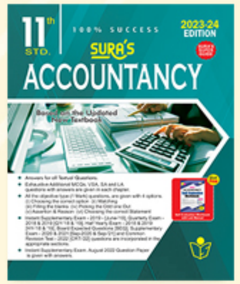
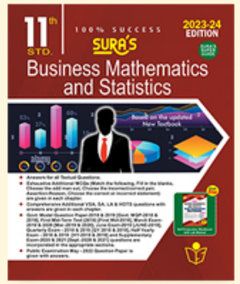
BASED ON THE UPDATED NEW TEXTBOOK





Limited stock Only

SURA'S

ENGLISH மற்றும் தமிழ் மீடியம்

11th std

School Guides

100% SUCCESS

orders@surabooks.com

அனைத்து புத்தகக் கடைகளிலும் கிடைக்கிறது

100/100

call @ 8124201000 | 8124301000

9600175757 / 8056294222 / 7871802000

2023-24 பதிப்பு

Available on

surabooks.com

SURA'S

PHYSICS

11th Standard

VOLUME - I & II

FREE Practice Workbook with Lab Manual

Based on the Updated New Textbook

Salient Features

- Prepared as per the **Updated New Textbook.**
- Answers for all **Textual Questions.**
- Exhaustive **Additional MCQs, VSA, SA & LA questions with answers** are given in each chapter.
- All the objective type **(1 Mark) questions,** are given with 4 options.
  - (i) Choose the correct option
  - (ii) Match the following
  - (iii) Fill in the blanks
  - (iv) Choose the odd one out
  - (v) Choose the correct pair
  - (vi) Choose the incorrect pair
  - (vii) Assertion-Reason
  - (viii) Choose the correct or incorrect statements
- Govt. Model Question Paper (2018) ***[Govt. MQP-2018]***, First Mid-Term Test (2018) ***[First Mid-2018]***, Quarterly Exam - 2018 & 2019 ***[QY-2018 & 2019]***, Half Yearly Exam- 2018 & 2019 ***[HY-2018 & 2019]***, Public Exam. March - 2019, 2020 & May - 2022 ***[Mar-2019, 2020 & May - 2022]***, Instant Supplementary Exam June - 2019 & August- 2022 ***[Jun.-2019 & Aug-'22]***, Govt.Suppl. Exam September - 2020 & 2021 ***[Sep.2020 & Sep.2021]*** and Common Revision Test ***[CRT-'22]*** questions are incorporated in the appropriate sections.
- Instant Supplementary Exam August 2022 Question Paper is given with answers.

SURA PUBLICATIONS
Chennai

2023-24 *Edition*

ISBN : 978-93-5330-539-0
Code No : SG 264

Author :

Mr.J.M.Joseph, *M.Sc.,B.Ed.,*
Chennai.

Reviewed by :

Mr. P. George Paul, *M.Sc.,M.Ed., M.Phil, PGDCA*
Vice-Principal
Annai Veilankanni's Matric Hr. Sec. School
81, VGP Salai, Saidapet, Chennai - 600 015

Head Office:

Sura Publications
1620, 'J' Block, 16th Main Road,
Anna Nagar, **Chennai - 600 040.**
Phones : 044 - 4862 9977, 044 - 4862 7755.
e-mail : orders@surabooks.com
website : www.surabooks.com

For Orders Contact

80562 94222
81242 01000
81243 01000
96001 75757
78718 02000
98409 26027

23/11/2022

CONTENTS

VOLUME - I

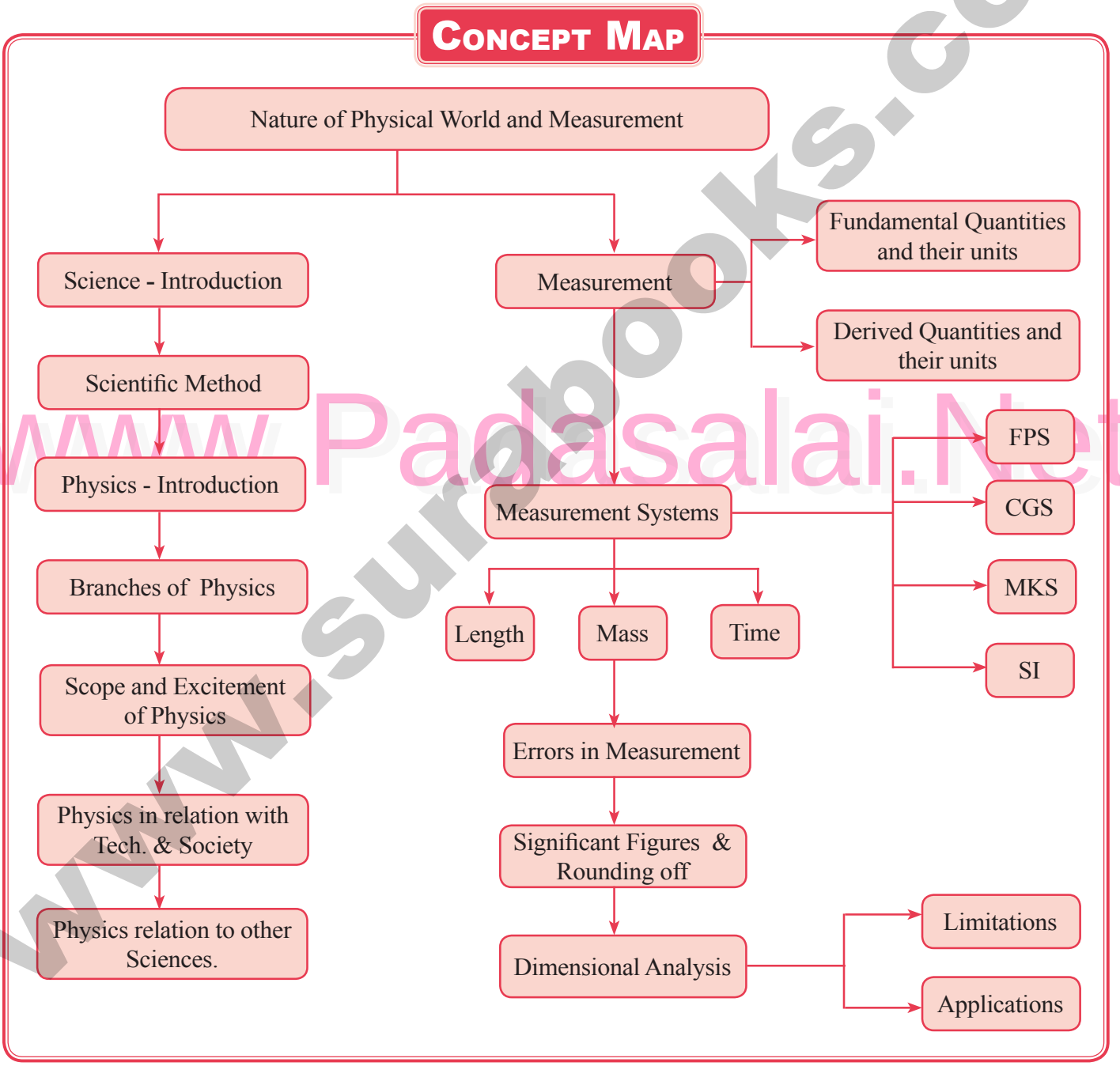
VOLUME - II

UNIT

01

Nature of Physical World and Measurement

Concept Map



FORMULAE TO REMEMBER

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

(2) π radian = 180°

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

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

Relations between radian, degree and minutes:

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

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

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

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

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

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

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

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

SOME COMMON PRACTICAL UNITS

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

Prefixes for Powers of Ten

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

IMPORTANT TERMS & DEFINITIONS

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

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

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

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

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]

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%]

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 *[Related to AMPMT 2008] [HY-2018]*

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

[Ans. (d) 7%]

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

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

[Ans. (c) 0.28%]

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

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

[Ans. (d) 6.3200 J]

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

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

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

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

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

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

[Ans. (b) torque and energy]

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

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

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

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

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

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

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

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

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

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

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

[Ans. (c) 40]

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

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

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

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

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

[Ans. (c) velocity]

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

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

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

II. Short Answer Questions.

1. Briefly explain the types of physical quantities.

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

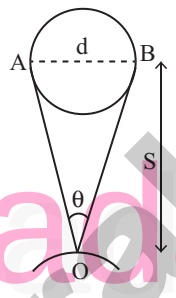
(ii) Fundamental or base quantities are quantities which cannot be expressed in terms of any other physical quantities. These are length, mass, time, electric current, temperature, luminous intensity and amount of substance.

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

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

Ans. O - observation point on earth.

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



(ii) ∠AOB = θ
S - average distance between moon and the surface of earth.

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

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

3. Write the rules for determining significant figures.

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

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

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

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

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

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

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

4. What are the limitations of dimensional analysis?

[Govt. MQP-2018; HY-2018; Jun.-2019; CRT & Aug-'22]

Ans. **Limitations of Dimensional analysis:**

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

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

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

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

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

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

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

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

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

III. Long Answer Questions

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

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

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

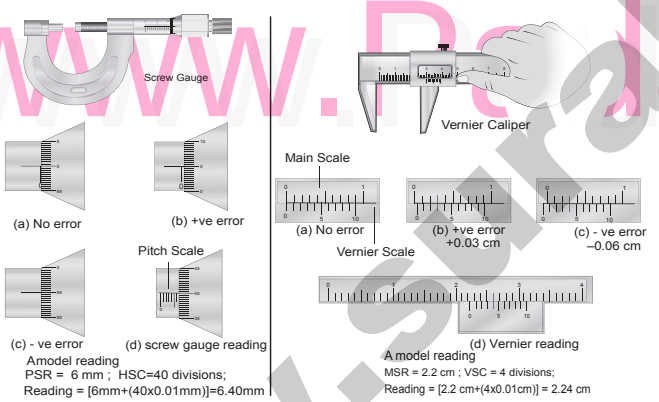
Ans. **Measurement of small distances:**

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

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

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

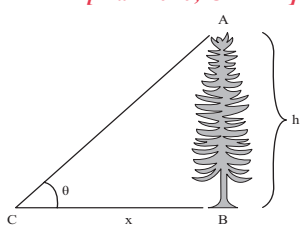
(4) A **vernier caliper** is a versatile instrument for measuring the dimensions of an object namely diameter of a hole, or a depth of a hole. The least count of vernier caliper is 0.01 cm.



Screw gauge and vernier caliper with errors

(ii) Triangulation method for the height of an accessible object : *[Mar-2020; CRT-'22]*

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



Triangulation method

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

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

RADAR method *[First Mid-2018]*

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

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

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

Speed = distance travelled / time taken

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

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

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

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

2. Explain in detail the various types of errors. *[Mar & QY-2019]*

Ans. **Types of errors :**

(a) Systematic error (b) Random error
(c) Gross error

(a) Systematic errors : They are reproducible inaccuracies that are consistently in the same direction.

It is classified as follows :

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

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

Verification :

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

Substituting dimensions

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

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

The equation is dimensionally correct.

5. Express 76 cm of mercury pressure in terms of Nm^{-2} using the method of dimensions.

[Sep.-2020 & 2021]

Solution:

In cgs system 76 cm of mercury pressure

$= 76 \times 13.6 \times 980$ dyne cm^{-2}

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

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

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

$M_1 = 1g, M_2 = 1$ kg

$L_1 = 1cm, L_2 = 1$ m

$T_1 = 1s, T_2 = 1$ s

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

Then

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

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

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

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

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

Additional Questions

I. Multiple Choice Questions : 1 Mark

A. Choose the best answer :

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

[JEE (advanced) 2016]

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

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

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

2. The word scientia is meaning to _____.

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

[Ans. (b) to know]

3. Astronomical Scale is dealt with the _____ Physics.

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

[Ans. (c) Macrospic]

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

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

[Ans. (d) quantum physics]

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

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

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

6. **The law of electricity and magnetism is used to**
(a) Wireless communication
(b) Nuclear reactor (c) Steam engine
(d) Aeroplane
[Ans. (a) Wireless communication]

7. **Match the following.**

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

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

[Ans:(d) b c d a]

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

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

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

[Ans: (b) b c d a]

9. **How many gram make 1 deca gram?**
(a) 10g (b) 100g (c) 1kg (d) 100kg
[Ans. (a) 10g]

10. **1 nano second is equivalent to**
(a) 10^{-6}s (b) 10^{-3}s
(c) 10^{-15}s (d) 10^{-9}s **[Ans. (d) 10^{-9}s]**

11. **Which unit is used to measure size of a nucleus?**
(a) Angstrom (b) Micron
(c) Nano (d) Fermi
[Ans. (d) Fermi]

12. **One parallactic second is,**
(a) 3.08×10^{16}m (b) 1.49×10^{11}m
(c) 9.46×10^{15}m (d) 1.66×10^{-27}m
[Ans. (a) 3.08×10^{16}m]

13. **How many light years make 1 parsec?**
(a) 3.26 (b) 6.67
(c) 1.5 (d) 9.4 **[Ans. (a) 3.26]**

14. **How many AU makes one metre?**
(a) 3.26×10^{11}AU (b) 1.496×10^{11}AU
(c) 3.08×10^{16}AU (d) 6.684×10^{-12}AU
[Ans. (d) 6.684×10^{-12}AU]

15. **One lunar month is equal to _____**
(a) 29.5 days (b) 27.3 days
(c) 365 days (d) 31 days
[Ans. (a) 29.5 days]

16. **What is the value of one light year in tera metre?**
(a) 9.46×10^{6}Tm (b) 9.46×10^{9} Tm
(c) 9.46×10^{2}Tm (d) 9.46×10^{3} Tm
[Ans. (d) 9.46×10^{3} Tm]

17. **The acceleration of 20 m/s^2 in km/h^2 is**
(a) 2.59×10^{5} km/h^2 (b) 1.29×10^{5} km/h^2
(c) 2.0×10^{3} km/h^2 (d) 3.5×10^{5} km/h^2
[Ans. (a) 2.59×10^{5} km/h^2]

18. **Which device is used for measuring the mass of atoms?**
(a) Spectrograph (b) Fermi
(c) Telescope (d) Microscope
[Ans. (a) Spectrograph]

19. **Which of the following statement is wrong?**
(a) one fermi = 10^{15}m
(b) All non-zero digits are significant.
(c) 1 AU = 1.496×10^{11}m
(d) Speed is a derived unit.
[Ans. (a) one fermi = 10^{15}m]

20. **Which of the following statement is wrong?**
(a) Strain is a dimensionless quantity.
(b) Fundamental quantity is also called the base quantity.
(c) force = mass × acceleration
(d) 1 Solar year = 1500 days.
[Ans. (d) 1 Solar year = 1500 days]

21. **Which of the following statement is true?**
(a) Velocity is a fundamental unit.
(b) 1 Solar day = 24 hours.
(c) 1 Shake = 10^{4}s
(d) mass is a derived unit.
[Ans. (b) 1 Solar day = 24 hours]

(ii) Light year :

It is the distance travelled by light in vacuum in one year. 1 ly = 9.467×10^{15}m

(iii) Parallactic second :

It is the distance at which an arc of length 1 astronomical unit subtends an angle of 1 second of arc.

1 par sec = 3.08×10^{16}m = 3.26 ly.

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

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

The three possible errors are

(i) Systematic errors

(ii) Random errors

(iii) Gross errors

17. What is Absolute Error.

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

$\Delta a_n = a_m - a_n$

18. What is Mean Absolute error?

Ans. The arithmetic mean of absolute errors in all the measurements is called the mean absolute error.

If a_m is the true value and Δa_m is the mean absolute error, then the magnitude of the quantity may lie between $a_m + \Delta a_m$ and $a_m - \Delta a_m$.

19. What is Percentage error?

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

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

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

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

21. Define Dimensional Constant. Give example.

Ans. Physical quantities which possess dimensions and have constant values are called dimensional constants. Examples are Gravitational constant, Planck's constant etc.

22. What is meant by Scientific method?

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

23. What do you mean by unification and reductionism?

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

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

24. What is Classical mechanics?

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

25. What is Thermodynamics?

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

26. What is the meaning of Acoustics?

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

27. What is Astrophysics?

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

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

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

29. What is meant by Range of masses?

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

30. What are types of discoveries in physics?

Ans. Discoveries in physics are of two types.

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

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

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

31. What is meant by Quantum mechanics?

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

32. What is meant by Range of time scales?

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

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

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

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

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

35. Define the SI unit of length.

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

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

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

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

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

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

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

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

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

40. What is meant by Parallax?

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

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

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

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

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

43. Define mass of a body.

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

III. Short Answer Questions :

3 Marks

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

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

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

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

2. What are fundamental units and derived units?

Ans. **Fundamental units:**

The units in which the fundamental quantities are measured are called fundamental units. It is also known as base units.

Derived units:

The units in which the derived quantities are measured are called Derived units.

Example:

$$\text{Unit of speed} = \frac{\text{Unit of distance}}{\text{Unit of time}} = \frac{m}{s} = ms^{-1}$$

ms^{-1} is a derived unit.

3. Give any three practical units of time.

Ans. **(i) Solar year :**

It is the time taken by the earth to complete one revolution around the sun in its orbit.

1 solar year = 365.25 average solar days.

(ii) Leap year:

The year which is divisible by 4 and in which the month of February has 29 days is called leap year.

(iii) Lunar month :

It is the time taken by the moon to complete one revolution around the earth in its orbit.

1 lunar month = 27.3 days.

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

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

Ans.

(i) 1 Mega ohm (MΩ) $= 10^6\ \Omega$
(ii) 1 milliampere (mA) $= 10^{-3}$A
(iii) 1 daca gram (da g) $= 10$g
(iv) 1 nano second (ns) $= 10^{-9}$s
(v) 1 microvolt (μV) $= 10^{-6}$V
(vi) 1 centimetre (cm) $= 10^{-2}$m

5. Distinguish between fundamental and derived units.

Ans.

	Fundamental Units	Derived Units
1.	Using fundamental units fundamental quantities are measured	Using derived units, derived quantities are measured
2.	These units cannot be expressed in terms of other fundamental units	These units can be expressed in terms of all fundamental units.
3.	**Examples :** metre, kilogram, second (m, s, kg. A. mol)	**Examples:** metre/second, newton/meter, kilogram/metre seconds. (m/s, kg/m^3)

6. What is Gross Error & How can it be minimised?

Ans. **Gross Error**

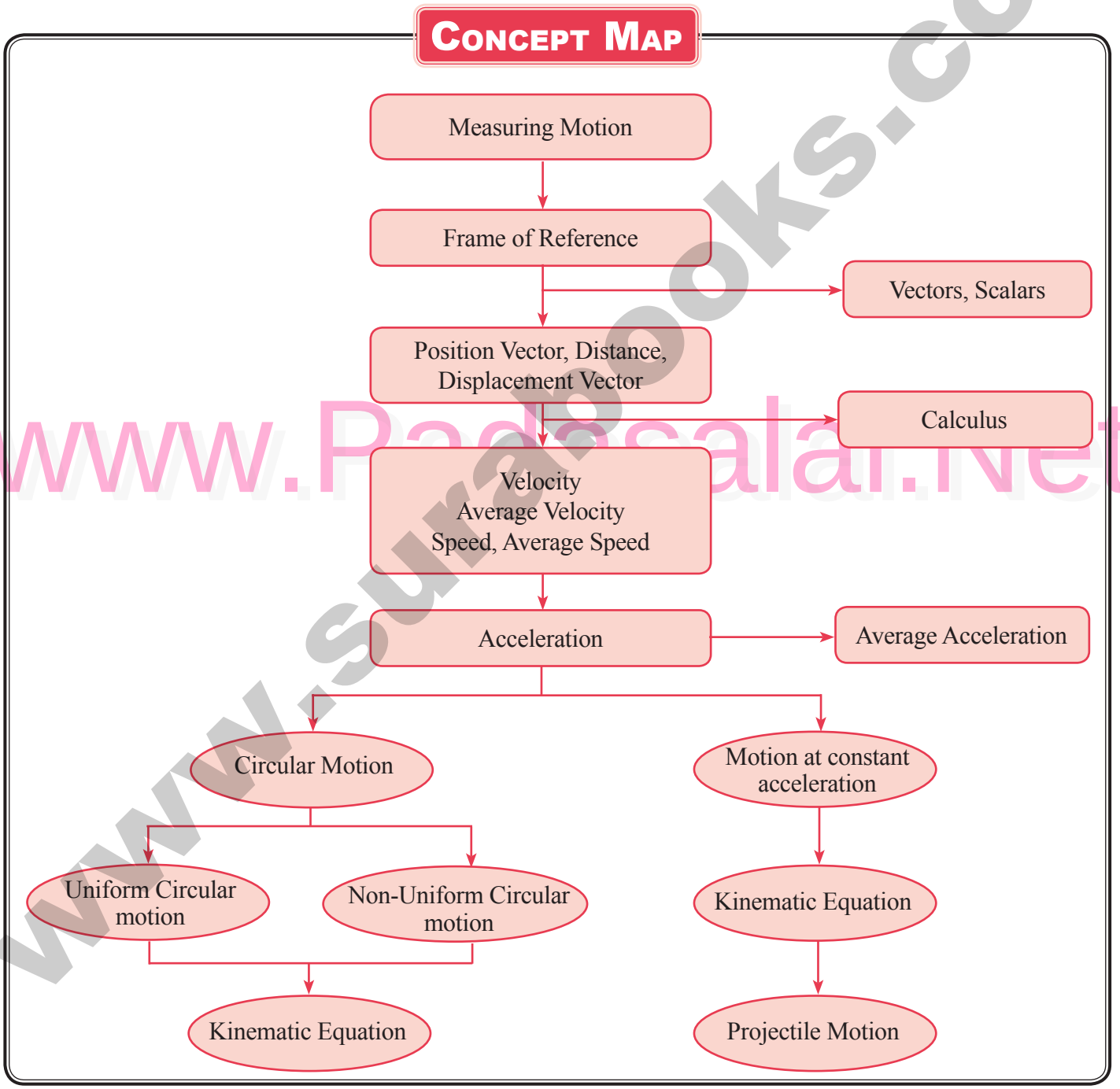
(i) The error caused due to the shear carelessness of an observer is called gross error.
For example
(ii) Reading an instrument without setting it properly.
(iii) Taking observations in a wrong manner without bothering about the sources of errors and the precautions.
(iv) Recording wrong observations. These errors can be minimized only when an observer is careful and mentally alert.

UNIT

02

KINEMATICS

CONCEPT MAP



FORMULAE TO REMEMBER

(1) Path length of distance, D = speed × time.

(2) Displacement = velocity × time.

(3) $\text{Speed} = \dfrac{\text{Distance}}{\text{Time}}$

(4) $\text{Velocity} = \dfrac{\text{Displacement}}{\text{Time}}$

(5) Relative velocity

(i) $\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ (ii) $\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$

(6) The equations of motion for accelerated body are:

(i) $v = u + at$ (ii) $S = ut + \frac{1}{2}at^2$ (iii) $v^2 = u^2 + 2as$ (iv) $S_n = u + \frac{a}{2}(2n-1)$

(7) The equations of motion for retarded body. Here a is negative.

(i) $v = u - at$ (ii) $S = ut - \frac{1}{2}at^2$ (iii) $v^2 = u^2 - 2as$ (iv) $S_n = u - \frac{a}{2}(2n-1)$

(8) The equations of motion for a body falling down under gravity. Here $a = +g$

(i) $v = u + gt$ (ii) $S = ut + \frac{1}{2}gt^2$ (iii) $v^2 = u^2 + 2gs$ (iv) $S_n = u + \frac{g}{2}(2n-1)$

(9) The equations of motion for a body going up against gravity. Here $a = -g$

(i) $v = u - gt$ (ii) $S = ut - \frac{1}{2}gt^2$ (iii) $v^2 = u^2 - 2gs$ (iv) $S_n = u - \frac{g}{2}(2n-1)$

(10) The maximum height attained by a body thrown vertically upwards with initial velocity u is, $S_{max} = \dfrac{u^2}{2g}$

(11) Total time taken by body in going up and coming down. $T = at = \dfrac{2u}{g}$

(12) The initial velocity of body in order to attain height h is, $u = \sqrt{2gh}$

(13) Unit vector $(\hat{A})$; $\hat{A} = \dfrac{\vec{A}}{A} = \dfrac{A_x\hat{i} + A_y\hat{j} + A_z\hat{k}}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$

(14) Area of parallelogram = $|\vec{A} \times \vec{B}|$

(15) Velocity of projectile at an instant of its flight is $v = \sqrt{v_x^2 + v_y^2}$

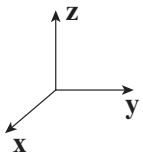
(16) Angular projection of projectile:

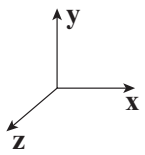
(i) Time of flight, $T = \dfrac{2u\sin\theta}{g}$

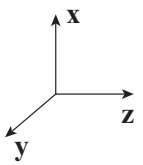
EVALUATION

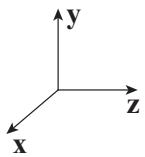
I. MULTIPLE CHOICE QUESTIONS:

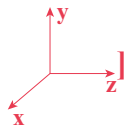
1. Which one of the following Cartesian coordinate systems is not followed in physics?

(a) 

(b) 

(c) 

(d) 

[Ans. (d) 

]

2. Identify the unit vector in the following. *[Mar-2020]*

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

(c) $\hat{k}-\frac{\hat{j}}{\sqrt{2}}$ (d) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

[Ans. (d) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$]

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

(a) Mass (b) length
(c) momentum
(d) magnitude of acceleration

[Ans. (c) momentum]

4. Two objects of masses m_1 and m_2 fall from the heights h_1 and h_2 respectively. The ratio of the magnitude of their momenta when they hit the ground is *(AIPMT 2012)*

(a) $\sqrt{\frac{h_1}{h_2}}$ (b) $\sqrt{\frac{m_1 h_1}{m_2 h_2}}$

(c) $\frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$ (d) $\frac{m_1}{m_2}$

[Ans. (c) $\frac{m_1}{m_2}\sqrt{\frac{h_1}{h_2}}$]

5. If a particle has negative velocity and negative acceleration, its speed *[First Mid. - 2018; HY-2018; QY-2019]*

(a) increases (b) decreases
(c) remains same (d) zero

[Ans. (a) increases]

6. If the velocity is $\vec{v}=2\hat{i}+t^2\hat{j}-9\vec{k}$, then the magnitude of acceleration at t = 0.5 s is *[QY. - 2018]*

(a) 1 ms^{-2} (b) 2 ms^{-2}
(c) zero (d) –1 ms^{-2}

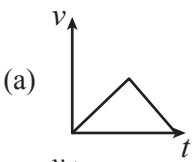
[Ans. (a) 1 ms^{-2}]

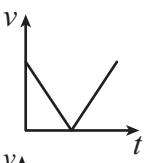
7. If an object is dropped from the top of a building and it reaches the ground at t = 4 s, then the height of the building is (ignoring air resistance) (g = 9.8 ms^{-2}) *[Aug-'22]*

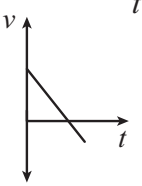
(a) 77.3 m (b) 78.4 m
(c) 80.5 m (d) 79.2 m

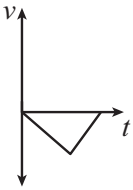
[Ans. (b) 78.4 m]

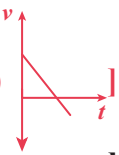
8. A ball is projected vertically upwards with a velocity *v*. It comes back to ground in time *t*. Which *v*-*t* graph shows the motion correctly? *(NSEP 00-01) [First Mid. - 2018]*

(a) 

(b) 

(c) 

(d) 

[Ans. (c) 

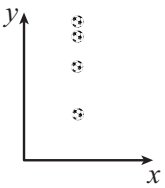
]

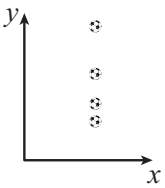
9. If one object is dropped vertically downward and another object is thrown horizontally from the same height, then the ratio of vertical distance covered by both objects at any instant t is

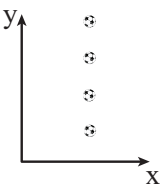
(a) 1 (b) 2 (c) 4 (d) 0.5

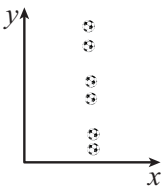
[Ans. (a) 1]

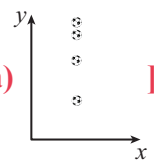
10. A ball is dropped from some height towards the ground. Which one of the following represents the correct motion of the ball?

(a) 

(b) 

(c) 

(d) 



[Ans. (a)]

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

[Sep-2020; Sep-2021; CRT & May 2022]

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

[Ans. (c) $-z$ direction]

12. If a particle executes uniform circular motion, choose the correct statement

(NEET 2016; Aug-'22)

(a) The velocity and speed are constant
(b) The acceleration and speed are constant.
(c) The velocity and acceleration are constant.
(d) The speed and magnitude of acceleration are constant. **[Ans. (d) The speed and magnitude of acceleration are constant.]**

13. If an object is thrown vertically up with the initial speed *u* from the ground, then the time taken by the object to return back to ground is

[Jun-2019; Sep-2021; CRT-'22]

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

(c) $\frac{u}{2g}$ (d) $\frac{2u}{g}$ **[Ans. (d) $\frac{2u}{g}$]**

14. Two objects are projected at angles 30° and 60° respectively with respect to the horizontal direction. The range of two objects are denoted as R_{30° and R_{60°. Choose the correct relation from the following. *[May-2022]*

(a) $R_{30^\circ} = R_{60^\circ}$ (b) $R_{30^\circ} = 4R_{60^\circ}$
(c) $R_{30^\circ} = \frac{R_{60^\circ}}{2}$ (d) $R_{30^\circ} = 2R_{60^\circ}$

[Ans. (a) $R_{30^\circ} = R_{60^\circ}$]

15. An object is dropped in an unknown planet from height 50 m, it reaches the ground in 2s . The acceleration due to gravity in this unknown planet is *[HY-2018]*

(a) $g = 20\ m\ s^{-2}$ (b) $g = 25\ m\ s^{-2}$
(c) $g = 15\ m\ s^{-2}$ (d) $g = 30\ m\ s^{-2}$

[Ans. (b) $g = 25\ m\ s^{-2}$]

II. Short Answer Questions.

1. Explain what is meant by Cartesian coordinate system?

Ans. At any given instant of time, the frame of reference with respect to which the position of the object is described in terms of position coordinates (x, y, z) is called **"Cartesian coordinate system"**.

2. Define a vector. Give examples.

Ans. Vector is a quantity which can be described by both magnitude and direction.

Examples:

Force, velocity, displacement, acceleration, etc.

3. Define a scalar. Give examples. *[QY. - 2019]*

Ans. Scalar is a property which can be described only by magnitude.

Examples :

Distance, mass, temperature, speed and energy.

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

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

(ii) Thus if there are two vectors $\vec{A}$ and $\vec{B}$ having an angle θ between them, then their scalar product is defined as $\vec{A} \cdot \vec{B} = AB \cos\theta$. Here, A and B are magnitudes of $\vec{A}$ and $\vec{B}$.

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

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

(ii) The direction of the product vector is perpendicular to the plane containing the two vectors, in accordance with the right hand screw rule or right hand thumb rule.

(iii) Thus, if $\vec{A}$ and $\vec{B}$ are two vectors, then their vector product is written as $\vec{A} \times \vec{B}$ which is a vector $\vec{C}$ defined by

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

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

Ans. If two vectors $\vec{A}$ and $\vec{B}$ are perpendicular to each other then their scalar product $\vec{A} \cdot \vec{B} = 0$, because cos 90°=0. Then the vectors $\vec{A}$ and $\vec{B}$ are said to be mutually orthogonal.

7. Define displacement and distance.

Ans. **(i)** **Displacement** is the difference between the final and initial positions of the object in a given interval of time. It is a vector quantity.

(ii) **Distance** is the actual path length travelled by an object in the given interval of time during the motion. It is a positive scalar quantity.

8. Define velocity and speed. *[First Mid-2018]*

Ans. **Velocity :**

Velocity is equal to rate of change of position vector with respect to time. Velocity is a vector quantity.

Speed :

It is the distance travelled in unit time. It is a scalar quantity.

9. Define acceleration.

Ans. It is the rate of change of velocity with time. It's SI unit is m s^{-2}.

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

Ans.

Velocity	Average Velocity
Velocity is equal to rate of change of position vector with respect to time.	Average velocity is the ratio of the displacement vector to the corresponding time interal.
$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$	$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t}$

11. Define a radian.

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

12. Define angular displacement and angular velocity. *[Sep-2021]*

Ans. **(i)** **Angular displacement:** The angle described by the particle about the axis of rotation (or center O) in a given time is called angular displacement. Its unit is radian.

(ii) **Angular velocity:** The rate of change of angular displacement is called **angular velocity**. Its unit is rad s^{-1}.

13. What is non uniform circular motion? *[CRT-'22]*

Ans. **(i)** When an object is moving on a circular path with change in speed and direction, it is called non-uniform circular motion.

(ii) For example, when the bob attached to a string moves in vertical circle, the speed of the bob is not the same at all time.

14. Write down the Kinematic equations for angular motion. *[CRT-'22]*

Ans. **Kinematic equations for Angular motion**

$$\omega = \omega_0 + \alpha t$$

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

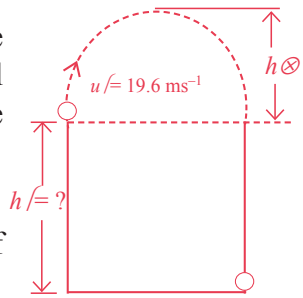
$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

$$\theta = \frac{(\omega_0 + \omega)t}{2}$$

where θ = angular displacement
ω = angular velocity
ω_0 = initial angular velocity
α = angular acceleration.
t = time.

3. 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 6 *s*. 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, $v^2 = u^2 - 2gh$

$0^2 = (19.6)^2 - 2gh'$

$2gh' = (19.6)^2$

$$h' = \frac{19.6 \times 19.6}{2 \times 9.8} = 19.6 \text{ m}$$

Times 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.

4. 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, $v = \frac{dx}{dt} = \frac{d}{dt}(2 - 5t + 6t^2)$

$\Rightarrow v = -5 + 12t$

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.

Additional Questions

I. Multiple Choice Questions — 1 Mark

A. Choose the best answer :

1. Distance is a scalar quantity and _____ is a vector.

(a) Speed (b) Length

(c) Time (d) Displacement

[Ans. (d) Displacement]

2. The length of a vector is _____

(a) always a negative quantity (b) always a positive quantity

(c) either positive or negative (d) denoted by 'λ'

[Ans. (b) always a positive quantity]

3. **Which one of the following statement is true?**
(a) A scalar quantity is conserved in a process
(b) A scalar quantity does not vary from one point to another in space
(c) A scalar quantity can never take –ve values
(d) A scalar quantity has only magnitude and no direction. **[Ans. (d) A scalar quantity has only magnitude and no direction.]**

4. **The angle between A = $i + j$ and B = $i - j$ is .**
(a) 45º (b) 90º
(c) –45º (d) 180º **[Ans. (b) 90º]**

5. **The component of position vector $\vec{r}$ along x-axis will maximum value if**
(a) $\vec{r}$ is along the x - axis
(b) $\vec{r}$ makes an angle of 45º with x - axis
(c) $\vec{r}$ is along the y - axis
(d) $\vec{r}$ is along –ve y - axis
[Ans. (a) $\vec{r}$ is along the x - axis]

6. **Consider the quantities pressure, power, energy, impulse, charge. Out of these, the only vector quantity is**
(a) pressure (b) power
(c) impulse (d) charge
[Ans. (c) impulse]

7. **Distance is a scalar quantity and _____ is a vector.**
(a) Speed (b) Length
(c) Time (d) Displacement
[Ans. (d) Displacement]

8. **The horizontal range of a projectile fired at an angle of 15º is 50 m. If it is fired with the same speed at angle of 45º, its range will be**
(a) 125 m (b) 75 m
(c) 100 m (d) 150 m
[Ans. (c) 100 m]

9. **The dimensions of physical quantity X in the equation, Force = X / Density is given by**
(a) $M^1L^4T^{-2}$ (b) $M^2L^{-2}T^{-2}$
(c) $M^2L^2T^{-2}$ (d) $M^1L^{-4}T^{-1}$
[Ans. (d) $M^1L^{-4}T^{-1}$]

10. **Choose the motion in two dimension from the following.**
(a) Motion of a train along a straight railway track
(b) An object falling freely under gravity close to the Earth.
(c) A particle moving along a curved path in a plane.
(d) Flying of a kite on a windy day.
[Ans. (c) A particle moving along a curved path in a plane]

11. **Which one of the following physical quantities cannot be represented by a scalar?**
(a) Mass (b) Length
(c) Momentum
(d) Magnitude of acceleration
[Ans. (c) Momentum]

12. **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) $g = 20\ ms^{-2}$ (b) $g = 25\ ms^{-2}$
(c) $g = 15\ ms^{-2}$ (d) $g = 30\ ms^{-2}$
[Ans. (b) $g = 25ms^{-2}$]

13. **A vector $\vec{A}$ points vertically upward and $\vec{B}$ point towards North. The vector product $\vec{A} \times \vec{B}$ is**
(a) along west (b) along east
(c) Zero (d) vertically downward
[Ans. (a) along west]

14. **The horizontal range of a projectile fixed at an angle of 15° is 50m if it is fixed with the same speed at angle of 45°, its range will be**
(a) 125m (b) 75m (c) 100m (d) 150m
[Ans. (c) 100m]

15. **Kinematics is the branch of mechanics which deals with the motion of objects without taking _____ into account**
(a) displacement (b) mass
(c) motion (d) force **[Ans. (d) force]**

26. What is degree? Express 1 radian in degree.

Ans. Degree is the unit of measurement which is used to determine the size of an angle.

$360^{o} = 2\pi$ radians or 1 radian = $\frac{180}{\pi}$ degrees which means 1 rad $\cong 57.27^{o}$.

27. Define angular acceleration.

Ans. The rate of change of angular velocity is called angular acceleration.

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt}$$

28. Define centripetal acceleration.

Ans. Even though the velocity is tangential at every point in the circle, the acceleration is acting towards the center of the circle. This is called centripetal acceleration. It always points towards the center of the circle.

29. What are the two quantities which have maximum values when the maximum height attained by the projectile is to the largest.

Ans. **(i)** Vertical component of initial velocity.
(ii) Time of flight.

30. State triangle law of addition of two inclined vectors. (or) State triangle law of vectors.

Ans. It is stated that if two vectors are represented by the two adjacent sides of a triangle in same order, then the resultant is given by the third side of the triangle in opposite order.

31. State right hand rule in vector product.

Ans. According to Right Hand Rule, if the curvature of the fingers of the right hand represents the sense of rotation of the object, then the thumb, held perpendicular to the curvature of the fingers, represents the direction of the resultant $\vec{C}$.

32. What is uniform motion?

Ans. If an object is moving with constant velocity, then the motion is called uniform motion.

33. What is non-uniform or accelerated motion?

Ans. If an object is moving with various velocity with time, then the motion is called non-uniform or accelerated motion.

34. What is free fall of a body?

Ans. The motion of a body falling towards the Earth from a small altitude,(h<<R), purely under the force of gravity is called free fall of a body.

35. What is centripetal acceleration or radial acceleration or normal acceleration?

Ans. The acceleration which is acting towards the center along the radial direction and perpendicular to linear velocity of circular motion is called centripetal acceleration.

36. Define one dimension motion. Give example.

Ans. One dimensional motion is the motion of a particle moving along a straight line. This motion is sometimes known as rectilinear or linear motion.

Examples:

(i) Motion of a train along a straight railway track.
(ii) An object falling freely under gravity close to Earth.

37. Define two dimension motion. Give example.

Ans. If a particle is moving along a curved path in a plane, then it is said to be in two dimensional motion.

Examples:

(i) Motion of a coin on a carrom board.
(ii) An insect crawling over the floor of a room.

38. How will you prove that two vector are orthogonal?

Ans. If two vectors are orthogonal (perpendicular) to each other, then their scalar product is zero or vector product is maximum.

39. Give the importance of displacement - time graph.

Ans. The slope of displacement - time graph gives the velocity of the object at given interval.

40. Give the importance of velocity - time graph.

Ans. **(i)** The slope of velocity - time graph gives the acceleration of the object at given interval.
(ii) The area under the velocity - time graph gives the displacement and distance travelled by the particle.

41. Give the importance of acceleration - time graph.

Ans. The area under the acceleration - time graph gives the velocity of the particle.

42. Give the equations of motion of a body thrown vertically upwards (against gravity).

Ans. Therefore equations of motion are,

$$v = u - gt$$

$$y = ut - \frac{1}{2}gt^2$$

$$v^2 = u^2 - 2gy$$

III. Short Answer Questions :

3 Marks

1. What do you mean by motion in one, two and three dimensions?

Ans. **Motion in one dimension**

(i) One dimensional motion is the motion of a particle moving along a straight line.

(ii) In this motion, only one of the three rectangular coordinates specifying the position of the object changes with time.

Motion in two dimensions

(i) If a particle is moving along a curved path in a plane, then it is said to be in two dimensional motion.

(ii) In this motion, two of the three rectangular coordinates specifying the position of object change with time.

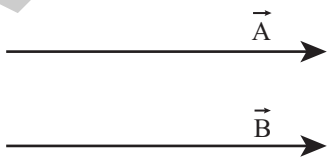
Motion in three dimensions

(i) A particle moving in usual three dimensional space has three dimensional motion.

(ii) In this motion, all the three coordinates specifying the position of an object change with respect to time. When a particle moves in three dimensions, all the three coordinates x, y and z will vary.

2. What is equal vectors?

Ans. **Equal vectors:** Two vectors $\vec{a}$ and $\vec{B}$ are said to be equal when they have equal magnitude and same direction and represent the same physical quantity

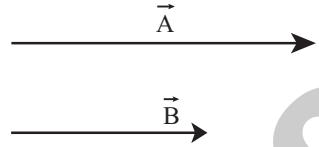


Geometrical representation of equal vectors

3. What is meant by Collinear vector? Explain them.

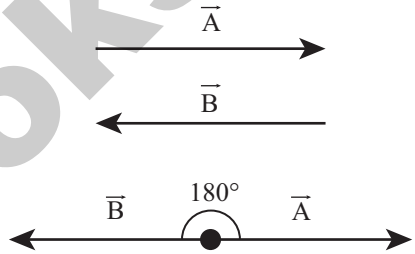
Ans. Collinear vectors are those which act along the same line. The angle between them can be 0° or 180°.

(i) **Parallel Vectors:** If two vectors $\vec{a}$ and $\vec{B}$ act in the same direction along the same line or on parallel lines, then the angle between them is 0°.



Geometrical representation of parallel vectors

(ii) **Anti-parallel vectors:** Two vectors $\vec{a}$ and $\vec{B}$ are said to be anti-parallel when they are in opposite directions along the same line or on parallel lines. Then the angle between them is 180°.



Geometrical representation of anti parallel vectors

4. Define (i) unit vector, (ii) Orthogonal unit vectors.

(i) **Unit vector:** A vector divided by its magnitude is a unit vector. The unit vector for $\vec{a}$ is denoted by $\hat{A}$. It has a magnitude equal to unity or one.

Since, $\hat{A} = \frac{\vec{A}}{A}$ we can write $\vec{A} = A\hat{A}$

Thus, we can say that the unit vector specifies only the direction of the vector quantity.

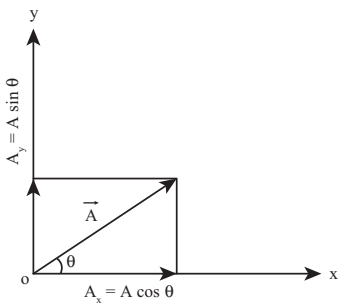
(ii) **Orthogonal unit vectors:** Let $\hat{i}$, $\hat{j}$ and $\hat{k}$ be three unit vectors which specify the directions along positive x–axis, positive y–axis and positive z–axis respectively. These three unit vectors are directed perpendicular to each other, the angle between any two of them is 90°. $\hat{i}$, $\hat{j}$ and $\hat{k}$ are examples of orthogonal vectors. Two vectors which are perpendicular to each other are called orthogonal vectors.

5. What do you mean by rectangular component of a vector? Explain how a vector can be resolved into two rectangular components in a plane?

Ans. **Rectangular component:** When a vector is resolved along two mutually perpendicular directions, the compounds so obtained are called rectangular components of the given vectors.

(i) In a 2-dimensional Cartesian coordinate system the vector $\vec{a}$ is given by

$$\vec{A} = A_x \hat{i} + A_y \hat{j}$$



Resolution of a vector

(ii) If $\vec{a}$ makes an angle θ with x axis, and A_x and A_y are the components of $\vec{a}$ along x-axis and y-axis respectively.

$A_x = A \cos\theta$, $A_y = A \sin\theta$ where 'A' is the magnitude (length) of the vector $\vec{a}$, $A \sqrt{A_x^2 + A_y^2}$

6. How are two vectors expressed in a Cartesian system? Explain the addition & subtraction using components.

Ans. **(i)** The two vectors $\vec{a}$ and $\vec{B}$ in a Cartesian coordinate system can be expressed as

$$\vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k},\ \vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$$

(ii) Then the addition of two vectors is equivalent to adding their corresponding x, y and z components.

$$\vec{A} + \vec{B} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$$

(iii) Similarly the subtraction of two vectors is equivalent to subtracting the corresponding x, y and z components.

$$\vec{A} - \vec{B} = (A_x - B_x)\hat{i} + (A_y - B_y)\hat{j} + (A_z - B_z)\hat{k}$$

The above rules form an analytical way of adding and subtracting two vectors.

7. How is the direction of vector product determined?

(i) By right hand screw rule.

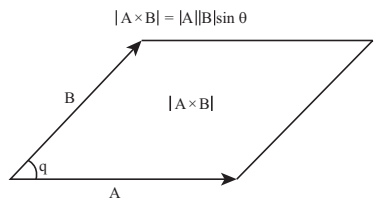
(ii) Right hand thumb rule

Ans. **(i)** If a right-handed screw whose axis is perpendicular to the plane formed by $\vec{a}$ and $\vec{B}$, is rotated from $\vec{a}$ to $\vec{B}$ through the smaller angle between them, then the direction of advancement of the screw gives the direction of $\vec{a} \times \vec{B}$ i.e. $\vec{C}$.

(ii) According to Right Hand Rule, if the curvature of the fingers of the right hand represents the sense of rotation of the object, then the thumb, held perpendicular to the curvature of the fingers, represents the direction of the resultant $\vec{C}$.

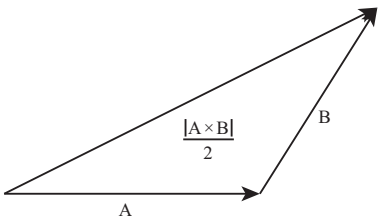
8. Obtain an expression for the area of triangle in terms of the grass product of two vectors representing the two sides of the triangle.

Ans. (i) If two vectors $\vec{a}$ and $\vec{B}$ form adjacent sides in a parallelogram, then the magnitude of $|\vec{A} \times \vec{B}|$ will give the area of the parallelogram as represented graphically in the figure (i).



(Fig-(i)) Area of parallelogram

It divides a parallelogram into two equal triangles as shown in the Fig-(ii). The area of a triangle with $\vec{a}$ and $\vec{B}$ as sides is $\frac{1}{2}|\vec{A} \times \vec{B}|$ This is shown in the Figure (ii).



(Fig- (ii)) Area of triangle

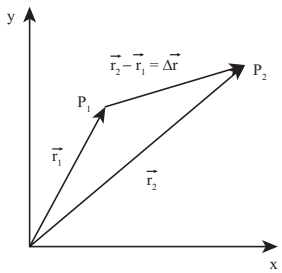
9. Write an expression for displacement vector in Cartesian coordinate system and also show graphically.

Ans. **(i)** In terms of position vector, the displacement vector is given as follows. Consider a particle moving from a point P_1 having position vector $\vec{r_1} = x_1\hat{i} + y_1\hat{j} + z_1\hat{k}$ to a point P_2 where its position vector is $\vec{r_2} = x_2\hat{i} + y_2\hat{j} + z_2\hat{k}$

(ii) The displacement vector is given by

$$\Delta\vec{r} = \vec{r_2} - \vec{r_1} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$$

(iii) This displacement is also shown in



Displacement vector

10. How is a function represented graphically and mathematically.

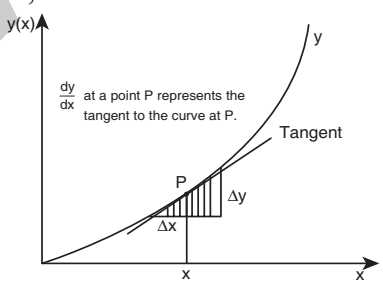
Ans. **(i)** If a function is represented by $y = f(x)$, then dy/dx represents the derivative of y with respect to x.

(ii) Mathematically this represents the variation of y with respect to change in x, for various continuous values of x.

(iii) Mathematically the derivative dy/dx is defined as follows

$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{y(x + \Delta x) - y(x)}{\Delta x} = \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x}$$

$\frac{dy}{dx}$ represents the limit that the quantity $\frac{\Delta y}{\Delta x}$ attains, as Δx tends to zero.



Derivative of a function

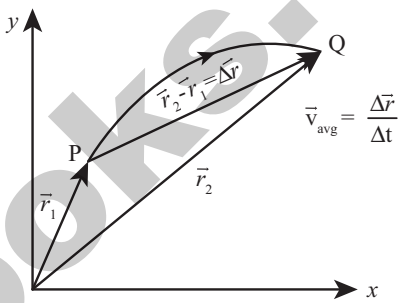
11. Define average velocity and represent it graphically.

Ans. **(i)** The average velocity is defined as ratio of the displacement vector to the corresponding time interval

$$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$$

(ii) It is a vector quantity. The **direction** of average velocity is **in the direction of the displacement vector** $(\Delta\vec{r})$.

(iii)



12. Write an expression for component of Instantaneous velocity or velocity and also define it.

Ans. **(i)** The instantaneous velocity at an instant t or simply 'velocity' at an instant t is defined as limiting value of the average velocity as $\Delta t \to 0$, evaluated at time t.

(ii) In other words, velocity is equal to rate of change of position vector with respect to time. Velocity is a vector quantity.

$$\vec{v} = \lim_{\Delta x \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

(iii) In component form, this velocity is

$$\vec{v} = \frac{d\vec{r}}{dt} = \frac{d}{dt}(x\hat{i} + y\hat{j} + z\hat{k})$$

$$= \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} + \frac{dz}{dt}\hat{k}$$

Here $\frac{dx}{dt} = v_x = x$ – component of velocity.

$\frac{dy}{dt} = v_y = y$ – component of velocity.

$\frac{dz}{dt} = v_z = z$ – component of velocity.

Numerical Problems

1. The displacement of a particle moving along x – axis is given by $x = 6t + 12\,t^2$, calculate the instantaneous velocity at $t = 0$ and $t = 2s$.

Solution:

Displacement of a particle $x = 6t + 12t^2$

Differentiate with respect to 't'

$$x = 6t + 12t^2$$

$$\frac{dx}{dt} = 6 + 24t \qquad [\because x^n = nx^{n-1}]$$

$\because$ The instantaneous velocity $v_i = \frac{dx}{dt} = 6 + 24t.$

Instantaneous velocity at $t = 0$,

$v_i = u + at = 6 + 24\,(0) = 6$

$\therefore\ v_i = 6$ m/s

Instantaneous velocity at $t = 2s$.

$v_i = u + a\,t = 6 + 24\,(2) = 6 + 48$

$\therefore\ v_i = 54\ \text{ms}^{-1}$

2. The displacement x of a particle varies with time 't' as, $x = 3t^2 - 4t + 30$. Find the position, velocity and acceleration of the particle at $t = 0$.

Solution:

Position of a particle $x = 3t^2 - 4t + 30$.

$$\text{velocity } v = \frac{dx}{dt} = \frac{d}{dt}(3t^2 - 4t + 30)$$

$$= 6t - 4 \qquad [\because x^n = nx^{n-1}]$$

$$\text{Acceleration } a = \frac{dv}{dt} = \frac{d}{dt}(6t - 4)$$

$$a = 6$$

At time $t = 0$, we have,

Position $x = 3t^2 - 4t + 30$

$= 3(0)^2 - 4(0) + 30$

$x = 30$ m.

Velocity $v = 6t - 4 = 6(0) - 4$

$= -4$ m/s $= -4\ \text{ms}^{-1}$

Acceleration $a = 6\ \text{ms}^{-2}$

$\because$ Position $x = 30$ m, Velocity $v = -4\ \text{ms}^{-1}$,

Acceleration $= 6\ \text{ms}^{-2}$

3. A particle is moving in a straight line its displacement at any instant t is given by $x = 5t^2 + 20t^3$. Find the average acceleration in the interval $t = 0$ to $t = 3$ seconds.

Solution:

Given equation $x = 5t^2 + 20t^3$

Time $t = 0$ to $t = 3$ s.

$$\text{Velocity of particle } v = \frac{dx}{dt}$$

$$v = \frac{d}{dt}(5t^2 + 20t^3)$$

Differentiate with respect to 't'

$$v = 10t + 60t^2$$

Again differentiate with respect to 't'

$$v = 10 + 120\,t$$

At $t = 0$, $v_0 = 10 + 120\,(0)$

$v_0 = 10$ m/s.

At $t = 2$ sec, $v_2 = 10 + 120\,(2)$

$v_2 = 10 + 240.$

$v_2 = 250\ \text{ms}^{-1}$

$\Delta v = v_2 - v_0$

$= 250 - 10$

$= 240\ \text{ms}^{-1}$

$\Delta t = t_2 - t_1 = 2 - 0 = 2.$

The average acceleration is,

$$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{240}{2}$$

$\therefore\ a_{ave} = 120\ \text{ms}^{-2}$

4. Two particles move along x axis. The position of particle 1 is given by $x = 6.0\,t^2 + 4.0\,t + 2.0$, acceleration of particle 2 is given by $a = -6.0\,t$ and $t = 0$, its velocity is 30 ms^{-1}. When the velocities of the particles match, find their velocities.

Solution:

List all informations about particle 1 and particle 2

For particle 1,

$$x_1 = 6.0\,t^2 + 4.0\,t + 2.0$$

For particle 2,

$$a_2 = -6.0\,t$$

14. Chennai is at a distance of 500 km from Coimbatore. (A) sets out from Coimbatore at a speed of 50 kmh^{-1} and (B) sets out at the same time from Chennai at a speed of 40 kmh^{-1}. When will they meet each other?

Solution:

Relative speed of A with respect to B

Speed of A, $v_A = 50$ km/h

Speed of B, $v_B = -40$ km/h

$\because$ Relative speed, v_{AB}

$$v_{AB} = v_A - v_B = 50 - (-40) = 50 + 40 = 90 \text{ km/h}$$

Time taken to cover a distance of 500 km with a speed of 90 km/h.

$$\text{Speed} = \frac{\text{distance}}{\text{time}};\ \text{time} = \frac{\text{distance}}{\text{speed}} = \frac{500}{90} = 5.55\,h$$

Hence they will meet after 5.55 hours from the start.

15. If $\vec{A} = 2\hat{i} - \hat{j}$ and $\vec{B} = 4\hat{i} + 3\hat{j}$ then, obtain the scalar magnitude and directions from x – axis of,

(i) $\vec{A}$ (ii) $\vec{B}$

(iii) $\vec{A} + \vec{B}$ (iv) $\vec{A} - \vec{B}$

Solution: $\vec{A} = 2\hat{i} - \hat{j}$, $\vec{B} = 4\hat{i} + 3\hat{j}$

(i) For $\vec{A}$:

$$\text{Magnitude of } \vec{A} = \sqrt{(2)^2 + (-1)^2} = \sqrt{4+1} = \sqrt{5}$$

$$\text{Direction of } \vec{A} = \tan\theta = \frac{-1}{2} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{2}\right)$$

(ii) For $\vec{B}$:

$$\text{Direction of } \vec{B} = \tan\theta = \frac{3}{4} \Rightarrow \theta = \tan^{-1}\left(\frac{3}{4}\right)$$

$$\text{Magnitude of } \vec{B} = \sqrt{(4)^2 + (3)^2} = \sqrt{16+9} = \sqrt{25} = 5$$

(iii) For $\vec{A} + \vec{B}$:

$$\vec{A} + \vec{B} = 2\hat{i} - \hat{j} + 4\hat{i} + 3\hat{j} = 6\hat{i} + 2\hat{j}$$

$$\text{Direction of } \vec{A} + \vec{B} = \tan\theta = \frac{2}{6} = \frac{1}{3} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{3}\right)$$

Magnitude of $\vec{A} + \vec{B}$

$$|\vec{A} + \vec{B}| = \sqrt{(6)^2 + (2)^2} = \sqrt{36+4} = \sqrt{40} = 6.3$$

$$\text{Magnitude} = 6.3 \text{ and direction } \theta = \tan^{-1}\left(\frac{1}{3}\right)$$

(iv) For $\vec{A} - \vec{B}$; $\vec{A} - \vec{B} = 2\hat{i} - \hat{j} - 4\hat{i} - 3\hat{j} = -2\hat{i} - 4\hat{j} = -\hat{i} - 2\hat{j}$

Magnitude and direction of $\vec{A} - \vec{B}$

$$|\vec{A} - \vec{B}| = \sqrt{(-1)^2 + (-2)^2} = \sqrt{1+4} = \sqrt{5}$$

$$\tan\theta = \frac{(-2)}{(-1)} = 2 \Rightarrow \theta = \tan^{-1}(2).$$

16. The position of a particle is given by $r = 2.00t\,\hat{i} - 1.00t^2\,\hat{j} + 3.00\,\hat{k}$ where t is in seconds and the coefficients have the proper units for r to be in metres. Find the velocity and acceleration of a particle then what is the magnitude and direction of velocity of the particle at t = 2 s?

Solution:

Given position of the particle is

$r = 2.00t\,\hat{i} - 1.00t^2\,\hat{j} + 3.00\,\hat{k}$

Velocity: The rate of change of position is called velocity

$$\text{velocity } v = \frac{dr}{dt} = \frac{d}{dt}(2.00t\,\hat{i} - 1.00t^2\,\hat{j} + 3.00\,\hat{k})$$

$$= \left[2.00\,\hat{i} - 2.00t\,\hat{j} + 0\right] \text{ms}^{-1};\ v = \left[2.00\,\hat{i} - 2.00t\,\hat{j}\right] \text{ms}^{-1}$$

Acceleration: The rate of change of velocity over time is called acceleration

$$\text{Acceleration } a = \frac{dv}{dt} = \frac{d}{dt}(2.00\hat{i} - 2.00t\,\hat{j})$$

$$= 0 - 2.00\,\hat{j} = -2.00\,\hat{j} \text{ ms}^{-2}$$

At time t = 2s:

$$\text{Velocity} = \left[2.00\,\hat{i} - 2.00t\,\hat{j}\right] ms^{-1},\ = \left[2.00\,\hat{i} - 2.00 \times 2\,\hat{j}\right]$$

$$= \left[2.00\,\hat{i} - 4.00\,\hat{j}\right]$$

Magnitude and direction of the particles.

$$|v| = \sqrt{(2)^2 + (-4)^2} = \sqrt{4+16} = \sqrt{20} = 4.47 ms^{-1}$$

If θ is the angle which v makes with x-axis, then,

$$\tan\theta = \frac{-4}{2} = -2 = -\tan 63.5°$$

θ = – 63.5° below the x- axis.

17. If position of a particle at instant t is given by $x = 3t^2$, find the velocity and acceleration of the particle.

Solution:

The position of the particle is $x = 3t^2$

Velocity (v) = ? and acceleration (a) = ?

Velocity of the particle:

$$v = \frac{dx}{dt} = \frac{d}{dt}(3t^2) \qquad [\because x^n = nx^{n-1}]$$

$$= 2 \times 3t = 6t \text{ ms}^{-1}$$

Acceleration of the particle:

$$a = \frac{dv}{dt} = \frac{d(6t)}{dt} = 6 \text{ ms}^{-2}$$

18. Determine that vector which when added to the resultant of $\mathbf{A} = 2\hat{i} - 4\hat{j} + 6\hat{k}$ and $\mathbf{B} = \hat{i} + 3\hat{j} - 3\hat{k}$ gives unit vector along z-direction.

Solution:

Given vectors,

$A = 2\hat{i} - 4\hat{j} + 6\hat{k}$ and $B = \hat{i} + 3\hat{j} - 3\hat{k}$

Thus the resultant vector is given by C = A + B

$$C = (2\hat{i} - 4\hat{j} + 6\hat{k} + \hat{i} + 3\hat{j} - 3\hat{k}) = 3\hat{i} - \hat{j} + 3\hat{k}$$

But the unit vector along the Z axis = $\hat{k}$

$$\text{Required vector} = \hat{k} - (3\hat{i} - \hat{j} + 3\hat{k})$$

$$= \hat{k} - 3\hat{i} + \hat{j} - 3\hat{k}; = -3\hat{i} + \hat{j} - 2\hat{k}$$

VALUE BASED QUESTIONS

1. Balu went to kuttraalam with his grandpa, when he saw the waterfalls falling down from the top of a mountain he could not believe his eyes. He loved admiring it. He asked grandpa how this is possible. Grandpa said even now the answer to this question from where the water is coming from the top of a mountain is a puzzle, but we got some scientific truths behind this flow.

(i) What is the science behind this flow or falling of these water falls?

(ii) Give the formula for time of flight of the waterfall.

(iii) What is the speed of flow of waterfall, when it reaches the ground.

Ans. **(i)** Actually the science behind this flow of water fall is an example for the projectile motion. In horizontal projection water comes from the top of the mountain with an initial horizontal velocity (u)

(ii) Time of flight: It is the time taken for the projectile (here waterfall) to complete its trajectory.

It's expression is $T = \sqrt{\frac{2h}{g}}$

h → vertical displacement from top to the ground level.

g → gravity

(iii) Using equations of linear motion,

$$v^2 = u^2 + 2as$$

If v is the final velocity after waterfall hits the ground, u is the initial velocity, $a = g$, $s = h$

Then $v^2 = u^2 + 2gh$

Final velocity of the waterfall $v = \sqrt{u^2 + 2gh}$

2. All planets were once fire balls from the sun, which have been projected out so many long years back. Now these fire balls have attained their solid surface, even though the central core is still hot. Neptune is the last planet in our solar system (out of eight). At what angle it should have been projected from the sun?

Ans. Since Neptune has been thrown at angle of 45°, it would have reached longer distance.

Total length $L = l_1 + l_2 = 20 + 500 = 520$ m

$$\text{Speed of train, } s = 40\,\text{kmh}^{-1} = 40 \times \frac{5}{18}\,\text{m/s} = 11\,\text{ms}^{-1}$$

$$\text{Time}(t) = \frac{\text{Distance}}{\text{Speed}} = \frac{520}{11} = 47\,\text{s}$$

5. The position of an particle is given by $x = 6t + 2t^3$. Find out whether its motion is uniform or non-uniform.

Solution:

The position of an particle $x = 6t + 2t^3$

By differentiating with respect to 't'

$$\frac{dx}{dt} = \frac{d}{dt}(6t + 2t^3); \quad \frac{dx}{dt} = 6 + 6t^2$$

$$\because \quad \text{velocity } v = \frac{dx}{dt} = 6 + 6t^2 \qquad \left[\because x^n = nx^{n-1}\right]$$

$$v = 6 + 6t^2$$

$\Rightarrow$ Velocity is dependent with time.

$\therefore$ The motion is non-uniform motion.

6. If three cars A, B and C move with velocities along different directions on the road side, what is the vector hidden in this case.

Ans. When two or more vectors lie on the same plane, those vectors are said to be coplanar vectors. Let velocity vector is taken for the three cars. All the velocity vectors are lying on the same plane called road surface. So, the vector concept behind this is coplanar vector.

7. (i) Name the quantity which remains unchanged during the flight of an oblique projection.

(ii) If the velocity of the projectile is 10 ms^{-1} at what angle to the horizontal should be projected as that it covers maximum horizontal distance?

Ans. (i) Horizontal component of velocity $u_x = u \cos\theta$

(ii) At an angle of 45º to the horizontal. Covers maximum distance.

8. A bus starting from rest moves with a uniform acceleration of 0.2 ms^{-2} for 3 minutes. Find the speed and distance travelled.

Solution:

Initial velocity 'u' = 0

Acceleration 'a' = 0.2 ms^{-2}

Time (t) = 3 minutes = 180 seconds.

Speed of a bus, $v = u + at = 0 + 0.2 \times 180$

$= 36$ m/s.

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

$$= 0 \times 180 + \frac{1}{2} \times 0.2 \times (180)^2 = 0 + \frac{1}{2} \times 0.2 \times 32400$$

$= 3240$ m $= 3.24$ km

9. A person travels along a straight road for the first half distance 4 m with a velocity 1 ms^{-1} and the second half distance 3 m with a velocity 0.7 ms^{-1}. What is the mean velocity of the person?

Solution:

Time taken by person to travel 4 m

$$t_1 = \frac{\left(\frac{d}{2}\right)}{v_1} = \frac{d}{2v_1}$$

Time taken by person to travel 3 m,

$$t_2 = \frac{\left(\frac{d}{2}\right)}{v_2} = \frac{d}{2v_2}$$

Mean (or) average velocity,

$$v_m = \frac{d}{t_1 + t_2} = \frac{d}{\frac{d}{2v_1} + \frac{d}{2v_2}} = \frac{\cancel{d}}{\cancel{d}\left(\frac{1}{2v_1} + \frac{1}{2v_2}\right)}$$

$$= \frac{2v_1v_2}{v_1 + v_2} = \frac{2 \times 1 \times 0.7}{1 + 0.7} = \frac{1.4}{1.7} = 0.82\ \text{ms}^{-1}$$

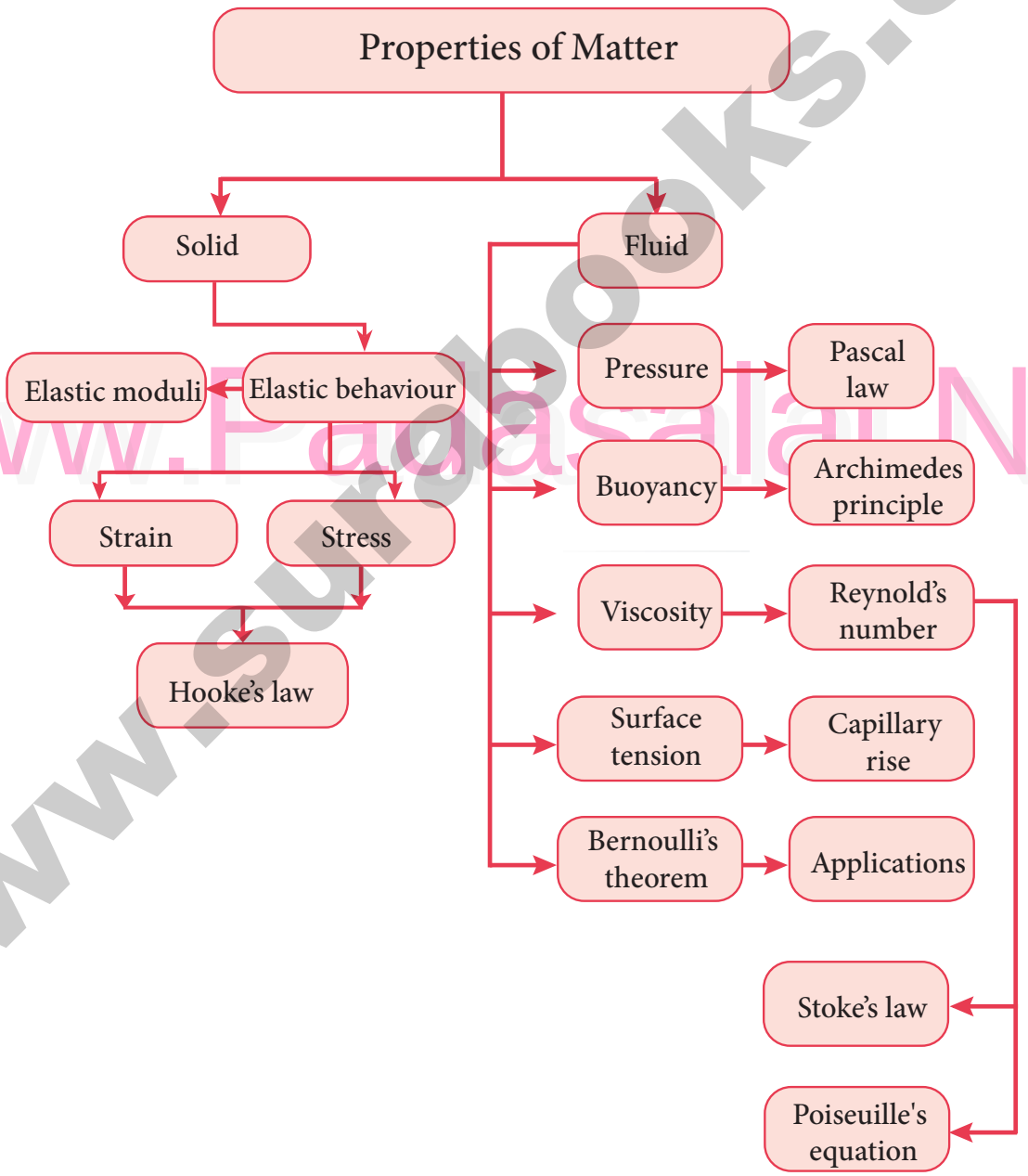
$\therefore$ Mean Velocity = 0.82 ms^{-1}

★ ★ ★ ★ ★

UNIT

07 PROPERTIES OF MATTER

CONCEPT MAP



FORMULAE TO REMEMBER

(1) Normal Stress $(S) = \frac{F}{A}$; $A = \pi r^2$; (F → Force; A → Area)

(2) Breaking force = Breaking stress × area of cross-section

(3) Longitudinal Strain = $\frac{\Delta l}{l} \Rightarrow \Delta l \rightarrow$ Change in length; $l \rightarrow$ Original length

(4) Volumetric Strain = $\frac{\Delta V}{V} \Rightarrow \Delta V \rightarrow$ Change in Volume; V → Original volume

(5) Shearing Strain, $\varepsilon_s = \theta$, $\varepsilon_s = \frac{x}{h} \Rightarrow \theta \rightarrow$ Angle of shear

(6) Pressure = $\frac{F}{A} = h\rho g$ (F → Force; A → Area)

Where,
h = height, ρ = Density of fluid, g = Acceleration due to gravity

(7) Gauge Pressure = Total Pressure – Atmospheric Pressure

(8) Hydraulic lift = $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

Where,
F_1, F_2 = Force on pistons of area of cross-sections A_1, A_2

(9) Archimedes' Principle
Loss of weight of body in liquid = weight of liquid displaced
= Volume × Density of liquid × g

(10) Laws of floatation :
A body will float if, Weight of the body = Weight of liquid displaced by the body.

(11) Density = $\frac{\text{Mass}}{\text{Volume}}$, Relative density = $\frac{\text{Density of substance}}{\text{Density of water at 4°C}}$

(12) Stroke's law: $F = 6\pi\eta r v$

(13) Bernoulli's theorem: $\frac{P}{\rho} + \frac{1}{2}v^2 + gh = \text{Constant}$

(14) Venturimeter: Volume of liquid flowing per second

$$V = a_1 a_2 \sqrt{\frac{2(\Delta P)}{\rho(a_1^2 - a_2^2)}}$$

(15) Velocity of efflux $v = \sqrt{2gh}$

Reynolds number = $R_c = \frac{\rho V D}{\eta}$

Poiseuille's equation = $V = \frac{\pi r^4 P}{8\eta l}$

IMPORTANT TERMS & DEFINITIONS

Stress : It is defined as the internal restoring force acting per unit area of a deformed body.

$$\text{Stress} = \frac{\text{Restoring force}}{\text{Area}} = \frac{F}{A}$$

The S.I. unit of stress is N/m^2 and its dimensional formula = $[M^1L^{-1}T^{-2}]$

Stress is scalar quantity.

Types of Stress:

(i) **Longitudinal Stress:** If a body changes its length under a deforming force and the stress is normal to the surface of the body then the stress is called longitudinal stress. The longitudinal stress can be a tensile stress or compressive stress.

(ii) **Volume Stress:** If a body changes its volume under a deforming force acting on every surface of the body, the stress set up in the body is volume stress.

(iii) **Tangential Stress:** When a deforming force applied tangentially to the surface of the body changes the shape of the body without changing its volume, the stress setup is known as tangential stress.

Strain: : It is defined as the ratio of change in Dimension of a deformed body because of a deforming force on it, to the original Dimension of the body it means

$$\text{Strain} = \frac{\text{Change in Dimension}}{\text{Original Dimension}}$$

Types of Strain:

(i) Longitudinal Strain = $\frac{\text{Change in length}}{\text{Original length}} = \frac{\Delta l}{l}$

(ii) Volumetric Strain = $\frac{\text{Change in Volume}}{\text{Original Volume}} = \frac{\Delta V}{V}$

(iii) **Shearing Strain:** It is the strain produced when a deforming force is acting tangentially to the surface of a body.

Hooke's law: : Hooke's law states that within elastic limit, stress is directly proportional to strain, stress α strain.

Deforming force: : Deforming force is that force which when applied changes the shape and size of the body.

Elasticity: : Elasticity it the property of the body by virtue of which the body regains its original shape and size when the deforming force are removed.

Perfectly elastic body: : The body which perfectly regains its original form on removing the external deforming force from it, e.g., quartz.

Plastic body:	:	The body which does not regain its original form at all on the removal of deforming force, however small the deforming force may be, e.g., putty and paraffin wax.
Elastic limit:	:	It is the limit or maximum stress upto which the body regains its original shape and size after the removal of deforming force.
Viscosity:	:	It is the property of a liquid or gas to oppose the relative motion between its layers.
Bernoulli's Theorem:	:	Bernoulli's Theorem state that the total energy of an incompressible non-viscous liquid in steady flow remain constant throughout the flow of the liquid i.e. $P + \rho gh + \frac{1}{2}\rho V^2 = \text{constant}$
Reynold Number:	:	A pure number which determines the nature of flow of liquid through a pipe.
Venturimeter:	:	A device used for measuring the speed of incompressible liquid and rate of flow of liquid through pipes.

EVALUATION

I. Multiple Choice Questions:

1. Consider two wires X and Y. The radius of wire X is 3 times the radius of Y. If they are stretched by the same load then the stress on Y is

(a) equal to that on X
(b) thrice that on X
(c) nine times that on X
(d) half that on X

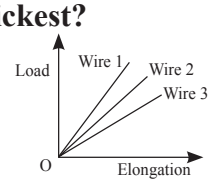
[Ans. (c) nine times that on X]

2. If a wire is stretched to double of its original length, then the strain in the wire is

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

[Ans. (a) 1]

3. The load - elongation graph of three wires of the same material are shown in figure. Which of the following wire is the thickest?



(a) wire 1
(b) wire 2
(c) wire 3
(d) all of them have same thickness

[Ans. (a) wire 1]

4. For a given material, the rigidity modulus is $\left(\frac{1}{3}\right)^{rd}$ of Young's modulus. Its Poisson's ratio is *[HY-2018]*

(a) 0 (b) 0.25 (c) 0.3 (d) 0.5

[Ans. (d) 0.5]

5. A small sphere of radius 2cm falls from rest in a viscous liquid. Heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity is proportional to *(NEET model 2018)*

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

[Ans. (d) 2^5]

6. Two wires are made of the same material and have the same volume. The area of cross sections of the first and the second wires are A and 2A respectively. If the length of the first wire is increased by Δl on applying a force F, how much force is needed to stretch the second wire by the same amount? *(NEET model 2018)*

(a) 2 F (b) 4 F (c) 8 F (d) 16 F

[Ans. (b) 4 F]

7. **With an increase in temperature, the viscosity of liquid and gas, respectively will**

(a) increase and increase (b) increase and decrease
(c) decrease and increase (d) decrease and decrease

[Ans. (c) decrease and increase]

8. **The Young's modulus for a perfect rigid body is**

(a) 0 (b) 1 (c) 0.5 (d) infinity

[Ans. (d) infinity]

9. **Which of the following is not a scalar?** *[HY-2019; Sep-2021; May-2022]*

(a) viscosity (b) surface tension
(c) pressure (d) stress **[Ans. (d) stress]**

10. **If the temperature of the wire is increased, then the Young's modulus will** *[Mar-2019]*

(a) remain the same (b) decrease
(c) increase rapidly
(d) increase by very a small amount

[Ans. (b) decrease]

11. **Copper of fixed volume V is drawn into a wire of length *l*. When this wire is subjected to a constant force F, the extension produced in the wire is Δl. If Y represents the Young's modulus, then which of the following graphs is a straight line?** *(NEET 2014 model)*

(a) Δl versus V (b) Δl versus Y
(c) Δl versus F (d) Δl versus $\frac{1}{l}$

[Ans. (c) Δl versus F]

12. **A certain number of spherical drops of a liquid of radius R coalesce to form a single drop of radius R and volume V. If T is the surface tension of the liquid, then**

(a) energy = $4 \text{ V T } \left(\frac{1}{r} - \frac{1}{R}\right)$ is released

(b) energy = $3 \text{ V T } \left(\frac{1}{r} + \frac{1}{R}\right)$ is absorbed

(c) energy = $3 \text{ V T } \left(\frac{1}{r} - \frac{1}{R}\right)$ is released

(d) energy is neither released nor absorbed

[Ans. (c) energy = $3 \text{ V T } \left(\frac{1}{r} - \frac{1}{R}\right)$ is released]

13. **The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied?**

(a) length = 200 cm, diameter = 0.5 mm
(b) length= 200 cm, diameter = 1 mm
(c) length = 200 cm, diameter = 2 mm
(d) length= 200 cm, diameter = 3 m

[Ans. (a) length = 200 cm, diameter = 0.5 mm]

14. **The wettability of a surface by a liquid depends primarily on** *[HY-2019] ; [Sep - 2020]*

(a) viscosity (b) surface tension
(c) density
(d) angle of contact between the surface and the liquid

[Ans. (d) angle of contact between the surface and the liquid]

15. **In a horizontal pipe of non-uniform cross section, water flows with a velocity of 1 ms^{-1} at a point where the diameter of the pipe is 20 cm. The velocity of water (1.5 ms^{-1}) at a point where the diameter of the pipe is (in cm)** *[Aug-'22]*

(a) 8 (b) 16 (c) 24 (d) 32

[Ans. (b) 16]

II. Short Answer Questions:

1. **Define stress and strain.**

Ans. The force per unit area is called as stress.

$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

The fractional change in the size of the object, when a force is applied, strain measures the degree of deformation.

$$\text{Strain, } \varepsilon = \frac{\text{Change in size}}{\text{Original size}} = \frac{\Delta l}{l}$$

2. **State Hooke's law of elasticity.** *[HY-2018; Aug-'22]*

Ans. Hooke's law is for a small deformation, when the stress and strain are proportional to each other.

Stress α Strain

$$\frac{F}{A} \alpha \frac{A}{L}$$

3. **Define Poisson's ratio.**

Ans. It is defined as the ratio of relative contraction (lateral strain) to relative expansion (longitudinal strain). It is denoted by the symbol μ.

$$\text{Poisson's ratio, } \mu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

4. Explain elasticity using intermolecular forces.

Ans. In a solid, interatomic forces bind two or more atoms together and the atoms occupy the positions of stable equilibrium. When a deforming force is applied on a body, its atoms are pulled apart or pushed closer. When the deforming force is removed, interatomic forces of attraction or repulsion restore the atoms to their equilibrium positions. If a body regains its original shape and size after the removal of deforming force, it is said to be elastic and the property is called elasticity.

5. Which one of these is more elastic, steel or rubber? Why? *[HY-2019]*

Ans. Steel is more elastic than rubber. If an equal stress is applied to both steel and rubber, the steel produces less strain. So the Young's modulus is higher for steel than rubber. The object which has higher young's modulus is more elastic.

6. A spring balance shows wrong readings after using for a long time. Why?

Ans. When a spring balance has been used for a long time, it develops an elastic fatigue, the spring of such a balance take longer time to recover its original configuration and therefore it does not give correct measurement.

7. What is the effect of temperature on elasticity?

Ans. As the temperature of substance increases, its elasticity decreases.

8. Write down the expression for the elastic potential energy of a stretched wire.

Ans. Consider a wire whose un-stretch length is L and area of cross section is A. Let a force produce an extension l.

The work done by the force F is equal to the energy gained by the wire.

The work done in stretching the wire by dl, $dW = F\,dl$

The total work done in stretching the wire from 0 to l is

$$W = \int_0^l F dl \qquad ....(1)$$

From Young's modulus of elasticity,

$$Y = \frac{F}{A} \times \frac{L}{l} \Rightarrow F = \frac{YAl}{L} \qquad ...(2)$$

Substituting equation (2) in equation (1), we get

$$W = \int_0^l \frac{YAl}{L} dl$$

$$W = \int_0^l \frac{YAl'}{L} dl' = \frac{YA}{L}\left(\frac{l'^2}{2}\right)\Big|_0^l = \frac{YA\,l^2}{L\;2} = \frac{1}{2}\left(\frac{YAl}{L}\right)l = \frac{1}{2}Fl$$

$$W = \frac{1}{2}Fl$$

This work done is known as the elastic potentia energy of a stretched wire.

9. State Pascal's law in fluids.

Ans. If the pressure in a liquid is changed at a particular point, the change is transmitted to the entire liquid without being diminished in magnitude.

10. State Archimedes principle.

Ans. It states that when a body is partially or wholly immersed in a fluid, it experiences an upward thrust equal to the weight of the fluid displaced by it and its upthrust acts through the centre of gravity of the liquid displaced.

Upthrust or buoyant force = weight of liquid displaced.

11. What do you mean by upthrust or buoyancy?

Ans. The upward force exerted by a fluid that opposes the weight of an immersed object in a fluid is called upthrust or buoyant force.

12. State the law of floatation.

Ans. The law of floatation states that a body will float in a liquid if the weight of the liquid displaced by the immersed part of the body equals the weight of the body.

13. Define coefficient of viscosity of a liquid.

Ans. The coefficient of viscosity of a liquid is the viscous force acting tangentially per unit area of a liquid layer having a unit velocity gradient in a direction perpendicular to the direction of flow of the liquid.

14. Distinguish between streamlined flow and turbulent flow. *[HY-2018; Aug-'22]*

Ans.

Streamlined flow		Turbulent flow	
(i)	When a liquid flows such that each particle of the liquid passing through a point moves along the same path with the same velocity as its predecessor then the flow of liquid is said to be a **streamlined flow**.	(i)	When a speed of the moving fluid exceeds the critical speed, vc the motion becomes turbulent.
(ii)	The velocity of the particle at any point is constant.	(ii)	The velocity changes both in magnitude and direction from particle to particle.
(iii)	The actual path taken by the particle of the moving fluid is called a streamline, which is a curve, the tangent to which at any point gives the direction of the flow of the fluid at that point.	(iii)	The path taken by the particles in turbulent flow becomes erratic and whirlpool-like circles called eddy current or eddies.

15. What is Reynold's number? Give its significance. *[Jun.-2019; May-2022]*

Ans. Reynold's number (Rc) is a dimensionless number, which is used to find out the nature of flow of the liquid.

$$R_c = \frac{\rho v D}{\eta}$$

where, ρ- density of the liquid, v –The velocity of flow of liquid. D- Diameter of the pipe, η - The coefficient of viscosity of the fluid.

16. Define terminal velocity.

Ans. The maximum constant velocity acquired by a body while falling freely through a viscous medium is called the terminal velocity V_T.

17. Write down the expression for the Stoke's force and explain the symbols involved in it.

Ans. Viscous force F acting on a spherical body of radius r depends directly on

(i) radius (r) of the sphere
(ii) velocity (v) of the sphere and
(iii) coefficient of viscosity η of the liquid

$F = 6\pi\eta\, rv$

Therefore $F \propto \eta^x r^y v^z \Rightarrow F = k\eta^x r^y v^z$, where k is a dimensionless constant.

Using dimensions, the above equation can be written as

$[MLT^{-2}] = k\,[ML^{-1}T^{-1}]^x \times [L]^y \times [LT^{-1}]^z$

On solving, we get $x=1$, $y=1$, and $z=1$

Therefore, $F=k\eta rv$

Experimentally, Stoke found that the value of $k = 6\pi$

$F = 6\pi\eta\, rv$

This relation is known as Stoke's law.

18. State Bernoulli's theorem.

Ans. According to Bernoulli's theorem, the sum of pressure energy, kinetic energy, and potential energy per unit mass of an incompressible, non-viscous fluid in a streamlined flow remains a constant.

$$\text{i.e.} \quad \frac{P}{\rho} + \frac{1}{2}v^2 + gh = \text{constant}$$

19. What are the energies possessed by a liquid? Write down their equations.

Ans. A liquid in motion possesses following three types of energy:

(i) **Kinetic energy:** It is the energy possessed by a liquid by virtue of its motion.

$$KE = \frac{1}{2}mv^2$$

$$KE \text{ per unit mass} = \frac{\frac{1}{2}mv^2}{m} = \frac{v^2}{2}$$

(ii) **Potential energy:** It is the energy possessed by a liquid by virtue of its height above the ground level.

$$PE = mgh$$

$$PE \text{ per unit mass} = \frac{mgh}{m} = gh$$

(iii) **Pressure energy:** It is the energy possessed by a liquid by virtue of its pressure.

$$\text{Pressure energy per unit mass} = \frac{P}{m/v}$$

20. Two streamlines cannot cross each other. Why?

Ans. If two streamlines cross each other, the fluid particle at the point of intersection will have two different directions of flow. This will destroy the steady nature of the fluid flow.

21. Define surface tension of a liquid. Mention its S.I unit and dimension.

Ans. The surface tension of a liquid is defined as the energy per unit area of the surface of a liquid

$$T = \frac{F}{l}$$

The SI unit and dimensions of T are N m^{-1} and M T^{-2}, respectively.

22. How is surface tension related to surface energy?

Ans. Consider a rectangular frame of wire ABCD in a soap solution. Let AB be the movable wire. Suppose the frame is dipped in soap solution, soap film is formed which pulls the wire AB inward due to surface tension. Let F be the force due to surface tension, then

$$F = (2T)l$$

Here, 2 is introduced because it has two free surfaces. Suppose AB is moved by a small distance Δx to a new position A′B′. Since the area increases, some work has to be done against the inward force due to surface tension.

Work done = Force × distance = $(2T\, l)\, (\Delta x)$

Increase in area of the film $\Delta A = (2l)\, (\Delta x) = 2l\, \Delta x$

Therefore,

$$\text{Surface energy} = \frac{\text{work done}}{\text{increase in surface area}}$$

$$= \frac{2Tl\Delta x}{2l\Delta x} = T$$

Hence, the surface energy per unit area of a surface is numerically equal to the surface tension.

23. Define angle of contact for a given pair of solid and liquid.

Ans. The angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid is known as the angle of contact between the solid and the liquid.

24. Distinguish between cohesive and adhesive forces.

Ans. The force between the like molecules which holds the liquid together is called 'cohesive force'. When the liquid is in contact with a solid, the molecules of these solid and liquid will experience an attractive force which is called **'adhesive force'**.

25. What are the factors affecting the surface tension of a liquid? *[HY-2019]*

Ans.

(1) **The presence of any contamination or impurities** considerably affects the force of surface tension depending upon the degree of contamination.

(2) **The presence of dissolved substances** can also affect the value of surface tension. For example, a highly soluble substance like sodium chloride (NaCl) when dissolved in water (H_2O) increases the surface tension of water. But the sparingly soluble substance like phenol or soap solution when mixed in water decreases the surface tension of water.

(3) **Electrification** affects the surface tension. When **a liquid is electrified, surface tension decreases**. Since external force acts on the liquid surface due to electrification, area of the liquid surface increases which acts against the contraction phenomenon of the surface tension. Hence, it decreases.

(4) **Temperature** plays a very crucial role in altering the surface tension of a liquid. Obviously, the **surface tension decreases linearly with the rise of temperature**.

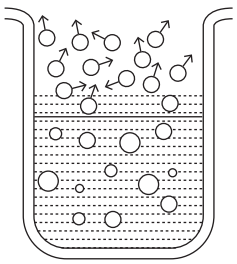
26. What happens to the pressure inside a soap bubble when air is blown into it?

Ans. The pressure inside the bubble is inversely proportional to the size of the bubble. As the size of the bubble increases while air is blown into it, the pressure decreases proportionally. Hence, the pressure decreases.

27. What do you mean by capillarity or capillary action?

Ans. The rise or fall of a liquid in a narrow tube is called capillarity or capillary action.

(iii) Experiment to demonstrate the boiling of H_2O at temperature below 100°C:



(1) The boiling point is the temperature at which a liquid's vapor pressure is equal to the surrounding pressure pushing down on it. For water on earth, the standard boiling point of water is given to be 100°C.

(2) This temperature assumes that the water has one atmosphere of pressure pushing down on it. When this pressure is decreased the temperature at which water can boil will decrease.

(3) To look at is another way, we can at water at the (simplified) molecular level.

(iv) Bubbles can form and rise since the vapor pressure can overcome atmospheric pressure liquid turning into bubbles and escaping as it boils.

Numerical Problems

1. The poisson ratio of a material is 0.5 if a force is applied to a wire of this material, there is a decrease in the cross sectional area by 4% what is the percentage increases in the length.

Solution:

$$A = \pi r^2 \text{ ; so } \frac{\Delta A}{A} = 2\frac{\Delta r}{r} = \frac{4}{100}$$

$$\text{given } \sigma = \frac{\Delta r/r}{\Delta l/l} = \frac{1}{2} \text{ or } \frac{\Delta l}{l} = \frac{2\Delta r}{r} = \frac{4}{100}$$

$\therefore$ % increase in length

$$\frac{\Delta l}{l} \times 100 = \frac{4}{100} \times 100 = 4\%$$

2. For a given material, the youngs modulus is 2 - 4 times that of rigidity modulus. What is its poisson's ratio?

Solution:

$$Y = 2\eta(1+\sigma) \text{ But } Y = 2.4\eta$$

$$2.4\,\eta = 2\eta(1+\sigma)$$

$$1+\sigma = 1.2$$

$$\Rightarrow \sigma = 0.2$$

3. The upper end of a wire of radius 4mm & length 100cm is clamped and its other end is twisted through an angle of 30°. Find the angle of shear.

Solution:

Angle of twist at free end

$$30° = \frac{30}{180} \times \pi \text{ rad} = \frac{\pi}{6} \text{ rad}$$

Displacement of free surface

$$\Delta L = \frac{2\pi r}{2\pi} \times \frac{\pi}{6}$$

$$= \frac{\pi r}{6} = \frac{\pi \times 0.4}{6} \text{cm}$$

$$\text{Angle of shear or shearing strain} = \frac{\Delta L}{L}$$

$$= \frac{\pi \times 0.4}{6 \times 100} \text{ rad}$$

$$= \frac{\pi \times 0.4}{6 \times 100} \times \frac{180}{\pi} \text{ degree} = 0.12°$$

4. A wire of length L and cross section A is made of material of youngs modulus y. It is stretched by an amount *x*. What is the work done?

Solution:

$$\Delta l = x \text{ ; } \quad y = \frac{F/A}{\Delta l/L} \text{ or } F = \frac{yA\,\Delta l}{L}$$

The work done from o to $x = \Delta l$ change in length.

$$\text{Average distance} = \frac{0+\Delta l}{2} = \frac{\Delta l}{2}$$

$$\text{work done} = \text{force} \times \text{distance}$$

$$= \frac{yA\,\Delta l}{L} \times \frac{\Delta l}{2} = \frac{yA\,(\Delta l)^2}{2L} = \frac{yA\,x^2}{2L}$$

5. The average depth of Indian ocean is about 3000 m. What is the fractional compression, ΔV/V of water at the bottom of ocean? (bulk modulus of water = 2.2×10^9 Nm^{-2} & g = 10 ms^{-2})

Solution:

$$\text{Pressure} = h\rho g = 3000 \times 1000 \times 10$$

$$= 3 \times 10^7 \text{ Nm}^2$$

Fraction all compression

$$\frac{\Delta V}{V} = \frac{\rho}{B} = \frac{3\times10^{7}\ Nm^{-2}}{2.2\times10^{9}\ Nm^{-2}}$$

$$= 1.36 \times 10^{-2} \text{ or } 1.36\%$$

6. A piece of solid weight 120g in air, 80g in water & 60g in liquid find the relative density of solid & liquid.

Solution:

Relative density of solid

$$= \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$$

$$= \frac{120}{120-80} = 3$$

Relative density of liquid

$$= \frac{\text{weight in air} - \text{weight in liquid}}{\text{weight in air} - \text{weight in water}}$$

$$= \frac{120-60}{120-80} = \frac{3}{2}$$

7. A body floats in water with 40% of its volume outside water. When the same body floats in oil 60% of its volume remains outside oil. What is the relative density of the oil?

Solution:

Let V be the total volume of body

When body is floating in water, then

$$V\rho_{body}\, g = 0.6$$

$$V\rho_{water}\, g \text{ (or) } \rho_{water} = \frac{\rho_{body}}{0.6}$$

When body is floating in oil, then

$$V\rho_{body}\, g = 0.4\, V\rho \text{ oil } g$$

$$\text{or } \rho \text{ oil} = \frac{\rho_{body}}{0.4}$$

Relative density of oil

$$= \frac{\rho_{oil}}{\rho_{water}} = \frac{\rho_{body}/0.4}{\rho_{body}/0.6} = \frac{6}{4}$$

$$= 1.5$$

8. $0.1m^3$ of water at 80°C is mixed with $0.3m^3$ of water at 60° C. What is the final temperature of the mixture?

Solution:

Volume of hot water $= 0.1\ m^3 = 0.1 \times 10^6 C$

$= 10^5\ C$

Mass of hot water, $m_1 = 10^5 \times 1 = 10^5$ g

Mass of hot water, $m_2 = (0.3 \times 10^6) \times 1$

$= 3 \times 10^5$ g

If θ is the final temperature of mixture, the heat loss by hot water = heat gained by cold water

$$10^5 \times 1 \times (80 - \theta) = 3 \times 10^5 \times 1 \times (\theta - 60)$$

$$(80 - \theta) = 3\theta - 180$$

$$\theta = 65°C$$

9. A soap bubble in vacuum has a radius of 3cm & another soap bubble in vacuum has a radius of 4cm if the 2 bubbles coalesce under isothermal conditions then what is radius of the new bubble?

Solution:

Pressure inside the bubble in vacuum $\rho = \frac{4S}{R}$

Volume of bubble, $V = \frac{4}{3}\pi r^3$

as PV = a constant

$$\frac{4s}{R}\times\frac{4}{3}\pi r^3 = \frac{4S}{r_1}\times\frac{4}{3}\pi r_1^3 + \frac{4S}{r_2}\times\frac{4}{3}\pi r_2^3$$

or $R^2 = r_1^2 + r_2^2$

$= 3^2 + 4^2 = 25$

$R = 5$ cm

10. An air bubble of radius *r* in water is at a depth h below the water surface at some instant if P is atmospheric pressure and d & T are the density and surface tension of water, what is the pressure inside the bubble?

Solution:

Excess of pressure inside air bubble in water $= \frac{2T}{r}$

Total pressure inside air bubble = atmosphere + pressure due to liquid column + excess pressure due to surface tension.

∴ Total pressure inside air bubble $= P + hpg + \frac{2T}{R}$

9. Are the intermolecular forces involved in the formation of liquid & solids different in nature? If yes how?

Ans. Yes. The intermolecular forces involved in the formation of liquids are attractive in nature while in the formation of solids, the repulsive intermolecular forces are more important.

10. What is a perfectly elastic body? Give example?

Ans. If on removal of deforming force, a body completely regains its original configuration, then it is said to be perfectly elastic.

Example: quartic

11. How does youngs modulus change with the rise of temperature?

Ans. Young's modulus decreases with the rise of temperature.

12. Why are springs made of steel & not of copper?

Ans. Young's modulus of steel is greater than that of copper. So steel spring is stretched lesser than a copper spring under the same deforming force. Moreover, steel returns to its original state more quickly than copper on the removal of deforming force.

13. State the 2 factors on which modulus of elastic depends.

Ans. **(i)** Nature of the material

(ii) Type of stress used in producing the strain

14. Possible to double the length of a metallic wire by apply in a force over it?

Ans. No. It is not possible because within elastic limit strain is only of the order of 10^{-3}, wires actually break much before it is stretched to double the length.

15. A wire fixed at the upper & stretches by length l by applying a force F. What is the work done by stretching the wire?

Ans. Work done in stretching the wire,

$$W = \frac{1}{2} \text{ stretching force} \times \text{increase in length}$$

$$= \frac{1}{2} Fl.$$

16. A wire suspended vertically from one of its end is stretched by attaching a weight of 200N to the lower end. The weight stretches the wire by 1mm. Find the elastic energy in the wire.

Ans. Here F = 100 N, l = 1 mm = 10^{-3}m

Elastic potential energy stored in the wire is

$$U = \frac{1}{2} Fl = \frac{1}{2} \times 200 \times 10^{-3} = 0.1 \text{ J}$$

17. What does slope of stress versus strain graph give?

Ans. It gives the modulus of elasticity.

VALUE BASED QUESTIONS

1. Rajesh went with his family for Bombay tour. The whole family was waiting for the arrival of train. Rajesh was standing near the pavement looking for the train. His family members were seated. When train came near Rajesh, he felt pulled by the train with a drag, but suddenly his grandma saved him from falling. Rajesh was shocked and nervous due to this incident. Why Rajesh experienced this pull?

(i) What does equation of continuity mean?

(ii) Give the expression for Bernoulli's theorem.

(iii) What is the speed of flow of waterfall, when it reaches the ground?

Ans. Rajesh experienced this pull, because of Bernoulli's theorem. As we know, pressure is inversely proportional to velocity; i.e. as velocity of air increases, the pressure of it decreases and vice versa. The region (air space) between Rajesh and the speeding train has air which is of greater velocity. So here in this region the pressure is less. But the region behind Rajesh has more pressure. i.e. velocity of air is less. Due to this reason, the pressure behind him, pushes him forward towards the train, so if is safer to keep distance from any moving objects like buses, lorries etc.

(i) Equation of continuity :

For an incompressible fluid, the mass is conserved i.e. $m_1 = m_2$

$a_1 v_1 \Delta t \cdot \rho = a_2 v_2 \Delta t \cdot \rho$

$a_1 v_1 = a_2 v_2 \Rightarrow av = \text{constant}$

i.e. $a \propto \frac{1}{v}$

a = cross – sectional area of the pipe

v = velocity of the fluid.

(ii) Mathematically, Bernoulli's theorem is expressed as

$$\frac{P}{\rho} + \frac{v^2}{2} + gh = \text{a constant}$$

i.e. Pressure head + Kinetic head + Gravitational head = constant.

2. A king ordered his Goldsmith to make a crown, which should be of pure gold. So the goldsmith made a crown of pure gold & brought it to the king. But the king was not contented with the crown as he suspected whether it is made of pure gold or not. So he called for Archimedes and asked him to check whether it is a pure gold crown. Archimedes was serious about this and went his home thinking how to solve this issue. He wanted to take bath, all of a sudden he jumped on to the bath tub. Water inside the tub had splashed out of it. An idea striked him suddenly he went running naked straight from his bathroom to the king's place shouting Eureka Eureka on the road side. From this what do we infer?

(i) How Archimedes would have solved this problem?

(ii) State Archimedes principle.

Ans. Archimedes discovered that the weight of his body is equal to the weight of the displaced (splashed) liquid out of the tub. So Archimedes principle was the out come of this incidence, here 'Eureka' means I have found out.

(i) Archimedes took that much amount Gold and immersed in water and measured its original weight. Then, when he immersed the crown, the weight of the actual gold was not shown by the duplicate gold crown, from this he guessed, the goldsmith had made the crown with some other metals too along with Gold. (i.e. Impure gold). Goldsmith was caught red handed by the king.

(ii) Archimedes Principle states that, when a body is partially or wholly immersed in a fluid, it experiences an upward thrust equal to the weight of the fluid displaced by it.

V. Conceptual Questions

1. Why coffee runs up into a sugar lump (a small cube of sugar) when one corner of the sugar lump is held in the liquid?

Ans. (i) If sugar cube is dropped into liquid the outermost layer has to dissolve first, then next layer, then next until the whole sugar is dissolved.

(ii) The coffee runs up into the pores of sugar lump due to capillary action of the liquid.

2. Why two holes are made to empty an oil tin?

Ans. When oil comes out from a hole of an oil tin, pressure inside it decreased than the atmosphere. Therefore, the surrounding air rush up into the same hole prevents the oil to come out. Hence two holes are made to empty the oil tin.

3. We can cut vegetables easily with a sharp knife as compared to a blunt knife. Why?

Ans. The stress produced on the vegetables by the sharp knife is higher than the blunt knife. So, Vegetables can be cut easily with the sharp knife.

4. Why the passengers are advised to remove the ink from their pens while going up in an aeroplane?

Ans. When an aero-plane ascends, the atmospheric pressure is decreased. Hence, the ink from the pen will leak out. So that, the passengers are advised to remove the ink from their pens while going up in the aero-plane.

5. We use straw to suck soft drinks, why?

Ans. When we suck the soft drinks through the straw, the pressure inside the straw becomes less than the atmospheric pressure. Due to the difference in pressure, the soft drink rises in the straw and we are able to enjoy it conveniently.

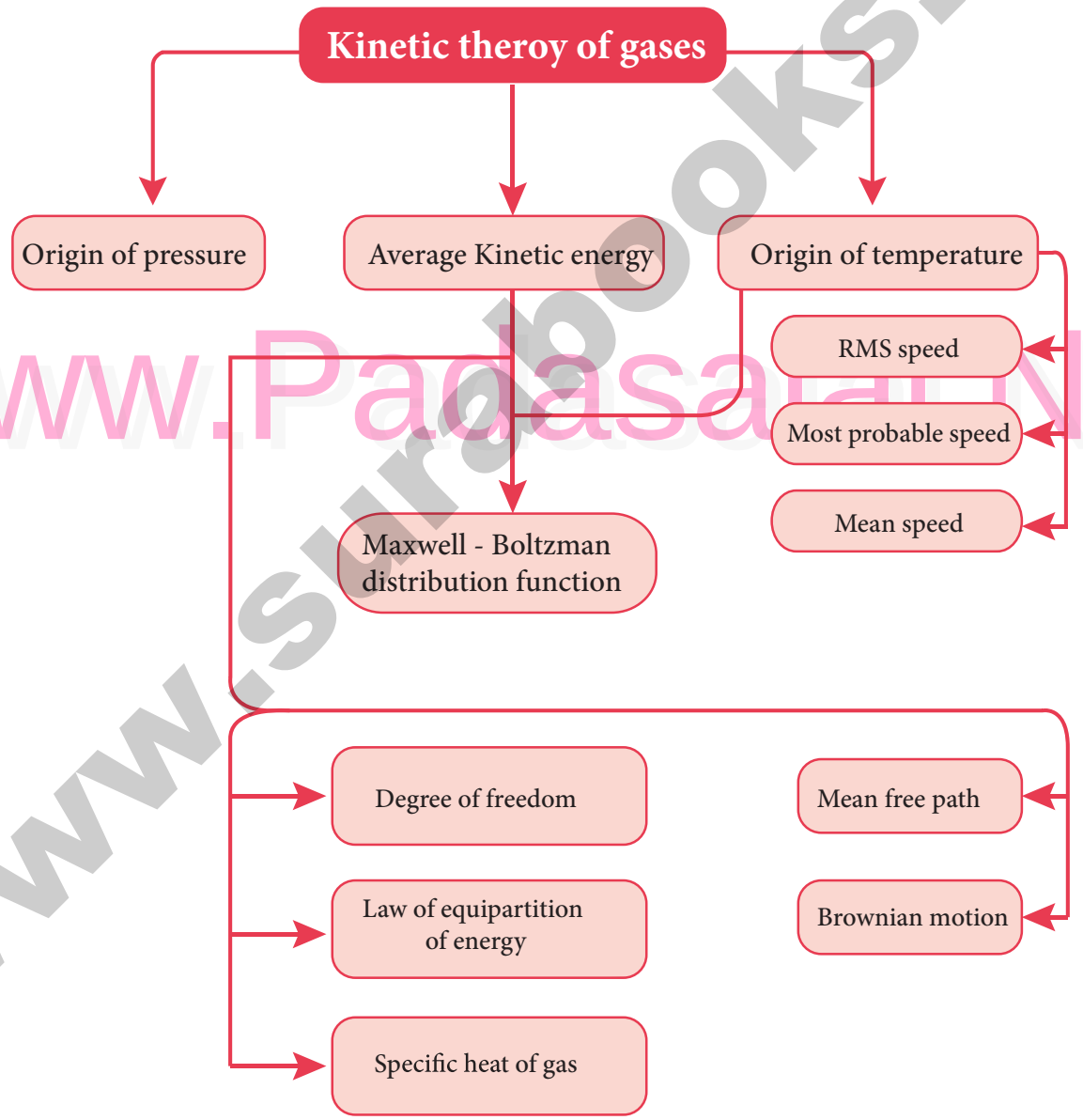
★★★★★

UNIT

09

KINETIC THEORY OF GASES

CONCEPT MAP



FORMULAE TO REMEMBER

(1) Ideal gas equation: $PV = nRT$

(2) Charles's law: $\frac{V}{T} = \text{constant}$

(3) Boyle's law: $PV = \text{constant}$

(4) Gay Lussac's law: $\frac{P}{T} = \text{constant}$

(5) Boltzmann's constant: $k_B = \frac{R}{N}$

$R \rightarrow$ Gas Constant; $N \rightarrow$ No. of gas molecules

(6) Pressure exerted by a gas: $P = \frac{1}{3} \cdot \frac{MN}{V} \cdot V_{rms}^2$

(or) $P = \frac{1}{3} PV_{rms}^2$

(7) *rms* velocity of gas molecule $V_{rms} = \sqrt{\frac{V_1^2 + V_2^2 + ...V_n^2}{N}} = \sqrt{\frac{3RT}{M}}$

[$R \rightarrow$ Gas Constant; $M \rightarrow$ Molar Mass; $T \rightarrow$ Temperature]

(8) Average K.E of a gas $E = \frac{3}{2} PV = \frac{3}{2} RT = \frac{3}{2} k_B NT$

(9) Ave. k . E per molecule of a gas $E = \frac{3}{2} k_B T$

(10) Relation between pressure and K.E: $P = \frac{2}{3} E$

IMPORTANT TERMS & DEFINITIONS

Boyle's law : It states that at constant temperature the volume of a g_n mass of a gas is inversely proportional to the pressure, i.e. $V \propto \frac{1}{P}$ or $PV = \text{constant}$

Charles's law : At constant pressure the volume of a g_n mass of a gas is directly proportional to its absolute temperature.

$$\frac{V}{T} = \text{constant} \quad \text{(or)} \quad V \propto T$$

Graham's law of diffusion : It states that the rate of diffusion of a gas is inversely proportional to the square root of its density.

Avogadro's law : It states that equal volume of all gases under similar conditions of temperature and pressure contain equal number of molecules.

Avogadro's no. : It is the number of particles present in one mole of a substance.

Degrees of freedom : The total number of independent modes in which a system can possess energy.

Law of equipartition of energy : For any system in thermal equilibrium, the total energy is equally distributed among its various degree of freedom and the energy associated with each degree of freedom is $\frac{1}{2} kT$.

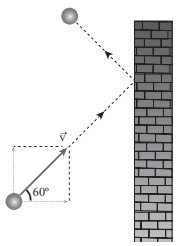
Mean free path : The average distant travelled by a gas molecule is known as mean free path.

Brownian motion : The zig – zag motion of gas molecules is Brownian motion. ∵ it occurs due to random collision of molecules.

EVALUATION

I. MULTIPLE CHOICE QUESTIONS:

1. A particle of mass m is moving with speed u in a direction which makes 60° with respect to x axis. It undergoes elastic collision with the wall. What is the change in momentum in x and y direction? *[Aug-'22]*



(a) $\Delta p_x = -mu, \Delta p_y = 0$
(b) $\Delta p_x = -2mu, \Delta p_y = 0$
(c) $\Delta p_x = 0, \Delta p_y = mu$
(d) $\Delta p_x = mu, \Delta p_y = 0$

[Ans. (a) $\Delta p_x = -mu, \Delta p_y = 0$]

2. A sample of ideal gas is at equilibrium. Which of the following quantity is zero?
(a) rms speed (b) average speed
(c) average velocity (d) most probable speed
[Ans. (c) average velocity]

3. An ideal gas is maintained at constant pressure. If the temperature of an ideal gas increases from 100K to 10000K then the rms speed of the gas molecules
(a) increases by 5 times (b) increases by 10 times
(c) remains same (d) increases by 7 times
[Ans. (b) increases by 10 times]

4. Two identically sized rooms A and B are connected by an open door. If the room A is air conditioned such that its temperature is 4°C lesser than room B, which room has more air in it?
(a) Room A (b) Room B
(c) Both room has same air
(d) Cannot be determined **[Ans. (a) Room A]**

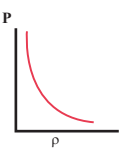
5. The average translational kinetic energy of gas molecules depends on
(a) number of moles and T
(b) only on T
(c) P and T
(d) P only **[Ans. (a) number of moles and T]**

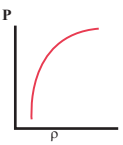
6. If the internal energy of an ideal gas U and volume V are doubled, then the pressure *[Sep-2021]*
(a) doubles (b) remains same
(c) halves (d) quadruples
[Ans. (b) remains same]

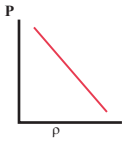
7. The ratio $\gamma = \frac{C_P}{C_V}$ for a gas mixture consisting of 8 g of helium and 16 g of oxygen is *(Physics Olympiad -2005)* *[Jun.-2019; May-2022]*
(a) $\frac{23}{15}$ (b) $\frac{15}{23}$ (c) $\frac{27}{17}$ (d) $\frac{17}{27}$
[Ans. (c) $\frac{27}{17}$]

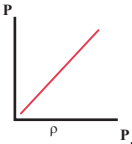
8. A container has one mole of monoatomic ideal gas. Each molecule has f degrees of freedom. What is the ratio of $\gamma = \frac{C_P}{C_V}$?
(a) f (b) $\frac{f}{2}$ (c) $\frac{f}{f+2}$ (d) $\frac{f+2}{f}$
[Ans. (d) $\frac{f+2}{f}$]

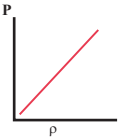
9. If the temperature and pressure of a gas is doubled the mean free path of the gas molecules
(a) remains same (b) doubled
(c) tripled (d) quadrapoled
[Ans. (a) remains same]

10. Which of the following shows the correct relationship between the pressure and density of an ideal gas at constant temperature? *[HY-2019]*
(a) 

(b) 

(c) 

(d) 

[Ans. (d) 

]

11. **A sample of gas consists of μ_1 moles of monoatomic molecules, μ_2 moles of diatomic molecules and μ_3 moles of linear triatomic molecules. The gas is kept at high temperature. What is the total number of degrees of freedom?**

(a) $[3\mu_1 + 7(\mu_2 + \mu_3)]\, N_A$
(b) $[3\mu_1 + 7\,\mu_2 + 6\mu_3]\, N_A$
(c) $[7\mu_1 + 3(\mu_2 + \mu_3)]\, N_A$
(d) $[3\mu_1 + 6(\mu_2 + \mu_3)]\, N_A$

[Ans. (a) $[3\mu_1 + 7(\mu_2 + \mu_3)]N_A$]

12. **If s_P and s_V denote the specific heats of nitrogen gas per unit mass at constant pressure and constant volume respectively, then** *(JEE 2007)*
[Sep-2020]

(a) $s_P - s_V = 28R$ (b) $s_P - s_V = R/28$
(c) $s_P - s_V = R/14$ (d) $s_P - s_V = R$

[Ans. (b) $s_P - s_V = R/28$]

13. **Which of the following gases will have least rms speed at a given temperature?**

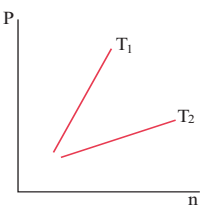
(a) Hydrogen (b) Nitrogen
(c) Oxygen (d) Carbon dioxide

[Ans. (d) Carbon dioxide]

14. **For a given gas molecule at a fixed temperature, the area under the Maxwell-Boltzmann distribution curve is equal to**

(a) $\frac{PV}{kT}$ (b) $\frac{kT}{PV}$
(c) $\frac{P}{NkT}$ (d) PV **[Ans. (a) $\frac{PV}{kT}$]**

15. **The following graph represents the pressure versus number density for ideal gas at two different temperatures T_1 and T_2. The graph implies**



(a) $T_1 = T_2$
(b) $T_1 > T_2$
(c) $T_1 < T_2$
(d) Cannot be determined **[Ans. (b) $T_1 > T_2$]**

II. Short Answer Questions :

1. **What is the microscopic origin of pressure?**

Ans. With the help of kinetic theory of gases, the pressure is linked to the velocity of molecules.

$$P = \frac{1}{3}\frac{N}{V} m\overline{v^2}$$

m- mass of a molecule ; N = Avogadro number
V - volume, $\overline{v^2}$ Avogadro velocity molecules.

2. **What is the microscopic origin of temperature?**

Ans. The average kinetic energy per molecule

$$\overline{K.E} = \epsilon = \frac{3}{2}kT.$$

The equation implies that the temperature of a gas is a measure of the average translational kinetic energy per molecule of the gas.

3. **Why moon has no atmosphere?** *[Jun.-2019]*

Ans. The escape speed of gases on the surface of Moon is much less than the root mean square speeds of gases due to low gravity. Due to this, all the gases escape from the surface of the Moon.

4. **Write the expression for rms speed, average speed and most probable speed of a gas molecule.**

Ans. Root mean square speed : (v_{rms})

$$v_{rms} = \sqrt{\overline{V}^2} = \frac{\sqrt{3kT}}{m} = 1.73\sqrt{\frac{kT}{m}}$$

Average Speed : $(\bar{v})$

$$\bar{v} = \frac{v_1 + v_2 + v_3 + \ldots . v_n}{N}$$

$$\bar{v} = \sqrt{\frac{8RT}{\pi m}} = \sqrt{\frac{8kT}{\pi m}} = 1.60\sqrt{\frac{kT}{m}}$$

Most probable speed : (v_{mp})

$$v_{mp} = \sqrt{\frac{2RT}{m}} = \sqrt{\frac{2kT}{m}} = 1.41\sqrt{\frac{kT}{m}}$$

5. **What is the relation between the average kinetic energy and pressure?**

Ans. The internal energy of the gas is given by

$$U = \frac{3}{2} NkT$$

The above equation can also be written as

$$U = \frac{3}{2} PV$$

since $PV = NkT$

$$P = \frac{2}{3} \overline{kE} \quad ...(1)$$

From equation (1), the pressure of the gas is equal to two thirds of internal energy per unit volume or internal energy density ($u = U/V$).

Writing pressure in terms of mean kinetic energy density using equation

$$P = \frac{1}{3} nm\overline{v^2} = \frac{1}{3} \rho \overline{v^2} \quad ...(2)$$

where $\rho = nm$ = mass density (n is number density)

Multiply and divide R.H.S of equation (2) by 2, we get

$$P = \frac{2}{3}\left(\frac{\rho}{2}\overline{v^2}\right) \quad ...(3)$$

$$P = \frac{2}{3} \overline{K.E}$$

From equation (3), pressure is equal to 2/3 of mean kinetic energy per unit volume.

6. Define the term degrees of freedom.

[Jun.-2019; Sep-2021; May-2022]

Ans. The minimum number of independent coordinates needed to specify the position and configuration of a thermodynamical system in space is called the degree of freedom of the system.

7. State the law of equipartition of energy.

Ans. According to kinetic theory, the average kinetic energy of system of molecules in thermal equilibrium at temperature T is uniformly distributed to all degrees of freedom (x or y or z directions of motion) so that each degree of freedom will get $\frac{1}{2}kT$ of energy. This is called law of equipartition of energy.

8. Define mean free path and write down its expression.

Ans. Average distance travelled by the molecule between two successive collisions is called mean free path (λ).

$$\lambda = \frac{KT}{\sqrt{2}\pi d^2 p}$$

9. Deduce Charles' law based on kinetic theory.

Ans. Charles' law:

From the equation, $P = \frac{2}{3}\frac{U}{V} = \frac{2}{3}u$, we get $PV = \frac{2}{3}U$.

For a fixed pressure, the volume of the gas is proportional to internal energy of the gas or average kinetic energy of the gas and the average kinetic energy is directly proportional to absolute temperature. It implies that

$V \alpha T$ or $\frac{V}{T}$ = constant

This is Charles' law.

10. Deduce Boyle's law based on kinetic theory.

Ans. Boyle's law:

From equation $P = \frac{2}{3}\frac{U}{V} = \frac{2}{3}u$, we know that $PV = \frac{2}{3}U$

But the internal energy of an ideal gas is equal to N times the average kinetic energy ($\in$) of each molecule.

$$U = N\in$$

For a fixed temperature, the average translational kinetic energy $\in$ will remain constant. It implies that

$PV = \frac{2}{3}N\in$ Thus PV = constant

Therefore, pressure of a given gas is inversely proportional to its volume provided the temperature remains constant. This is Boyle's law.

11. Deduce Avogadro's law based on kinetic theory.

Ans. Avogadro's law:

(i) This law states that at constant temperature and pressure, equal volumes of all gases contain the same number of molecules. For two different gases at the same temperature and pressure, according to kinetic theory of gases,

From equation

$$P = \frac{1}{3}\frac{N_1}{V} m_1 \overline{v_1^2} = \frac{1}{3}\frac{N_2}{V} m_2 \overline{v_2^2} \quad ....(1)$$

where $\overline{v_1^2}$ and $\overline{v_2^2}$ are the mean square speed for two gases and N_1 and N_2 are the number of gas molecules in two different gases.

(ii) At the same temperature, average kinetic energy per molecule is the same for two gases.

$$\frac{1}{2}m_1\overline{v_1^2} = \frac{1}{2}m_1\overline{v_2^2} \quad ....(2)$$

Dividing the equation (1) by (2) we get $N_1 = N_2$

(iii) This is Avogadro's law. It is sometimes referred to as Avogadro's hypothesis or Avogadro's Principle.

12. List the factors affecting the mean free path. *[Sep. 2020]*

Ans. (i) Mean free path increases with increasing temperature. As the temperature increases, the average speed of each molecule will increase. It is the reason why the smell of hot sizzling food reaches several meter away than smell of cold food.

(ii) Mean free path increases with decreasing pressure of the gas and diameter of the gas molecules.

13. What is the reason for Brownian motion?

Ans. (i) According to kinetic theory, any particle suspended in a liquid or gas is continuously bombarded from all the directions so that the mean free path is almost negligible.

(ii) This leads to the motion of the particles in a random and zig–zag manner.

III. Long Answer Questions

1. Write down the postulates of kinetic theory of gases. *[Mar-2019; Sep-2020]*

Ans. (i) All the molecules of a gas are identical, elastic spheres.

(ii) The molecules of different gases are different.

(iii) The number of molecules in a gas is very large and the average separation between them is larger than size of the gas molecules.

(iv) The molecules of a gas are in a state of continuous random motion.

(v) The molecules collide with one another and also with the walls of the container.

(vi) These collisions are perfectly elastic so that there is no loss of kinetic energy during collisions.

(vii) Between two successive collisions, a molecule moves with uniform velocity.

(viii) The molecules do not exert any force of attraction or repulsion on each other except during collision. The molecules do not possess any potential energy and the energy is wholly kinetic.

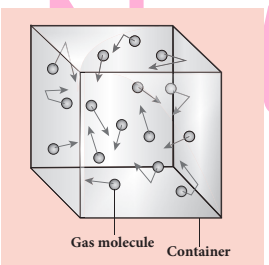
(ix) The collisions are instantaneous. The time spent by a molecule in each collision is very small compared to the time elapsed between two consecutive collisions.

(x) These molecules obey Newton's laws of motion even though they move randomly.

2. Derive the expression of pressure exerted by the gas on the walls of the container.

Ans. **Expression for pressure exerted by a gas :**

(i) Consider a monoatomic gas of N molecules each having a mass m inside a cubical container of side l as shown in the figure (a).



(a) Container of gas molecules

(ii) The molecules of the gas are in random motion. They collide with each other and also with the walls of the container. As the collisions are elastic in nature, there is no loss of energy, but a change in momentum occurs.

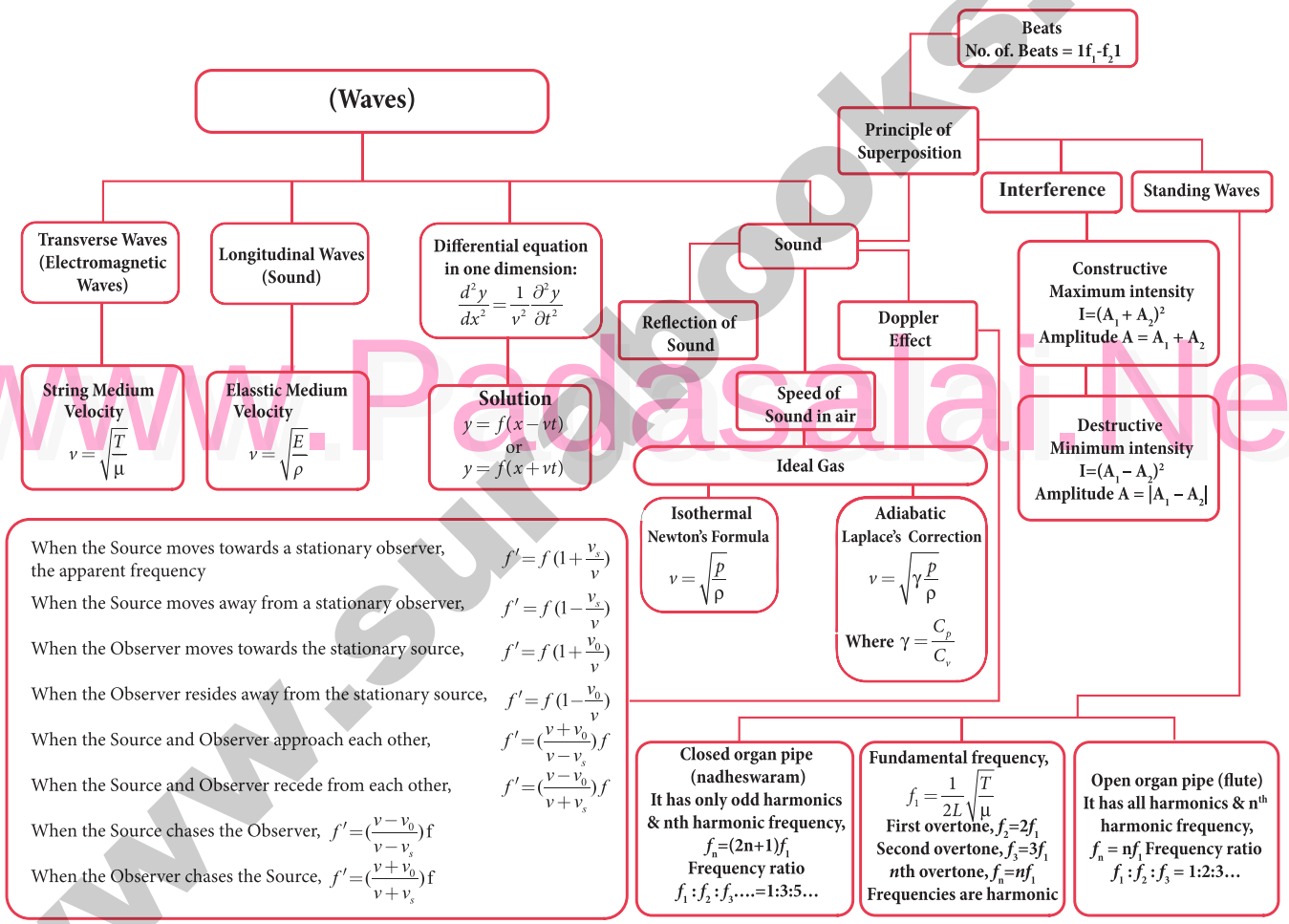
(iii) The molecules of the gas exert pressure on the walls of the container due to collision on it. During each collision, the molecules impart certain momentum to the wall. Due to transfer of momentum, the walls experience a continuous force. The force experienced per unit area of the walls of the container determines the pressure exerted by the gas. It is essential to determine the total momentum transferred by the molecules in a short interval of time.

UNIT

11

WAVES

CONCEPT MAP



FORMULAE TO REMEMBER

(1) Velocity of the wave is $v = \lambda f$.

(2) Velocity of transverse wave on a string is $v = \sqrt{\frac{T}{\mu}}\ ms^{-1}$

(3) Velocity of longitudinal wave in an elastic medium is $v = \sqrt{\frac{E}{\rho}}\ ms^{-1}$

(4) Wave number $k = \frac{2\pi}{\lambda}$ rad m^{-1}.

(5) For constructive interference, $I_{maximum} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = (A_1 + A_2)^2$

(6) For destructive interference, $I_{minimum} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = = (A_1 - A_2)^2$

(7) Sound intensity level, $\Delta L = 10 \log_{10} \left|\frac{I_1}{I_0}\right|$ *decibel*.

(8) Frequency of the (Closed organ pipe) n^{th} harmonic is $f_n = (2n + 1) f_1$.

(9) Frequency of the (Open organ pipe) n^{th} harmonic is $f_n = n f_1$.

(10) When the Source moves towards a stationary observer, the apparent frequency $f' = f\left(1 + \frac{v_s}{v}\right)$

(11) When the Source moves away from the observer $f' = f\left(1 - \frac{v_s}{v}\right)$

(12) When the Observer moves towards the stationary source, $f' = f\left(1 + \frac{v_0}{v}\right)$

(13) When the Observer recedes away from the stationary source, $f' = f\left(1 - \frac{v_0}{v}\right)$

(14) When the Source and Observer approach each other, $f' = \left(\frac{v + v_0}{v - v_s}\right) f$

(15) When the Source and Observer recede from each other, $f' = \left(\frac{v - v_0}{v + v_s}\right) f$

(16) When the Source chases the Observer, $f' = \left(\frac{v - v_0}{v - v_s}\right) f$

(17) When the Observer chases the Source, $f' = \left(\frac{v + v_0}{v + v_s}\right) f$

(18) To find end correction, $e = \frac{L_2 - 3L_1}{2}$

$L_2 \rightarrow$ Length at which second resonance Occur

$L_1 \rightarrow$ Length at which first resonance Occur

EVALUATION

I. MULTIPLE CHOICE QUESTIONS:

1. A student tunes his guitar by striking a 120 Hertz with a tuning fork, and simultaneously plays the 4th string on his guitar. By keen observation, he hears the amplitude of the combined sound oscillating thrice per second. Which of the following frequencies is the most likely the frequency of the 4th string on his guitar?

(a) 130 (b) 117 (c) 110 (d) 120

[Ans. (b) 117]

2. A transverse wave moves from a medium A to a medium B. In medium A, the velocity of the transverse wave is 500 ms^{-1} and the wavelength is 5 m. The frequency and the wavelength of the wave in medium B when its velocity is 600 ms^{-1}, respectively are *[Sep-2021; May-2022]*

(a) 120 Hz and 5 m
(b) 100 Hz and 5 m
(c) 120 Hz and 6 m
(d) 100 Hz and 6 m **[Ans. (d) 100 Hz and 6 m]**

3. For a particular tube, among six harmonic frequencies below 1000 Hz, only four harmonic frequencies are given : 300 Hz, 600 Hz, 750 Hz and 900 Hz. What are the two other frequencies missing from this list?

(a) 100 Hz, 150 Hz
(b) 150 Hz, 450 Hz
(c) 450 Hz, 700 Hz
(d) 700 Hz, 800 Hz

[Ans. (b) 150 Hz, 450 Hz]

4. Which of the following options is correct?

A	B
(1) Quality	(A) Intensity
(2) Pitch	(B) Waveform
(3) Loudness	(C) Frequency

Options for (1), (2) and (3), respectively are

(a) (B),(C) and (A) (b) (C), (A) and (B)
(c) (A), (B) and (C) (d) (B), (A) and (C)

[Ans. (a) (B),(C) and (A)]

5. Eqution of travelling wave on a stretched string of linear density 5 g/m is $y = 0.03 \sin(450t - 9x)$, where distance and time are measured in SI units. The tension in the string is

(a) 5 N (b) 12.5 N
(c) 7.5 N (d) 10 N

[Ans. (b) 12.5 N]

6. 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) 4.30 (b) 0.23 (c) 5.30 (d) 1.23

[Ans. (a) 4.30]

7. A person standing between two parallel hills fires a gun and hears the first echo after t_1 sec and the second echo after t_2 sec. The distance between the two hills is *[HY-2019]*

(a) $\frac{v(t_1 - t_2)}{2}$ (b) $\frac{v(t_1 t_2)}{2(t_1 + t_2)}$
(c) $v(t_1 + t_2)$ (d) $\frac{v(t_1 + t_2)}{2}$

[Ans. (d) $\frac{v(t_1 + t_2)}{2}$]

8. An air column in a pipe which is closed at one end, will be in resonance with the vibrating body of frequency 83Hz. Then the length of the air column is *[Mar-2020]*

(a) 1.5 m (b) 0.5 m (c) 1.0 m (d) 2.0 m

[Ans. (c) 1.0 m]

9. The displacement y of a wave travelling in the x direction is given by $y = (2 \times 10^{-3})$ $\sin(300t - 2x + \frac{\pi}{4})$, where x and y are measured in metres and t in second. The speed of the wave is

(a) 150 ms^{-1} (b) 300 ms^{-1}
(c) 450 ms^{-1} (d) 600 ms^{-1}

[Ans. (a) 150 ms^{-1}]

10. Consider two uniform wires vibrating simultaneously in their fundamental notes. The tensions, densities, lengths and diameter of the two wires are in the ratio 8 : 1, 1 : 2, x : y and 4 : 1 respectively. If the note of the higher pitch has a frequency of 360 Hz and the number of beats produced per second is 10, then the value of x : y is

(a) 36 : 35 (b) 35 : 36 (c) 1 : 1 (d) 1 : 2

[Ans. (a) 36 : 35]

11. Which of the following represents a wave?

(a) $(x - vt)^3$ (b) $x(x + vt)$
(c) $\frac{1}{(x+vt)}$ (d) $\sin(x + vt)$

[Ans. (d) $\sin(x + vt)$]

12. A man sitting on a swing which is moving to an angle of 60° from the vertical is blowing a whistle which has a frequency of 2.0 k Hz. The whistle is 2.0 m from the fixed support point of the swing. A sound detector which detects the whistle sound is kept in front of the swing. The maximum frequency the sound detector detected is

(a) 2.027 kHz (b) 1.974 kHz
(c) 9.74 kHz (d) 1.011 kHz

[Ans. (a) 2.027 kHz]

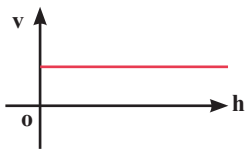
13. Let $y = \frac{1}{1+x^2}$ at t = 0 s be the amplitude of the wave propagating in the positive x-direction. At t = 2 s, the amplitude of the wave propagating becomes $y = \frac{1}{1+(x-2)^2}$. Assume that the shape of the wave does not change during propagation. The velocity of the wave is

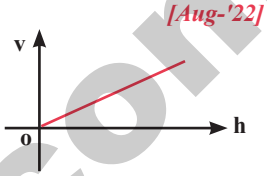
(a) 0.5 m s^{-1} (b) 1.0 m s^{-1}
(c) 1.5 m s^{-1} (d) 2.0 m s^{-1}

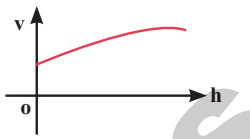
[Ans. (b) 1.0 m s^{-1}]

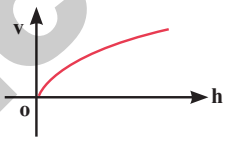
14. A uniform rope having mass m hangs vertically from a rigid support. A transverse wave pulse is produced at the lower end. Which of the following plots shows the correct variation of speed v with height h from the lower end?

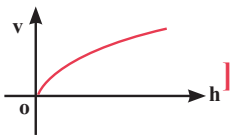
[Aug-'22]

(a) 

(b) 

(c) 

(d) 

[Ans. (d) 

]

15. An organ pipe A closed at one end is allowed to vibrate in its first harmonic and another pipe B open at both ends is allowed to vibrate in its third harmonic. Both A and B are in resonance with a given tuning fork. The ratio of the length of A and B is

(a) $\frac{8}{3}$ (b) $\frac{3}{8}$ (c) $\frac{1}{6}$ (d) $\frac{1}{3}$

[Ans. (c) $\frac{1}{6}$]

II. Short Answer Questions:

1. What is meant by waves?

Ans. The disturbance which carries energy and momentum from one point in space to another point in space without the transfer of the medium is known as a wave.

2. Write down the types of waves.

Ans. waves can be classified into two types

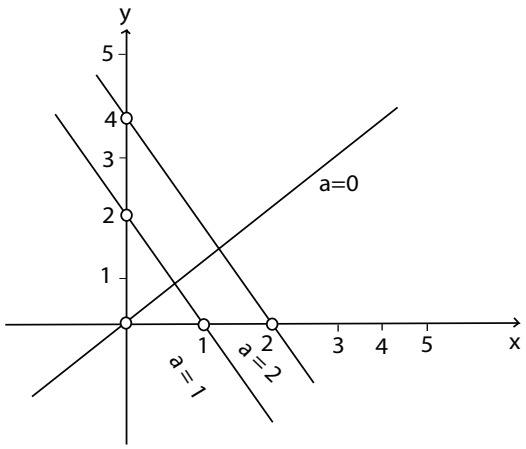
1. Transverse waves
2. Longitudinal waves

3. What are transverse waves? Give one example.

Ans. In transverse wave motion, the constituents of the medium oscillate or vibrate about their mean positions in a direction perpendicular to the direction of propagation (direction of energy transfer) of waves.

Example: light (electromagnetic waves)

when a = 2; x = 2; y = 2 + 2 = 4



Explanation:

This implies, when increasing the value of a, the line shifts towards right side at a = 0, and line shifts towards left side at a = 1, 2, …. For a = vt, y = x – vt satisfies the differential equation. Though this function satisfies the differential equation, it is not finite for all values of x and t. Hence it does not represent a waves.

14. Write down the factors affecting velocity of sound in gases. *(Mar-2020)*

Ans. **(i)** Effect of Pressure
(ii) Effect of Temperature
(iii) Effect of Density
(iv) Effect of Moisture (humidity)
(v) Effect of Wind

15. What is meant by an echo? Explain.

Ans. An echo is a repetition of sound produced by the reflection of sound waves from a wall, mountain or other obstructing surfaces. The speed of sound in air at 20°C is 344 $m\ s^{-1}$. If we shout at a wall which is at 344 m away, then the sound will take 1 second to reach the wall. After reflection, the sound will take one more second to reach us. Therefore, we hear the echo after two seconds.

Scientists have estimated that we can hear two sounds properly if the time gap or time interval between each sound is $\left(\frac{1}{10}\right)^{\text{th}}$ of a second (persistence of hearing) i.e., 0.1 s. Then,

$$\text{Velocity} = \frac{\text{Distance travelled}}{\text{time taken}} = \frac{2d}{t}$$

$$2d = 344 \times 0.1 = 34.4 \text{ m}$$
$$d = 17.2 \text{ m}$$

The minimum distance from a sound reflecting wall to hear an echo at 20°C is 17.2 meter.

III. Long Answer Questions

1. Discuss how ripples are formed in still water.

Ans. A stone is dropped in a trough of still water, we can see a disturbance produced at the place where the stone strikes the water surface is seen. This disturbance spreads out (diverges out) in the form of concentric circles of ever increasing radii (ripples) and strike the boundary of the trough. This is because **some of the kinetic energy of the stone is transmitted to** the water molecules on the surface. Actually the particles of the water (medium) themselves do not move outward with the disturbance. This can be observed by keeping a paper strip on the water surface. The strip moves up and down when the disturbance (wave) passes on the water surface. This shows that the water molecules only undergo vibratory motion about their mean positions.

2. Briefly explain the difference between travelling waves and standing waves.

Ans.

S. No	Travelling Waves (or) Progressive Waves	Standing Waves (or) Stationary Waves
	Crests and troughs are formed in transverse progressive waves, and compression and rarefaction are formed in longitudinal progressive waves. These waves move forward or backward in a medium i.e., they will advance in a medium with a definite velocity.	Crests and troughs are formed in transverse stationary waves, and compression and rarefaction are formed in longitudinal stationary waves. These waves neither move forward nor backward in a medium i.e., they will not advance in a medium.
2.	All the particles in the medium vibrate such that the amplitude of the vibration for all particles is same.	Except at nodes, all other particles of the medium vibrate such that amplitude of vibration is different for different particles. The amplitude is minimum or zero at nodes and maximum at anti-nodes.
3.	These wave carry energy while propagating.	These waves do not transport energy.

Conceptual Questions

1. Why is it that transverse waves cannot be produced in a gas? Can the transverse waves be produced in solids and liquids?

Ans. Transverse waves travel in the form of crests and troughs and so involve change in shape. As gas has no elasticity of shape, transverse waves cannot be produced in it.

Yes. solids and liquid have elasticity so transverse wave can be produced.

2. Why is the roar of our national animal different from the sound of a mosquito?

Ans. Roaring of a national animal (tiger) produces a sound of low pitch and high intensity or loudness, whereas the buzzing of mosquito produces a sound of high pitch and low intensity or loudness.

3. A sound source and listener are both stationary and a strong wind is blowing. Is there a Doppler effect?

Ans. Yes. It does not matter whether there is sound source or transmission media in motion.

4. In an empty room why is it that a tone sounds louder than in the room having things like furniture etc.

Ans. Sound is a form of energy. The furniture which act as obstacles absorbs most of the energy. So the intensity of sound become low but in empty room, due to the absence of obstacles the intensity of sound remain mostly same and we feel it louder.

5. How do animals sense impending danger of hurricane?

Ans. Some animals are believed to be sensitive to low frequency sound waves emitted by hurricanes. They can also detect the slight fall in air pressure and water pressure that signal a storm's approach.

6. Is it possible to realize whether a vessel kept under the tap is about to fill with water?

Ans. The frequency of the note produced by an air column is inversely proportional to its length. As the level of water in the vessel rises, the length of the air column above it decreases. It produces sound of decreasing frequency. i.e., the sound becomes shorter. From the shrillness of sound, it is possible to realize whether the vessel is filled with water.

$v_{min} = 11.71\ ms^{-1}$.

★★★★★

Register Number | | | | | | | |

11th STD.

INSTANT SUPPLEMENTARY EXAM - AUGUST 2022

Part - III

PHYSICS

(With Answers)

TIME ALLOWED : 3.00 HOURS] [MAXIMUM MARKS : 70

Instructions : (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART - I

Note : (1) Answer **all** the questions. **(15 × 1 = 15)**

(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. A ball of mass 1 kg and another of mass 2 kg are dropped from a tall building whose height is 80 m. After a fall of 40 m each towards Earth, their respective kinetic energies will be in the ratio of

(a) $\sqrt{2}$:1 (b) 1 : $\sqrt{2}$ (c) 2 : 1 (d) 1 : 2

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

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

3. A pendulum is hung in a very high building oscillates to and fro motion freely like a simple harmonic oscillator. If the acceleration of the bob is 16 ms^{-2} at a distance of 4 m from the mean position, then the time period is

(a) 2 s (b) 1 s (c) 2πs (d) πs

4. g_e and g_p donote the acceleration due to gravity in the Earth and a planet. The mass and radius of the planet are twice that of the Earth. Then _____.

(a) $g_p = \frac{g_e}{2}$ (b) $g_p = 2g_e$

(c) $g_p = g_e$ (d) $g_p = \frac{g_e}{\sqrt{2}}$

5. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force 30 N?

(a) 0.25 rad s^{-2} (b) 25 rad s^{-2}

(c) 5 ms^{-2} (d) 25 ms^{-2}

6. When a cycle tyre suddenly bursts, the air inside the tyre expands. This process is :

(a) Isothermal (b) Adiabatic

(c) Isobaric (d) Isochoric

7. If a particle executes uniform circular motion, choose the correct statement

(a) The velocity and speed are constant

(b) The acceleration and speed are constant.

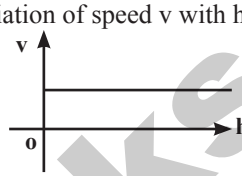
(c) The velocity and acceleration are constant.

(d) The speed and magnitude of acceleration are constant.

8. An object of mass 10 kg is hanging on a spring scale which is attached to the roof of a lift. If the lift is in free fall, the reading in the spring scale is :

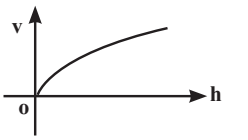
(a) 98 N (b) Zero (c) 49 N (d) 9.8 N

9. A uniform rope having mass m hangs vertically from a rigid support. A transverse wave pulse is produced at the lower end. Which of the following plots shows the correct variation of speed v with height h from the lower end?

(a) 

(b) 

(c) 

(d) 

10. If an object is at rest and no external force is applied on the object, the static friction acting on the object is :

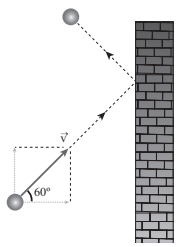
(a) zero (b) μ_s mg

(c) μ_s mg sin θ (d) μ_s mg cos θ

11. In a horizontal pipe of non-uniform cross section, water flows with a velocity of 1 ms^{-1} at a point where the diameter of the pipe is 20 cm. The velocity of water (1.5 ms^{-1}) at a point where the diameter of the pipe is (in cm)

(a) 8 (b) 16 (c) 24 (d) 32

12. A particle of mass m is moving with speed u in a direction which makes 60° with respect to x axis. It undergoes elastic collision with the wall. What is the change in momentum in x and y direction?



(a) $\Delta p_x = -mu; \Delta p_y = 0$

(b) $\Delta p_x = -2mu; \Delta p_y = 0$

(c) $\Delta p_x = 0; \Delta p_y = mu$

(d) $\Delta p_x = mu; \Delta p_y = 0$

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

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

(c) torque and power (d) force and torque

14. A book is at rest on the table which exerts a normal force on the book. If this force is considered as reaction force, what is the action force according to Newton's third law?

(a) Gravitational force exerted by Earth on the book

(b) Gravitational force exerted by the book on Earth

(c) Normal force exerted by the book on the table

(d) None of the above

15. In stationary waves, the distance between a node and its neighbouring anti-node is :
(a) $\frac{\lambda}{4}$ (b) $\frac{\lambda}{2}$ (c) $\frac{3\lambda}{4}$ (d) λ

PART - II

Note: Answer **any six** questions. Q.No **24** is **compulsory**. **(6 × 2 = 12)**

16. Write any two limitations of dimensional analysis?
17. What is meant by Escape speed in the case of the Earth?
18. A mobile phone tower transmits a wave signal of frequency 900 MHz. Calculate the length of the waves transmitted from the mobile phone tower.
19. State Stefan - Boltzmann Law.
20. Define centre of mass.
21. What is meant by periodic and non-periodic motion?
22. state Hooke's Law of Elasticity.
23. Define Inertia.
24. Consider two trains A and B moving along parallel tracks with same velocity in the same direction. Let the velocity of each train be 50km / hr due east. Calculate the relative velocities of the trains.

PART - III

Note: Answer **any six** questions. Q. No **33** is **compulsory.** **(6 × 3 = 18)**

25. State Newton's three laws of motion.
26. An electron of mass 9.1×10^{-31} kg revolves around a nucleus in a circular orbit of radius 0.53Å. What is the angular momentum of the electron? (Velocity of electron $v = 2.2 \times 106$ ms^{-1})
27. Distinguish between streamlined flow and turbulent flow.
28. What is meant by Gross Error? How shall we minimize it?
29. Derive an expression for Energy of Satellite.
30. Show that path of a projectile is a parabola in horizontal projection.
31. Derive the relation between momentum and kinetic energy.
32. State the laws of Simple Pendulum.
33. During a cyclic process, a heat engine absorbs 500 J of heat from a hot reservoir, does work and ejects an amount of heat 300 J into the surroundings (Cold reservoir). Calculate the efficiency of the heat engine.

PART - IV

Note: Answer **all** the questions. **(5 × 5 = 25)**

34. (a) Derive an expression for moment of Inertia of a rod about its centre and perpendicular to the axis of the rod.
(OR)
(b) What is a Sonometer? Give its construction and working. Explain how to determine the frequency of tuning fork using sonometer.
35. (a) What is Inelastic collision? Derive an expression for loss of kinetic energy in perfect inelastic collision.
(OR)
(b) Explain in detail the kinetic interpretation of temperature.
36. (a) Explain in detail about the Newton's Law of cooling.
(OR)
(b) Describe the method of measuring angle of repose.
37. (a) Explain in detail the Triangle Law of Vector Addition.
(OR)
(b) Derive Poiseuille's formula for the volume of a liquid flowing per second through a pipe under streanlined flow.
38. (a) Write a note on Triangulation method and radar method to measure larger distances.
(OR)
(b) Explain the variation of 'g' with depth from the Earth's surface.

ANSWERS

PART - I

1. (d) 1 : 2
2. (b) 78.4 m
3. (d) πs
4. (a) $g_p = \frac{g_e}{2}$
5. (a) 0.25 rad s^{-2}
6. (b) Adiabatic
7. (d) The speed and magnitude of acceleration are constant.
8. (b) Zero
9. (d) 

10. (a) zero
11. (b) 16
12. (a) $\Delta p_x = -mu$; $\Delta p_y = 0$
13. (b) torque and energy
14. (c) Normal force exerted by the book on the table
15. (a) $\frac{\lambda}{4}$

PART - II

16. (i) This method gives no information about the dimensionless constants in the formula like 1, 2, ……..π, e (Euler number), etc.
(ii) This method cannot decide whether the given quantity is a vector or a scalar.
17. The escape speed is independent of the direction in which the object is thrown. Irrespective of whether the object is thrown vertically up, radially outwards or tangentially it requires the same initial speed to escape Earth's gravity.
This can be written as, ve = $\sqrt{2gR_E}$
18. Frequency, $f = 900$ MHz $= 900 \times 10^6$ Hz
The speed of wave is $c = 3 \times 10^8$ ms^{-1}
$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{900 \times 10^6} = 0.33$ m