} x 1.496 x 10^{11}

d = 1.39 x 10^9 m

3. Given : Mass of Sun = 2.0 x 10^{30} kg, radius of Sun = 7.0 x 10^8 m. In what range do you expect the mass density of sun to be ? In the range of densities of solids or liquids or gases ? Give an explanation of the result arrived at.

Solution:

Density of Sun = $\frac{\text{Mass}}{\text{Volume}}$

$= \frac{2.0 \times 10^{30}}{4/3\, \pi\, (7.0 \times 10^8)^3}$ kg m^{-3}

= 1.39 x 10^3 kg m^{-3}

So, the mass density of Sun is in the range of densities of solids.

4. The distance of a galaxy from the earth is of the order of 10^{25}m. What is the time taken by light to reach the earth from the galaxy ?

Solution: Speed of light c = 3 x 10^8 ms^{-1}

Time taken by light to reach the earth from the galaxy t = $\frac{d}{c}$

$= \frac{10^{25}}{3 \times 10^8}$

= 0.33 x 10^{17}

t = 3.3 x 10^{16}s

5. A physical quantity x is related to four measurable quantities a, b, c and d as follows x = $a^2b^3c^{5/2}d^{-2}$. The percentage of error in the measurement of a, b, c and d are 1%, 2%, 2% and 4% respectively. What is the percentage of error in quantity x ?

Solution: x = $a^2b^3c^{5/2}d^{-1/2}$

Percentage error in x = $\frac{\Delta x}{x}$ x 100

$= \left[2\left(\frac{\Delta a}{a}\right) + 3\left(\frac{\Delta b}{b}\right) + \frac{5}{2}\left(\frac{\Delta c}{c}\right) + 2\left(\frac{\Delta d}{d}\right)\right] \times 100$

$= 2 \times 1\% + 3 \times 2\% + \frac{5}{2} \times 2\% + 2 \times 4\%$

= 21%

6. In an experiment, the value of refractive index of glass were found to be 1.54, 1.53, 1.44, 1.54, 1.56 and 1.45 in successive measurements. Calculate (i)Mean value of refractive index of glass (ii) Absolute error in each measurement (iii) Mean absolute error (iv) relative error and (v) percentage error.

Solution: **(i) Mean value of refractive index**

$\mu_m = \frac{\mu_1 + \mu_2 + \mu_3 + \mu_4 + \mu_5 + \mu_6}{6}$

$= \frac{1.54 + 1.53 + 1.44 + 1.54 + 1.56 + 1.45}{6}$

= 1.51

ii) Absolute error:

$\Delta\mu = \mu_m - \mu.$

$\Delta\mu_1$ = 1.54 - 1.51 = + 0.03

$\Delta\mu_2$ = 1.53 - 1.51 = + 0.02

$\Delta\mu_3$ = 1.44 - 1.51 = - 0.07

$\Delta\mu_4$ = 1.54 - 1.51 = + 0.03

$\Delta\mu_5$ = 1.56 - 1.51 = + 0.05

$\Delta\mu_6$ = 1.45 - 1.51 = - 0.06

iii) Mean absolute error:

$\Delta\mu_m = \frac{\Sigma\Delta\mu_m}{n}$

$= \frac{0.03 + 0.02 + 0.07 + 0.03 + 0.05 + 0.06}{6}$

$= \frac{0.26}{6}$ = 0.04

iv) Relative error:

$S_\mu = \frac{\Delta\mu_m}{\mu_m} = \frac{0.04}{1.51}$ = 0.02649 = 0.03.

v) Percentage error:

μ = 0.03 x 100 = 3%

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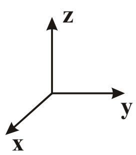
UNIT -2

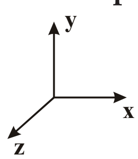
KINEMATICS

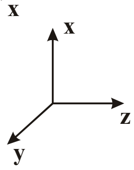
PART - I TEXTBOOK EVALUATION

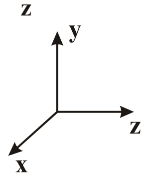
I. Multiple Choice questions (1 Mark)

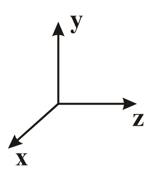
1. Which one of the following cartesian coordinate systems is not followed in physics?

a) 

b) 

c) 

d) 

Ans : (d) 

Solution :

In physics, the co-ordinate systems of direction is considered by clockwise direction. (a), (b), (c) are in Anticlockwise direction.

d) clock wise direction.

2. Identify the unit vector in the following **March - 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) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

Solution :

$|A| = \sqrt{1+1} = \sqrt{2}$

Unit vector $\hat{A} = \frac{\vec{A}}{|A|} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$

3. Which one of the following physical quantities cannot be represented by a scalar? **March - 2023**

a) Mass b) length

c) momentum d) magnitude of acceleration

Ans: (c) momentum

Solution :

Momentum is vector quantity $\vec{p} = m.\vec{v}$

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)

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) $\frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$

Solution :

When they hit the ground $v^2 = 2gh$

$\Rightarrow v = \sqrt{2gh}\ ;\ p = mv = m\sqrt{2gh}$

$p_1 \alpha\ m_1\sqrt{h_1}\ ;\ p_2 \alpha\ m_2\sqrt{h_2}$

$p_1/p_2 = \frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$

5. If a particle has negative velocity and negative acceleration, its speed. **HY - 2018** **QY - 2019**

a) increases b) decreases

c) remains same d) Zero

Ans: (a) increases

Solution :

V = -v (ie) a = -v/t

speed |(-v)| = v increases

6. **If the velocity is $\vec{v} = 2\hat{i}+t^2\hat{j}-9\hat{k}$, then the magnitude of acceleration at t=0.5s is**

a) 1 m s^{-2} b) 2 m s^{-2} c) Zero d) -1 m s^{-2}

Solution : **Ans: (a) 1 m s^{-2}**

$a = \frac{d\vec{v}}{dt} = \frac{d}{dt}(2\hat{i}+t^2\hat{j}-9\vec{K})$ **QY - 2018**

$a = 2t\hat{j}\ ;\ t = 0.5,\ a = 2 \times 0.5 = 1m\ s^{-2}$

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7. If an object is dropped from the top of a building and it reaches the ground at t=4s, then the height of the building is (ignoring air resistance) (g = 9.8 m s^{-2})

a) 77.3 m b) 78.4 m c) 80.5 m d) 79.2 m

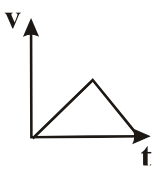
Ans : (b) 78.4 m

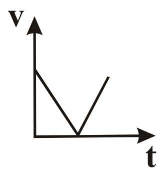
Solution : **AUG - 2022**

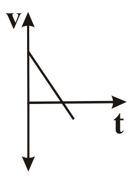
$s = ut + \frac{1}{2} gt^2$; u= 0

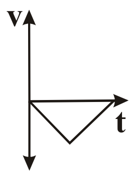
$$s = \frac{gt^2}{2} = \frac{9.8 \times 4 \times \cancel{4}^2}{\cancel{2}} = 78.4\text{m}$$

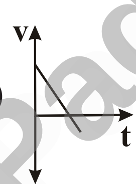
8. A ball is projected vertically upwards with a velocity v. It comes back to ground in time t. Which v-t graph shows the motion correctly? **NSEP-2000-2001**

a) 

b) 

c) 

d) 

Ans: (c) 

Solution :

The velocity decreases untill the maximum height in upward. When the ball slows down the velocity increases. (c) denotes this condition

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

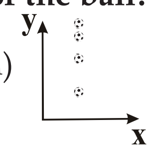
Ans: (a) 1

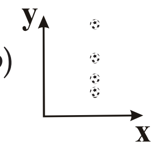
Solution :

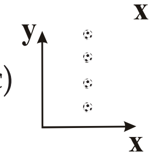
Two objects have an equal height. so 'g' also equal

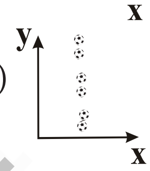
$h = \frac{1}{2} gt^2$; $t = \sqrt{\frac{2h}{g}}$; $h_1 / h_2 = 1$

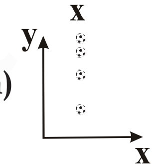
10. A ball is dropped from some height towards the ground. Which one of the following represents the correct motion of the ball?

a) 

b) 

c) 

d) 

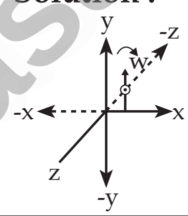
Ans: (a) 

11. If a particle executes uniform circular motion in the xy plane in clock wise direction, then the angular velocity is in

a) +y direction b) +z direction
c) -z direction d) -x direction

Ans: (c)-z direction

Solution : **Sep-2020, Aug-2021** **May-2022**



12. If a particle executes uniform circular motion, choose the correct statement. **[NEET-2016]**

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. **Aug-2022**

Ans: (d) The speed and magnitude of acceleration are constant

Solution :

In a uniform circular motion, the velocity changed continously. But their magnitude is 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 **June - 19** **Aug- 2021**

a) $\frac{u^2}{2g}$ b) $\frac{u^2}{g}$ c) $\frac{u}{2g}$ d) $\frac{2u}{g}$

Ans: d) $\frac{2u}{g}$

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Solution :

Motion is upward s = ut – ½ gt²

Motion in downward s = -ut +½ gt²

ut – ½ gt² = -ut + ½ gt²

$2u\cancel{t} = gt^{\cancel{2}}$ $t = \frac{2u}{g}$

14. Two objects are projected at angles 30⁰ 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) $R_{30°} = \frac{R_{60°}}{2}$ d) $R_{30°} = 2R_{60°}$

Solution : **Ans: (a)** $R_{30°} = R_{60°}$

$R = \frac{u^2 \sin 2\theta}{g}$, $R \alpha \sin 2\theta$

$R_{30°} = \sin(2 \times 30°)$

$R_{30°} = \sin 60° = \frac{\sqrt{3}}{2}$

$R_{60°} = \sin(2 \times 60°)$

$= \sin(90° + 30°)$

$= \cos 30° = \frac{\sqrt{3}}{2}$

$\therefore R_{30°} = R_{60°}$

15. An object is dropped in an unknown planet from height 50m, it reaches the ground in 2s. The acceleration due to gravity in this unknown planet is

a) $g = 20\ m\ s^{-2}$ b) $g = 25\ m\ s^{-2}$

c) $g = 15\ m\ s^{-2}$ d) $g = 30\ m\ s^{-2}$ HY-2018

Solution : **Ans: b) $g = 25\ m\ s^{-2}$**

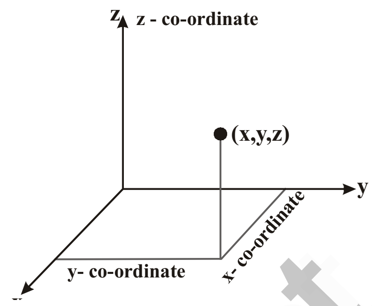
$h = \frac{1}{2} gt^2$

$g = \frac{2h}{t^2} = \frac{2 \times 50}{2^2}$

$= 25\ ms^{-2}$

II. Short Answer Questions

1. Explain what is meant by Cartesian Coordinate system?



At any given instant of time, the frame of reference with respect to which the position of the object described interms of position co-ordinates (x, y, z) is called Cartesian Co-ordinate system.

2. Define a vector. Give examples. HY-2018

The physical quantity which is described by both magnitude and direction are called vector. Examples : Force, Velocity, Displacement, Acceleration.

3. Define a scalar. Give examples. HY-2018 MAR-2023

The physical quantity which is described only by magnitude are called scalar. Examples : Distance, Mass, Time, Speed.

4. Write a short note on the scalar product between two vectors. QY-2019

The scalar product (or) dot product of two vectors is defined as the product of the magnitude of both the vectors and the cosine of the angle between them.

$\vec{A}.\vec{B} = AB\cos\theta$

5. Write a short note on vector product between two vectors. HY-2018

The vector product (or) cross product of two vectors is defined as another vectors having a magnitude equal to the product of the magnitude of two vectors and the sine of the angle between them.

$\vec{C} = \vec{A} \times \vec{B} = (AB\sin\theta)\hat{n}$

6. How do you deduce that two vectors are perpendicular?

(i) The scalar product of two vectors $\vec{A}.\vec{B} = 0$ then these two vectors are perpendicular

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to each other because cos 90° = 0, then $\vec{A}\cdot\vec{B} = AB\cos\theta = AB\cos 90° = 0$.

Then the vectors $\vec{A}$ and $\vec{B}$ are said to be mutually orthogonal.

(ii) The vector product of two vectors will have maximum magnitude when sin 90^0 =1

i.e. θ = 90° then $(\vec{A}\times\vec{B})_{max} = AB\,\hat{n}$ then the vectors $\vec{A}$ and $\vec{}$ are orthogonal to each other.

7. Define displacement and distance. March - 2020

Distance : Distance is the actual path length travelled by an object in the given interval of time.

Displacement : Displacement is the difference between the final and initial positions of the object in a given interval of time.

8. Define Velocity and Speed.

Velocity : The rate of change of displacement of the particle (or) speed of the particle in a given direction. Its unit is ms^{-1}. It is a vector quantity.

Vector = Displacement / Time

Speed : The distance travelled in unit time. It is a scalar quantity and its SI unit is ms^{-1}.

Speed = Path length / Time

9. Define acceleration.

- The acceleration of the particle at an instant is equal to rate of change of Velocity.
- Acceleration is a vector quantity. Its SI unit is ms^{-2} and its dimensional formula is $M^0L^1T^{-2}$.

10. What is the difference between velocity and average velocity.

S.No.	Velocity	Average Velocity
1.	Velocity is equal to rate of change of position vector with respect to time.	The average velocity is defined as rate of the displacement vector to the corresponding time interval.
2.	Velocity $\vec{v} = d\vec{r}/dt$	Average Velocity $\vec{v}_{avg} = \frac{\Delta \vec{r}}{dt}$

11. Define a radian.

One radian is the angle substended at the center of a circle by an arc that is equal in length to the radius of the circle.

1 rad ≃ 57.295° (or) 1 rad = $\frac{180}{\pi}$ degree

12. Define angular displacement and angular velocity. Aug-2021

i) **Angular displacement :** The angle described by particle about the axis of rotation in a given time is called angular displacement. The unit of angular displacement is radian. Angular displacement θ = s / r

ii) **Angular Velocity :** The rate of change of angular displacement is called angular velocity.

The unit of angular velocity is radian per second. Angular Velocity ω = dθ / dt

13. What is non uniform circular motion?

The velocity changes in both speed and direction during the circular motion is called non uniform circular motion.

14. Write down the Kinematic equations for angular motion.

i) $\omega = \omega_0 + \alpha t$ ii) $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

iii) $\omega^2 = \omega_0^2 + 2\alpha\theta$ iv) $\theta = \frac{(\omega_0 + \omega)t}{2}$

15. Write down the expression for angle made by resultant acceleration and radius vector in the non uniform circular motion.

θ = resultant acceleration angle

V^2/r = centripetal acceleration

a_t = resultant acceleration

The angle is given by $\tan\theta = \frac{a_t}{(V^2/r)}$

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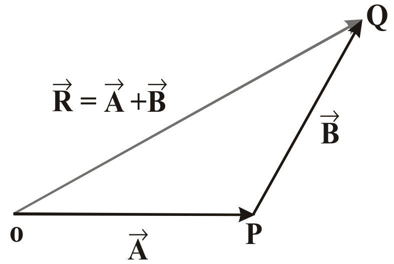
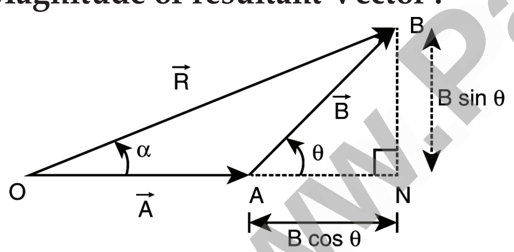
III. Long Answer Questions

1. Explain in detail the triangle law of addition. QY-2018, 2019, June-2019, Aug-2022, Mar-2023



- The two vectors are represented by two adjacent sides of a triangle taken in the same order. Then the resultant is given by the third side of the triangle.
- The head of the first vector $\vec{A}$ is connected to the tail of second vector $\vec{B}$.
- Let θ be the angle between $\vec{A}$ and $\vec{B}$.
- $\vec{R}$ is the resultant vector connecting the tail of the first vector $\vec{A}$ to the head of the second vector $\vec{B}$.
- $\vec{R} = \vec{A} + \vec{B}$

1) Magnitude of resultant Vector :



- Consider the triangle ABN which is obtained by extending the side OA to ON.

$\cos\theta = \frac{AN}{B}$ ∴ $AN = B\cos\theta$ ....(1)

$\sin\theta = \frac{BN}{B}$ ∴ $BN = B\cos\theta$ ....(2)

For Δ OBN, $OB^2 = ON^2 + BN^2$ ....(3)

$R^2 = (A+B\cos\theta)^2 + (B\sin\theta)^2$

$R^2 = A^2+B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$

$R^2 = A^2+B^2(\cos^2\theta + \sin^2\theta) + 2AB\cos\theta$

$R^2 = A^2+B^2 + 2AB\cos\theta$

$$R = \sqrt{A^2+B^2+2AB\cos\theta} \quad ....(4)$$

2) Direction of resultant Vectors :

$|\vec{A}+\vec{B}| = \sqrt{A^2+B^2+2AB\cos\theta}$ ....(5)

In ΔOBN

$\tan\alpha = \frac{BN}{ON} = \frac{BN}{OA+AN}$

$\tan\alpha = \frac{B\sin\theta}{A+B\cos\theta}$

$$∴ \alpha = \tan^{-1}\left(\frac{B\sin\theta}{A+B\cos\theta}\right) \quad ....(6)$$

2. Discuss the properties of scalar and vector products. QY-2018 HY-2018, 2019 Mar-2023

Properties of scalar Product :

(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. θ < 90°) and negative if the angle between them is obtuse. (90° < θ < 180°)

(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

$$\theta = \cos\theta^{-1}\left[\frac{\vec{A}\cdot\vec{B}}{AB}\right]$$

(v) The scalar product of two vectors will be maximum when cosθ = 1, i.e. θ = 0° When the vectors are parallel $(\vec{A}\cdot\vec{B})_{max} = AB$

Properties of vector product :

(i) The vector product of any two vectors is always another vector whose the direction is perpendicular to the plane containing them two vectors.

(ii) The vector product of two vectors is not commutative i.e. $\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$ But $\vec{A}\times\vec{B} = -\left[\vec{B}\times\vec{A}\right]$

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(iii) The vector product of two vectors will have maximum magnitude when $\sin\theta = 1$ i.e. $(\theta = 90^o)$ $(\vec{A}\times\vec{B})_{max} = AB\,\hat{n}$.

(iv) The vectors product of two non - zero vectors will be minimim when $|\sin\theta| = 0$ i.e. $\theta = 0^o$ (or) 180^o $(\vec{A}\times\vec{B})_{mini} = 0$

(v) The self cross product i.e. product of a vectors with itself is the null vector.

$$\vec{A}\times\vec{A} = AA\sin 0^o\,\hat{n} = \vec{0}$$

3. Derive the kinematic equations of motion for constant acceleration. **GMQ - 2018** **QY - 2019** **Sep-2020** **Aug -2021** **May-2022**

➢ Consider an object moving in a straight line with uniform constant acceleration 'a'.

Velocity - time relation :

i) The acceleration of the body at any instant is given by the first derivative of velocity with respect to time.
$a = dv/dt$ (or) $dv = a.dt$ ....(1)
Integrating on both sides

$$\int_u^v dv = \int_0^t a\,dt = a\int_0^t dt$$

$$[v]_u^v = a[t]_0^t$$

$$v - u = at$$

$$\boxed{v = u + at} \quad .... (2)$$

Displacement - time relation :

ii) The velocity of the body is given by the first derivative of the displacement with time.

$v = ds/dt$

$ds = v.dt$ ....(3)

since $v = u+at$

$ds = (u+at)\,dt$ ....(4)

Integrating on both sides

$$\int_0^s ds = \int_0^t u\,dt + \int_0^t at\,dt$$

$$\boxed{s = ut + \tfrac{1}{2}at^2} \quad .... (5)$$

Velocity - displacement relation :

iii) The acceleration is given by the first derivative of velocity with respect to time.

$$a = \frac{dv}{dt} = \frac{dv}{ds}\cdot\frac{ds}{dt} = v.\frac{dv}{ds} \qquad \left(\frac{ds}{dt} = v\right)$$

$$a = \tfrac{1}{2}\frac{d(v^2)}{ds} \text{ (or)}$$

$$ds = \frac{1}{2a}d(v^2) \quad .... (6)$$

Integrating on both sides

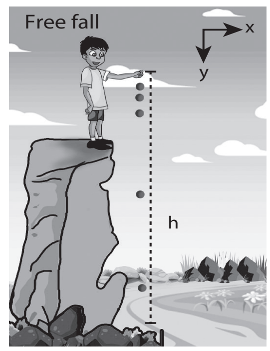
$$\int_0^s ds = \int_u^v \frac{1}{2a}d(v^2) \text{ (or)}$$

$$\therefore s = \frac{1}{2a}(v^2 - u^2)$$

$$\boxed{v^2 = u^2 + 2as} \quad .... (7)$$

4. Derive the equations of motion for a particle (a) falling vertically (b) projected vertically. **Mar - 2019**

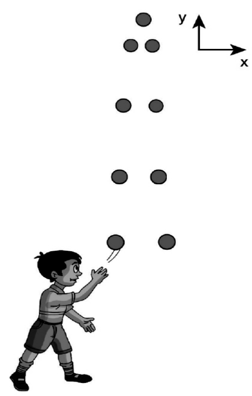
i) A body falling vertically from a height h :



➢ Consider an object of mass in falling from a height h.

➢ Let us choose the downward direction as positive y axis.

➢ The object experience acceleration 'g' due to gravity which is constant near the surface of the earth.



The acceleration $\vec{a} = g\,\hat{j}$

By comparing the components we get,

$a_x = 0,\ a_z = 0,\ a_y = g$

$a_y = a = g$

➢ If the particle is thrown with initial velocity u downward which is in negative y axis.

➢ Then velocity and position of the particle at any time t is given by,

$v = u+gt$ .... (1)

$y = ut+\tfrac{1}{2}gt^2$ .... (2)

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The square of the speed of the particle is

$v^2 = u^2 + 2gy$ .... (3)

Suppose the particle starts from rest

Then $u = 0$

$v = gt$ .... (4)

$y = \frac{1}{2} gt^2$ .... (5)

$v^2 = 2gy$ .... (6)

The time (t = T) taken by the particle to reach the ground (for which y = h), is given by using equation (5)

$h = \frac{1}{2} gT^2$ .... (7)

$T = \sqrt{\frac{2h}{g}}$ ....(8)

The speed of the particle when it reaches the ground (y = h)

$V_{ground} = \sqrt{2gh}$ .... (9)

b) A body thrown vertically upwards :

- An object of mass m thrown vertically upwards with an initial velocity u.
- The acceleration a = -g and g points towards the negative y axis.
- The Kinematic equations for this motion are The velocity and position of the object at any time t are,

$v = u - gt$ .... (10)

$s = ut - \frac{1}{2} gt^2$ .... (11)

The velocity of the object at any position

$v^2 = u^2 - 2gy$ ....(12)

5. Derive the equation of motion, range and maximum height reached by the particle thrown at an obligue angle θ with respect to the horizontal direction.

GMQ-2018, QY-2018, HY-2018

- Consider an object thrown with initial velocity $\vec{u}$ at an angle θ with the horizontal.

Then $\vec{u} = u_x \hat{i} + u_y \hat{j}$

Where $u_x = u\cos\theta$ is the horizontal component.

$u_y = u\sin\theta$ is the vertical component of velocity.

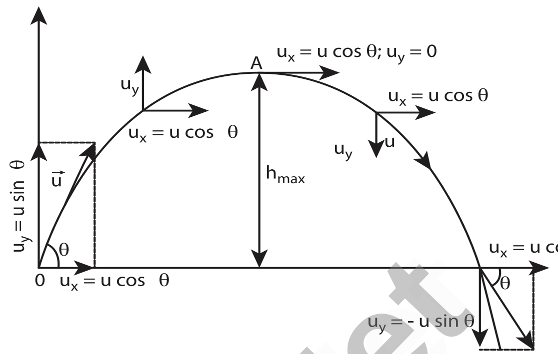
After the time t_1 the velocity along horizontal motion

$v_x = u_x + a_x t = u_x = u\cos\theta$

The horizontal distance is

$s_x = u_x t + \frac{1}{2} a_x t^2$

Here $s_x = x$, $u_x = u\cos\theta$, $a_x = 0$



$x = u\cos\theta . t$ (or)

$t = \frac{x}{u\cos\theta}$ .... (1)

For vertical motion $v_y = u_y + a_y t$

Here $u_y = u\sin\theta$, $a_y = -g$

$v_y = u\sin\theta - gt$ .... (2)

The vertical distance travelled by the projectile is

$s_y = u_y t + \frac{1}{2} a_y t^2$

Here $s_y = y$, $u_y = u\sin\theta$, $a_y = -g$

then $y = u\sin\theta . t - \frac{1}{2} gt^2$ .... (3)

Substitute the 't' value from the equation (1) in equation (3), we have

$y = u\sin\theta \frac{x}{u\cos\theta} - \frac{1}{2} g \frac{x^2}{u^2\cos^2\theta}$ .... (4)

$y = x\tan\theta = \frac{1}{2} g \frac{x^2}{u^2\cos^2\theta}$ ....(4)

The path followed by the projectile is an inverted parabola.

Maximum (h_{max})

The maximum vertical distance travelled by projectile during its journey is called maximum height.

For vertical part of motion,

$v_y^2 = u_y^2 + 2a_y s$

Here, $u_y = u\sin\theta$, $a_y = -g$, $s = h_{max}$; $v_y = 0$

$0 = u^2\sin^2\theta - 2gh_{max}$

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$$h_{max} = \frac{u^2 \sin^2\theta}{2g} \qquad ....(5)$$

Horizontal Range (R) :

The maximum horizontal distance between the point of projection and the point on the horizontal plane where the projectile hits the ground is called horizontal range (R).

Range R = Horizontal component of velocity × time of flight

$R = u\cos\theta \times T_f$

$$R = u\cos\theta \times \frac{2u\sin\theta}{g} = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$R = \frac{u^2 \sin 2\theta}{g} \qquad ....(6)$$

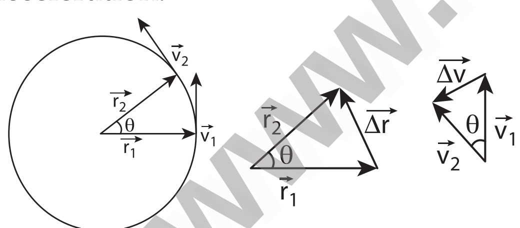
The maximum possible range is reached when $\sin 2\theta = 1$,

When $2\theta = \pi/2$ (or) $\theta = \pi/4$

$$R_{max} = u^2/g \qquad ....(7)$$

6. Derive the expression for centripetal acceleration. GMQ-2018, March - 2020

- The acceleration acting on an object towards the center of the circle in a uniform circular motion is known as centripetal acceleration.



- The directions of position and velocity vectors shift through the same angle θ in small interval of time Δt as shown in the above figure
- For uniform circular motion

$$r = |\vec{r}_1| = |\vec{r}_2| \text{ and } v = |\vec{v}_1| = |\vec{v}_2|$$

- If the particle moves from position vector $\vec{r}_1$ to $\vec{r}_2$
- The displacement $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$
- Then change in velocity $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

then $\frac{\Delta r}{r} = -\frac{\Delta v}{v} = \theta$ ....(1)

Here negative sign implies that Δv points radially inward, towards the centre of the circle.

$$\Delta v = -v\left(\frac{\Delta r}{r}\right)$$

$$a = \frac{\Delta v}{\Delta t} = -\frac{v}{r}\left(\frac{\Delta r}{\Delta t}\right) = \frac{-v^2}{r}$$

For uniform circular motion $v = r\omega$

Then centripetal acceleration $a = \frac{-v^2}{r} = -\omega^2 r$

7. Derive the expression for total acceleration in the nonuniform circular motion.

- If the speed of the object in circular motion is not constant then it is called non-uniform motion.

Example : The bob attached to a string moves in vertical circle.

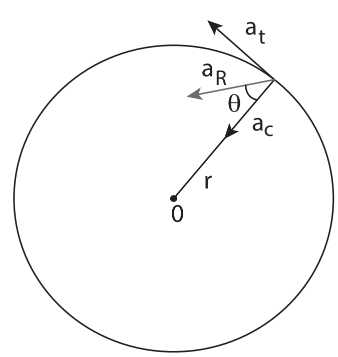
- The speed of the bob is not the same at all time.
- The speed is not same in circular motion, the particle will have both centripetal and tangential acceleration.
- The centripetal acceleration is v^2/r

The magnitude of resultant acceleration is

$$a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}$$

- The resultant acceleration makes an angle θ with the radius vector.

The angle is given by $\tan\theta = \frac{a_t}{\left(v^2/r\right)}$



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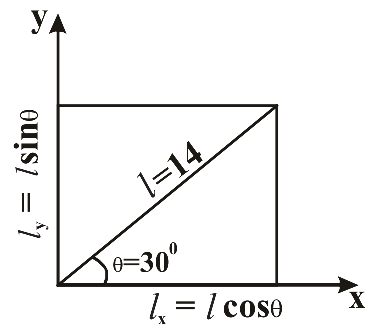
IV. Exercises

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? GMQ-2018, June - 2019

$l = 1\text{m}, \theta = 30^{\circ}, l_x = ?\ l_y = ?$

Formula $l_x = l\cos\theta,\ l_y = l\sin\theta$



Solution :

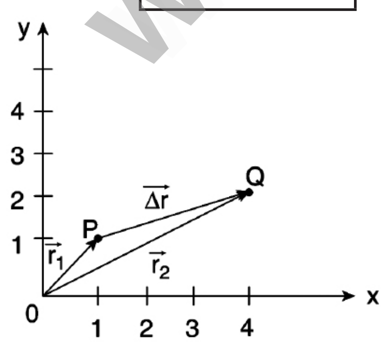
i) $l_x = l\cos\theta = l\cos 30^{\circ}$ $l_x = \sqrt{3}/2$

ii) $l_y = l\sin\theta = l\sin 30^{\circ} = 1/2$ $l_y = 0.5$

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.

$\Delta\vec{r} = ?$

Formula : $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$



Solution :

$\Delta\vec{r} = (\hat{i} + 2\hat{j}) - (3\hat{i} + 4\hat{j})$

$= (1-3)\hat{i} + (2-4)\hat{j}$

$\Delta\vec{r} = -2\hat{i} - 2\hat{j}$ $\Delta\vec{r} = -2(\hat{i} - \hat{j})$

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.

$\vec{r}_1 = 5\hat{i} + 6\hat{j}, \vec{r}_2 = 2\hat{i} + 3\hat{j}, \Delta t = 5\text{s}, v_{avg} = ?$

$$v_{avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{r_2 - r_1}{\Delta t}$$

Solution :

$$v_{avg} = \frac{(2\hat{i}+3\hat{j}) - (5\hat{i}+6\hat{j})}{5} = \frac{(2-5)\hat{i} + (3-6)\hat{j}}{5}$$

$$v_{avg} = \frac{-3\hat{i} - 3\hat{j}}{5}$$

$$v_{avg} = -3/5(\hat{i} + \hat{j})$$

4. Convert the vector $\vec{r} = 3\hat{i} + 2\hat{j}$ into a unit vector.

$\vec{r} = 3\hat{i} + 2\hat{j}$, Unit vector = ?

Formula : $\hat{r} = \frac{\vec{r}}{|r|}$

Solution : $\hat{r} = \frac{3\hat{i} + 2\hat{j}}{\sqrt{9+4}}$

$$\hat{r} = \frac{3\hat{i} + 2\hat{j}}{\sqrt{13}}$$

5. What are the resultants of the vector product of two given vectors given by May - 2022

$\vec{A} = 4\hat{i} - 2\hat{j} + \hat{k}$, and $\vec{B} = 5\hat{i} + 3\hat{j} - 4\hat{k}$?

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$$\vec{C} = \vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 4 & -2 & 1 \\ 5 & 3 & -4 \end{vmatrix}$$

$$= \hat{i}(8-3) + \hat{j}(5+16) + \hat{k}(12+10)$$

$$\mathbf{\vec{A} \times \vec{B} = 5\hat{i} + 21\hat{j} + 22\hat{k}}$$

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?

Range = 4× Maximum height

Solution : $R = \dfrac{u^2 \sin 2\theta}{g}$, $h_{max} = \dfrac{u^2 \sin^2\theta}{2g}$

$$\frac{u^2 \sin 2\theta}{g} = 4 \times \frac{u^2 \sin^2 \theta}{2g}$$

$$\sin 2\theta = 2\sin^2\theta$$

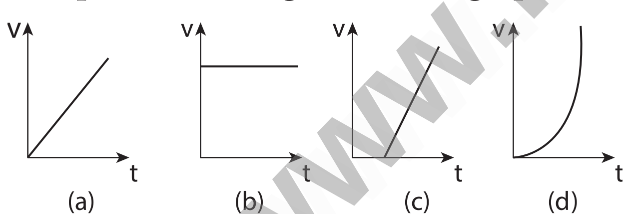
$$2 \sin\theta \cos\theta = 2\sin^2\theta$$

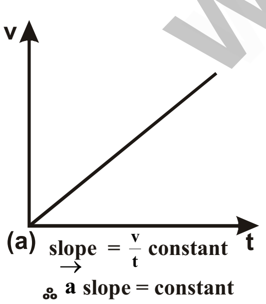
$$\frac{\sin\theta}{\cos\theta} = 1$$

$$\tan\theta = 1$$

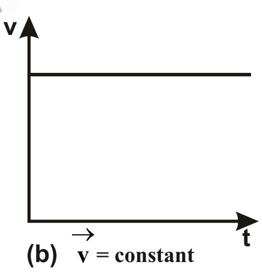
$$\theta = \tan^{-1}(1) = 45^\circ$$

7. The following graphs represent velocity - time graph. Identify what kind of motion a particle undergoes in each graph.

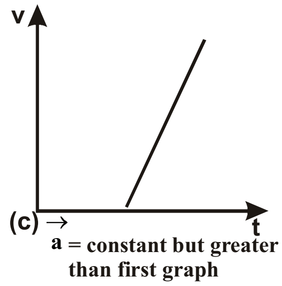




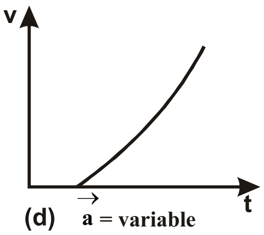
a) It represents Uniform acceleration



b) It represents Uniform Velocity

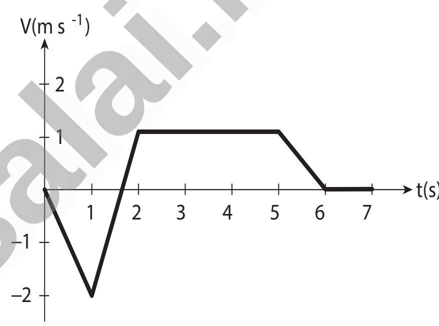


c) Greater changes in velocity and taking place increases acceleration



d) 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.



a) ➢ From 0 to 1.5s the particle moving in a opposite direction

➢ From 1.5s to 2s the particle is moving with increasing velocity

➢ From 2s to 5s velocity of the particle is Constant of magnitude $1m^{-1}$

➢ From 5s to 6s velocity of the particle is decreasing.

➢ From 6s to 7s the particle is at rest.

b) Distance covered by the particle = Area Covered under (v-t) graph

= ½×2×1.5+½×1×0.5 = 1.5+0.25 = **1.75m**

Displacement of the particle

= -½×2×1.5+½×1×0.5

Displacement = -1.5+0.25 = **-1.25m**

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

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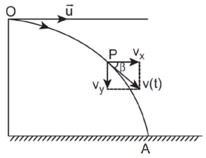
v_x = Remains constant
v_y = decreases and increases
a = remains downward
r = varies



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.

For maximum range θ = 40°

Range of projectile R_{max}

$$= \frac{v^2}{g} \; ; \sin 2\theta = \frac{v^2}{g}$$

$$\text{Sin } 90^o = \frac{v^2}{g}$$

Here R_{max} - radius of the area covered

area covered = $\pi r^2 = \pi R^2_{max}$

$$= \pi\left(\frac{v^2}{g}\right)^2 = \frac{\pi v^4}{g^2}$$

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).

Planet	Range
Jupiter	50m
Earth	75 m
Mars	90 m
Mercury	95 m

$$\text{Range} = \frac{v^2}{g}\sin 2\theta \;\; ∴ \; g \;\alpha\; \frac{1}{\text{range}}$$

Ascending order of the planet with respect to their g is mercury, mars, earth, jupiter.

12. The resultant of two vectors A and B is perpendicular to vector A and its magnitude is equal to half of the magnitude of vector B. Then the angle between A and B is

a) 30° b) 45° c) 150° d) 120°

$C = \frac{1}{2}\vec{B}$

A+B = C ∝ = 90° (vertical)

Angle between $\vec{A},\vec{B}$ is C, $\frac{B}{2} = B\,Sin\,\theta$

$$\text{Sin}\theta = \frac{B/2}{B} = \frac{B}{2B} = \frac{1}{2}$$

Sinθ = ½

θ = 30°

The angle between $\vec{A}$ and $\vec{B}$ = 180° - 30° = 150°

13. Compare the components for the following vector equations

a) $T\hat{j} - mg\hat{j} = ma\hat{j}$ b) $\vec{T}+\vec{F} = \vec{A}+\vec{B}$

c) $\vec{T} - \vec{F} = \vec{A} - \vec{B}$ d) $T\hat{j} + mg\hat{j} = ma\hat{j}$

a) T - mg = ma

b) $\vec{T}_x + \vec{F}_x = \vec{A}_x + \vec{B}_x$ (or) $\vec{T}_y + \vec{F}_y = \vec{A}_y + \vec{B}_y$

c) $\vec{T}_x - \vec{F}_x = \vec{A}_x - \vec{B}_x$ (or) $\vec{T}_y - \vec{F}_y = \vec{A}_y - \vec{B}_y$

d) T + mg = ma

14. Calculate the area of the triangle for which two of its sides are given by the vectors $\vec{A} = 5\hat{i} - 3\hat{j}$, $\vec{B} = 4\hat{i} + 6\hat{j}$

Solution : Area of the triangle = $\frac{1}{2}|\vec{A}\times\vec{B}|$

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -3 & 0 \\ 4 & 6 & 0 \end{vmatrix} = \hat{i}(0) + \hat{j}(0) + \hat{k}(30+12) = 42\hat{k}$$

$$|\vec{A}\times\vec{B}| = \sqrt{42^2} = 42$$

Area of the triangle = $\frac{1}{2}|\vec{A}\times\vec{B}| = \frac{1}{2}\times 42$

Area = 21 square units

15. If Earth completes one revolution in 24 hours, what is the angular displacement made by Earth in one hour. Express your answer in both radian and degree.

Time period of earth = 24 hours

Earth Covers 360° in 24 hours

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Angular displacement in hour = $\frac{360°}{24} = 15° = \pi/12$

Angular displacement in radian = $\frac{15°}{57.295°}$

= 0.26 rad

16. A object is thrown with initial speed 5m s^{-1} with an angle of projection 30°. What is the height and range reached by the particle? March - 2020

Initial Speed u= 5ms^{-1}, θ= 30°, h_{max}=? R=?

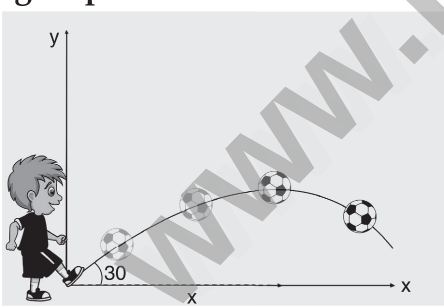
i) Maximum highest reached = $h_{max} = \frac{u^2 \sin^2\theta}{g}$

$$h_{max} = \frac{u^2 \sin^2\theta}{2g} = \frac{25\times(½)^2}{2\times9.8} = 0.318m$$

ii) Range $R = \frac{u^2 \sin 2\theta}{g}$

$$R = \frac{u^2 \sin 2\theta}{g} = \frac{25\times\sin 60°}{9.8} = 2.21m$$

17. A foot - ball player hits the ball with speed 20m s^{-1} with angle 30° with respect to horizontal direction as shown in the figure. The goal post is at distance of 40 m from him. Find out whether ball reaches the goal post?



Given : u = 20ms^{-1}, θ = 30°,

Distance of the goal post = 40m

Solution : $R = \frac{u^2 \sin 2\theta}{g}$

$$R = \frac{400\times\sin 60°}{9.8} = \frac{400\times\sqrt{3}/2}{9.8}$$

R = 35.35 m

The distance of the goal post is 40m. But the range of the ball is 35.35m only. so the ball will not reach the goal post

18. If an object is thrown horizontally with an initial speed 10 m s^{-1} from the top of a building of height 100 m. what is the horizontal distance covered by the particle?

Given : u = 10ms^{-1}, h = 100m, R = ?

Range $R = u\sqrt{2h/g} = 10\sqrt{\frac{200}{9.8}} = 45.1m$

R = 45m

19. An object is executing uniform circular motion with an angular speed of $\frac{\pi}{12}$ radian per second. At t = 0 the object starts at an angle θ = 0. What is the angular displacement of the particle after 4 s?

Angular speed = π/12 rad/s^{-1}

Angular speed = $\frac{\text{Angular displacement}}{\text{time taken}}$ = —

$\omega = \frac{\pi}{12}$; t= 4s, θ = ?

$\omega = \frac{\theta}{t}$; $\theta = \frac{\pi}{12}\times 4 = 60°$

$\frac{\pi}{3} = 1.0476 \text{ rad (or)} \frac{180°}{3} = 60°$

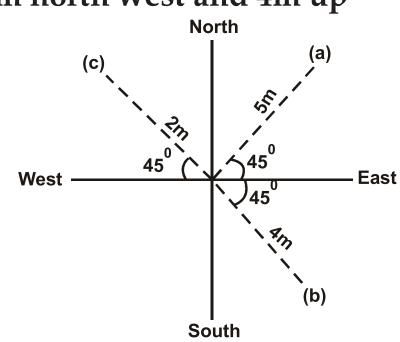
Angular displacement θ = 60°

20. Consider the x - axis as representing east, the y - axis as north and z-axis as vertically upwards. Give the vector representing each of the following points.

a) 5m north east and 2m up

b) 4 m south east and 3m up

c) 2m north west and 4m up



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Length along X axis = $5\cos 45^\circ = \frac{5}{\sqrt{2}}\hat{i}$

Length along Y axis = $5\sin 45^\circ = \frac{5}{\sqrt{2}}\hat{j}$

Length along Z axis = $2\hat{k}$

In Vector rotation = $\frac{5}{\sqrt{2}}\hat{i}+\frac{5}{\sqrt{2}}\hat{j}+2\hat{k} = \frac{5(\hat{i}+\hat{j})}{\sqrt{2}}+2\hat{k}$

b) Length along X axis = $4\cos 45^\circ = \frac{4}{\sqrt{2}}\hat{i}$

Length along Y axis = $-4\sin 45^\circ = \frac{-4}{\sqrt{2}}\hat{j}$

Length along Z axis = $3\hat{k}$

In Vector rotation = $\frac{4}{\sqrt{2}}\hat{i}-\frac{4}{\sqrt{2}}\hat{j}+3\hat{k} = \frac{4(\hat{i}-\hat{j})}{\sqrt{2}}+3\hat{k}$

c) Length along X axis = $-2\cos 45^\circ = \frac{-2}{\sqrt{2}}m = \frac{-2}{\sqrt{2}}\hat{i}$

Length along Y axis = $2\sin 45^\circ = \frac{2}{\sqrt{2}}m = \frac{2}{\sqrt{2}}m$

$= \frac{2}{\sqrt{2}}\hat{j}$

Length along Z axis = $4m = 4\hat{k}$

∴ In Vector rotation = $-\sqrt{2}\hat{i}+\sqrt{2}\hat{j}+4\hat{k}$

$= \sqrt{2}(-\hat{i}+\hat{j})+4\hat{k}$

21. The Moon is orbiting the Earth approximately once in 27 days, what is the angle transversed by the Moon per day?

Period of moon = 27 days

∴ In 27 days moon covers = 360°

In one day angle transversed by moon = $\frac{360^\circ}{27}$ = **$13^\circ 3'$**

22. An object of mass m has angular acceleration ∝ = − 0.2 rad s^{-2}. What is the angular displacement covered by the object after 3 second? (Assume that the object started with angle zero with zero angular velocity).

$\alpha = 0.2$ rad s^{-2}, $t = 3$s, $\omega_0 = 0$, $\theta = ?$

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2} \times 0.2 \times 9 = 0.9$

θ = 0.9 rad (or) **$51^\circ 54'$**

PART - II - GMQ, GOVT. EXAM QUESTIONS

I. Choose the best answer

1. The maximum value of fractional error in division of two quantities i.e., $x = \frac{A}{B}$ is GMQ - 2018

a) $\frac{\Delta x}{x} = \mp\left(\frac{\Delta A}{A}+\frac{\Delta B}{B}\right)$ 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: a) $\frac{\Delta x}{x} = \mp\left(\frac{\Delta A}{A}+\frac{\Delta B}{B}\right)$

2. The unit vector in the direction of $\vec{A} = \hat{i}+\hat{j}+\hat{k}$ is GMQ - 2018

a) $\hat{i}+\hat{j}+\hat{k}$ b) $\frac{\hat{i}+\hat{j}+\hat{k}}{\sqrt{2}}$

c) $\frac{\hat{i}+\hat{j}+\hat{k}}{\sqrt{3}}$ d) $\frac{\hat{i}+\hat{j}+\hat{k}}{\sqrt{6}}$

Ans: c) $\frac{\hat{i}+\hat{j}+\hat{k}}{\sqrt{3}}$

3. Which of the following physical quantities have same dimensional formula? GMQ - 2018

a) Torque and Work done

b) Energy and Angular momentum HY - 2018

c) Force and Torque

d) Angular momentum and Linear momentum

Ans: a) Torque and Work done

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4. **Which one of the following is a scalar quantity?** QY - 2019 MAR - 2020

a) speed b) velocity
c) displacement d) linear momentum

Ans: a) speed

5. **If the object dropped vertically from the top of the building takes 2 second to reach the ground then the height of the building is ($g = 10\ ms^{-2}$)** QY - 2019

a) 10 m b) 16m
c) 20 m d) 25 m

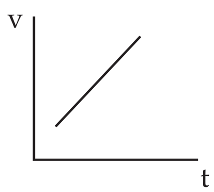
Ans: c) 20 m

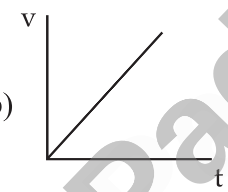
6. **A particle is in circular motion with an acceleration α = 0.2 rad s^{-2}. What is the angular displacement made by the particle after 5s ?** HY - 2019

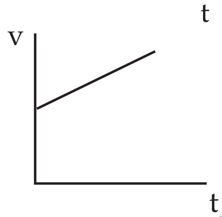
a) 2.5 rad b) 25 rad
c) 250 rad d) 2500 rad

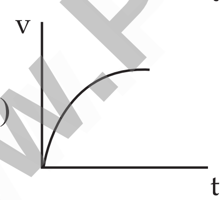
Ans: a) 2.5 rad

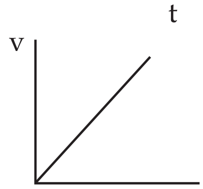
7. **An object is dropped from rest. Its $v - t$ graph is :** HY - 2019

a) 

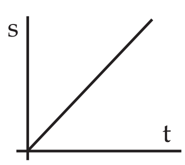
b) 

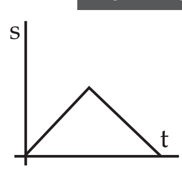
c) 

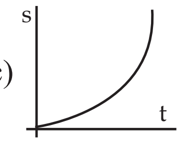
d) 

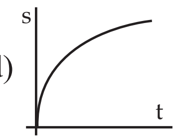
Ans: b) 

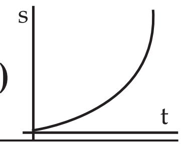
8. **Which graph represents uniform acceleration** Mar - 2019

a) 

b) 

c) 

d) 

Ans: c) 

9. **What is the angular displacement made by a particle after 5 s, when it starts from rest with an angular acceleration 0.2 rad s^{-2}?** Mar - 2019

a) 4 rad b) 1 rad
c) 2.5 rad d) 5 rad

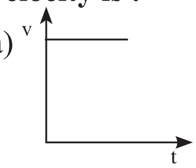
Ans: b) 1 rad

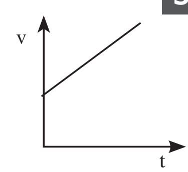
10. **If the position vector of a particle is given by $\vec{r} = 5t^2\hat{i} + 7t\hat{j} + 4\hat{k}$, then its velocity lies in :** June - 2019

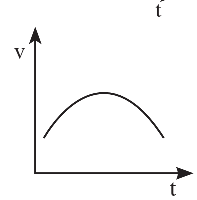
a) X - Z plane b) X - Y plane
c) along Y - direction d) along X - direction

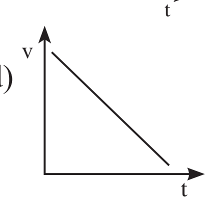
Ans: b) X - Y plane

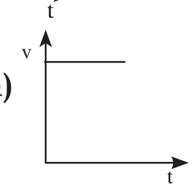
11. **The velocity-time (v-t) graph representing motion of particle moving with uniform velocity is :** SEP - 2020

a) 

b) 

c) 

d) 

Ans: a) 

12. **A stone of mass 0.5 kg tied to a string executes uniform circular motion in a circle of radius 2 m with a speed of $4ms^{-1}$. The magnitude of tension acting on the stone will be :** Sep-2020

a) 3N b) 10 N
c) 0.5 N d) 4 N

Ans: d) 4 N

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13. If an object is falling from a height of 20m, then the time taken by the object to reach the ground: (ignore air resistance and take $g = 10ms^{-2}$) Mar-2023

a) 2s b) 1.732s
c) 1.532s d) 1.414s

Ans: a) 2s

Solution :

$h = \frac{1}{2}gt^2$ | $20 = 5t^2$ | $\frac{20}{5} = t^2$ | $t = 2$

$20 = \frac{1}{2}(10)t^2$ | $20 = 5t^2$ | $4 = t^2$

II. Short Answer Questions

1. Is zero relative velocity possible ? Explain. QY - 2018

Yes, it is possible.
If two objects A and B travel in the same direction with same velocity their relative velocities.
$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B = 0$ Also
$\vec{V}_{BA} = \vec{V}_B - \vec{V}_A = 0$ (Since velocity of each object is same)
Each object will appear to be at rest with respect to other.

2. Define position vector. QY - 2018

Vector which denotes the position of a particle at any instant of time, with respect to some reference frame or coordinate system.

3. Differentiate scalar - vector quantities. HY - 2018 JUN-2019

Scalar	Vector
➢ It is a property which have magnitude only	➢ It is a quantity which is described by both magnitude and direction
➢ Example: Distance, mass, temperature	➢ Example: Force, Velocity

4. Define point mass. QY - 2019

The mass of any object be assumed to be concentrated at a point. Then this idealized mass is called "point mass". (Ex). A small stone in the air.

5. What is projectile ? Give example. (or) Define projectile. Give examples. MAR - 2019 QY - 2019

When an object is thrown in the air with some initial velocity (NOT just upwards), and then allowed to move under the action of gravity alone, the object is known as a projectile.

Example :

1. An object dropped from window of a moving train.
2. A bullet fired from a rifle.
3. A ball thrown in any direction.

III. Long Answer Questions

1. Find horizontal range and time of flight projectile in horizontal projection.

Time of flight : GMQ - 2018

- ➢ The time taken for the projectile to complete its trajectory is called time of flight.
- ➢ Height of tower is h, time taken - T then $s_y = u_y t + ½at^2$
  Here $s_y = h$, $t = T$, $u_y = 0$
  Then $h = ½gT^2$ or $T = \sqrt{\frac{2h}{g}}$
- ➢ The time of flight for projectile motion depends on the height of the tower, but is independent of the horizontal velocity of projection.

Horizontal Range :

- ➢ The horizontal distance covered by the projectile from the foot of tower to the point where the projectile hits the ground is called horizontal range.
- ➢ For horizontal motion $s_x = u_x t + ½ at^2$
- ➢ $s_x = E$, $U_x = u$, $a = 0$, T is time of flight, then horizontal range = uT
- ➢ Time of flight $T = \sqrt{\frac{2h}{g}}$
- ➢ The horizontal range of the particle is
  $R = u\sqrt{\frac{2h}{g}}$
  The range R is directly proportional to the initial velocity 'u' and inversely proportional to acceleration due to gravity 'g'.

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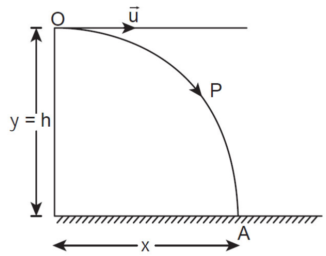
2. Show that the path followed by a projectile is a parabola. HY-2019 SEP-2021 AUG - 2022

Projectile in horizontal projection:



- Consider a projectile, say a ball, thrown horizontally with an initial velocity $\vec{u}$ from the top of a tower of height (h).
- Then the horizontal distance travelled by the ball is $x(t) = x$.

  Vertical distance travelled is y(t) = y
- Since this is two-dimensional motion, the velocity will have both horizontal component u_x and vertical component u_y.
- The distance travelled by the projectile at a time t is given by the equation

  $x = u_x t + \frac{1}{2}at^2$

  Since a = 0 along x direction,

  $x = u_x t$ ...... (1)

Motion along downward direction :

- Here $u_y = 0$, a = g, s = y

  from equation $y = u_y t + \frac{1}{2}at^2$

  we get : $y = \frac{1}{2}gt^2$ .... (2)
- Substitute the value of t from equation (1) in equation (2)

$$y = \frac{1}{2}g\frac{x^2}{u_x^{\,2}} = \left(\frac{g}{2u_x^{\,2}}\right)x^2$$

$y = Kx^2$ .... (3)

Where $K = \frac{g}{2u_x^{\,2}}$ is a constant.

Equation (3) is the equation of a parabola. Thus the path followed by the projectile is a parabola.

IV. Problems

1. A particle moves in a circle of radius 10 m. Its linear speed is given by v = 3t, where t is the time in second and v is in ms^{-1}. Compute the centripetal and tangential acceleration at time t= 2s. GMQ - 2018

Solution :

The linear speed at S = 2 s

$S = 3t = 6ms^{-1}$

The centripetal acceleration at s = 2 s is

$$S_x = \frac{v^2}{r} = \frac{(6)^2}{10} = 3.6m\ s^{-2}$$

The tangential acceleration is at

$$a_t = \frac{dv}{dt} = 3ms^{-2}$$

2. A man of 50 kg is standing on the school play ground at Trichy. The latitude of Trichy is 10.8º. GMQ - 2018

a. Calculate the centrifugal force experienced by the man.

b. With what minimum angular speed the earth must rotate so that the magnitude of gravitational force is equal to the magnitude of centrifugal force that he experiences? (Radius of the earth is 6400 km and g = 10 ms^{-2})

c. Calculate the time (in hour) to complete one rotation (one day) of the earth with the new angular speed.

Solution :

a. m = 50kg ; θ = 10.8

R - radius of the earth = 6400×10^3m

Centrifugal force $F_c = m\omega^2 R\cos\theta$.

The angular velocity (ω) of earth = $\frac{2\pi}{T}$

$\omega = \frac{2\pi}{T}$

T - time period of the earth (24 hours)

$$= \frac{2\pi}{24\times60\times60} = \frac{2\pi}{86400} = 7.2685\times10^{-5} rad\,s^{-1}$$

∴ $F_c = 50\times(7.268\times10^{-5})^2\times6400\times10^3\times\cos 10.8$

$F_c = 1.66N$

b. Gravitational force = F_g = mg

= 50 x 10 = 500N

Minimum angular speed ω = ?

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If $F_g = F_c$

$500 = m\omega^2 R\cos\theta$

$$\omega_{new} = \frac{500}{50\times 6400\times 10^3 \times \cos 10.8} = 1.59\times 10^{-6}$$

$\omega_{new} = 1.261 \times 10^{-3}$ rad s^{-1}

c. Time taken to complete one rotation of the earth (T) = ?

New angular speed

$\omega_{new} = 1.261 \times 10^{-3}$rad s^{-1}

$$\omega = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{\omega} = \frac{6.28}{1.261\text{x}10^{-3}}$$

$$= 4.985\times 10^3 \text{ s}$$

$$T = \frac{4.985\times 10^3}{3600} = 1.4\text{h}$$

3. The velocities of three particles A, B and C are $\vec{v}_A = (3\hat{i} - 5\hat{j} + 2\hat{k})\ ms^{-1}$, $\vec{v}_B = (\hat{i} + 2\hat{j} + 3\hat{k})\ ms^{-1}$ and $\vec{v}_C = (5\hat{i} + 3\hat{j} + 4\hat{k})\ ms^{-1}$, respectively. Which particle travels at neither greatest nor lowest speed ?

Solution : GMQ - 2018 HY - 2018

We know that speed is the magnitude of the velocity vector. Hence,

Speed of A = $|\vec{v}_A| = \sqrt{(3)^2 + (-5)^2 + (2)^2}$

$= \sqrt{9+25+4} = \sqrt{38}ms^{-1}$

Speed of B = $|\vec{v}_B| = \sqrt{(1)^2 + (2)^2 + (3)^2}$

$= \sqrt{1+4+9} = \sqrt{14}ms^{-1}$

Speed of C = $|\vec{v}_C| = \sqrt{(5)^2 + (3)^2 + (4)^2}$

$= \sqrt{25+9+16} = \sqrt{50}ms^{-1}$

The particle C has the greatest speed.

$= \sqrt{50} > \sqrt{38} > \sqrt{14}$

4. What is the angle of projection to have a maximum range in 'kitti pull' ? If one strikes kitti pull with of $98ms^{-1}$ what is the maximum range achieved ? QY - 2018

Solution :

For maximum range, angle of projection $\theta = 45^o$

Range R = $\frac{2\pi}{\omega}$ $\therefore \theta = 45^o$

maximum range $R_{max} = \frac{u^2}{g}$

$$R_{max} = \frac{98\times 98}{9.8} = 980\text{m}$$

5. A car moving with a speed of 40 km / hr comes to rest at a distance of 2m after applying brakes. If the same car is moving with a speed of 80 km / hr, what is the minimum stopping distance ? HY - 2018

Solution :

$u_1 \quad = 40\text{km/hr}, v = 0, s_1 = 2\text{m}$

$u_1 \quad = \frac{40\times 10^3}{3600} = \frac{200}{18}ms^{-1}$

$v_1^2 \quad = u_1^2 + 2as \quad (v_1 = 0)$

$\Rightarrow u_1^2 \quad = -2as_1$

$\Rightarrow u_1^2 \quad = -2 \times a \times 2$

$$\Rightarrow a = \frac{u_1^2}{-4} = -\frac{\left(\frac{200}{18}\right)^2}{4} = -\frac{200}{18}\times\frac{200}{18}\times\frac{1}{4}$$

$$\Rightarrow a = -\frac{1000}{324} = 30.864 \simeq 31$$

$\Rightarrow a \quad = -31ms^{-2}$

$u_2^2 \quad = -2as_2$

$\frac{u_2^2}{2a} \quad = \frac{u_2^2}{62}$

$$s_2 = \frac{\left(\frac{400}{18}\right)^2}{62} = \frac{400}{18}\times\frac{400}{18}\times\frac{1}{62}$$

$s_2 = 7.96\text{m}$

6. Position vectors of two point masses 10 kg and 5kg are $(3\vec{i} + 2\vec{j} + 4\vec{k})$ m and $(3\vec{i} + 6\vec{j} + 5\vec{k})$ m respectively. Locate the position of center of mass. HY - 2018

Solution :

$$\vec{r} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$$

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$$\vec{r} = \frac{10(3\hat{i}+2\hat{j}+4\hat{k})+5(3\hat{i}+6\hat{j}+5\hat{k})}{10+5}$$

$$\vec{r} = \left[3\hat{i}+\frac{10}{3}\hat{j}+\frac{13}{3}\hat{k}\right]m.$$

7. A particle moves along the x-axis in such a way that its coordinates x-varier with time 't' according to the equation $x = 2 - 5t + 6^2$. What is the initial velocity of the particle ? **HY - 2019** **May-2022**

Solution :

$x = 2 - 5t + 6t^2$

Velocity, $v = \frac{dx}{dt} = \frac{d}{dt}(2 - 5t + 6t^2)$

or $v = -5 + 12t$

For initial velocity, $t = 0$

$\therefore$ Initial velocity $= -5\ ms^{-1}$

- The negative sign implies that at $t = 0$ the velocity of the particle is along negative x direction.
- Average speed = total path length / total time period.

8. Suppose an object is thrown with initial speed 10m s^{-1} at an angle $\pi / 4$ with the horizontal, what is the range covered? Suppose the same object is thrown similarly in the Moon, will there be any change in the range ? If yes, what is the change ? (The acceleration due to gravity in the Moon $g_{moon} = \frac{1}{6}g$) **HY - 2019**

Solution :

In projectile motion, the range of particle is given by

$$R = \frac{u^2 \sin 2\theta}{g}$$

$$\theta = \frac{\pi}{4};\ u = v_0 = 10m\ s^{-1}$$

$$\therefore R_{earth} = \frac{(10)^2 \sin \pi/2}{9.8} = 100/9.8$$

$R_{earth} = 10.20$ m (Approximately 10 m)

If the same object is thrown in the moon, the range will increase because in the moon, the acceleration due to gravity is smaller than g on Earth.

$$g_{moon} = \frac{g}{6}$$

$$R_{moon} = \frac{u^2 \sin 2\theta}{g_{moon}} = \frac{v_0^2 \sin 2\theta}{g/6}$$

$\therefore R_{moon} = 6\ R_{earth}$

$R_{moon} = 6 \times 10.20 = 61.20$ m.

(Approximately 60m)

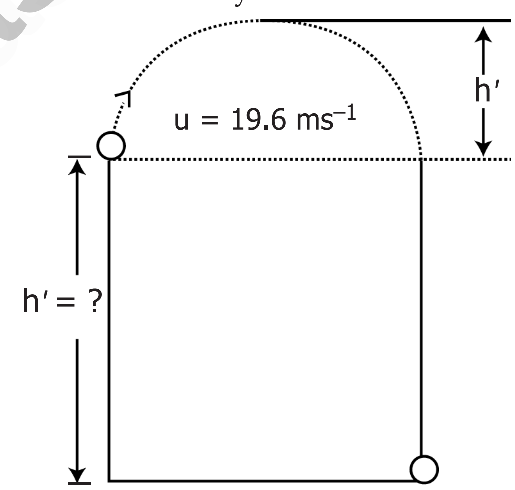
The range attained on the moon is approximately that on Earth.

9. A ball is thrown vertically upwards with the speed of 19.6 ms^{-1} from the top of a building and reaches the earth in 6s. Find the height of the building. **MAR - 2019**

Solution :

Let h height of the building let the ball attain height h' above the building

At h' the velocity $v = 0$



By applying equation of motion

$v^2 = u^2 - 2gh$

$0^2 = (19.6)^2 - 2gh$

$2gh' = (19.6)^2$

$h' = \frac{19.6 \times 19.6}{2 \times 9.8}$

$h' = 19.6$ m

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Time taken by the ball to reach h' is t' (say)

$v = u + at \; [a = -g, t = t']$

$0 = 19.6 - gt'$

$t' = \frac{19.6}{9.8} = 2s$

Time taken by the ball to fall from height (h + h') = 6S – 2S = 4S

We know that, $S = ut + \frac{1}{2}gt^2$

i.e. $(h + h') = ut + \frac{1}{2}gt^2$

Here $u = 0$

So, $h + h' = \frac{1}{2}gt^2$

$h + 19.6 = \frac{1}{2} \times 9.8 \times (4)^2$

$h = 9.8 \times 8 - 19.6$

$h = 78.4 - 19.6$

height of the building h = 58.8 m

10. A car takes with the velocity $50ms^{-1}$ on a circular road of radius of curvature 10m. Calculate the centrifugal force experienced by a person of mass 60kg inside the car. **MAR - 2019**

Solution :

Velocity $v = 50ms^{-1}$

Radius of curvature r = 10m

Mass m = 60kg

$F = \frac{mv^2}{r} = \frac{60 \times 50 \times 50}{10} = \frac{150000}{10}$

$\therefore F = 15{,}000N$

11. The position vector and angular velocity vector of a particle executing uniform circular motion at an instant are $2\hat{i}$ and $4\hat{k}$ respectively. Find its linear velocity at that instant. **SEP -2020**

Solution :

Position Vector $\vec{\gamma} = 2\vec{i}$

Angular Velocity $\vec{\omega} = 4\vec{k}$

Linear Velocity $\vec{v} = \vec{\omega} \times \vec{r}$

$= 4\vec{k} \times 2\vec{i}$

$$v = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ 0 & 0 & 4 \\ 2 & 0 & 0 \end{vmatrix}$$

$= \vec{r}(0) - \vec{j}(0-8) + \vec{k}(0)$

$= 8\vec{j}$

12. A train was moving at the rate of $54 \; kmh^{-1}$. When brakes were applied, it came to rest within a distance of 225m. Calculate the retardation produced in train. **SEP -2020**

Solution :

The final velocity of the particle, v = 0

The initial velocity of the particle,

$u = 54 \times \frac{5}{18} ms^{-1} = 15 \; ms^{-1}$

s = 225 m

Retardation is always against the velocity of the particle.

$v^2 = u^2 - 2as$

$0 = (15)^2 - 2a(225)$

$450a = 225$

$a = \frac{225}{450} ms^{-2} = 0.5 \; ms^{-2}$

Hence, retardation = $0.5 \; ms^{-2}$

13. Consider two trains A and B moving along parallel tracks with the same velocity in the same direction. Let the velocity of each train be $50 \; km \; h^{-1}$ due east. Calculate the relative velocities of the trains. **AUG - 2022**

Solution :

Relative velocity of B with respect toA,

$V_{BA} = V_B - V_A$

$= 50 \; km \; h^{-1} + (-50) \; km \; h^{-1}$

$= 0 \; km \; h^{-1}$

Similarly, relative velocity of A with respect to B i.e., V_{AB} is also zero.

Thus each train will appear to be at rest with respect to the other.

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PART - III ADDITIONAL QUESTIONS

I. Matching Type Questions

1.

	Linear motion		Angular motion
1.	$v = u+at$	(i)	$\theta = (\omega_0 + \omega)\, t/2$
2.	$s = ut+\frac{1}{2} at^2$	(ii)	$\omega_2 = (\omega_0{}^2 + 2\alpha\,\theta)$
3.	$v^2 = u^2+2as$	(iii)	$\theta = \omega_0 t + \frac{1}{2} at^2$
4.	$s = \frac{(v+u)t}{2}$	(iv)	$\omega = \omega_0 + \alpha t$

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

Ans : (c) d c b a

2.

	Physical Quantity		Formula
(1)	Angular acceleration (∝)	(a)	v^2/r
(2)	Centripetal acceleration a_c	(b)	θ/t
(3)	Angular displacement (θ)	(c)	ω/t
(4)	Angular Velocity (ω)	(d)	s/r

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

Ans : (d) c a d b

3.

	Statement		Physical quantity
(1)	Length of a vector	(a)	radian
(2)	Length of one divided by the radius of the arc	(b)	displacement
(3)	Rate of change of angular displacement	(c)	norm of the vector
(4)	Shortest distance between Initial final position	(d)	angular velocity

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

Ans : (b) c a d b

II. Statement type Questions

1. **(I) Area of a Triangle in vectors is** $\frac{1}{2}\left(\vec{A}\times\vec{B}\right)$

(II) Area of a Parallelogram in vectors is $\left|\vec{A}\times\vec{B}\right| = \left|\vec{A}\right|\left|\vec{B}\right|\sin\theta$

Which Statement is incorrect?

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

Ans : (d) I only

2. **(I) Acceleration which is acting away from the center of the circle is called Centripetal Acceleration.**

(II) If the speed of the object in a circular motion is not constant, it is called a non - uniform circular motion.

Which Statement is correct?

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

Ans : (a) II only

III. Assertion & Reason type Questions :

Direction :

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

b) Assertion and Reason are true but Reason is not the explanation of the Assertion.

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GOVT. QUESTION PAPER - MARCH 2023

11 - PHYSICS

Time Allowed : 3.00 Hours Maximum Marks : 70

PART - I

Note : i) Answer All the questions.
ii) Choose the most appropriate answer from the given four alternatives and write the option code and the corresponding answer. **15 x 1 = 15**

1. If a wire is stretched to double of its original length, then the strain in the wire is:
   a) 3 **b) 1** c) 4 d) 2
2. Round off the number 19.95 into three significant figures.
   a) 20.1 b) 19.9 c) 19.5 **d) 20.0**
3. The graph between volume and temperature in Charle's law is:
   a) a straight line b) an ellipse c) a parabola d) a circle
4. In the given SHM y = 2 sin (20πt + 1.5) the frequency of oscillation is:
   a) 10 Hz b) 20 Hz c) 15 Hz d) π Hz
5. The kinetic energy of the satellite orbiting around the earth is:
   a) greater than potential energy b) equal to potential energy
   c) zero **d) less than potential energy**
6. The centrifugal force appears to exist:
   a) in any accelerated frame b) only in inertial frames
   c) both in inertial and non-inertial frames **d) only in rotating frames**
7. If an object is falling from a height of 20 m, then the time taken by the object to reach the ground: (ignore air resistance and take g = 10 ms^{-2})
   a) 2 s b) 1.732 s c) 1.532 s d) 1.414 s
8. The fundamental frequency of closed organ pipe whose length is 10 cm is:
   a) 4.5 vHz **b) 2.5 vHz** c) 10 vHz d) 2 vHz
9. A particle executing SHM crosses points A and B with the same velocity. Having taken 3 s in passing from A to B, it returns from B to A after another 3 s. The time period is:
   a) 12 s b) 15 s c) 9 s d) 6 s
10. If the temperature and pressure of a gas is doubled, the mean free path of the gas molecules:
    a) tripled **b) remains same** c) quadrupled d) doubled
11. A uniform force of $\left(2\hat{i} + \hat{j}\right)$ N acts on a particle of mass 1 kg. The particle displaces from position $\left(3\hat{j} + \hat{k}\right)$ m to $\left(5\hat{i} + 3\hat{j}\right)$ m. The workdone by the force on the particle is:
    a) 10 J b) 9 J c) 12 J d) 6 J
12. A rigid body rotates with an angular momentum L. If its kinetic energy is halved, the angular momentum becomes:
    a) 2 L b) L **c) $\frac{L}{\sqrt{2}}$** d) L / 2
13. Which one of the following physical quantities cannot be represented by a scalar?
    a) Momentum b) Mass
    c) Magnitude of acceleration d) Length

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14. The dimensional formula for coefficient of viscosity is:
    a) $ML^{-2} T^{-2}$ b) MLT^{-2} c) $ML^{-1} T^{-2}$ **d) $ML^{-1} T^{-1}$**
15. A sound wave whose frequency is 5000 Hz travels in air and then hits the water surface. The ratio of its wavelengths in water and air is:
    a) 5.30 **b) 4.30** c) 1.23 d) 0.23

PART - II

Answer any six questions. Question No. 24 is Compulsory. **6 x 2 = 12**

16. Write the rules for determining significant figures. **Unit 1**
17. Define scalar. Give examples. **Unit 2**
18. Under what condition will a car skid on a levelled circular road? **Unit 11**
19. Write any two differences between conservative and non-conservative Force. **Unit 3**
20. What are the conditions in which Force cannot produce Torque? **Unit 5**
21. State Newton's Universal Law of Gravitation. **Unit 6**
22. Define Poisson's ratio. **Unit 7**
23. State zeroth Law of Thermodynamics. **Unit 8**
24. Two objects of masses 3 kg and 6 kg are moving with the same momentum of 30 $kgms^{-1}$. Will they have same kinetic energy? **Unit 4**

PART - III

Answer any six questions. Question No. 33 is Compulsory. **6x3=18**

25. What is Gross Error? State the reasons for it and how to minimise the errors. **Unit 1**
26. Write the properties of scalar product of two vectors. **Unit 2**
27. State the differences between centripetal force and centrifugal force. **Unit 3**
28. State the various types of potential energy. Explain its formulae. **Unit 4**
29. Explain geostationary satellites. **Unit 6**
30. Write the practical applications of capillarity. **Unit 7**
31. State the Laws of Simple Pendulum. **Unit 10**
32. Write down the postulates of kinetic theory of gases. **Unit 9**
33. During a cyclic process, a heat engine absorbs 600 J of heat from a hot reservoir, does work and ejects an amount of heat 200 J into the surroundings (cold reservoir). Calculate the efficiency of the heat engine. **Unit 8**

PART - IV

Answer all the questions. **5 x 5 = 25**

34. a) Obtain an expression for the time period T of a simple pendulum. The time period depends on: **Unit 1**
    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 $k = 2\pi$)

(OR)

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b) Explain in detail the Triangle Law of Vector Addition. **Unit 2**

35. a) Show that in an inclined plane, angle of friction is equal to angle of repose. **Unit 3**

(OR)

b) Derive an expression for power and velocity. **Unit 3**

36. a) Derive the expression for moment of inertia of a rod about its centre and perpendicular to the rod. **Unit 5**

(OR)

b) Explain the variation of Acceleration due to gravity (g) with depth from the earth's surface. **Unit 6**

37. a) Derive the expression for the terminal velocity of a sphere moving in a high viscous fluid using Stoke's law. **Unit 7**

(OR)

b) Derive Meyer's relation for an ideal gas. **Unit 8**

38. a) Derive the expression of pressure exerted by the gas molecules on the walls of the container. **Unit 9**

(OR)

b) Derive Newton's formula for velocity of sound waves in air. Explain the Laplace's correction in it. **Unit 11**

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