Integrated Syllabus
USEFUL FOR ALL BOARDS

IIT FOUNDATION & OLYMPIAD

EXPLORER

CLASS - IX

BRAIN MAPPING ACADEMY

Be Early! Be Smart!

PHYSICS

IIT FOUNDATION & OLYMPIAD

EXPLORER

PHYSICS

CLASS - IX

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Preface

Speed and accuracy play an important role in climbing the competitive ladder. Students have to integrate the habit of being able to calculate and function quickly as well as efficiently in order to excel in the learning culture. They need to think on their feet, understand basic requirements, identify appropriate information sources and use that to their best advantage.

The preparation required for the tough competitive examinations is fundamentally different from that of qualifying ones like the board examinations. A student can emerge successful in a qualifying examination by merely scoring the minimum percentage of marks, whereas in a competitive examination, he has to score high and perform better than the others taking the examination.

This book provides all types of questions that a student would be required to tackle at the foundation level. The questions in the exercises are sequenced as *Basic Practice, Further Practice, Multiple Answer Questions, Paragraph Questions, Numerical Problems, Conceptual Questions and Brain Nurtures.* Simple questions involving a direct application of the concepts are given in *Basic Practice.* More challenging questions on direct application are given in *Further Practice.* Questions involving higher order thinking or an open-ended approach to problems are given in *Brain Nurtures.* These questions encourage students to think analytically , to be creative and to come up with solutions of their own. Constant practice and familiarity with these questions will not only make him/her conceptually sound, but will also give the student the confidence to face any entrance examination with ease.

Valuable suggestions as well as criticism from the teacher and student community are most welcome and will be incorporated in the ensuing edition.

Publisher

CONTENTS

Chapter 1

Measurement

Common misconception	Fact
1. Parallactic second is commonly understood, as a unit of time.	1. It is the distance at which an arc of length one astronomical unit subtends an angle of one second of an arc. 1 parsec = 3.08×10^{16} m
2. Weight is generally expressed in terms of gmwt, kgwt	2. Atomic weight and molecular weights are relative masses and are mere numbers. For example, the atomic weight of oxygen is 16. This means that weight of oxygen is 16 times heavier than $1/12^{th}$ of the mass of C^{12} isotope of carbon.
3. Volt is associated commonly with electrical potential so electron volt is misunderstood as the unit of potential	3. Electrovolt is the smallest unit of energy.

SYNOPSIS

INTRODUCTION

Physics is a branch of science that describes the physical state of matter and universe. In describing the physical state, one needs to involve in measuring various physical quantities. Hence, in the study of physics, measurement is one of the inevitable part. Apart from measuring one needs to identity the physical quantities involved, the proper devices used to measure them, the units involved and the techniques for their accurate measurement.

Physical Quantity

Any quantity which can be measured is called a physical quantity.

Example

length, mass, time, force etc.,

Standard unit

To measure a physical quantity, we need a standard of the same quantity called a unit. The measurement of a physical quantity means to express the number of times its standard unit contained in that physical quantity. A standard unit must be possible to be defined without any ambiguity and any change with respect to space and time.

Types of physical quantities

Physical quantities are classified into two types:

1. Fundamental quantities

The physical quantities which does not depend on other physical quantities are called fundamental quantities. For example length, mass, time etc.,

Fundamental units

The units used to measure fundamental quantities are called fundamental units. For example metre, kilogram, second etc.,

2. Derived quantities

The physical quantities which are derived from the fundamental quantities are called derived quantities.

Example

1. $\text{Density} = \dfrac{\text{mass}}{\text{volume}}$

2. $\text{Velocity} = \dfrac{\text{displacement}}{\text{time}}$

3. $\text{Acceleration} = \dfrac{\text{change in velocity}}{\text{time}}$

Derived Units

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

Example

SI unit of density is kg m^{-3}, velocity is m s^{-1}, acceleration is m s^{-2}

System of units

Types of system of units	Mass	Length	Time
CGS system	gram (g)	centimetre (cm)	second (s)
MKS system	kilogram (kg)	metre (m)	second (s)
FPS system	pound (P)	foot (F)	second (s)
SI system	kilogram (kg)	metre (m)	second (s)

The S.I. system contains seven fundamental quantities with their units and two supplementary quantities with their units.

The following table shows the fundamental quantities and their units in S.I. system.

	Physical Quantity	Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Temperature	kelvin	K
5.	Luminous intensity	candela	Cd
6.	Electric current	ampere	A
7.	Amount of substance	mole	mol
Supplementary Quantities		**Unit**	**Symbol**
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

Obtaining units of a derived quantities

The unit of a physical quantity can be obtained with the help of its formula or expression.

How to obtain:

1. Write the measuring formula of the physical quantity.
2. Check the terms present in the measuring formula.
3. Substitute the units of the terms identified.

Rules of writing units

1. Full stop or punctuation mark should not be used within or at the end of symbol of unit.

   Example

   10 kg but not 10 kg.
2. Plural form should not be used in units.

   Example

   10 kg but not 10 kgs.
3. Full names of units named after scientists should not be written with initial lower case letter.

   Example

   newton but not SIR Isaac Newton or Newton
4. The capital letter should be taken as a symbol for the unit named after a scientist.

   Example

   A for ampere, N for newton.
5. Compound prefixes should be avoided.

   Example

   pF for picofarad but not μμf.

Some interesting units

1. Units named after scientists

Force – newton	–	N
Energy – joule	–	J
Power – watt	–	W
Pressure – pascal	–	Pa
Charge – coulomb	–	C
Frequency – hertz	–	Hz
Potential – volt	–	V
Current – ampere	–	A

2. Though rainfall is a liquid, it is not measured in litres but is measured in millimetres.
3. Size of atom is measured in Angstrom (A°) whereas size of nucleus is measured in fermi.

   1 A° = 10^{-10} m, 1 fermi = 10^{-15} m
4. Though the SI unit of pressure is N m^{-2}, we also measure pressure in (a) mm of Hg (b) pascal (c) atmosphere (d) torr

   1 pascal = 1 N m^{-2}, 1 atm = 760 mm of Hg = 1.013×10^6 dynes cm^{-2} =1.1013×10^5 N m^{-2}, 1 torr = 1 mm of Hg
5. The loudness of sound is measured in decibels.
6. The units used in air and sea navigation is nautical mile.

   1 nautical mile = 1852 m
7. To measure very heavy objects or a large amount of mass, the units quintal or metric ton are used.

   1 metric ton = 1000 kg 1 quintal = 100 kg
8. Solar day is the time taken by the earth to complete one revolution around the sun.

   1 Solar day = 86400 s
9. Lunar Month is the time taken by the moon to complete one revolution around the sun.

   1 Lunar month = 27.3 solar days
10. Horse Power is a practical unit of power.

    1 HP = 746 watt

Conversion of units

Conversion of units is done in two ways

1. Conversion of bigger units into smaller units and vice versa.
2. Conversion from one system of units to another.

Conversion of bigger units into smaller units and vice versa

For this we need to know certain prefixes which are given below.

Positive multiples of 10	Prefix	Symbol	Negative multiples of 10	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

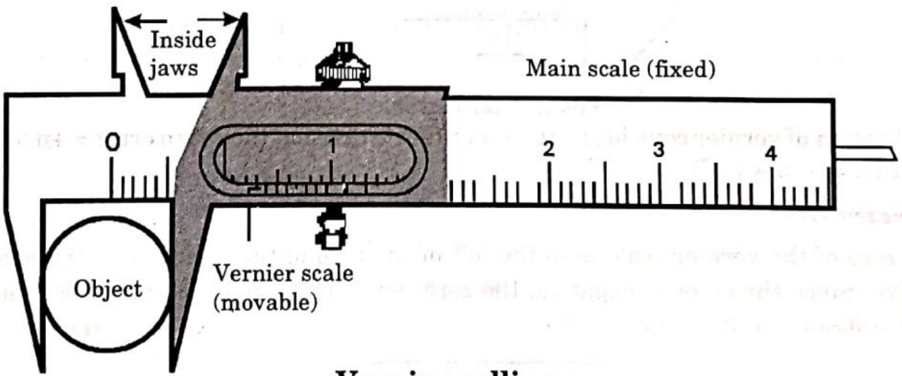
MEASUREMENT OF LENGTH

Length is one of the fundamental quantity. It is the distance between any two fixed points either in a straight or a curved path. The SI unit of length is metre. The other units usually used are km, cm, mm etc.,

Metre scale, vernier calipers, screw gauge are common devices used to measure length. A metre scale can measure a length of 1 mm accurately i.e. least count is 1 mm.

VERNIER CALIPERS

Vernier callipers is an instrument used to measure the length of small objects. The instrument was designed in the year 1630 by the French mathematician Vernier.



Vernier callipers

Principle of vernier callipers

Let the length of one main scale division be 1 M.S.D. Consider 'n' number of divisions on the vernier such that the length of n divisions are equal to (n – 1) M.S.D.

$$n \text{ V.S.D} = (n-1) \text{ M.S.D}$$

$$\therefore \text{ Least count} = \frac{1}{n} \times \text{value of one main scale division.}$$

Least count

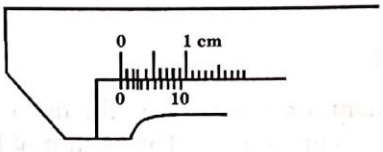
The Least Count (L.C) or vernier constant of a vernier is the smallest length that can be accurately measured with it and is equal to the difference between a Main Scale Division (M.S.D) and a Vernier Scale Division (V.S.D).

L.C = 1 M.S.D – 1 V.S.D

Least count = 0.1 mm or 0.01 cm

Zero Error

When the two jaws of a vernier calipers are brought in contact with each other, then the zero of the vernier should coincide with the zero of the main scale. Sometimes they may not coincide. In such case, we say that the instrument has a zero error.

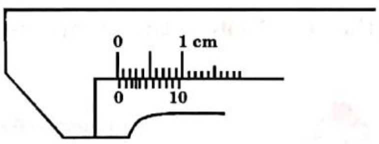


No zero error

There are two kinds of zero errors namely positive zero error and negative zero error.

Positive zero error

If the zero of the vernier scale is to the right of the zero of the main scale, the error is positive. Since the zero error is positive, the zero correction is negative, because measured length is more than the actual length.

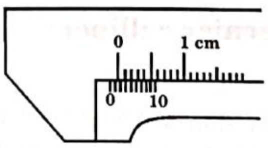


Positive zero error

If n^{th} division of vernier coincides with a main scale division then zero error = +n × L.C., correction = – (n × L.C)

Negative zero error

If the zero of the vernier scale is to the left of the zero of the main scale, the error is negative. Since the error is negative, the zero correction is positive, because measure length is less than the actual length.



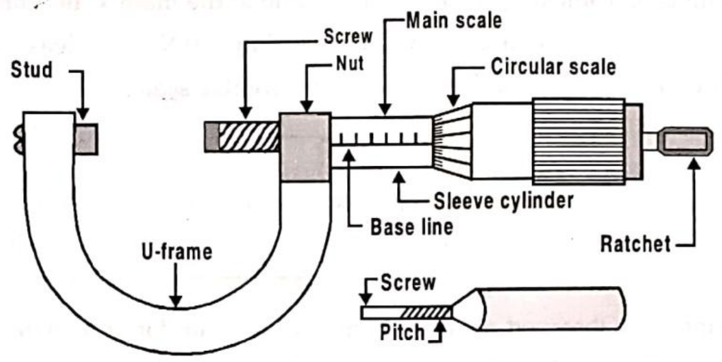
Negative zero error

If the n^{th} division of the vernier coincides with a main scale division, then the zero error = – (N – n) L.C.

Correction = +(N – n) L.C.

SCREW GUAGE

A screw gauge works on the principle of a screw in a nut.



Screw gauge

Pitch of the Screw

It is the distance travelled by the tip of the screw for one complete rotation of its head.

$$\text{Pitch of the screw} = \frac{\text{distance travelled by the screw}}{\text{number of rotations}} = \frac{x}{n} = P$$

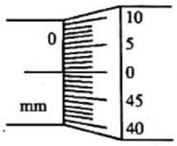
Now the diameter (or) thickness of the object is given as;

$$d = P.S.R. + [(H.S.R.) \times L.C]$$

Same units must be used for both the measurements.

Zero error

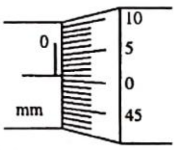
When the stud and the tip of the screw of a screw gauge are in contact with each other, the zeroes of the head scale should coincide with the index line. If this does not happen, then the instrument is said to have a **zero error.**



No Zero Error

Positive zero error

If the zeroth division of the circular scale is 'below' the reference (index) line of the main scale, the error is said to be positive and the correction is negative.



Positive Error

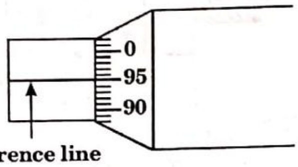
Zero error = +n × least count and the correction = –n × least count.

Negative zero error

Similarly, if the zeroeth division of the circular scale is 'above' the reference line of the main scale, the error is said to be negative and the correction is positive. If n is the circular scale division coinciding with the index line of the main scale, then the

Zero error = – (N – n) × least count and the correction = +(N – n) × least count

Where 'N' is the total number of divisions on the circular scale.



True measurement = Observed measurement + Correction for zero error.

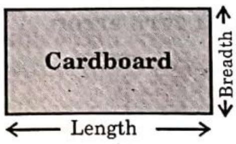
Observed measurement = (M.S.R.) + (H.S.R. × L.C.)

Back-lash Error

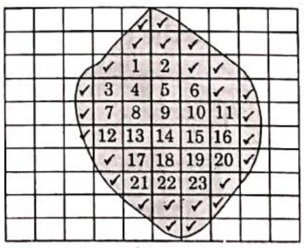
Sometimes the tip of screw does not move backward for a part of rotation of head in reverse direction because of wear and tear of threads. This is called backlash error. The backlash error can be avoided by not rotating the head in the reverse direction once the object is held between the two studs.

MEASUREMENT OF AREA

Area is a derived quantity, that is obtained by multiplying the two measurements of a regular body. For example the area of a rectangle is calculated as the product of its length and breadth. The SI unit of area is m^2 or square metre. The other units of area are cm^2, mm^2, km^2 etc.,



The area of an irregular object can be calculated by drawing the outline of its shape on a graph paper. The number of complete squares are calculated, next the squares greater than half are also counted as a square, leaving the squares less than half. The sum of all the squares gives the area of leaf to be that many cm^2



MEASUREMENT OF VOLUME

Volume is the space occupied by an object. The SI unit of volume is m^3 or cubic metre. The other units of volume are cm^3, ml, l etc.,

$1\ ml = 1\ cm^3$

$1\ ml = 10^{-6}\ m^3$

$1\ l = 10^3\ cm^3 = 10^3\ ml$

$1\ l = 10^{-3}\ m^3$

Volume of regular bodies can be calculated by measuring the dimensions necessary for the calculations. The volume of a cube is given by $(side)^3$.

Volume of Liquids

Volume of liquids can be measured using the following apparatus.

Measuring Jar

It is graduated in ml from bottom to top and used to measure required amount of liquid.

Measuring Flask

It has one mark etched on neck and the liquid of only volume of its capacity can be measured.

Pipette

It is filled by sucking the liquid into it. It is used to take up only a fixed amount of liquid.

Burette

It resembles a measuring jar with a pitch cock provided at the bottom. It is used to take desired amount of liquids.

Volume of Irregular Solids

1. *To find the volume of solid insoluble in water but heavier than water*

(a) Take some water in a measuring jar.

(b) Let the volume of water taken be $V_1\ cm^3$

(c) Now immerse the solid completely in water using a string.

(d) Note the level of water, let it be $V_2\ cm^3$

(e) So, volume of solid = $(V_2 - V_1)\ cm^3$

2. *To find the volume of solid insoluble in water but lighter than water*

(a) Take some water in a measuring jar along with a sinker.

(b) Let the volume of water along with the sinker taken be $V_1\ cm^3$

(c) Now tie the solid to the sinker and immerse completely into water using a string.

(d) Note the level of water, let it be $V_2\ cm^3$

(e) So, volume of solid = $(V_2 - V_1)\ cm^3$

3. *To find the volume of single drop of water*

(a) Take a clean burette with water, clamp it upright.

(b) Remove any air bubbles formed.

(c) Now allow water to trickle slowly drop by drop, count number of drops when known volume of water has been drained out.

(d) Therefore, average volume of a single drop = $\dfrac{\text{volume of water drained out}}{\text{number of drops}}$

4. *To find the average volume of lead shots*

(a) Take a measuring jar with water of volume V_1 cm^3

(b) Drop n number of lead shots into the water and note the final level of water as V_2 cm^3

(c) Therefore, average volume of lead shot = $\left(\dfrac{V_2 - V_1}{n}\right) cm^3$

MEASUREMENT OF MASS

Mass is the quantity of matter present in a body. The SI unit of mass is kilogram. The other units used to measure mass are mg, quintal, tonne, etc.,

Common balance, physical balance are commonly used to measure mass of a body which work on the principle of moments.

WEIGHT

The force of gravity with which a body is pulled towards the centre of the earth.

Weight (w) = mass (m) × acceleration due to gravity (g)

$g = 9.8 \text{ m s}^{-2}$

The SI unit of weight is newton (N). The other units are kgwt, kgf, dynes.

1 kgwt = 1 kgf = 9.8 N

1 N = 10^5 dynes

A spring balance is used to measure the weight of a body.

DENSITY

It is defined as mass per unit volume of the substance. Density is a derived unit. It is a scalar quantity.

Measuring formula

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{i.e., } d = \frac{M}{V}$$

Units

S.I. unit of density is $kg\ m^{-3}$

C.G.S unit of density is $g\ cm^{-3}$

$1\ kg\ m^{-3} = 10^{-3}\ g\ cm^{-3}$

Relation between the SI and CGS units

$$1\ kg\,m^{-3} = \frac{1\ kg}{1\ m^3} = \frac{1\ kg}{1\ m \times 1\ m \times 1\ m} = \frac{1000\,g}{100\,cm \times 100\,cm \times 100\,cm} = \frac{1g}{1000\,cm^3}$$

$$\therefore\ 1\ kg\,m^{-3} = \frac{1}{1000}\,g\,cm^{-3} \text{ or } 1\ g\ cm^{-3} = 1000\ kg\ m^{-3}$$

$\therefore$ Density of a substance in SI system = 1000 × density of the substance in CGS system.

RELATIVE DENSITY

It is the ratio of the density of the substance to the density of water at 4° C.

$$\text{Relative density (R.D.)} = \frac{\text{density of the substance}}{\text{density of water at } 4^\circ C}$$

$$= \frac{\text{mass of the substance}}{\text{volume of the substance}} \div \frac{\text{mass of water at } 4^\circ C}{\text{volume of water at } 4^\circ C}\left[D = \frac{M}{V}\right]$$

Relative density does not have any units.

MEASUREMENT OF TIME

Time is the interval between two events. SI unit of time is second. The other units to measure time are hour, minute, century, decade etc.,

1 h= 3600 s	1 century = 100 years	1 millineium = 1000 years
1 min = 60 s	1 decade = 10 years	

Simple pendulum is one of the devices used to measure time.

General terms related to Simple Pendulum:

1. ***Length of the bob***
   The distance between the point of suspension of the bob to the centre of the bob.
2. ***Frequency***
   The number of oscillations made in one second.
3. ***Time period***
   The time taken to complete one oscillation.
4. ***Amplitude***
   The maximum displacement of the bob, from the mean position

LAWS OF SIMPLE PENDULUM

1. The time period of a simple pendulum of constant length is independent of the amplitude of the bob (provided the angular amplitude of the bob is very small)
2. The time period of a simple pendulum of constant length is independent of the size, shape, mass and material of the bob.
3. The time period of a simple pendulum of constant length is directly proportional to the square root of the length of the simple pendulum.

   Let a simple pendulum of length l executes oscillations whose time period is T then

$$T \propto \sqrt{l}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{l}{g}}$$ Where, g = acceleration due to gravity of earth

SIGNIFICANT FIGURES

In each numerical data either exact numbers or measured numbers (quantities) are specified. Exact numbers are those without any uncertainty or error.

The error or uncertainty of the results of a mathematical operation may be computed by statistical methods. A simple procedure for estimating this uncertainty involves the use of significant figures (sf). The degree of accuracy of a measured quantity depends on how finely divided the measuring scale of the instrument is, e.g., you might measure the length of an object as 3.5 cm with one instrument and 3.54 cm with another; the second instrument provides more significant figures and a greater degree of accuracy.

In general, the number of significant figures of a numerical quantity is the number of reliably known digits it contains.

The following rules are used while writing significant figures

1. Zeros at the beginning of a number are not significant. They merely locate the decimal point. 0.0254 m three significant figures (2, 5, 4)
2. Zeros within a number are significant. 104.6 m four significant figures (1, 0, 4, 6)
3. Zeros at the end of a number after the decimal point are significant. 2705.0 m five significant figures (2, 7, 0, 5, 0)
4. In whole numbers without a decimal point that end in one or more zeros, e.g., 500 kg– the zeros may or may not be significant.

The rules for rounding off numbers are as follows

1. If the next digit after the last significant figure is 5 or greater, round up : Increase the last significant figure by 1 (*e.g.*, 2.136 becomes 2.14 rounded to 3 significant figures.)
2. If the next digit after the last significant figure is less than 5, round down : Do not change the last significant figure. (*e.g.*, 2.132 becomes 2.13 rounded to 2 significant figures.)

SOLVED EXAMPLES

Example 1:

Find the CGS unit of force

Solution:

1. Force = mass × acceleration.
2. Mass is a fundamental quantity, and acceleration is a derived quantity which can be written as:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

for unit purpose, $\text{acceleration} = \frac{\text{length}}{(\text{time})^2}$

3. Substituting the units of the quantities we have CGS unit of force

$$= \frac{\text{CGS unit of mass} \times \text{CGS unit of length}}{(\text{CGS unit of time})^2} = \frac{\text{g cm}}{\text{s}^2}$$

$\therefore$ CGS unit of force is $\text{g}\frac{\text{cm}}{\text{s}^2}$ which is also named as dyne

Example 2:

If the 3^{rd} division of the vernier coincides with 3^{rd} division of a main scale, then find the correction to be made.

Solution:

Zero correction = – 3 × 0.01 cm = – 0.03 cm

Example 3:

A vernier callipers has 20 divisions on the vernier scale. 1 cm on main scale is divided into 20 equal parts. Find the least count of the vernier.

Solution:

Number of divisions on vernier scale = 20 i.e., N = 20

$$1 \text{ cm} = 20 \text{ divisions}, \ \frac{1 \text{ cm}}{20} = 1 \text{ division}$$

$$\Rightarrow \ 1 \text{ main scale division} = \frac{1}{20} \text{ cm} = 0.05 \text{ cm}$$

Find L.C = ?

$$\therefore \ \text{Least count (L.C)} = \frac{1\text{MSD}}{\text{Number of vernier scale divisions}} = \frac{0.05 \text{ cm}}{20} = 0.0025 \text{ cm}$$

Example 4:

While measuring the length of a chalkpiece by vernier callipers the main scale reading is 4.6 cm and the 6^{th} division on vernier scale is found to coincide with a division on the main scale. Find the length of the chalk, if L.C of vernier is 0.01 cm and zero error is –0.02 cm.

Solution:

M.S.R = 4.6 cm, V.S.D = 6, L.C = 0.01 cm, zero error = -0.02 cm

correct length of chalk = M.S.R + (V.S.D × L.C) ± error

In this case error is negative, then the correction will be positive.

∴ Correct length = M.S.R + (V.S.D × L.C) + correction

= 4.6 cm + (6 × 0.01 cm) + 0.02 cm

= 4.6 cm + 0.06 cm + 0.02 cm = 4.68 cm

Example 5:

Find the least count of a screwgauge whose head scale is divided into 100 divisions and moves 10 mm for 10 rotations of the head.

Solution:

$$\text{Pitch of the screw } P = \frac{x}{n} = \frac{10 \text{ mm}}{10} = 1 \text{ mm}$$

$$\text{Least count} = \frac{\text{pitch of the screw}}{\text{number of head scale divisions}} = \frac{1\text{mm}}{100} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

Example 6:

Find the least count of a screwgauge whose head is divided into 200 divisions and moves through 5 mm for 5 rotations of the head.

Solution:

$$\text{Pitch of the screw} = \frac{x}{n} = \frac{5 \text{ mm}}{5} = 1 \text{ mm}$$

$$\text{Least count} = \frac{\text{pitch of the screw}}{\text{number of head scale divisions}} = \frac{1\text{mm}}{200} = 0.005 \text{ mm} = 0.0005 \text{ cm}$$

Example 7:

While measuring the diameter of a steel ball the following readings were noted :

1. P.S.R. = 8 mm 2. H.S.R. = 42
3. L.C. = 0.01 mm 4. Error = –0.05 mm. Find out the diameter.

Solution:

Correction is + 0.05 mm

Diameter = P.S.R. + (H.S.R. + n) L.C. (or) P.S.R + (H.S.R × L.C.) + Correction

= 8 mm + (42 × 0.01 mm) + 0.05 mm = 8.47 mm

Example 8:

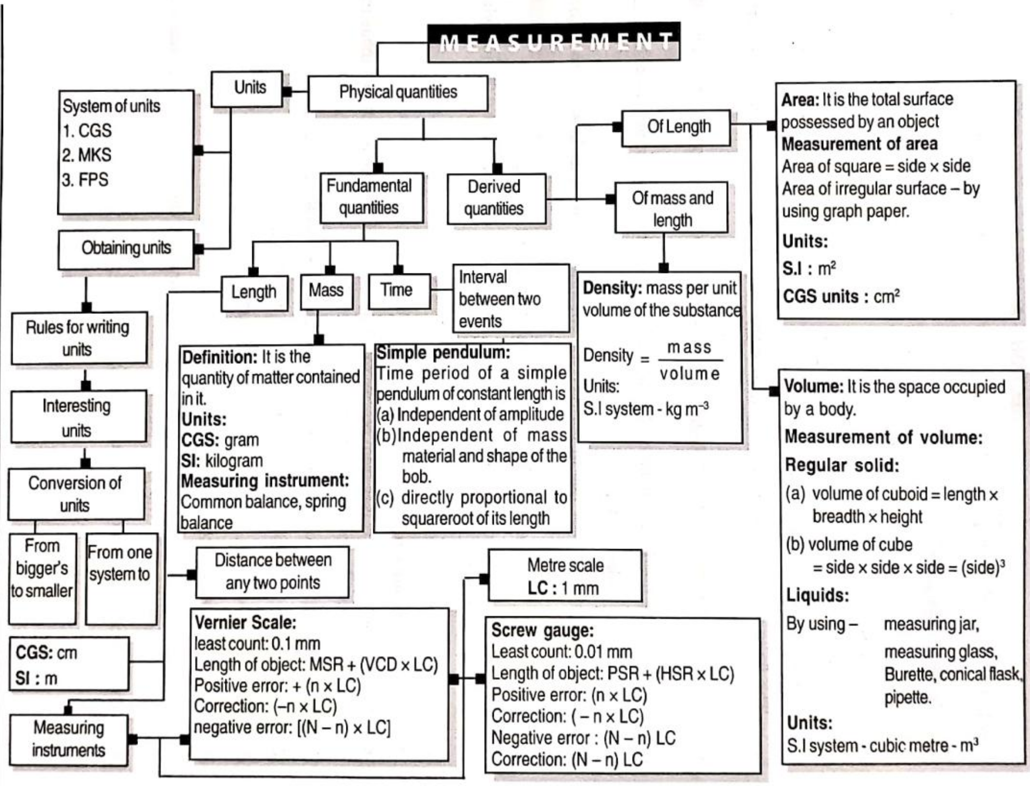
Head of a screw gauge is divided into 50 divisions. It advances 2 mm when screw is turned though 4 rotations. Find the pitch of the screw and L.C. of the instrument.

Solution:

$$\text{Pitch} = \frac{x}{n} = \frac{2 \text{ mm}}{4} = 0.5 \text{ mm}$$

$$\text{L.C.} = \frac{\text{pitch of the screw}}{\text{no. of head scale divisions}} = \frac{0.5 \text{ mm}}{50} = \frac{1}{100} = 0.01 \text{ mm}$$

CONCEPT MAP


MEASUREMENT
Physical quantities
Units
System of units
1. CGS
2. MKS
3. FPS
Obtaining units
Rules for writing units
Interesting units
Conversion of units
From bigger's to smaller
From one system to
CGS: cm
SI : m
Measuring instruments
Fundamental quantities
Derived quantities
Length
Mass
Time
Interval between two events
Definition: It is the quantity of matter contained in it.
Units:
CGS: gram
SI: kilogram
Measuring instrument:
Common balance, spring balance
Simple pendulum:
Time period of a simple pendulum of constant length is
(a) Independent of amplitude
(b) Independent of mass material and shape of the bob.
(c) directly proportional to squareroot of its length
Distance between any two points
Metre scale
LC : 1 mm
Vernier Scale:
least count: 0.1 mm
Length of object: MSR + (VCD × LC)
Positive error: + (n × LC)
Correction: (–n × LC)
negative error: [(N – n) × LC]
Screw gauge:
Least count: 0.01 mm
Length of object: PSR + (HSR × LC)
Positive error: (n × LC)
Correction: (– n × LC)
Negative error : (N – n) LC
Correction: (N – n) LC
Of Length
Of mass and length
Density: mass per unit volume of the substance
Density = mass / volume
Units:
S.I system - kg m⁻³
Area: It is the total surface possessed by an object
Measurement of area
Area of square = side × side
Area of irregular surface – by using graph paper.
Units:
S.I : m²
CGS units : cm²
Volume: It is the space occupied by a body.
Measurement of volume:
Regular solid:
(a) volume of cuboid = length × breadth × height
(b) volume of cube = side × side × side = (side)³
Liquids:
By using – measuring jar, measuring glass, Burette, conical flask, pipette.
Units:
S.I system - cubic metre - m³

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. Volume is a derived quantity of ________.
2. SI unit of energy is ________.
3. A speed of 90 km h^{-1} is equal to ________ m s^{-1}
4. Symbol of candela is ________.
5. The force of gravity with which a body is attracted towards the centre of the earth is ________.
6. The pitch of screw of a screw gauge that advances 5 mm for 5 complete rotations of its head is ________.
7. If zero of the head scale is below the index line, then the error is said to be ________.
8. ________ g make 8.6 tonnes.
9. If the zero of a vernier lies in between 4.6 cm and 4.7 cm on main scale, the MSR is ________.
10. A ________ unit does not change with respect of space and time.
11. The number of divisions on head scale of a screw gauge of least count 0.01 mm with a pitch of 1.2 mm is ________.
12. 1 h 18 min = ________ s
13. ________ decades make 2009 years
14. If the level of water raises from 60 cm^3 to 80 cm^3 on placing a stone x into a measuring jar, then the volume of the stone is ________ litre
15. In a given place, two pendulums of same length, have same ________.
16. The standard quantity used for comparison is called ________.
17. SI unit of density is ________ times its CGS unit.
18. If 1 mg ns^{-1} = 10^x μg ps^{-1}, then the value of x is ________.
19. In a screw gauge, the pitch of the screw is 0.5 mm and the number of circular scale divisions are 50, then the least count is ________.
20. The number of significant figures in 500.06 is ________.

TRUE OR FALSE

21. Smaller the unit of measurement smaller is its numerical value.
22. 10 mN is equal 10^{-3} dynes.
23. Mass of a material varies with temperature.
24. Weight of a body varies from place to place.
25. A measuring jar is graduated in ml from bottom to top.
26. 4.32×10^5 seconds make a week.
27. The ratio of CGS unit of volume to that of SI unit of volume is $1 : 10^6$.
28. An iron ball and a copper ball of same mass can occupy same volume.
29. Light year is the unit of time.
30. An area of one square mm is 10,000 times greater than one square cm.
31. The distance between two atoms in a molecule is measured in order of Angstrom.
32. The total height of 10 identical coins each of thickness 0.5 cm placed one over the other is 50 mm.
33. 10^{-9} mm make 1 km.
34. One metre makes 10^2 cm.
35. Time period of a seconds pendulum is independent of its length.

MATCH THE FOLLOWING

36.

Column A	*Column B*
A. Force	p. $N\ m^{-2}$
B. Energy	q. $J\ s^{-1}$
C. Power	r. $kg\ m\ s^{-2}$
D. Pressure	s. erg
E. Velocity	t. $m\ s^{-1}$

37.

Column A	*Column B*
A. Pressure	p. $\frac{\text{work}}{\text{time}}$
B. Work	q. $\frac{\text{displacement}}{\text{time}}$
C. Velocity	r. mass × acceleration
D. Power	s. force × displacement
E. Force	t. $\frac{\text{force}}{\text{area}}$

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. The time periods of two simple pendulums of different lengths is the same on two different planets. If the lengths of the two pendulums are in the ratio of 1 : 9, then the ratio of the accelerations due to gravity on the two planets is:

   (A) 1 : 3 (B) 1 : 9 (C) 3 : 1 (D) 9 : 1

2. If the length of a seconds pendulum on a planet is 2 m, then the acceleration due to gravity on the surface of that planet is:

   (A) 9.8 m s^{-2} (B) 19.6 m s^{-2} (C) $2\pi^2$ m s^{-2} (D) $4\pi^2$ m s^{-2}

3. 7.9 kg of steel scrap was melted and recast into a cuboid of block 20 cm long, 10 cm wide and 5 cm high. The density of steel is:

   (A) 7.9 kg m^{-3} (B) 7900 kg m^{-3} (C) 7.9 g cm^{-3} (D) 790 kg m^{-3}

4. The diameter of a wire as measured by a screw gauge of pitch 0.5 mm is 8.3 mm. The pitch scale reading is:

   (A) 16 (B) 8 (C) 4 (D) 80

5. If the length of a vernier scale having 25 divisions correspond to 23 main scale divisions, then given that 1 M.S.D = 1 mm, the least count of the vernier calipers is:

   (A) 80 μm (B) 0.04 mm
   (C) 0.08 cm (D) None of the above

6. In a given system of units, the ratio of the unit of volume to the area gives the unit of:

   (A) mass (B) length (C) time (D) temperature

7. Which of the following is not a derived quantity?

   (A) The floor area of a room (B) The height of a room
   (C) The volume of air in a room (D) The weight of air in a room

8. The volume of a single liquid drop can be measured using a:

   (A) measuring jar (B) measuring flask (C) pipette (D) burette

9. Which of the following is the CGS unit of relative density?

   (A) kg m^2 s^{-2} (B) kg m^{-3}
   (C) g cm^{-3} (D) None of the above

10. If the units of length and time are doubled, the unit of speed:

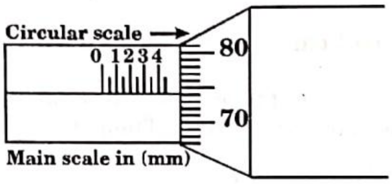
    (A) doubles (B) gets halved
    (C) becomes one–third (D) remains constant

11. The number of significant figures in 10.02 is:
(A) 1 (B) 2 (C) 3 (D) 4

12. The least count of a vernier calipers having 20 vernier divisions when 1 M.S.D. = 0.1 cm is:
(A) 0.5 mm (B) 0.05 cm (C) 0.05 mm (D) 0.5 cm

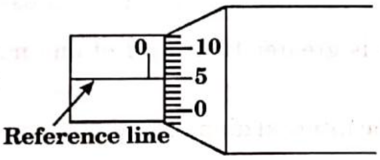
13. If the time taken by the bob of a simple pendulum to go from one extreme position to the other extreme position is 0.75 s, the time period of the pendulum is:
(A) 1.5 s (B) 0.75 s (C) 0.375 s (D) 3 s

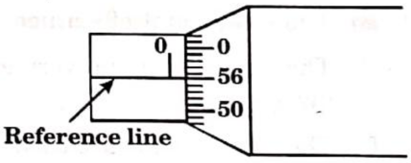
14. The number of significant figures of 0.0632 m is:
(A) 5 (B) 4 (C) 3 (D) 2

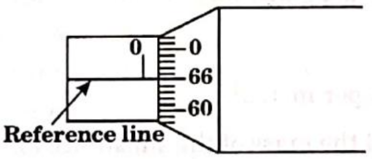
15. 

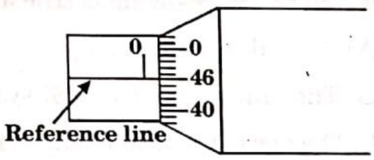
In the above figure division indicated as 1, 2, 3 .... represents mm then M.S.R is:
(A) 4 mm (B) 4.5 mm (C) 4.2 mm (D) 4.3 mm

16. The figures shown in options represent the position of zero's of headscale and pitch scale when two studs are in contact with each other. Which of the following figures has positive zero error?

(A) 

(B) 

(C) 

(D) 

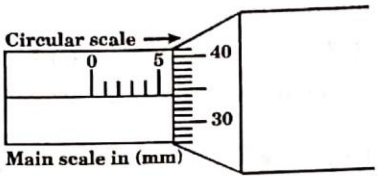
17. A screw gauge has a negative zero error. Which is correct among these ?
[Hint : n is the total number of circular scale divisions]

(A) Correction = – coinciding division of C.S × L.C

(B) Correction = + coinciding division of C.S × L.C

(C) Correction = + [[n – coinciding division of C.S] × L.C]

(D) Correction = + [[n + coinciding division of C.S] × L.C]

18. 

The figure shows a screw gauge in which circular scale has 200 divisions. Then the radius of the wire is:

(A) 0.02585 cm (B) 25.85 cm (C) 2.585 cm (D) 0.2585 cm

19. If 6 mm is the distance moved by the thimble on the main scale for 6 rotations then pitch of the screw is:

(A) 1 mm (B) 1 cm (C) 0.1 mm (D) 0.01 cm

20. The circular scale of a screw gauge has 100 divisions. Its spindle moves forward by 2.5 mm when given five complete turns. Then the least count of screw gauge is:

(A) 0.005 cm (B) 0.005 mm (C) 0.0005 mm (D) 0.0005 cm

MULTIPLE ANSWER QUESTIONS

1. Choose the correct statement from the following options.

(A) If the zeroeth division of the vernier and main scales of a standard vernier callipers coincide then measured length is equal to the actual length.

(B) The least count of vernier scale is 0.9 mm.

(C) The length of a one vernier scale division is greater than that of one main scale division.

(D) The internal jaws are used for measuring the internal diameter of a hollow cylinder.

2. Which of the following is true about the density of a substance?

(A) It is a derived quantity.

(B) The unit of density in SI system is kilogram per metre^3.

(C) The density of a substance can be measured if the mass of the substance for a certain volume is known.

(D) Density is a vector quantity

3. Among the following identify the derived quantities.

(A) Gravitational constant (B) Frequency

(C) Electric charge (D) Electric current

4. The unit for power is:

(A) $J\ s^{-1}$ (B) $g\ m^2\ s^{-3}$ (C) $kg\ cm^2\ s^{-3}$ (D) $dyne\ s^{-2}$

5. Which of the following statements below should be used while using the symbol for a unit of a physical quantity?

   (A) The symbol named after scientist should have capital letter.

   (B) They take plural forms.

   (C) They can be written in full.

   (D) They should be written only in the agreed symbols.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statements of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** kilogram is a standard unit of mass.
   Reason: kilogram is well defined and invariant.
2. **Assertion:** Time period of a simple pendulum is independent of length of simple pendulum.
   Reason: Time period of a simple pendulum is the number of oscillations made by it in one second.
3. **Assertion:** A screw gauge of pitch 1 mm advances $\frac{3}{4}$ mm for three fourth rotation of head.
   Reason: Pitch is the distance moved by the screw for one complete rotation of head.
4. **Assertion:** $1\ mm^2 = 10^{-6}\ m^2$
   Reason: The numerical value of physical quantity is less for a smaller unit.
5. **Assertion:** The SI unit of volume is m^3.
   Reason: Volume is a derived quantity of length.
6. **Assertion:** A vernier calipers has a positive error of 0.5 mm then the correction is –0.5 mm.
   Reason: Incase of positive zero error, measured length is greater than the actual length.
7. **Assertion:** The SI unit of weight is newton.
   Reason: Weight is the force of gravity with which a body is attracted towards the earth.
8. **Assertion:** 10 decades make a century.
   Reason: 1 century makes 100 years and 1 decade make 10 years.

9. **Assertion:** The least count of vernier calipers is 0.1 mm.

Reason: $LC = \frac{1MSD}{1VSD}$

10. **Assertion:** The watches having hours hand, minutes hand and seconds hand have least count as 1 ms.

Reason: Least count is the measurement that can be measured accurately by an instrument.

PARAGRAPH QUESTIONS

Passage - I

I. A micrometer screw gauge has a negative error of 7 divisions. While measuring the diameter of a wire the reading on main scale is 2 divisions and 78^{th} circular scale division, coincides with base line. The number of divisions on main scale are 10 to a centimetre and the circular scale has 100 divisions.

(i) Find the pitch of the screw.

(A) 0.01 mm (B) 0.01 cm (C) 0.1 cm (D) 0.001 mm

(ii) Calculate the least count of the screw gauge.

(A) 10^{-2} cm (B) 10^{-3} mm (C) 10^{-3} cm (D) 10^{-3} m

(iii) What is the observed diameter of the wire?

(A) 1.78 cm (B) 1.98 cm (C) 2.78 cm (D) 0.278 cm

(iv) What is the correct diameter of the wire?

(A) 2.72 mm (B) 2.86 mm (C) 2.71 mm (D) 1.72 mm

SECTION – B

NUMERICAL PROBLEMS

1. Two spheres made of different materials but having the same mass, have radii in the ratio 3 : 4. Find the ratio of their densities.
2. While measuring the diameter of a lead shot using screw gauge, the pitch scale reading and the head scale reading were found to be 4.0 mm and 50 respectively. If the least count of the instrument is 0.01 mm and zero error is –0.45 mm, then find the diameter of the lead shot in m
3. The relative density of mercury is 13.6. If the volume of water is ten times the volume of mercury then find the ratio of the mass of mercury to mass of water.
4. A screw gauge has 50 divisions on its head scale and the head scale moves 0.4 mm when rotated by four fifth of a rotation then find the pitch and least count of the screw gauge in mm

5. A student mistaken the least count of a vernier callipers as 0.01 mm instead of 0.01 cm and found that the length of a copper rod was 6.506 cm. If one MSD = 1 mm, then find (1) the main scale reading; (2) the vernier coinciding division; (3) the correct length of the rod.

6. A simple pendulum bob takes 0.5 seconds to move from mean position to an extreme end, then find the length of the simple pendulum approximately in m (take $g = 9.8\ m\ s^{-2}$).

7. A screw gauge has a least count equal to 0.0005 mm. The spindle of the gauge advances 0.1 mm, when the screw is turned through 2 revolutions. Find the number of divisions thimble of the screw gauge contains.

8. In a vernier callipers, 20 divisions on the vernier scale coincides with 17 divisions on the main scale. If one cm on the main scale is divided into 20 equal parts, then find the least count of the callipers.

9. Two metals of relative densities 10 and 20 are taken and two alloys are prepared from the given metals. The first alloy contains equal masses of the two given metals. The other alloy contains equal volumes of the two given metals. If two cubes are made out of these two alloys, then find the ratio of the densities of the two cubes.

10. How many days are present from year 2005 to 2008 including these years?

CONCEPTUAL QUESTIONS

1. When asked to find the diameter of a rod without using vernier callipers a student used a string and a metre scale, and determined the diameter of the rod quite accurately. Can you explain how he did it?

2. In an arbitrarily chosen system of units and measurements, the area was taken as a fundamental quantity and one unit area, denoted as A, is defined as the total surface area of the cube of unit length as side. Find the unit of length in this system.

3. If the number of divisions on the vernier scale of a standard vernier callipers is N, then N is always equal to (N – 1) main scale divisions. Would the vernier callipers be rendered useless if N is equal to fewer number of main scale divisions, for example N = (N – 3) M.S.D.? Why? How would the least count calculations be modified?

4. When the jaws of a vernier callipers are in contact with each other, the zeroeth division of the vernier scale does not coincide with the zeroeth division of the main scale but coincides with the second division on it. Discuss the accuracy of the observed readings done with the instrument.

5. Are there more nanoseconds in a second than the number of seconds in a year?

6. Is the measure of an angle dependent upon the unit of length?

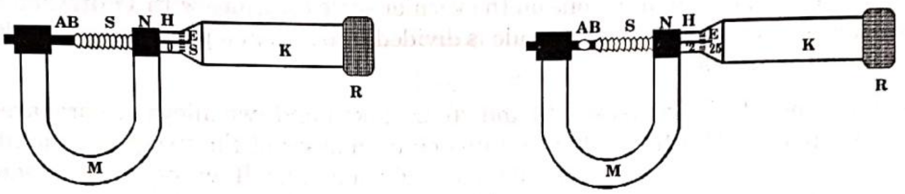
SECTION – C

PREVIOUS CONTEST QUESTIONS

1. A cube has a side of length 1.2×10^{-2} m. Calculate its volume.

   (A) $1.728 \times 10^{-6}\ m^3$ (B) $1.44 \times 10^{-4}\ m^3$ (C) 1.2×10^{-8} (D) $0.4 \times 10^{-2}\ m^3$

2. The circular scale of a screw gauge has 50 divisions and pitch of 0.5 mm. Find the diameter of sphere. Main scale reading is 2.



   (A) 1.2 mm (B) 1.25 mm (C) 2.22 mm (D) 2.25 mm

3. N divisions on the main scale of vernier callipers coincide with (N + 1) divisions on the vernier scale. If each divisions on the main scale of a units, determine the least count of instrument.

   (A) (N + 1) Main scale division (B) $(N + 1)^{-1}$ Main scale divisions
   (C) N Main scale division (D) (1 – N) Main scale divsions

4. A light year is unit of:

   (A) acceleration (B) distance (C) speed (D) time

5. A wire of length 50 cm has a mass of 20 g. If its radius is halved by stretching, its new mass per unit length will be:

   (A) 0.4 g cm^{-1} (B) 0.2 kg m^{-1} (C) 0.1 gr cm^{-1} (D) 0.2 g cm^{-1}

6. Thickness of the page on which your are writing is the order of:

   (A) 0.1 cm (B) 0.1 micrometer (C) 0.1 angstrom (D) 0.1 mm

7. 1 horse power is equal to ..... watt:

   (A) 746 (B) 500 (C) 646 (D) 700

8. Which of the following is the smallest unit?

   (A) millimetre (B) angstrom (C) fermi (D) metre

9. Which of the following is not a unit of time?

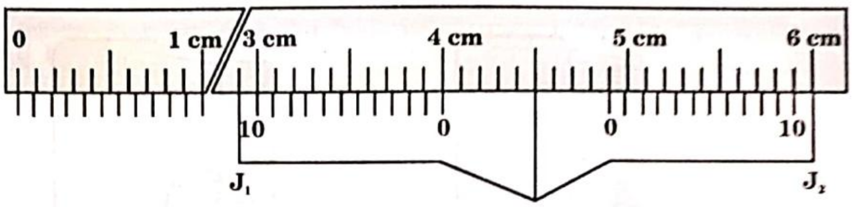
   (A) hour (B) nano second (C) microsecond (D) light year

10. Parallactic second is a unit of:

    (A) time (B) speed
    (C) distance (D) none of these

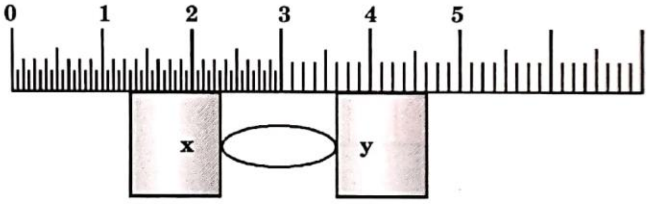
BRAIN NURTURES

1.

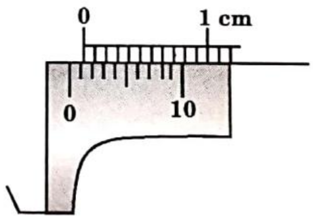


A vernier callipers has two vernier scales sliding over a metre scale. When the two jaws of the callipers coincide with each other the zeroeth divisions of the vernier scales coincide with the main scale divisions as shown in the figure. When a lead shot is held between these jaws gently then the zeroeth division of vernier scale on jaw J_1 lies in between 3.6 cm and 3.7 cm of the main scale with its vernier coinciding division as 3 and the zeroeth division of the vernier scale on jaw J_2 lies in between 6.2 cm and 6.3 cm of the main scale with the vernier coinciding division as 4. Find the diameter of the lead shot.

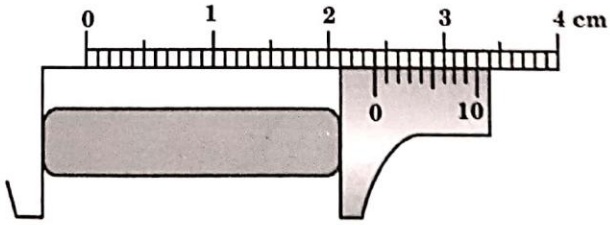
2. In the figure given above the main scale is marked in inches. Determine the length of the object held between the two blocks. If 1 inch = 2.54 cm, find the length in cm.



3. Find the distance between zero of main scale and zero of vernier scale.

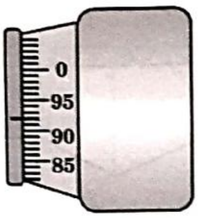


4. The correct length of a rod when measured with the help of a vernier calipers is 25.4 mm.

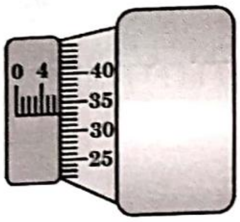


5. The diameter of a lead shot is measured with a screw gauge with reading as shown in the figure. Find the volume of lead shot in SI units.

Pitch = 1 mm



Reading with the tip of the screw in contact with the stud

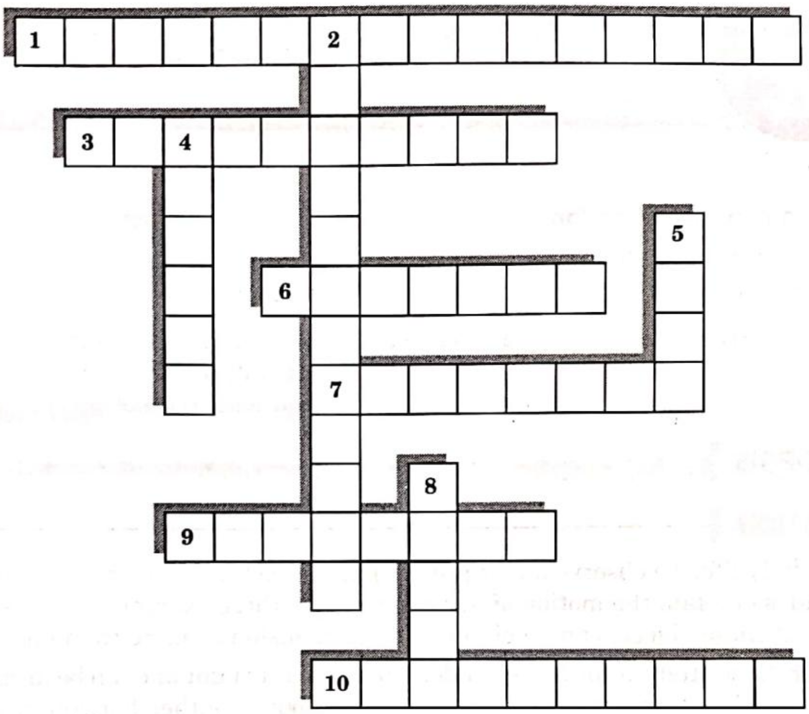


Reading with the wire held between the screw and the stud.

6. A decimal system of units for time is used in which one mean solar day is divided into 10 decidays, 1 deciday into 10 centidays and so on. How many oscillations would a seconds pendulum make in one milliday? (Take 1 day = 24 hours).

7. If an atom were enlarged to the size of the earth ($\approx 10^7$ m), how large would its nucleus be?

CROSSWORD PUZZLE



ACROSS

1 The quantity that can be measured

3 The smallest length than can be measured accurately by an instrument is

6 Ratio of mass to volume

7 In scientific research or experiments measurement must be

9 SI unit of mass

DOWN

2 $m\ s^{-2}$ is the SI unit of.

4 SI unit of current

5 CGS unit of force

8 The difference between the measured value and the true value is

Chapter 2

Motion in one dimension

Common misconception	Fact
1. A body moving with uniform motion, moves with uniform acceleration.	1. A body moving with uniform motion has uniform speed but not uniform acceleration.
2. A body having zero velocity has no acceleration	2. When a body is thrown vertically up. At its highest point, the body possess zero velocity and finite acceleration.

SYNOPSIS

INTRODUCTION

In our daily life, we observe a mosquito flying, the cars moving on a road, the motion of the blades of a fan, the motion of our hand etc., In these examples, we observe that the motion of these objects can be either in one dimension or more than one dimension.

In general, the study of the bodies under motion in a straight line can be in one dimension. One dimensional motion refers to motion of a body in either horizontal or in vertical direction is learnt under the topic motion in one dimension.

REST

A body is said to be at rest if it does not change its position with respect to the surroundings and time. For example a book on the table, a house, a tree etc.,

MOTION

A body is said to be in motion if it changes its position with respect to the surroundings and time. For example a moving car water flowing in a river.

Rest and motion are relative. For example a man on the earth is at rest with respect to the earth. But he is in motion with respect to Sun.

TYPES OF MOTION

A body under motion can exhibit mainly three types of motion.

Translatory motion

A body moving in a straight line is said to undergo translatory motion. A translatory motion may be a straight line (rectilinear) motion or a curvilinear motion.

An apple falling from a tree is an example of rectilinear motion.

A car moving along a curved road is an example of curvilinear motion.

Rotatory motion

A body cannot be treated as a point and all the particles move simultaneously along circles (whose centres lie on a line called axis of rotation) by shifting through an angle in a given time, the motion is rotatory.

Oscillatory motion

If a periodic motion is within certain limits or if it is to and fro or up and down, it is said to be oscillatory motion.

DISTANCE

The total length of the path covered by the body is called distance. It is a scalar quantity.

Units

C.G.S: centimetre (cm), S.I.: metre (m)

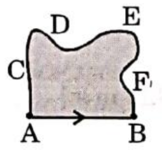
DISPLACEMENT

The shortest possible distance from the initial and the final positions of the body is called displacement. It is a vector quantity.

Units

C.G.S: centimetre (cm), S.I: metre (m)

Example



If a body starts from A and travels along the path ACDEF and reaches B, then:
Distance travelled by the body = length of the curve ACDEFB
Displacement of the body = AB

SPEED

The distance travelled by the body in unit time is called speed. It is a scalar quantity. Speed can either be positive or zero.

$$\Rightarrow \quad \text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

Units

C.G.S: cm s^{-1}, S.I.: m s^{-1}

Other units of speed are km h^{-1}, miles h^{-1}

$$1 \text{ km h}^{-1} = \frac{1000 \text{ m}}{3600 \text{ s}} = \frac{5}{18} \text{ m s}^{-1}$$

TYPES OF SPEED

Uniform Speed

If a body travels equal distances in equal intervals of time, however small these intervals may be, then it is said to be moving with uniform speed.

Non-uniform Speed

If a body travels unequal distances in equal intervals of time or equal distances in unequal intervals of time, the body is said to be travelling with non-uniform or variable speed.

Average Speed

The ratio of the total distance travelled to the total time of travel is called average speed.

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

VELOCITY

The time rate change of displacement is called velocity. Velocity can be either positive or zero or negative. Velocity is a vector quantity.

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}}$$

Units

C.G.S: cm s^{-1} S.I.: m s^{-1}

TYPES OF VELOCITY

Uniform velocity

If a body travels equal displacements in equal intervals of time, however small these time intervals may be, the body is said to be travelling with uniform velocity.

Non-uniform or variable velocity

If a body covers unequal displacements in equal intervals of time or equal displacements in unequal intervals of time, then it is said to be travelling with non-uniform velocity.

Average Velocity

The ratio of the total displacement to the total time taken by a body is called average velocity.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

ACCELERATION

The rate of change of velocity of a body is called acceleration.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

Unit:

C.G.S: cm s^{-2}, S.I.: m s^{-2}

Note: If a body moves with uniform velocity, then the acceleration is equal to zero.

TYPES OF ACCELERATION

Uniform acceleration

If equal changes in velocity takes place in equal intervals of time, however small these intervals may be, the body is said to be travelling with uniform acceleration.

Example

A freely falling body possesses uniform acceleration.

Non-uniform acceleration

If unequal changes in velocity takes place in equal intervals of time, then the body is said to be moving with non–uniform acceleration.

Negative acceleration

If the velocity of the body gradually decreases w.r.t time, the acceleration is said to be negative, which is called deceleration or retardation.

EQUATIONS OF MOTION

Consider a body moving with an initial velocity u. Let it be travelling along a straight line with uniform acceleration a. Let v be its final velocity after time t. The displacement of the body in this time be S.

$v = u + at$ $S = ut + \frac{1}{2}at^2$

$v^2 - u^2 = 2aS$ $S_n = u + \frac{a}{2}(2n - 1)$

Gravity

The force with which the earth pulls an object towards it is called the gravitational force of earth or gravity of the earth.

The equations of motion for a body falling down under gravity

(a) The earth exerts a gravitational force on all bodies.

(b) At a given place, acceleration due to this force 'g' is a constant that is directed towards the earth.

Therefore, bodies moving under gravity will be subjected to this uniform acceleration due to gravity 'g'.

Equations of motion for a freely falling body

Consider a body falling from a height '*h*', under acceleration due to gravity '*g*'. The initial velocity of a freely falling body is 0.

$$v = gt$$

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

$$v^2 = 2gh$$

$$S_n = g\left(n - \frac{1}{2}\right)$$

Equations of motion for a body thrown vertically upwards

If a body is thrown vertically up with an initial velocity (u).
Hence $a = -g$.

(i) $v = u - gt$ (ii) $h = ut - \frac{1}{2}gt^2$

(iii) $v^2 - u^2 = -2gh$ (iv) $h_n = u - g\left(n - \frac{1}{2}\right)$

Maximum height reached by the body

$$H = \frac{u^2}{2g}$$

∴ Therefore, the maximum height reached by the body is directly proportional to the square of the initial velocity.

Time of Ascent

The time taken by body thrownup to reach maximum height 'h' is called its time of ascent.

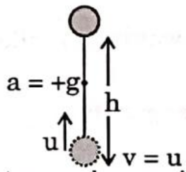
$$t_a = \frac{u}{g}$$

Hence time of ascent t_a is directly proportional to the initial velocity u.

Time of Descent

The time taken by a freely falling body to reach the ground is called the time of descent.

$$t_d = \sqrt{\frac{2h}{g}}$$



and $h = \frac{v^2}{2g}$, $t_d = \sqrt{\frac{2 \times v^2}{2g \times g}} = \frac{v}{g}$

But, we know that u = v i.e., projected velocity of a body is equal to the velocity of the body on reaching the ground.

$t_d = \frac{u}{g}$ = time of ascent (t_a) ∴ Time of ascent = Time of descent

Time of flight

Time of flight is the time for which a body remains in the air and is given by sum of time of ascent and time of descent.

Therefore, $t = t_a + t_d$

$$t = \frac{u}{g} + \frac{u}{g}$$

$\therefore$ Time of flight, $t = \frac{2u}{g}$

Velocity on reaching ground

When a body is dropped from a height h, its initial velocity is zero. Let the final velocity on reaching the ground be v. For a freely falling body.

$v^2 - u^2 = 2gh$

but $u = 0$

$\therefore$ $v^2 - 0 = 2gh; v = \sqrt{2gh}$

Body projected vertically up from the top of a tower

If a body is projected vertically up from the top of a tower of height 'h' with velocity 'u'.

(a) displacement after time t is $S = ut - \frac{1}{2}gt^2$

(b) velocity after time t is $v = u - gt$.

(c) its velocity on reaching the ground is $\sqrt{u^2 + 2gh}$

(d) its maximum height above the ground is $\{h + (u^2/2g)\}$

GRAPHS

In physics we often use graphs as important tools for analysing certain concepts.

Displacement–time graphs:

These graphs are very useful in studying the linear motion of the body. The displacement is plotted on the Y – axis and the time on X – axis.

These graphs are very helpful in finding the velocity of body, as the slope of graph $\left(\frac{Y - axis}{X - axis}\right)$ is equal to $\frac{\text{Displacement}}{\text{Time}}$

Conclusions from Displacement - Time Graph

1. If the graph is parallel to time axis, then body is stationary.
2. If graph is a straight line, then body is moving with a uniform velocity. The velocity can be found out by finding the slope of the graph.
3. The graph can never be parallel to displacement axis, as it means that displacement increases indefinitely, without any increase in time, which is impossible.
4. If graph is a curve, it means the body is moving with a variable velocity, and hence, it has some acceleration.

Velocity-Time Graphs

(a) In these graphs generally, the velocity is plotted on Y-axis and time on X-axis. The slope of such graphs gives acceleration.

(b) As, velocity ÷ time = acceleration, the acceleration will be positive if the slope is positive, and negative if the slope is negative.

(c) The area of graph under velocity – time curve, gives displacement of body.
Displacement = Velocity × Time.

(d) If velocity – time graph is parallel to time axis, then:
   (i) Body is moving with uniform velocity.
   (ii) Its acceleration is zero.
   (iii) Its displacement can be found by finding the area of the graph.

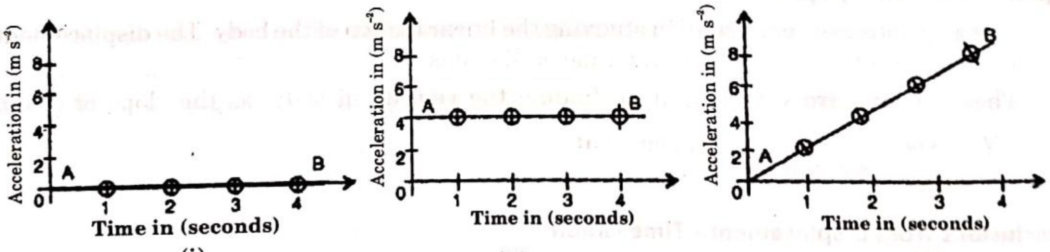
Conclusions

(i) If velocity – time graph is a straight line but moving away from velocity time axis, then:
   (a) Body is moving with variable velocity.
   (b) It has uniform acceleration, which can be found by the slope of graph.
   (c) Displacement can be found, by finding area under the velocity - time graph.
   (d) If slope is positive, then the body has positive acceleration and vice – versa.

(ii) If the velocity – time graph is a curve, then:
   (a) The body has variable velocity and variable acceleration.
   (b) Area under the curve represents displacement.
   (c) Acceleration at any instant can be found by finding slope at that point.

Acceleration – time graph

Figure (i) represents an acceleration – time graph, AB coinciding with time axis. From the figure it is clear that acceleration of the body is zero hence, it is moving with a uniform velocity.



(i) (ii) (iii)

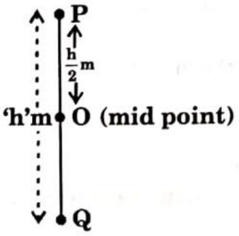
Figure (ii) represents an acceleration – time graph, parallel to time axis. From figure it is clear that as acceleration does not change, therefore body is moving with a uniform acceleration and variable velocity. The area of graph, i.e., Acceleration × Time gives change in velocity.

Figure (iii) represents an acceleration – time graph moving away from time as well as acceleration axis. From the graph it is clear that the body is moving with variable velocity and variable acceleration. Area of the graph gives change in velocity.

SOLVED EXAMPLES

Example 1:

A body drops a coin from top of a tower. Coin takes 't' seconds to come down from the top of a tower. Calculate time taken to cover half the height of the tower.



Solution:

Case – I

Time taken by coin be t_n

acceleration $a_1 = g$

initial velocity $u_1 = 0$

distance travelled by coin $s_1 = h$

$$h = \frac{1}{2}gt_n^2 \quad \text{..... (1)}$$

Case – II

Time taken by coin to cover half height of tower be t^1

acceleration $a_2 = g$

initial velocity $u_2 = 0$

distance travelled by coin $s_2 = \frac{h}{2}$

$$\therefore \quad \frac{h}{2} = \frac{1}{2}gt^{1^2} \quad \text{...... (2)}$$

Dividing (1) by (2) we get

$$\frac{(1)}{(2)} = \frac{h}{\frac{h}{2}} = \frac{\frac{1}{2}gt^2}{\frac{1}{2}gt^{1^2}} \Rightarrow 2 = \frac{t^2}{t^{1^2}} \Rightarrow t^{1^2} = \frac{t^2}{2} = t^1 = \frac{t}{\sqrt{2}}\,s$$

Example 2:

A rock is dropped from a top of hill and strikes the ground 6 seconds later. How much is the height of hill in metres?

Solution:

Given,

Initial velocity of the rock, $u = 0$

Time taken, $t = 6$ S

acceleration due to gravity, $g = 9.8\ m\ s^{-2}$

height of the hill $h = ?$

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

$$h = \frac{1}{2} \times 9.8 \times (6)^2 = \frac{1}{2} \times 9.8 \times 36$$

$$h = 176.4 \text{ metre}$$

The height of the hill is 176.4 m

Example 3:

A ball is dropped from a tower of height 30 meters. Find time taken to fall through this height.

Solution:

Initial velocity of ball u = 0

height of tower h = 30 m

acceleration due to gravity $g = 9.8\ m\ s^{-2}$

time taken 't' = ?

$$v^2 - u^2 = 2gh$$
$$v^2 - (0)^2 = 2 \times 9.8 \times 30$$
$$v^2 = 588 = \sqrt{588}$$
$$v = 24.24\ m\ s^{-1}$$

Substitute this 'v' value in equation v = u + gt

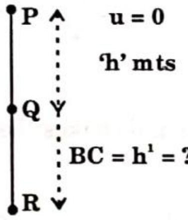
$$v = gt\ (\therefore\ u = 0)$$
$$t = \frac{v}{g}$$
$$t = \frac{24.24}{9.8} = 2.47\ s$$

Example 4:

A body falling from rest has a velocity 'v' after its fall through a distance 'h'. Find the distance it has a fall down in terms of h further, for its velocity to become double.

Solution:

Let a body starting from rest travel a distance of 'h' m from P to Q during which acquires a velocity v_1. Its velocity becomes 2 v point R.



Case – I	Case – II
PQ	QR
$S_1 = h$	$S_2 = BC = h^1 = ?$
$v_1 = v$	$v_2 = 2v$
$u_1 = 0$	$u_2 = 0$
Let $a_1 = g$	$\therefore$ $a_2 = g$

Applying $v^2 - u^2 = 2as$ in both cases we get

$v^2 - 0^2 = 2gh$ $\qquad$ $(2v)^2 - v^2 = 2gh^l$

$\Rightarrow$ $v^2 = 2gh$ ----- (1) $\qquad$ $\Rightarrow$ $3v^2 = 2gh^l$ ----- (2)

dividing equation (2), (1) we get

$$\frac{(2)}{(1)} = \frac{3v^2}{v^2} = \frac{2gh^l}{2gh} \Rightarrow h^l = 3h$$

Example 5:

A ball takes t seconds to fall from a height h_1 and 2t seconds to fall from height h_2 then find the ratio of h_1 and h_2 .

Solution:

Case – I
height $h = h_1$
Time taken $t_1 = t$

Case – II
height $h = h_2$
time $t_2 = 2t$

we know that, $t = \sqrt{\frac{2h}{g}}$

since $h \alpha t^2$, as the ratio of both cases gives us

$$\frac{h_1}{h_2} = \frac{t^2}{(2t)^2} = \frac{t^2}{4t^2} = \frac{1}{4}$$

The ratio of h_1 and h_2 is 1 : 4.

Example 6:

A stone is dropped from the top of the tower and reaches ground is 4 s. Find the height of tower.

Solution:

acceleration due to gravity (g), = 9.8 m s^{-2}
time taken by stone to reach ground, t = 3 s
height of tower h = ?
we know that

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

$$h = \frac{1}{2} \times 9.8 \times (4)^2$$

$$h = \frac{1}{2} \times 9.8 \times 16 = 78.4 \text{ m}$$

∴ The height of the tower is 78.4 m

Example 7:

A body falling from rest covered distances S_1, S_2, and S_3 in first, second, third seconds of its fall. Calculate the ratio of S_1, S_2 and S_3 respectively.

Solution:

Initial velocity of the body u = 0

We know that = $S = \frac{1}{2} at^2$

for body covers distance $S_1 = \frac{1}{2} g \times (1)^2 = \frac{1}{2} g$

$$\therefore \quad S_1 = \frac{1}{2} g$$

$$S_1 + S_2 = \frac{1}{2} g \times (2)^2 = 2g$$

$$S_1 + S_2 + S_3 = \frac{1}{2} g \times (3)^2 = 4.5g$$

$$S_1 = \frac{1}{2} g$$

$$S_2 = 2g - \frac{1}{2} g = 1.5g$$

$$S_3 = 4.5g - 2g = 2.5g$$

$$\therefore \quad S_1 : S_2 : S_3 = \frac{1}{2} g : 1.5g : 2.5g = 1 : 3 : 5$$

Example 8:

Drops of oil fall from the barrel of height 9 m at regular intervals of time. The first drop reaches the ground at the same instant the fourth drop starts its fall. What are the distances of the second and fourth drop from the barrel:

Solution:

Height of the tank = 9 m

we know that

$$h = \frac{1}{2} g t^2$$

Barrel

$t =$ → fourth

$t''' = t$ → third

$t'' = 2t$ → second

$t' = 3t$ → first drop

For first drop $t' = 3t$

$$\therefore \quad 9 = \frac{1}{2} g (3t)^2$$

$$\frac{1}{2} g t^2 = 1$$

For the second drop

$$t'' = 2t$$

$$h_2 = \frac{1}{2} g (2t)^2$$

$$= 4 \times \frac{1}{2} g t^2 = 4 \times 1 \text{ m} = 4 \text{ m}$$

For the third drop $t''' = t$

$$h_3 = \frac{1}{2} g t^2 = 1 \text{ m}$$

Therefore the distance of second and third drops are 4 m and 1 m respectively.

Example 9:

A body is projected vertically upwards with a velocity 30 m s^{-1}. Find the maximum height reached by the body. Take g = 10 m s^{-2}

Solution:

Initial velocity of the body, u = 30 m s^{-1}

acceleration due to gravity g = 10 m s^{-2}

Maximum height reached by body $h = \frac{u^2}{2g} = \frac{(30)^2}{2 \times 10} = \frac{900}{20} = 45$ m

The maximum height reached by vertically projected body in 45 m.

Example 10:

A ball is thrown vertically, upwards and reaches to a maximum height of 15 m. Calculate the velocity with which the ball was thrown upwards.

Solution:

The maximum height reached by ball h = 15 m

acceleration due to gravity, g = 9.8 m s^{-2}

we know that $u = \sqrt{2gh}$

$= \sqrt{2 \times 9.8 \times 15} = 17.15$ m s^{-1}

Example 11:

A stone is thrown vertically upwards with an initial velocity of 45 m s^{-1}. Calculate the time taken by the stone to rise to its maximum height.

Solution:

Initial velocity of stone, u = 45 m s^{-1}

Acceleration due to gravity, g = 9.8 m s^{-2}

Time of ascent, $t = \frac{u}{g}$

$t = \frac{45}{9.8}$

t = 4.59 s

Example 12:

A ball is projected with a velocity 98 m s^{-1}. Calculate after how much time it will strikes the ground.

Solution:

Initial velocity of the ball, u = 98 m s^{-1}

Acceleration due to gravity, g = 9.8 m s^{-2}

Time of flight = ?

Time of flight $t = \frac{2u}{g} = \frac{2\times98}{9.8} = 20$ s

Example 13:

A ball thrown vertically upwards with a speed of v attains a height h_1. Another ball thrown upwards from the same point with a speed of 2v attains a height h_2. Then find the value h_2 in terms of h_1.

Solution:

$$h = \frac{u^2}{2g}$$

i.e., $h \alpha u^2$

If velocity is doubled, then height becomes quadrupled. $\therefore h_2 = 4h_1$

Example 14:

A ball is dropped from the top of a tower 100 m high and at the same time another ball is projected vertically upwards from the ground with a velocity of 25 m s^{-1}. Find the height where the two balls will meet?

Solution:

Let two ball meet at a height of x m above the ground after its from the start

Downward direction

Initial velocity, u = 0

S = 100 – x

acceleration due to gravity, g = 9.8 m s^{-2}

Upward direction

Initial velocity, u = 25 m s^{-1}

acceleration – g = – 9.8 m s^{-2}

distance travelled by second ball = x

applying equation $S = ut + \frac{1}{2}gt^2$ in both the cases.

$100 - x = 0 \times t + \frac{1}{2} 9.8 \times t^2$

$100 - x = 4.9\ t^2$ —— (1)

$x = 25\ t - \frac{1}{2} \times 9.8 \times t^2$

$x = 25t - 4.9\ t^2$ —— (2)

Adding equation (1) and (2)

$$100 - x + x = 25\ t - 4.9\ t^2 + 4.9\ t^2$$

$$25t = 100, \quad t = 4\ s$$

Substituting value of t in equation (2)

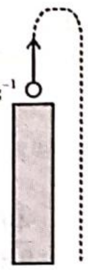
$$x = 25 \times 4 - 4.9 \times 4^2 = 100 - 78.4 = 21.6\ m$$

The balls will meet at a height of 21.6 m above the ground 4 s after start.

Example 15:

From the top a building 39.2 m, ball is thrown vertically upward with a velocity 9.8 m s^{-1} find the time when the ball will hit the ground.

Solution:



As time cannot be -ve

Here $u = +9.8\ m\ s^{-1}$, $h = -\ 39.2\ m$, $g = -9.8\ m\ s^{-2}$

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

$$-\ 39.2 = 9.8\ t - \frac{1}{2} \times 9.8t^2$$

$$4.9t^2 - 9.8\ t - 39.2 = 0$$

$$(t + 2)\ (t - 4) = 0$$

$$t = -2\ s, 4\ s$$

$$t = 4\ s$$

Example 16:

Four balls are dropped gently from the top of a tower at intervals of one-one second. The first ball reaches the ground after 4 seconds of dropping. What are the distances between first and second, and third, and fourth ball at any instant? ($g = 9.8\ m\ s^{-2}$).

Solution:

From second equation of motion

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

For 1st ball $h_1 = 0 + \frac{1}{2} \times 9.8\ (4)^2 = 78.4$ m, For 2nd ball $h_2 = 0 + \frac{1}{2} \times 9.8\ (3)^2 = 44.1$ m

For 3rd ball $h_3 = 0 + \frac{1}{2} \times 9.8\ (2)^2 = 19.6$ m, For 4th ball $h_4 = 0 + \frac{1}{2} \times 9.8\ (1)^2 = 4.9$ m

Distance between 1st and 2nd ball is

$$h_1 - h_2 = 78.4 - 44.1 = 34.3\ m$$

Distance between 2nd and 3rd ball is

$$h_2 - h_3 = 44.1 - 19.6 = 24.5\ m$$

Distance between 3rd and 4th ball is

$$h_3 - h_4 = 19.6 - 4.9 = 14.7\ m$$

Example 17:

A boy standing on a stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49 m s^{-1}

(a) How much time does the ball take to returns to his hands?

(b) If the left starts moving up with a uniform speed of 5 m s^{-1}, and the boy again throws the ball up with the maximum speed he can, how long does the ball take to return to his hands?

Solution:

(a) $v(0) = 49$ m s^{-1}, $a = -9.8$ m s^{-2}, $t = ?$, $v(t) = 0$

$v(t) = v(0) + at$

$0 = 49 - 9.8\,t$ or $9.8\,t = 49$ or $t = \frac{49}{9.8}\,s = 5\,s$

This is the time taken by the ball to reach the maximum height. The time of descent is also 5 s. So, the total time after which the ball comes back is 5 s + 5 s i.e., 10 s

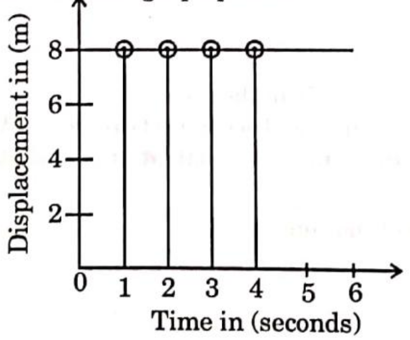
(b) The uniform velocity of the lift does not change the relative motion of ball and lift. So, the ball would take the same total time i.e., it would come back after 10 second.

Aliter: 'u' = 49 m s^{-1}, 'a' = 9.8 m s^{-2}, t = ?, v = 0

Using $v = u + at$, $0 = 49 - 9.8\,t$ or $9.8\,t = 49$ or $t = \frac{49}{9.8}\,s = 5\,s$

Example 18:

What does the displacement – time graph parallel to time axis as shown in figure imply?



Solution:

It means that the body is not changing its position with respect to time. In other words, body is stationary.

Example 19:

Plot a displacement-time graph of a body with the values of displacement and time are shown in the table below:

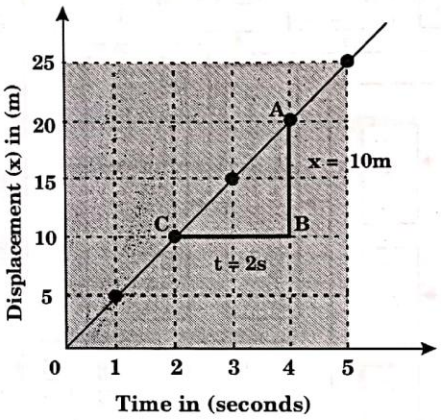
Displacement in metres	0	5	10	15	20	25
Time in seconds	0	1	2	3	4	5

Solution:

Since graph is a straight line, therefore it means that displacement is proportional to time. In other words, body is covering equal distances in equal intervals of time in specified direction, and hence, is moving with a uniform velocity.
The slope of this graph gives uniform velocity.

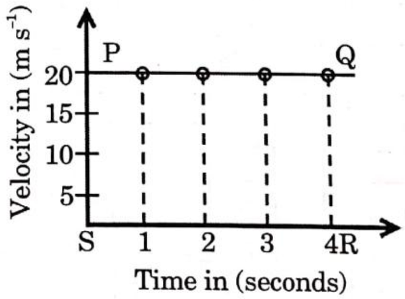
Thus, velocity of body $= \frac{\Delta \vec{x}}{\Delta t} = \frac{AB}{BC} = \frac{10m}{2s} = 5\ m\ s^{-1}$

Where Δx is short distance and Δt is a short interval of time.



Example 20:

A velocity – time graph is plotted below. Find the acceleration and displacement.



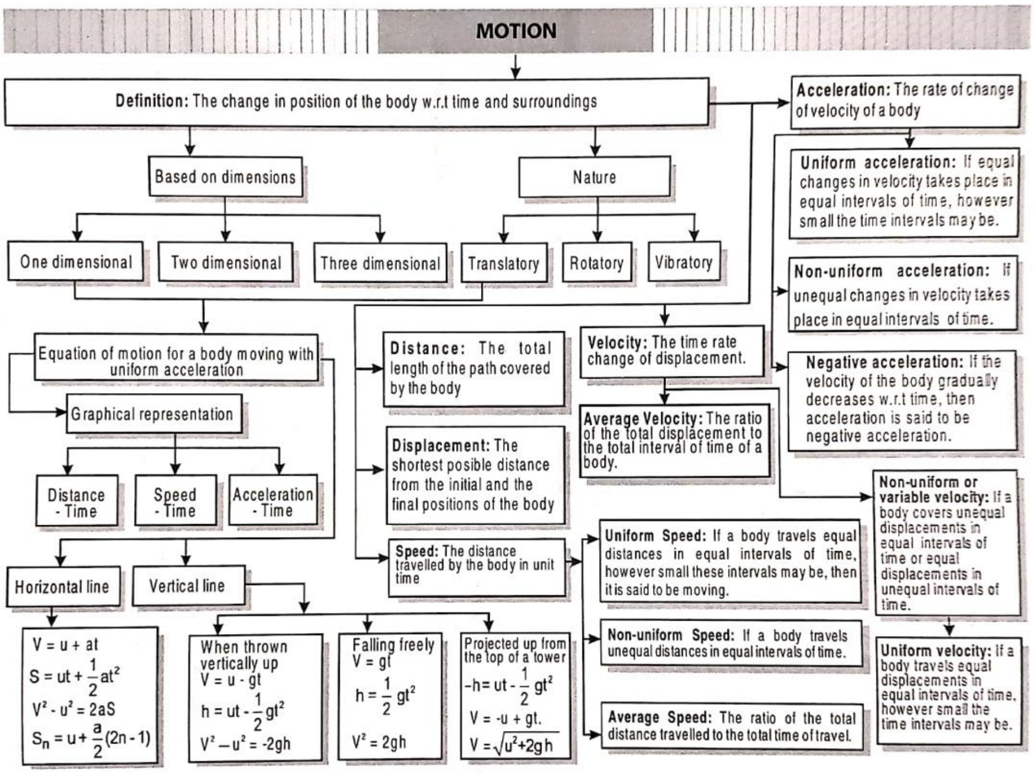
Solution:

(i) Velocity-time graph PQ, when a body is moving with a uniform velocity of 20 $m\ s^{-1}$
As the slope of graph is zero, therefore its acceleration is zero.

(ii) The distance covered by the body in specified direction (displacement) can be calculated by finding the area of rectangle PQRS.

Thus, Displacement = PS × SR = 20 $m\ s^{-1}$ × 4 s = 80 m

CONCEPT MAP


MOTION
Definition: The change in position of the body w.r.t time and surroundings
Based on dimensions
Nature
One dimensional
Two dimensional
Three dimensional
Translatory
Rotatory
Vibratory
Equation of motion for a body moving with uniform acceleration
Graphical representation
Distance - Time
Speed - Time
Acceleration - Time
Horizontal line
Vertical line
V = u + at
S = ut + 1/2 at²
V² - u² = 2aS
Sn = u + a/2 (2n - 1)
When thrown vertically up
V = u - gt
h = ut - 1/2 gt²
V² – u² = -2gh
Falling freely
V = gt
h = 1/2 gt²
V² = 2gh
Projected up from the top of a tower
-h = ut - 1/2 gt²
V = -u + gt.
V = √(u²+2gh)
Distance: The total length of the path covered by the body
Displacement: The shortest posible distance from the initial and the final positions of the body
Speed: The distance travelled by the body in unit time
Velocity: The time rate change of displacement.
Average Velocity: The ratio of the total displacement to the total interval of time of a body.
Uniform Speed: If a body travels equal distances in equal intervals of time, however small these intervals may be, then it is said to be moving.
Non-uniform Speed: If a body travels unequal distances in equal intervals of time.
Average Speed: The ratio of the total distance travelled to the total time of travel.
Acceleration: The rate of change of velocity of a body
Uniform acceleration: If equal changes in velocity takes place in equal intervals of time, however small the time intervals may be.
Non-uniform acceleration: If unequal changes in velocity takes place in equal intervals of time.
Negative acceleration: If the velocity of the body gradually decreases w.r.t time, then acceleration is said to be negative acceleration.
Non-uniform or variable velocity: If a body covers unequal displacements in equal intervals of time or equal displacements in unequal intervals of time.
Uniform velocity: If a body travels equal displacements in equal intervals of time, however small the time intervals may be.

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. For a body moving along a circular path, the average velocity and average speed can never be ________.
2. When a particle moves in a straight line from point A to point B the distance covered is ________ the magnitude of the displacement.
3. Average velocity of a body is the ratio of the ________ of the body to the total time taken.
4. The ratio of magnitude of average velocity to average speed is ________.
5. If a body does not change its position with respect to its surroundings, the body is said to be ________.
6. Area under the velocity–time graph gives ________.
7. The equations of motion are applicable only when the body moves with ________ acceleration.
8. The time taken by a body which is falling freely from a height 'h' to reach the ground is ________.
9. A body projected vertically up with a velocity 'u' attains a maximum height H. If it is thrown up with velocity 2u, it attains a maximum height of ________.
10. Two balls are dropped from heights h_1 and h_2 respectively. The ratio of their velocities on reaching the ground is ________.
11. The sum of the time of ascent and the time of descent is called ________.
12. During upward motion of a body projected vertically upward, the angle between velocity and 'g' is ________.
13. 72 km h^{-1} = ________ m s^{-1}
14. A body is first displaced by 5 m and then by 12 m in different directions. The minimum displacement it can have is ________ m.
15. A car attains a velocity of 10 m s^{-1} in 5 s. If initially it had been at rest, its acceleration must be ________.
16. Two balls are projected horizontally from the top of a building simultaneously with velocities 12 m s^{-1} and 15 m s^{-1} respectively. The ratio of times taken by them to reach the ground is ________.
17. A particle is projected up with a velocity of 20 m s^{-1} from the tower of height 25 m. Its velocity on reaching the ground is ________ m s^{-1}.
18. A freely falling body travels with uniform ________.

19. If a body starts from rest and moves with uniform acceleration, then displacement of the body is directly proportional to __________.

20. The ratio of velocities acquired by a freely falling body starting from rest at the end of 1 second and 2 seconds is __________.

TRUE OR FALSE

21. The velocity of a body can change even if its acceleration is zero.

22. The displacement of a body has the same direction as that of its average velocity.

23. The direction of acceleration due to gravity is always vertically downward.

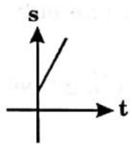
24. Displacement time graph of a body moving with uniform velocity is always a straight line.

25. Displacement of a particle moving in a circle at any two different instants of time is zero.

26. A body which is displaced would definitely have covered some distance.

27. Motion of an ant on a floor along the edges is an example of translatory motion.

28. A body at rest with initial displacement can be shown in the displacement (s) versus time (t) graph given below.



29. The ratio of the heights from which two bodies are dropped is 3 : 5 respectively. The ratio of their final velocities is $\sqrt{5} : \sqrt{3}$

30. A body moving with equal displacements in equal intervals of time is said to be moving with uniform velocity.

31. A body having uniform speed will always have uniform velocity.

32. A freely falling body means a body whose acceleration is equal to the acceleration due to gravity but its initial velocity may or may not be zero.

33. The acceleration of a moving body can be found from area under velocity time graph.

34. If Akhil takes 10 hours and Santosh takes 12 hours to travel to chennai from hyderabad then the average velocity of Akhil is more than that of Santosh.

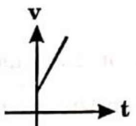
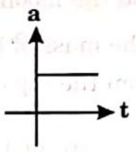
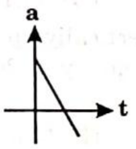
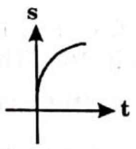
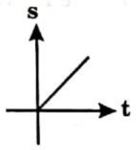
35. A body moving in a straight line can have constant velocity with varying speed.

MATCH THE FOLLOWING

36.

Column A	Column B
A. 36 km h^{-1}	p. 2000 mm
B. 1 m s^{-2}	q. 980 cm s^{-2}
C. 15 cm s^{-1}	r. 12960 km h^{-2}
D. 9.8 m s^{-2}	s. 10 m s^{-1}
E. 0.02 km	t. 0.54 km h^{-1}

37.

Column A	Column B
A. Uniform velocity	p. 
B. Uniform acceleration	q. 
C. Uniform retardation	r. 
D. Uniform acceleration with initial velocity	s. 
E. Decreasing acceleration at steady rate	t. 

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. At the maximum height of a body thrown vertically up:

(A) velocity is not zero but acceleration is zero.

(B) acceleration is not zero but velocity is zero.

(C) both acceleration and velocity are zero.

(D) both acceleration and velocity are not zero.

2. To reach the same height on the moon as on the earth, a body must be projected up with:

(A) higher velocity on the moon

(B) lower velocity on the moon

(C) same velocity on the moon and earth

(D) it depends on the mass of the body

3. A body dropped from the top of a tower reaches the ground in 4 s. Height of the tower is:

(A) 39.2 m (B) 44.1 m (C) 58.8 m (D) 78.4 m

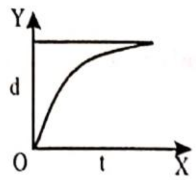
4. A body projected vertically up with a velocity of 10 m s^{-1} reaches a height of 20 m. If it is projected with a velocity of 20 m s^{-1}, then the maximum height reached by the body is:

(A) 20 m (B) 10 m (C) 80 m (D) 40 m

5. A stone is dropped from a rising balloon at a height of 300 m above the ground and it reaches the ground in 10 s. The velocity of the balloon when it was dropped is:

(A) 19 m s^{-1} (B) 19.6 m s^{-1} (C) 29 m s^{-1} (D) 0 m s^{-1}

6. The distance of a particle as a function of time is shown below. The graph indicates that



(A) the particle starts with certain velocity but the motion is retarded and finally the particle stops.

(B) the velocity of the particle is constant throughout

(C) the acceleration of the particle is constant throughout.

(D) the particle starts with another constant velocity the motion is in acceleration and finally the particle moves with another constant velocity.

7. A driver applies brakes when he sees a child on the railway track, the speed of the train reduces from 54 km h^{-1} to 18 km h^{-1} in 5 s. What is the distance travelled by the train during this interval of time?

(A) 52 m (B) 50 m (C) 25 m (D) 80 m

8. The speed of a car reduces from 15 m s^{-1} to 5 m s^{-1} over a displacement of 10 m. What is the uniform acceleration of the car?

(A) –10 m s^{-2} (B) +10 m s^{-2} (C) 2 m s^{-2} (D) 0.5 m s^{-2}

9. A body travels at a speed of 10 m s^{-1} for a time interval 't' and next at a speed of 40 m s^{-1} for next time interval 't'. Find average speed for the total journey.

(A) 40 m s^{-2} (B) 20 m s^{-2} (C) 5 m s^{-2} (D) 25 m s^{-2}

10. A body falls from a height of 200 m. If gravitational attraction ceases after 2 s, further time taken by it to reach the ground is (g = 10 m s^{-2}).

(A) 5 s (B) 9 s (C) 13 s (D) 17 s

11. A body thrown vertically up with a velocity 'u' reaches the maximum height 'h' after 'T' second. Correct the statement among the following is:

(A) at a height $\frac{h}{2}$ from the ground its velocity is $u/2$

(B) at a time T its velocity is 'u'

(C) at a time '$2T$' its velocity is $-u$

(D) at a time $2T$ its velocity is $-6u$

12. A body projected up with a velocity u reaches height h. To reach double the height, it must be projected up with a velocity of:

(A) $2u$ (B) $\frac{u}{2}$ (C) $\sqrt{2}\ u$ (D) $\frac{u}{\sqrt{2}}$

13. A train travels between two stations 'P' and 'Q'. It travels with a velocity 20 km h^{-1} from P to Q and returns to station P with a velocity 30 km h^{-1}. The average speed for the total journey.

(A) 25 km h^{-1} (B) 24 km h^{-1} (C) 6.67 m s^{-1} (D) 0 m s^{-1}

14. A ball is released from the top of a tower of height h metres. It takes T seconds to reach the ground. What is the position of the ball in T/3 seconds?

(A) h/9 metres from the ground (B) 7h/9 metres from the ground

(C) 8h/9 metres from the grounds (D) 17h/18 metres from the ground

15. A ball is thrown vertically upwards. It has a speed of 10 m s^{-1}, when it has reached one half of its maximum height. How high does the ball rise? (Take g = 10 m s^{-2})

(A) 10 m (B) 5 m (C) 15 m (D) 20 m

16. If a ball is thrown vertically upwards with speed u, the distance covered during the last t seconds of its ascent is:

(A) ut (B) $\frac{1}{2}gt^2$ (C) $(u + g t) t$ (D) $ut - \frac{1}{2} g t^2$

17. A stone is thrown with an initial speed of 4.9 m s^{-1} from a bridge in vertically upward direction. It falls down in water after 2 s. The height of the bridge is :

(A) 24.7 m (B) 19.8 m (C) 9.8 m (D) 4.9 m

18. A particle is thrown vertically upwards. Its velocity at one fourth of the maximum height is 20 m s^{-1}. Then, the maximum height attained by it is

(A) 16 m (B) 10 m (C) 8 m (D) 18 m

19. A stone is dropped from certain height, which can reach the ground in 5 s. After 3 s of its fall, it is again allowed to fall. Then, the time taken by the stone to reach the ground for the remaining distance is:

(A) 3 s (B) 4 s (C) 2 s (D) none of these

20. The distances travelled by a body falling freely from rest in the first, second and third seconds are in the ratio:

(A) 1 : 2 : 3 (B) 1 : 3 : 5 (C) 1 : 4 : 9 (D) None of the above

MULTIPLE ANSWER QUESTIONS

1. The ratio of time taken by two cars P, Q starting from rest moving along a straight road with equal accelerations is $\sqrt{2} : 1$, then the:
   (A) final velocity of car P > final velocity of car Q.
   (B) final velocity of car P < final velocity of car Q.
   (C) ratio of V_P to V_Q is $2 : \sqrt{2}$.
   (D) ratio of distance travelled by car 'P' to car 'Q' is 2 :1
2. A person, seated in a train under motion, is at rest with reference to:
   (A) the train.
   (B) a person watching him from the front seat.
   (C) a car moving in the opposite to the train.
   (D) trees on the ground.
3. The direction of motion of a body is decided by _________ of the body.
   (A) velocity (B) acceleration (C) displacement (D) speed
4. A train covers equal displacements in equal intervals of time then it moves with:
   (A) uniform acceleration. (B) uniform motion.
   (C) uniform speed. (D) uniform velocity.
5. The ratio of distances travelled by two bodies A and B starting from rest moving along a straight line with equal acceleration is n, then (Assume t_A, t_B as time taken by bodies A and B respectively).

(A) $t_A \geq t_B$, if $n \geq 1$ (B) $t_A \leq t_B$, if $n \leq 1$

(C) $t_A = t_B$, if n = 1 (D) $t_A > t_B$, if n < 1

6. A body having zero speed:

(A) is always under rest. (B) has zero acceleration.

(C) has uniform acceleration. (D) always under motion.

7. Using the table given below the values of velocity at the end of t seconds for a body under linear motion, It can be concluded that body moves with:

V (m s^{-1})	0	6	12	24	30	36	42
t(s)	0	2	4	8	10	12	14

(A) uniform speed (B) uniform motion

(C) uniform acceleration (D) uniform velocity

8. A particle initially starts from rest, travels a distance Y in the first two seconds and a distance of X in next two seconds then,

(A) X = 2Y (B) X + Y = 4X (C) X + Y = 4Y (D) X = 3Y

9. The ratio of distances travelled by a uniformly accelerated body form rest in first second, second second and third second is:

(A) 1 : 3 : 5

(B) an integral multiple of odd number ratio less than 7

(C) an integral multiple of odd natural numbers.

(D) 1 : 4 : 9

10. The velocity of a body is given by the equation v = 6 – 0.02 t, where t is the time taken. The body is undergoing:

(A) uniform retardation of 0.02 m s^{-2} (B) uniform acceleration of 0.02 m s^{-2}

(C) uniform retardation of –0.02 m s^{-2} (D) uniform acceleration of –0.02 m s^{-2}

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statement of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** If the magnitude of displacement is zero, then it is not a vector quantity.

Reason: A vector needs both magnitude and direction.

2. **Assertion:** Acceleration and displacement are in the opposite direction during retardation.

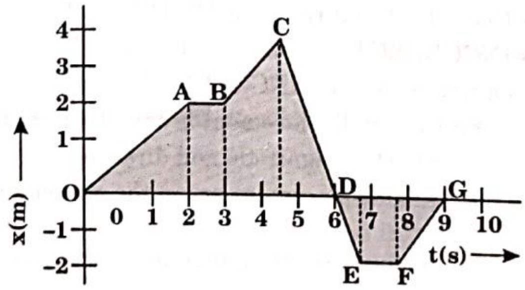
Reason: Acceleration is given as the change in velocity per unit time.

3. **Assertion:** The time for which a body remains in the air is called as time of flight.
   Reason: Time of flight is inversely proportional to the initial velocity.
4. **Assertion:** The maximum height reached by an object projected up is directly proportional to the initial velocity u.
   Reason: The maximum height reached by an object thrown up with an initial velocity u is given by $h = \frac{u^2}{2g}$.
5. **Assertion:** The time of flight 'T' is the sum of time of ascent and time of descent.
   Reason: The time of ascent is equal to the time of descent.
6. **Assertion:** Heavier bodies fall with greater acceleration.
   Reason: Gravitational force is more on heavier bodies.
7. **Assertion:** Maximum possible height attained by the projectile is $\frac{u^2}{2g}$, where u is initial velocity
   Reason: To attain maximum height, particle is thrown vertically upwards at $\theta = 90°$
   $H = \frac{u^2}{2g}\sin^2\theta \Rightarrow H_{max} = \frac{u^2}{2g}$.
8. **Assertion:** Two bodies of different masses are dropped from same height reach the ground at same instant of time.
   Reason: Time of flight depends upon the mass of the bodies.
9. **Assertion:** Distance covered by a moving body is always greater than zero.
   Reason: Displacement of a particle can be greater than or less than or equal to zero.
10. **Assertion:** A stone dropped from a height moves with constant velocity.
    Reason: Time of descent is directly proportional to the square root of the velocity of the body.

PARAGRAPH QUESTIONS

Passage - I

I. A dancer demonstrating dance steps along a straight line. The position time graph is given below.



(i) Find the average speed for the dance step depicted by CD.
(A) 1 m s^{-1} (B) 1.33 m s^{-1} (C) 2.75 m s^{-1} (D) 0.89 m s^{-1}

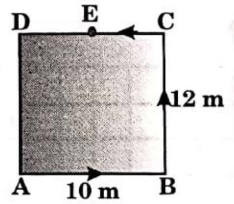
(ii) Find the average velocity for the dance step depicted by AB.
(A) 1 m s^{-1} (B) 1.33 m s^{-1} (C) 2.75 m s^{-1} (D) 0 m s^{-1}

(iii) Find the average velocity of the dancer during time interval between t = 4.5 s to t = 9 s
(A) 1 m s^{-1} (B) – 1.33 m s^{-1} (C) 2.75 m s^{-1} (D) – 0.89 m s^{-1}

SECTION – B

NUMERICAL PROBLEMS

1. The length of a minute hand of a clock is 4 cm. Find the displacement and average velocity of the tip of the minute hand when it moves during a time interval from
(a) 3 : 15 pm to 3 : 30 pm (b) 4 : 15 pm to 4 : 45 pm.
2. If the distance travelled by a body in the nth second is given by (4 + 6 n) m then find the initial velocity and acceleration of the body.
3. An insect moves along the sides of a wall of dimensions 12 m × 5 m starting from one corner and reaches the diagonally opposite corner. If the insect takes 2 s for its motion then find the ratio of average speed to average velocity of insect.
4. A particle starts moving from point A, along a rectangular plot via the path shown. If the time taken to reach the point E (where E is midpoint of D and C) be 0.5 s, then find the average speed and average velocity of the particle.



5. A car moving at a certain speed stops on applying brakes with in 16 m. If the speed of the car is doubled, maintaining the same retardation. then at what distance does it stop? Also calculate the percentage change in this distance.
6. Two bodies, initially separated by x m and having an initial velocity 2 m s^{-1} each, are moving towards each other along a straight line. If the rate of increase of their speeds is 3 m s^{-2} and 2 m s^{-2} respectively and the two meet after 4 seconds, find x.
7. Two stones A and B are dropped from the top of two different towers such that they travel 44.1 m and 63.7 m in the last second of their motion respectively. Find the ratio of the heights of the two towers from where the stones were dropped.
8. A body projected vertically up has displacement 20 m in the first 'n' seconds while it was moving up. Find its magnitude of displacement in the last 'n' seconds while falling down.
9. A body is dropped from certain height H. If the ratio of the distances travelled by it in (n – 3) seconds to (n – 3)nd second is 4 : 3, find H. (Take g = 10 m s^{-2})
10. Find the initial velocity of projection of a ball thrown vertically up if the distance moved by it in 3rd second is twice the distance covered by it in 5th second. (Take g = 10 m s^{-2})
11. A stone falls freely from rest, and the total distance covered by it in the last second of its motion, equals the distance covered by it in the first three seconds of its motion. Find

the time for which stone remains in the air and the total height from where stone is dropped.

12. From the top of a 40 m tall multi-storeyed building, a boy projects a stone vertically upwards with an initial velocity 10 m s^{-1} such that, it eventually falls to the ground. After how long will the stone strike the ground? (Take $g = 10$ m s^{-2})

13. A stone is dropped from a height of 125 m. If $g = 10$ m s^{-2}, what is the ratio of the distances travelled by it during the first and the last second of its motion?

14. A velocity – time graph is shown below in figure (i) and (ii) find the acceleration and displacement.

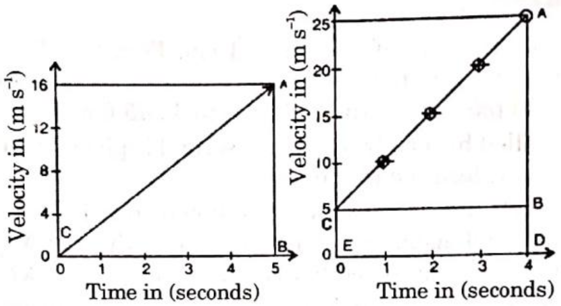
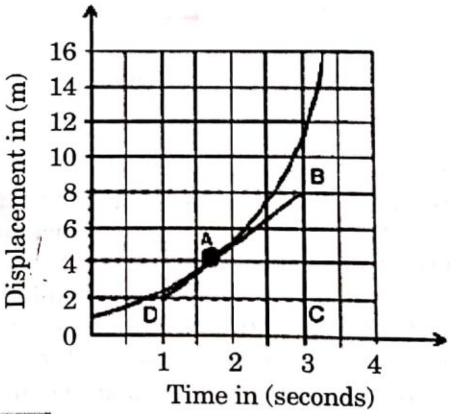


Fig. (i) Fig. (ii)

15. The displacement - time graph is shown in figure below. What do this graph represent? Find velocity at point A.



CONCEPTUAL QUESTIONS

1. Can distance travelled be equal to magnitude of displacement for a moving body. If so, how should the particle be moving?
2. Can a moving body have uniform velocity and non uniform speed?
3. Can a moving body have non uniform velocity and uniform speed?
4. Is it possible for an accelerating body to have zero velocity? Explain.
5. Is it possible for a body moving with a uniform speed to have acceleration? Explain.

6. Are the equations of motion applicable to bodies projected vertically up with any velocity, say 8 km s^{-1}, for determining the maximum height?

7. Is it possible for a body undergoing linear motion to have velocity and acceleration in opposite direction. Explain?

8. A body traversed half of the distance with a velcoity V_0. The remaining part V_1 for half of the time and with the velocity V_2 for the other half of the time. Find the average velocity of the body over the whole journey.

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. Two bodies of different masses m_a and m_b are dropped from two different heights i.e., a and b. The ratio of time taken by both bodies to drop through these distance is:

(A) $\sqrt{a} : \sqrt{b}$ (B) $\frac{m_a}{m_b} : \frac{b}{a}$ (C) a : b (D) $a^2 : b^2$

2. Two bodies, one held 30 cm directly above the other, are released simultaneously and allowed to fall freely under gravity. After 2 s their relative separation will be:

(A) 10 cm (B) 20 cm (C) 30 cm (D) zero

3. A ball is released from the top of height 'h' metres. It takes 't' seconds to reach the ground. Where is the ball at the time t/2 s?

(A) At $\left(\frac{h}{4}\right)$ from the ground

(B) At $\left(\frac{h}{2}\right)$ from the ground

(C) At $\left(\frac{3h}{4}\right)$ from the ground

(D) Depends upon mass and volume of the ball

4. A body is released from a height and it falls freely towards the earth. Exactly 1 s later another body is released. What is the distance between the two bodies 2 s after the release of the second body?

(A) 4.9 m (B) 9.8 m (C) 24.5 m (D) 50 m

5. A stone is dropped into a lake from a tower 500 m high. The sound of the splash will be heard by a man on the tower after:

(A) 21 s (B) 10 s (C) 11.5 s (D) 14 s

6. A particle starts moving from rest with uniform acceleration. It travels a distance X in the first three seconds and a distance Y in next three seconds, then:

(A) Y = X (B) Y = 3X (C) Y = 2X (D) Y = 4X

7. A stone thrown vertically upwards with an initial velocity u from the top of a tower, reaches the ground with a velocity 3 u. The height of the tower is:
(A) $3\ u^2/g$ (B) $4\ u^2/g$ (C) $6\ u^2/g$ (D) $9\ u^2/g$

8. From a place where, $g = 9.8\ m\ s^{-2}$, a stone is thrown upwards with a velocity of $4.9\ m\ s^{-1}$. The time taken by the stone to return to the earth is:
(A) 2 s (B) 1 s (C) 4 s (D) 8 s

9. A stone is thrown vertically up from the ground. It reaches a maximum height of 50 m in 10 s. After what time will it reach the ground from the maximum height?
(A) 5 s (B) 10 s (C) 20 s (D) 25 s

10. A body thrown vertically up reaches a maximum height of 50 m. Another body with double the mass thrown up with double the initial velocity will reach a maximum height of:
(A) 100 m (B) 200 m (C) 400 m (D) 50 m

11. Two stones are dropped down simultaneously from different heights. At the starting time, the distance between them is 30 cm. After 1 s, the distance between the two stones will be ($g = 10\ m\ s^{-2}$).
(A) 10 cm (B) 20 cm (C) 30 cm (D) 0 cm

12. A body falling for 2 s, covers a distance equal to that covered in the next second:
(A) 30 m (B) 10 m (C) 60 m (D) 20 m

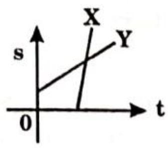
13. The distance moved by a freely falling body during the 1st, 2nd, 3rd seconds of its motion are proportional to:
(A) 1 : 2 : 3 (B) 1 : 3 : 5 (C) 1 : 4 : 9 (D) 1 : 1 : 1

14. A gun is fired at a target. At the moment of firing, the target is released and allowed to fall freely under gravity. Then the bullet:
(A) misses the target by passing above it (B) hits the target
(C) misses the target by passing below it (D) may or may not hit

15. A freely falling body has a velocity V after falling through a distance h. The distance it has to fall down further for its velocity to become 2V is:
(A) 3h (B) 2h (C) h (D) 4h

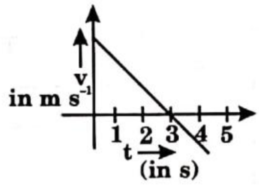
BRAIN NURTURES

1.

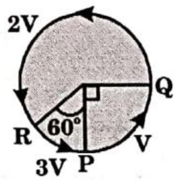


The figure given above shows the distance-time graph of particles X and Y. Identify the particle moving with greater speed. Also find the type of speed exhibited by each particle. [Hint slope = tan θ].

2. The following graph represents the velocity–time graph of a body projected vertically upward under gravity. Find the maximum height attained by the body. (Take $g = 10 \text{ m s}^{-2}$)



3. A particle moves along a circular path in the anti–clock wise direction. It travels with a speed 'V' from the point 'P' to 'Q', next from 'Q' to 'R' with a speed of '2V' and remaining distance from 'R' to 'P' with a speed '3V'. Find average speed for the total journey.



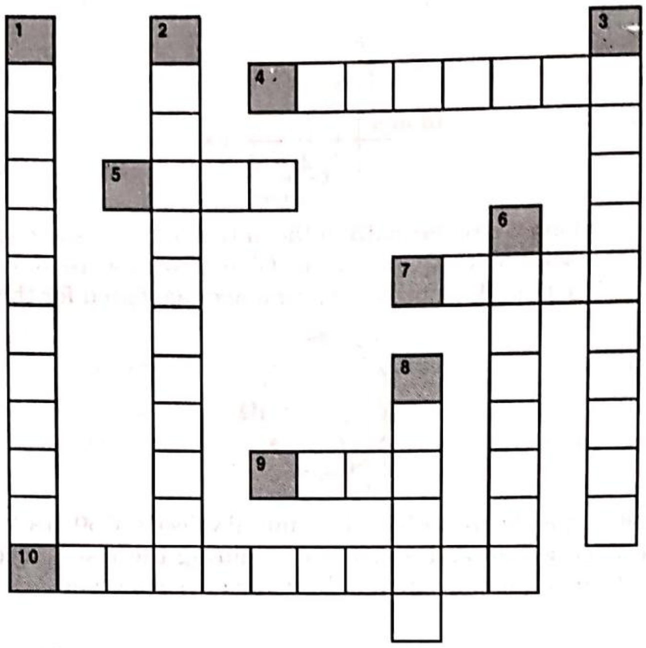
4. A bullet is fired vertically upwards with an initial velocity of 50 m s^{-1}. It covers a distance h_1 during the first second and a distance h_2 during the last 3 seconds of its upward motion. If $g = 10 \text{ m s}^{-2}$, how are h_1 and h_2 related to each other.

5. A stone is dropped into a well and the sound of the splash is heard $3\frac{1}{8}$ s later. If the velocity of sound in air is 352.8 m s^{-1}, find the depth of the well. ($g = 9.8 \text{ m s}^{-2}$).

6. A, B, C and D are points in a vertical line such that, AB = BC = CD. If a body falls from rest from A, prove that the time of descent through AB, BC and CD are in the ratio $1 : \sqrt{2} - 1 : \sqrt{3} - \sqrt{2}$.

7. The helicopter rises from rest on the ground vertically upwards with a constant acceleration g/8. A food packet is dropped from the helicopter when it has risen to a height h. Show that the time taken by the packet to reach the ground is $2\left(\frac{h}{g}\right)^{1/2}$.

CROSSWORD PUZZLE



ACROSS

4 Area under a speed time graph

5 Initial velocity of a freely falling body

7 Rate of change of distance

9 No change in the position of a body with respect to surroundings

10 Motion exhibited by body moving in a straight line

DOWN

1 Shortest distance taken from initial point to final point

2 Physical quantity whose CGS unit is cm s^{-2}

3 Negative acceleration

6 Rate of change of displacement

8 The change in position of a body with respect to surrounding

Chapter 3

Newton's Laws of Motion

Common misconception	Fact
1. Action and reaction cancels each other.	1. As action and reaction does not act on the same body they never cancel each other.
2. Force is not needed to keep a body moving with uniform velocity.	2. No force is required to keep a body moving with uniform velocity (provided friction is not present). This is due to the inertia of the body to change its state.

SYNOPSIS

INTRODUCTION

It is our common observation that an object such as a chair lying in a room or a vehicle parked outside the house remains at rest unless a push or a pull is given to it. Such an object cannot move on its own. In other words, force has to be applied in order to move an object at rest. Also, if an object is moving along a straight line with some velocity, it is found that the force is required to change its direction of motion or the magnitude of the velocity. In other words, force is an agent, which causes acceleration. However, in certain cases, the acceleration caused by the force may be practically zero.

Hence, force is a push or a pull which produces or tends to produce motion in a body at rest; stops or tends to stop a body which is in motion, increases or decreases the magnitude of velocity of the moving body or changes the direction of motion of the moving body.

GALILEO'S EXPERIMENT

Galileo was the first to demonstrate the relationship between motion and force. He released a ball from rest on one of the inclined plane, the ball rolled down the inclined plane, similarly if the ball is made to move upwards it travelled upwards to attain certain height. From the above illustration he concluded that (i) a body when rolled down an inclined plane, the velocity of the body increases while the velocity of the body decreases when the body rolls up the plane. (ii) if inclination of anyone of the plane varies, the ball will attain different heights.

If a double inclined plane is used with different. It can be observed that as the slope of an inclined plane is changed, body reaches same height travelling longer distance. In the limiting case, if the slope of a plane is made zero, the ball travels an infinite distance. Hence based on the above facts it can be summarised that, if the external force is zero, a body at rest continues to be at rest and a body in motion continues to move with uniform velocity. These ideas suggested by Galileo were later formulated into a law by Newton as Newton's first law of motion.

NEWTON'S FIRST LAW OF MOTION

A particle remains at rest or moves in a straight line with a constant speed unless it is compelled to change that state by an external unbalanced force. First law of motion gives the definition of inertia.

INERTIA

Inertia of rest

Tendency of a body to continue in its state of rest.

Example

When a bus starts suddenly, the passengers fall backwards. This is due to inertia of rest.

Inertia of motion

Tendency of a body to continue in its state of motion.

Example

A bicycle is observed to move forward even when pedaling is stopped, this is due to inertia of motion.

Inertia of direction

Tendency of a body to continue to move with uniform motion in a linear direction.

To change the state of rest or of uniform motion of a body an external unbalanced force is needed. This force depends on the inertia which in turn depends on the mass of the body. Hence, mass is the measure of inertia of a body.

LINEAR MOMENTUM (p)

The total quantity of motion contained in a body is known as its momentum. It is a vector quantity.

Momentum is measured as the product of mass and velocity. p = mV

SI unit of momentum = SI unit of mass × SI unit of velocity = kg × m s^{-1} = kg m s^{-1}

CGS unit of momentum = GCS unit of mass × CGS unit of velocity = g × cm s^{-1}
= g cm s^{-1}

NEWTON'S SECOND LAW OF MOTION

The rate of change of momentum of a particle is directly proportional to the force acting on it and takes place in the direction of applied force.

Mathematically,

$$\vec{F} \propto \frac{\Delta \vec{P}}{\Delta t}$$

$$\Rightarrow \vec{F} = k\left[\frac{\vec{P}_2 - \vec{P}_1}{\Delta t}\right] \Rightarrow k\left(\frac{m\vec{v} - m\vec{u}}{\Delta t}\right) = k\left(m\left(\frac{\vec{v} - \vec{u}}{\Delta t}\right)\right) = km\left(\frac{\Delta \vec{v}}{\Delta t}\right)$$

F = kma

The value of constant of proportionality can be taken as 1 when unit of force is chosen in such a way that it produces unit acceleration by a unit mass then F = ma.

Units of force

Absolute units and gravitational units are two types of units.

System of units	Absolute unit	Gravitational unit
SI	newton	kilogram weight or kilogram force
CGS	dyne	gram weight or gram force

1 N = 10^5 dyne, 1 kgf = 10^3 gf = 9.8 N

IMPULSE

The product of force and time for which the force acts is called impulse. When a large force acts on a body for a very short duration of time then this large force is called impulsive force.

Impulse = force × time = mat

$$= m\left(\frac{\vec{v} - \vec{u}}{t}\right)t = m(\vec{v} - \vec{u})$$

Hence, impulse is also defined as change in momentum. It is a vector quantity. The SI unit of impulse is N s or kg m s^{-1} and in CGS system dyne second or g cm s^{-1}

NEWTON'S THIRD LAW OF MOTION

Whenever two bodies exert force on each other, the force exerted by first body on the second (action) is equal in magnitude but opposite in direction to the force exerted by second body on the first (reaction).

Illustration of Newton's third law of motion

When a rubber ball is struck against a wall, the ball bounces back due to the reaction of the wall.

When a person jumps out of a boat, the boat is pushed in the backward direction due to reaction.

APPARENT WEIGHT OF A PERSON IN A LIFT

Let a person of mass 'm' standing on a weighing machine placed on the floor of a lift. His actual weight is 'mg' which acts vertically down. The reaction offered by the weighing machine is 'R' which is also called apparent weight of that person.

a. ***When lift is at rest***

From the Newton's law, the net force acting on him will be zero

So, $R - mg = 0 \Rightarrow R = mg$

i.e., His apparent weight is equal to his actual weight.

b. ***When lift moves upwards or downwards with uniform velocity***

Net acceleration of lift is zero. So, net force acting on him will be zero.

So, $R - mg = 0 \Rightarrow R = mg$

i.e., His apparent weight is equal to his actual weight.

c. ***When lift moves upwards with constant acceleration 'a'***

Net force on the person acts vertically upwards.

So, $R - mg = ma \Rightarrow R = mg + ma$

i.e., His apparent weight is greater than his actual weight.

d. ***When lift moves downwards with constant acceleration 'a'.***

Net force on the person acts vertically downwards.

So, $mg - R = ma \Rightarrow R = mg - ma$

i.e., His apparent weight is less than his actual weight.

e. ***If lift falls freely***

His apparent weight will be zero (or he feels weightless).

LAW OF CONSERVATION OF LINEAR MOMENTUM

From the Newton's second law of motion $F = \frac{\Delta p}{\Delta t}$, if external force acting on the system is zero then change in linear momentum of the system is zero which means linear momentum of the system is constant. This is called law of conservation of linear momentum which states that, 'In the absence of external force, the total linear momentum of the system remains constant'.

This law is universal. It is true not only for collision between astronomical bodies but also for collision between atomic particles.

Applications

a. ***Recoil of a gun***

Let a gun and a bullet in its barrel constitute a system. Initially both are at rest. When the bullet is fired, it moves forward and gun recoils. Since external force acting on the system is zero the total linear momentum remains constant i.e., linear momentum of the bullet will be equal and opposite to linear momentum of the gun.

$V_{re} = \frac{mV}{M}$ where m, M, V, V_{re} denote mass of the bullet, mass of the gun, velocity of the bullet and recoil velocity of the gun.

b. Explosion of a bomb

Let a bomb of mass 'm' at rest explodes into number of pieces of masses m_1, m_2, ...,m_n with velocity v_1, v_2, ... v_n respectively. The explosion is caused due to internal forces. The external force on the bomb (system) is zero hence its linear momentum before explosion is equal to total linear momentum of all pieces after explosion.

i.e., $\text{zero} = m_1\vec{v}_1 + m_2\vec{v}_2 + \text{----------} + m_n\vec{v}_n$

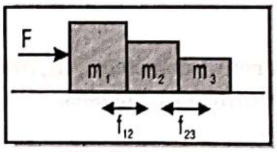
Let a machine gun fire 'n' bullets each of mass 'm' with a velocity 'v' in a time interval 't'. To hold the gun in the same position the force to be exerted is

$$F = -\frac{nmv}{t}$$

The working of a rocket and jet plane is based on law of conservation of linear momentum.

CONTACT FORCES

A system consists of the bodies of different masses as shown which are in contact. A force F is applied as shown. All the bodies move with the same acceleration 'a'.



for m_1 : $F - f_{12} = m_1a$, for m_2: $f_{12} - f_{23} = m_2a$, for m_3: $f_{23} = m_3a$

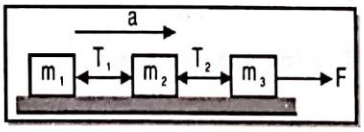
$$a = \frac{F}{(m_1 + m_2 + m_3)}$$

Contact force between m_1 and m_2 is $f_{12} = \frac{(m_2 + m_3)F}{(m_1 + m_2 + m_3)}$

Contact force between m_2 and m_3 is $f_{23} = \frac{m_3F}{(m_1 + m_2 + m_3)}$

CONNECTED BODIES

1. Masses m_1, m_2, m_3 are connected by light strings and are pulled as shown. Then



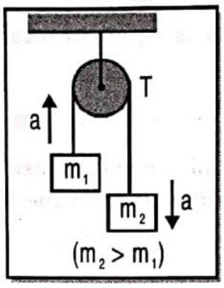
for m_1: $T_1 = m_1a$, for m_2: $T_2 - T_1 = m_2a$, for m_3: $F - T_2 = m_3a$

(a) acceleration of the system $a = \frac{F}{(m_1 + m_2 + m_3)}$

(b) $T_1 = m_1 a$

(c) $T_2 = (m_1 + m_2)\,a$ (T_1 and T_2 are tensions in the strings)

2. When two bodies are connected by a light string passing over a light pulley.



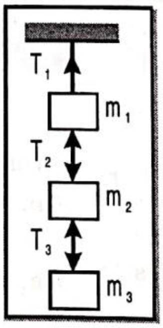
for m_1: $T - m_1 g = m_1 a$, for m_2: $m_2 g - T = m_2 a$

Acceleration of each body.

$$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g, \qquad T = \frac{2m_1 m_2 g}{(m_1 + m_2)}$$

Thrust on the pulley = 2T

3. Consider three blocks of different masses m_1, m_2 and m_3 connected by strings as shown. The system is at rest and for different masses.



for m_3: $T_3 = m_3 g$,

for m_2: $T_2 = m_2 g + T_3 \Rightarrow T_2 = (m_2 + m_3)g$

for m_1: $T_1 = T_2 + m_1 g \Rightarrow T_1 = (m_1 + m_2 + m_3)g$

SOLVED EXAMPLES

Example 1:

A force acts for 10 s on a body of mass 10 kg after which the force cease and the body describes 50 m in the next 5 s. Find the magnitude of the force.

Solution:

Here, initial velocity of the body, u = 0; M = 10 kg; t = 10 s

After the force ceases, the body covers 50 m in 5 s.

Therefore, final velocity of the body,

$$v = \frac{\text{distance}}{\text{time}} = \frac{50}{5} = 10\,\text{m s}^{-1}$$

Now, v = u + at

$\therefore$ 10 = 0 + a × 10 or a = 1 m s^{-2}

Therefore, force applied on the body,

F = Ma = 10 × 1 = 10 N

Example 2:

A cricket ball of mass 500 g is moving with speed of 36 km h^{-1}. It is reflected back with the same speed. What is the impulse applied on it?

Solution:

Here, M = 500 g = 0.5 kg

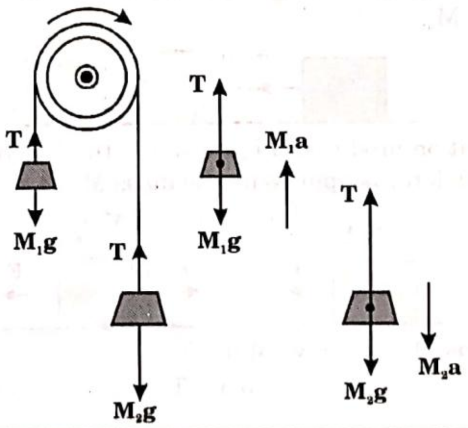
u = 36 km h^{-1} = 10 m s^{-1}; v = –10 m s^{-1}

Now, impulse = Mu – Mv = M(u – v)

= 0.5[10 – (–10)] = 10 kg m s^{-1}

Example 3:

Two masses 7 kg and 12 kg are connected at the two ends of a light inextensible string that passes over a frictionless pulley. Find the acceleration of the masses and the tension in the string, when the masses are released.



Solution:

Let $M_1 = 7$ kg and $M_2 = 12$ kg

The tension (T) in the string acts as shown in figure. Suppose that the system moves with an acceleration a as shown in the figure.

For mass M_1: Figure (a) is free–body diagram for the mass M_1.

$\therefore M_1 a = T - M_1 g$ ------------(1)

For mass M_2: Figure (b) is free–body diagram for mass M_2.

$\therefore M_2 a = M_2 g - T$ ------------(2)

Adding the equations (1) and (2), we get

$(M_1 + M_2)a = (M_2 - M_1)g$

$$a = \frac{(M_2 - M_1)g}{M_1 + M_2}$$

Substituting for M_1, M_2 and g, we have

$$a = \frac{(12-7)\times 9.8}{(12+7)} = 2.58 \text{ m s}^{-2}$$

From the equation (1), we have

$T = M_1 a + M_1 g$

$= 7 \times 2.58 + 7 \times 9.8 = 86.66$ N

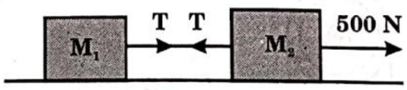
Example 4:

A horizontal force of 500 N pull two masses 10 kg and 20 kg (lying on a frictionless table) connected by a light string. What is the tension in the string?

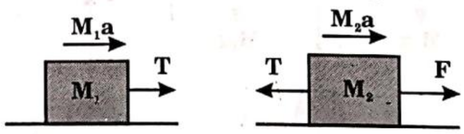
Solution:

Suppose that the mass $M_1 = 10$ kg and $M_2 = 20$ kg are connected to each other by a light string and are placed on frictionless table.

When force is applied on $M_2 = 20$ kg, figure shows the case, when the force of 500 N is applied on the mass M_2.



Let a be the acceleration produced. Figure shows the free body diagrams for masses M_1 and M_2, When the force is applied on the mass M_2.



For the motion of mass M_1, we have $M_1 a = T$

$10\,a = T$ ------------(1)

For the motion of mass M_2, we have $M_2 a = F - T$

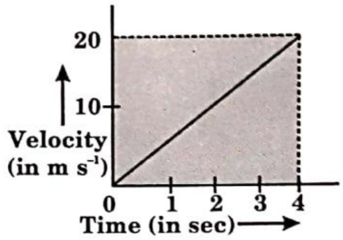
$20\ a = 500 - T$ --------- (2)

Dividing the equation (2) by (1), we have

$$\frac{20\ a}{10\ a} = \frac{500 - T}{T} \Rightarrow 2\ T = 500 - T \Rightarrow T = \frac{500}{3} = 166.67\ N$$

Example 5:

The velocity–time graph of a ball moving on the surface of a floor is given below:



Calculate the force acting on the ball, if mass of the ball is 200 g.

Solution:

The graph shows that the velocity of the ball at t = 0 is 0.

⇒ initial velocity of the ball = u = 0

From the graph, final velocity of the ball after 4 seconds = v = 20 m s^{-1}

Mass of the ball = m = 200 g = $\frac{200}{1000}$ kg = $\frac{1}{5}$ kg

Force acting on the ball = F = ?

We know that, $F = ma = m\left(\frac{v-u}{t}\right)$ -------------- (1) $\left[\therefore a = \frac{v-u}{t}\right]$

Substituting the above values in (1), we have

Force acting on the ball = $F = ma = \frac{1}{5}\left(\frac{20-0}{4}\right) = \frac{1}{5} \times 5 = 1\ N$

Therefore force acting on the ball is 1 N.

Example 6:

A cricket ball of mass 120 g is moving with a velocity of 12 m s^{-1}, it turns back and moves with a velocity of 20 m s^{-1} when hit by a bat. Find the impulse and the force, if the force acts for 0.02 s.

Solution:

If u = –12 m s^{-1}, v= 20 m s^{-1}, t = 0.02 s

(∴ ball moves in opposite direction)

impulse = change in momentum

$= m(v - u)$

$= 0.12\,(20 + 12) = 0.12\,(32) = 3.84$ N s

$$\text{Force} = \frac{\text{change in momentum}}{\text{time}} = \frac{3.84}{0.02} = 192 \text{ N}$$

Example 7:

The ratio of magnitude of recoil of residual nucleus of U^{238} to the magnitude of velocity of a particle x emitted is 2 : 117. Find the mass of the particle x.

Solution:

Given, $\frac{v_n}{v_x} = \frac{2}{117}$

$m_x v_x + m_n v_n = 0$

$m_x v_x = - m_n v_n$

$\frac{v_n}{v_x} = \frac{m_x}{m_n}$

$\frac{2}{117} = \frac{m_x}{(238 - m_x)} \Rightarrow 476 - 2\,m_x = 117\,m_x$

$m_x = \frac{476}{119} = 4$

∴ Mass of a particle x is 4.

Example 8:

Two bodies have masses in the ratio 3 : 4. When a force is applied on the first body, it moves with an acceleration of 6 m s^{-2}. How much acceleration will the same force produce in the other body?

Solution:

Let the force acting on the two bodies be 'F' N.

Case – I

Mass of the 1st body = m_1 = '3 m' kg

Acceleration of the 1st body = a_1 = 6 m s^{-2}

$F_1 = m_1 \times a_1 = 3\text{ m} \times 6 = 18\text{ m}$

$\Rightarrow$ F = '18 m' N ------------- (1)

Case – II

Mass of the 2nd body = m_2 = '4 m' kg

Acceleration of the 2nd body = a_2 = ?

$F_2 = m_2 \times a_2 = 4\text{ m} \times a_2 = 4ma_2$

$\Rightarrow$ F = '4 ma_2' N ---------------- (2)

Dividing (1) with (2)

$$\frac{F}{F} = \frac{18\ m}{4\ ma_2} \Rightarrow 4a_2 = 18 \Rightarrow a_2 = \frac{18}{4} = 4.5\ m\ s^{-2}$$

Therefore, acceleration produced in the second body by application of same force is 4.5 m s^{-2}.

Example 9:

A motor car running at the rate of 7 m s^{-1} can be stopped by the brakes in 10 m. Prove that the total resistance to the motion, when the brakes are on, is one fourth of the weight of the car.

Solution:

Here, u = 7 m s^{-1}; v = 0; S = 10 m

Now, $v^2 - u^2 = 2aS$

$0^2 - 7^2 = 2a \times 10 = 2.45\ m\ s^{-2}$

Let M be mass of the motor car.

Therefore, resistance due to brakes, F = Ma = M × 2.45 N

$$\therefore \frac{F}{Mg} = \frac{M \times 2.45}{M \times 9.8} = \frac{1}{4}$$

Example 10:

A bullet of mass 60 g moving with a velocity of 500 m s^{-1} is brought to rest in 0.01 s. Find the impulse and the average force of blow.

Solution:

Here M = 60 g = 6×10^{-3} kg; u = 500 m s^{-1}; v = 0 and t = 0.01 s

Now, impulse I = Mv – Mu = M(v – u) = 60×10^{-3} (0 – 500) = – 30 N s

If F is average force of blow, then I = Ft

$$F = \frac{I}{t} = \frac{-30}{0.01} = -3{,}000\ N = -3\ kN$$

FORCE

Force is that which tends to change the state of a body

Newton's I law: It gives definition of force. Every body continues in its state of rest or of uniform motion in a straight line unless it is compelled by an external force to change that state.

- **Inertia:** The property of a body by which it is unable to change its own state.
  Types: (a) inertia of rest
  (b) inertia of motion
  (C) inertia of direction.

Newton's II[nd] law: It gives formula of force. The rate of change of momentum of a body is directly proportional to the external force acting on it.

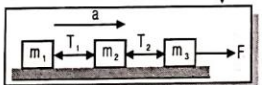
- **Momentum:** The product of mass and velocity of a body.
  Formula: p = mv
  Units: g cm s^{-1} (CGS)
  kg m s^{-1} (MKS)

- **Impulse:** The change in linear momentum of the body when a large force acts on a body for short interval of time.
  Formula: I = Ft
  Units: dyne s (CGS)
  N s (SI)

Newton's III law: It gives about amount of force exerted on bodies. Whenever a body exerts force on other body, the force exerted by the first body is equal and opposite to the force exerted by the second body on the first.

- **Law of conservation of linear momentum:** When two bodies collide with each other, the total momentum of the system before collision is equal to the total momentum of the system after collision.

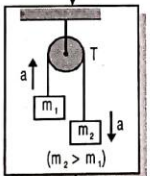
Connecting bodies



$$a = \frac{F}{(m_1 + m_2 + m_3)}$$

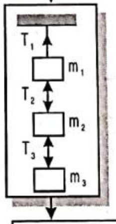
$T_1 = m_1 a$

$T_1 = (m_1 + m_2)a$



$$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$$

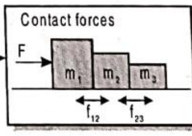
$$T = \frac{2m_1 m_2 g}{(m_1 + m_2)}$$



$T_1 = (m_1 + m_2 + m_3)(g + a)$

$T_2 = (m_2 + m_3)(g + a)$

$T_3 = m_3(g + a)$



$$a = \frac{F}{(m_1 + m_2 + m_3)}$$

$$f_{12} = \frac{(m_2 + m_3)F}{(m_1 + m_2 + m_3)}$$

$$f_{23} = \frac{mF_3}{(m_1 + m_2 + m_3)}$$

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. When a running horse suddenly stops, the rider falls ________.
2. The mud from the wheel of a moving vehicle flies off ________.
3. When a body is travelling at constant velocity, the net force on it is ________.
4. If the same force is applied on two bodies of different masses for the same time, then the change produced in the momentum of the two bodies is also ________.
5. The SI unit of linear momentum is ________.
6. The paired forces always acts on ________ bodies.
7. The acceleration produced by a force in the motion of a body depends only upon its ________.
8. A 10 N force applied on a body produces in it an acceleration of 2 m s^{-2}. The mass of the body is ________.
9. Rocket works on the principle of ________.
10. Newton's first law of motion gives the concept of ________.
11. Momentum is a measure of quantity of ________.
12. Newton's second law gives the measure of ________.
13. When we jump out of a boat standing in water it moves ________.
14. To reduce the momentum of a given body to half its original value then the velocity must be ________.
15. A body is acted upon by a constant force then it will have a uniform ________.

TRUE OR FALSE

16. If a body is moving with a constant speed along a straight line; then in order to change its direction of motion, an external force has to be applied in a direction normal to the direction of motion.
17. Inertia means resistance to the change of state.
18. If two bodies of different masses move with the same momentum, then heavier body will have greater velocity.
19. The linear momentum of a body at rest is zero.
20. When the net force acting on a system is zero the body may move with uniform acceleration.
21. Walking is more easier on the ground than on sand. In the former case reaction comes into play more quickly.

22. The area under a force time graph gives acceleration.
23. A canon after firing recoils due to newton's third law of motion.
24. A force must act on a vehicle moving on a rough road in a straight line with uniform velocity.
25. The weight of a freely falling body is always constant.

MATCH THE FOLLOWING

26.

Column A	Column B
A. Inertia	p. Newton's III law
B. Recoil of a gun	q. kgf
C. Momentum	r. 10^5 g cm s^{-1}
D. 1 kg m s^{-1}	s. Newton's I law
E. Weight	t. Newton's II law

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. China wares are wrapped in straw or paper before packing. This is the application of concept of:

   (A) impulse (B) momentum (C) acceleration (D) force

2. In a game of tug of wars, a condition of equilibrium exists. Both the teams pull the rope with a force of 10^4 N. The tension in the rope is:

   (A) 10^4 N (B) 10^5 N (C) 0 N (D) 2×10^4 N

3. A spring balance is graduated on sea level. If a body is weighed at consecutively increasing heights from earth's surface, the weight indicated by the balance:

   (A) will go on increasing continuously (B) will go on decreasing continuously
   (C) will remain same (D) will first increase and then decrease

4. A truck and a car are moving with equal velocity, on applying brakes, both will stop after certain distance and then:

   (A) truck will cover less distance before stopping
   (B) car will cover less distance before stopping
   (C) both will cover equal distance
   (D) none

5. A man is walking from east to west on a level rough surface. The force on the man is directed:

   (A) from west to east (B) from east to west
   (C) along the north (D) along the west

6. In which of the following cases, the net force is not zero?

(A) An object floating in air.

(B) A ball freely falling from a certain height.

(C) A cork floating on the surface of water.

(D) All the cases.

7. A car and a lorry are moving with same momentum, if same braking force is applied, then:

(A) car comes to rest in shorter distance.

(B) lorry comes to rest in shorter distance.

(C) both travels same distance before coming to rest.

(D) none

8. Inertia is the property of a body by virtue of which the body is:

(A) unable to change by itself the state of rest.

(B) unable to change by itself the state of uniform motion.

(C) unable to change by itself the direction of motion.

(D) unable to change by itself the state of rest or of uniform linear motion.

9. While dusting a carpet, we give a sudden jerk or beat with a stick because:

(A) inertia of rest keeps the dust in its position and the dust is removed by movement of carpet away.

(B) inertia of motion removes dust.

(C) no inertia involved in process.

(D) jerk compensates for the force of adhesion between dust and carpet and dust is removed.

10. The impulse of a body is equal to:

(A) rate of change of its momentum.

(B) change in its momentum.

(C) the product of force applied on it and the time of application of the force.

(D) both (B) and (C)

11. Two bodies A and B, moving in the same direction collide and after collision , move with the common velocity in the direction of A.

(A) The magnitude of force exerted by A on B is greater than the magnitude of force exerted by B on A.

(B) Both exert equal but opposite force on each other.

(C) The change in momentum of A and B are equal but opposite in direction.

(D) Both (B) and (C)

12. A force acts on a body of mass 3 kg such that its velocity changes from 4 m s^{-1} to 10 m s^{-1}. The change in momentum of the body is:

(A) 42 kg m s^{-1} (B) 2 kg m s^{-1} (C) 18 kg m s^{-1} (D) 14 kg m s^{-1}

13. While opening a tap with two fingers, the forces applied are:
(A) equal in magnitude
(B) parallel to each other
(C) opposite in direction
(D) All the above

14. When a body is stationary, then:
(A) there is no force acting on it.
(B) the body is in vacuum.
(C) the force acting on it is not in contact with it.
(D) the net forces acting on it balances each other.

15. Inertia of a body has direct dependence on:
(A) velocity (B) volume (C) mass (D) density

16. A bullet of mass 20 g is fired from a rifle of 8 kg with a velocity of 100 m s^{-1}. The velocity of recoil of the rifle is:
(A) 0.25 m s^{-1} (B) 25 m s^{-1} (C) 2.5 m s^{-1} (D) 250 m s^{-1}

17. A force 100 N acts in a body mass 2 kg for 10 s. The change in the velocity of the body is:
(A) 100 m s^{-1} (B) 250 m s^{-1} (C) 500 m s^{-1} (D) 1000 m s^{-1}

18. A ship of mass 3×10^7 kg initially at rest is pulled by a force of 5×10^4 N through a distance of 3 m. Assuming resistance due to water is negligible. Then the speed of the ship is:
(A) 0.1 m s^{-1} (B) 0.2 m s^{-1} (C) 0.3 m s^{-1} (D) 0.4 m s^{-1}

19. The time, in which a force of 2 N produces a change as momentum of 0.4 kg m s^{-1} in the body whose mass is 1 kg is:
(A) 0.2 s (B) 0.02 s (C) 0.5 s (D) 0.05 s

20. The engine of a car produces an acceleration of 4 m s^{-2} in a car, if this car pulls another car of same mass, what is the acceleration produced?
(A) 8 m s^{-2} (B) 2 m s^{-2} (C) 4 m s^{-2} (D) 1/2 m s^{-2}

MULTIPLE ANSWER QUESTIONS

1. The accelerated motion of a body can occur:
(A) due to change in its speed only.
(B) due to change in direction of motion only.
(C) due to change in both speed and direction of motion.
(D) due to constancy of velocity.

2. Which of the following statements are correct for action and reaction forces?
(A) These act on two different bodies.
(B) These are equal in magnitude but opposite in direction.
(C) These act on a single body.
(D) These are necessary to explain reactions in third law.

3. Which of the following statements are correct regarding linear momentum of a body?

(A) It is a measure of quantity of motion contained by the body.

(B) Change in momentum is the measurement of impulse.

(C) Impulse and acceleration act in same direction to the change in momentum.

(D) Incase of uniform circular motion, the linear momentum is conserved.

4. Which of the following statements are true?

(A) Impulse is the product of force and time for which the force acts.

(B) SI unit of impulse is N s

(C) When two bodies have the same velocity; the lighter body has more momentum.

(D) Conservation of linear momentum has no connection with "Newton's third law of motion".

5. Which of the following statements are true?

(A) When the mass of a body is doubled then the momentum of a body is also doubled, provided the body maintains the same velocity.

(B) We feel pain in the hand on hitting the wall, this is a consequence of Newton's third law of motion.

(C) A table cloth can be pulled from a table without dislodging the dishes. This is due to inertia of rest.

(D) Momentum is a vector quantity.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statements of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** Inertia is the property by virtue of which the body is unable to change by itself the state of rest only.

   Reason: The bodies do not change their state unless acted upon by an unbalanced external force.

2. **Assertion:** If the net external force on the body is zero, then its acceleration is zero.

   Reason: Acceleration does not depend on force.

3. **Assertion:** If two objects of different masses have same momentum, the lighter body possess greater velocity.

   Reason: For all bodies momentum always remains same.

4. **Assertion:** A rocket works on the principle of conservation of linear momentum.

   Reason: Whenever there is the change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

5. **Assertion:** The acceleration produced by a force in the motion of a body depends only upon its mass.

   Reason: Larger is the mass of the body, lesser will be the acceleration produced.

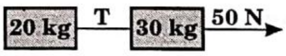
6. **Assertion:** Newton's third law of motion is applicable only when bodies are in motion.

   Reason: Newton's third law applies to all types of forces. e.g. gravitational, electric or magnetic forces etc.,

PARAGRAPH QUESTIONS

Passage - I

I. A 20 kg block is connected to a 30 kg block. A force of 50 N pulls the blocks to the right as shown in figure.



(i) Find the magnitude of acceleration of 30 kg block?

(A) 0.5 m s^{-2} (B) 1 m s^{-2} (C) 2 m s^{-2} (D) 5 m s^{-2}

(ii) Find the magnitude of tension T in the rope that connects the two blocks?

(A) 20 N (B) 10 N (C) 40 N (D) 30 N

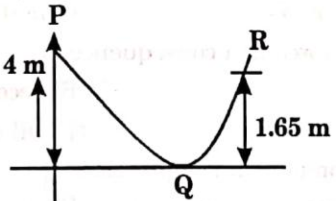
(iii) What is the magnitude of acceleration of the 20 kg block?

(A) 0.5 m s^{-2} (B) 2 m s^{-2} (C) 2.5 m s^{-2} (D) 1 m s^{-2}

SECTION – B

NUMERICAL PROBLEMS

1. A force of 64 dyne is inclined to the horizontal at an angle of 60°. Find the acceleration in a mass of 8 g, which moves in a horizontal direction.
2. A force of 10 N acts on a body for 3 microsecond (μs). Calculate the impulse. If mass of the body is 5 g, calculate the change of velocity.
3. A hammer weighing of 1 kg moving with the speed of 10 m s^{-1} strikes the head of a nail driving it 10 cm into a wall. Neglecting the mass of the nail, calculate (i) the acceleration during the impact (ii) the time interval during the impact and (iii) the impulse.
4. A spring balance is attached to the ceiling of a stationary lift. A man suspends a block from the hook of the spring balance and the balance reads 98 N. What will be the reading of the spring balance, if the lift starts moving downwards with an acceleration of 2 m s^{-2}?
5. Two bodies have masses in the ratio 3 : 4. When a force is applied on the first body, it moves with an acceleration of 6 m s^{-2}. How much acceleration will the same force produce in the other body?
6. A bullet of mass 5 g travelling at a speed of 120 m s^{-1} penetrates deeply into a fixed target and is brought to rest in 0.01 s. Calculate the average force exerted on the bullet.
7. Certain force 'F' units is needed to produced certain acceleration in a sphere of radius 'r' units. To produce same acceleration in sphere made of same material of radius '2r' units, then find the force required.
8. A force of 20 N acting on a body of mass 10 kg is found to double its velocity in 8 s. Find its initial velocity?
9. A hammer of mass 5 kg moving with a speed of 2 m s^{-1} strikes the head of a nail driving it 20 cm into the wall. Find the impulse.
10. A 2000 kg automobile is travelling at 54 kmph. Find the average force to stop it in 25 m.
11. On a body of mass m_1 certain force is applied which produces an acceleration of 6 m s^{-2}. The same force applied on mass m_2 gives it an acceleration of 4 m s^{-2}. If two masses are fixed together and the same force is applied to the combination then find the acceleration it would produce.
12. The driver of a car moving at a speed of 10 m s^{-1} sees a child and immediately applies brakes to bring the car to rest in 150 m just in time to save the child. If the mass of car is 1140 kg, that of driver to 60 kg, what is the magnitude of retarding force on the vehicle?
13. A nail of mass 'm_1' kg is being hammered by a hammer of mass 'm_2' kg with a velocity of 'v' m s^{-1} such that the nail drives by 's' m into a wall. Find the average resistance offered by the wall to the penetration of nail.
14. A bead starts sliding from a point P on a frictionless wire with initial velocity of 5 m s^{-1}. Find the velocity of bead at point R (take g = 10 m s^{-2})



15. The ratio of recoil of residual nucleus of Th^{232} to the velocity of a particle x emitted out is 1 : 57. Find the mass of particle x emitted.

CONCEPTUAL QUESTIONS

1. Why is a person falling on a cemented floor injured, while a person falling on a heap of sand is not?
2. When equal forces are acting on two different bodies, the acceleration varies directly with the mass of the body. Explain.
3. A body starting from rest is moving at constant acceleration. After travelling a certain distance 'x', its momentum is 'k' units. What would be the momentum of the body at double the initial distance?
4. Why a horse cannot pull a cart and run in the empty space?
5. Why an athlete runs some steps before taking the jump?
6. It is easy to catch a table tennis ball than a cricket ball, even when both are moving with the same velocity. Why?
7. Why are shockers used in scooters and cars? Explain.
8. The force F_1, F_2 and F_3 are acting on a particle of mass m, such that F_2 and F_3 are mutually perpendicular and under their effect, the particle remains stationary. What will be the acceleration of the particle, if the force F_1 is removed?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. A gun fires a bullet of mass 50 g with a velocity of 30 m s^{-1}. Because of this gun is pushed back with a velocity of 1 m s^{-1}. Mass of the gun is:
   (A) 3.5 kg (B) 30 kg (C) 1.5 kg (D) 20 kg
2. The average force necessary to stop a hammer with 25 N – s momentum in 0.05 s expressed in N is:
   (A) 500 (B) 125 (C) 50 (D) 25
3. A scooter of mass 120 kg is moving with a uniform velocity of 108 km h^{-1}. The force required to stop the vehicle in 0.1 s is:
   (A) 260 N (B) 360 N (C) 460 N (D) 560 N
4. A lift is moving down with a retardation of 5 m s^{-2}. The percentage change in weight of person in the lift is (g = 10 m s^{-2}):
   (A) 100 (B) 25 (C) 50 (D) 75
5. A force of 100 N acts on a body of mass 2 kg for 10 s. The change in momentum of the body is:
   (A) 100 N–s (B) 250 N–s (C) 500 N–s (D) 1000 N–s
6. Physical independence of force is a consequence of:
   (A) third law of motion (B) second law of motion
   (C) first law of motion (D) all of these
7. Conservation of linear momentum is equivalent to:
   (A) newton's first law of motion (B) newton's second law of motion
   (C) newton's third law of motion (D) none of these

8. The time, in which a force of 2 N produces a change as momentum of 0.4 kg m s^{-1} in the body is:
(A) 0.2 s (B) 0.02 s (C) 0.5 s (D) 0.05 s

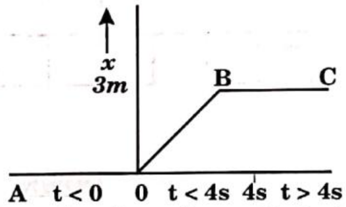
9. A body of mass 4 kg weight 4.8 kg when suspended in moving lift. The acceleration of the lift is:
(A) 9.8 m s^{-2} downwards (B) 9.80 m s^{-2} upwards
(C) 1.96 m s^{-2} downwards (D) 1.96 m s^{-2} upwards

10. If two balls each of mass 0.06 kg moving in opposite directions with speed of 4 m s^{-1} collide and rebound with same speed, then the impulse imparted to each ball due to other is:
(A) 0.48 kg m s^{-1} (B) 0.53 kg m s^{-1} (C) 0.81 kg m s^{-1} (D) 0.92 kg m s^{-1}

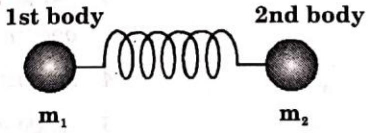
BRAIN NURTURES

1. Explain how a ball thrown upwards in a train moving with uniform velocity, returns to the thrower.

2. Figure given below shows the position–time graph of a particle of mass 4 kg. Find the impulse at t = 0 and t = 4 s. The motion may be considered one dimensional.



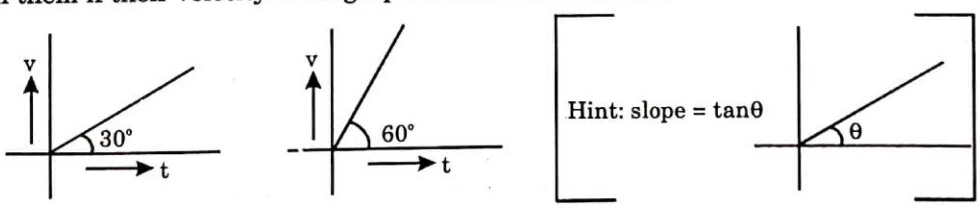
3. Two bodies of masses m_1 kg and m_2 kg and are attached at the free ends of a spring. The bodies are pulled apart and released. If acceleration of first body is 'a' m s^{-2}, then find the acceleration of the second body.



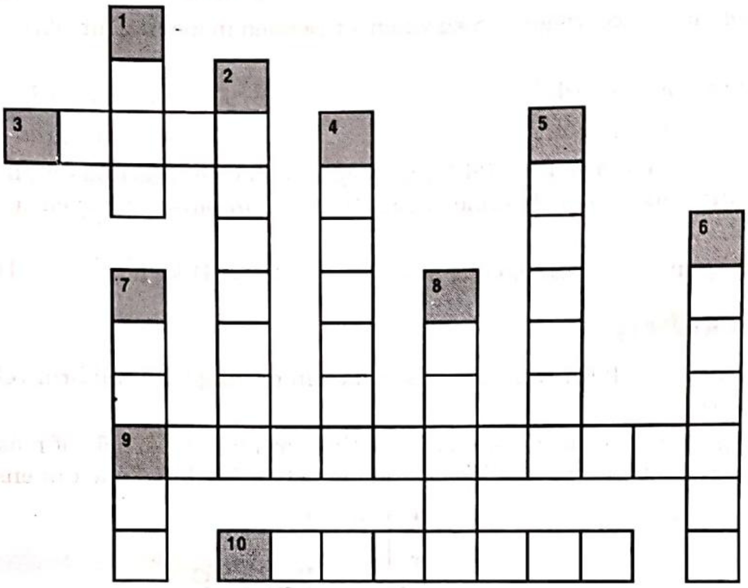
4. A machine gun fires 'x' bullets per sec into a target. Each bullet weighs 'm' kg and has a speed of 'y' m s^{-1}. Find the force necessary to hold the gun in position.

5. A force 'F' N acts on a sphere producing an acceleration of a m s^{-2}. From this can you find the density of the material of the sphere, if its volume is V m^3?

6. There are two bodies of masses m and m/2 respectively. Find the ratio of the force acting on them if their velocity–time graphs are as shown below:



CROSSWORD PUZZLE



ACROSS

3 *Physical quantity whose CGS unit is dyne*

9 *The sparks coming out off a grinding stone flies off*

10 *Product of mass and velocity*

DOWN

1 *Apparent weight of a person in a lift moving with uniform velocity*

2 *For every action there will an equal and opposite*

4 *Product of force and time*

5 *Tendency of a body to continue its state*

6 *10^{-5} newton equals to*

7 *The type of quantity momentum is*

8 *SI unit of force*

Chapter 4

Work, Power and Energy

Common misconception	Fact
1. Energy can be created or destroyed.	1. Energy can neither be created nor be destroyed. It can only be changed from one form to another.
2. Whenever we carry a load, then we say work has been done.	2. We do work only if we carry a load and move it through a distance. No work is done if the load does not move through a distance.
3. The terms energy and power are same.	3. The term 'energy' is different from 'power'. Energy refers to the capacity to perform the work. Power determines the rate of performing the work. Thus, in determining power, time taken to perform the work is significant but it is of no importance for measuring energy of a body.

SYNOPSIS

INTRODUCTION

A man is sitting in a chair. Though he does not attend to any work physically, his eyes do their work by seeing, the nose does its work by smelling and breathing. Even the internal organs do their work, the heart goes on beating and pumping blood to various parts of the body, the lungs work by filtering the air breathed by the liver etc. But according to physics, the quantity of work done is a force causing a displacement. Work has nothing to do with the amount of time in which this force acts to cause the displacement.

If two people a hiker and a rock climber might do the same amount of work, yet the hiker does the work in considerably less time than the rock climber. The quantity which has to do with the rate at which a certain amount of work is done is known as the power. The hiker has a greater power rating, than the rock climber.

Energy is the word often used in our day to day life. A man does laborious work or a child works energetically, then we say that they have full of energy. Much the similar way, in physics, too anything that has the ability to do work is said to possess energy.

WORK

Work is said to be done by a force on a body, when the force displaces the body through a certain distance in the direction or against the direction of the force.

Measurement of work

The amount of work done by a body is measured as the product of magnitude of the force applied and the distance moved by the point of application in the direction of force.

Work = force . displacement of the body

W = F . S

work is a scalar quantity.

Units

Absolute units

S.I. unit: newton – meter or joules

C.G.S unit: dyne – cm or ergs

Gravitational units

S.I unit: kgwt – m, 1 kgwt–m = 9.8 newton – m = 9.8 J

C.G.S unit: gwt – cm, 1 gwt – cm = 980 dyne – cm or 980 erg

WORK DONE IN DIFFERENT CASES

The magnitude of work done mainly depends on the magnitude of force and displacement. So, it can be expressed in following cases.

Case 1: Displacement in the direction of force:

A force '$\vec{F}$' acting on an object. The object has a displacement 'S' in the direction of force. Then the work done is the product of force and displacement.

Work done (W) = Force (F) $\times$ displacement in same direction.

Formula: W = F S

Case 2: Displacement at an angle (θ) with the force:

When a force $\vec{F}$ moves the body by a distance S is a direction at an angle θ with the force. Work done is given by:

Work = Horizontal component of force in direction of displacement $\times$ displacement

$W = (F\cos\theta)S$

$W = FS\cos\theta$

Note

1. If $\theta < 90^0$, $\cos\theta$ is positive. So work done is positive.

2. If $\theta > 90^0$. $\cos\theta$ is negative. So work done is negative.

3. If $\theta = 90^0$. $\cos 90^\circ = 0^\circ$ So no work is done by the force on the body.

4. If $\theta = 180^0$, $\cos 180^\circ = -1$ So work done is negative.

Case 3: Work done against gravity

Let a body of mass (m) lifted by an upward a force (F = mg) through a height.

Then, work done = force × distance

$W = FS = mgh$ ($g = 9.8\ m\ s^{-2}$ or $10\ m\ s^{-2}$)

Case 4: Displacement and force are in opposite direction

By applying force 'F' a moving car is tried to stop the car. If the car comes to rest after travelling some distance 'S' opposite to the direction of force, then the force is applied opposite to the direction of the displacement. So the displacement is taken as '– S'. Work done = Force acting × displacement in opposite direction.

$W = F \times (-S) = -FS$

Case 5: Where work is not done

(a) Work is zero if applied force is zero (W = 0 if F = 0)

(b) Work is zero if $\cos\theta$ is zero or $\theta = \pi/2$.

(c) Work done is zero when displacement is zero.

POWER

Power is defined as the rate of doing work. It is a scalar quantity.

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

$$P = \frac{W}{t} = \frac{F \times S}{t}$$

$$P = F \times v \qquad \left(\therefore v = \frac{S}{t}\right)$$

Power = Force × velocity

Units

C.G.S unit = erg s^{-1}

MKS unit of power = J s^{-1}

SI unit of power = watt

$1\ \text{watt} = \frac{1\ \text{joule}}{1\ \text{second}}$. Bigger units of power are 1 kilowatt (kW) (= 1000 W), 1 Mega watt (MW) (= 10^6 W)

Horse Power

1 Horse power = 746 watts

Power is calculated using different expressions depending on the situation

1.	Power to move a body	$P = \frac{FS}{t}$
2.	Power to pull a body	$P = \frac{-FS}{t}$
3.	Power to stop a body:	$P = \frac{FS\cos\theta}{t}$
4.	Power to lift a body against gravity	$P = \frac{mgh}{t}$

ENERGY

Energy is the capacity (or) the ability of a body to do work. It is a scalar quantity.

Units

S.I unit: joule (J)

CGS unit: erg

Other units of power

- (a) Electrical units of energy: watt-hour and kilowatt-hour (kWh). 1 kWh = 3.6×10^6 J

  (b) Units of heat energy: calorie and kilocalorie. 1 calorie = 4.18 J (or) 4.2 J

  (c) Units of atomic energy: electron-volt. 1 eV = 1.6×10^{-19} J

Different forms of energy

The energy possessed by a body is due to its state of rest (or) of uniform motion is called mechanical energy. The mechanical energy is found in two forms viz., kinetic energy (K.E.) and potential energy (P.E.)

KINETIC ENERGY

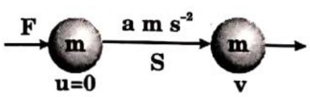
The work done by a body by virtue of its motion is called kinetic energy.

Examples

1. Energy possessed by a shooting arrow.
2. Energy possessed by blowing wind.
3. Energy possessed by a speeding vehicle.

Mathematical expression for K.E

Consider a body of mass (m) at rest. When a force is applied it sets into motion and acquires a velocity after travelling distance of 's'.



K.E. = Force × Displacement = ma × S .... (1)

from equation of motion, $v^2 - u^2 = 2aS$

$$a = \frac{v^2 - u^2}{2S}$$

Substituting above value in equation (1) we get,

$$\text{Kinetic energy} = m \times \frac{v^2 - u^2}{2S} \times S$$

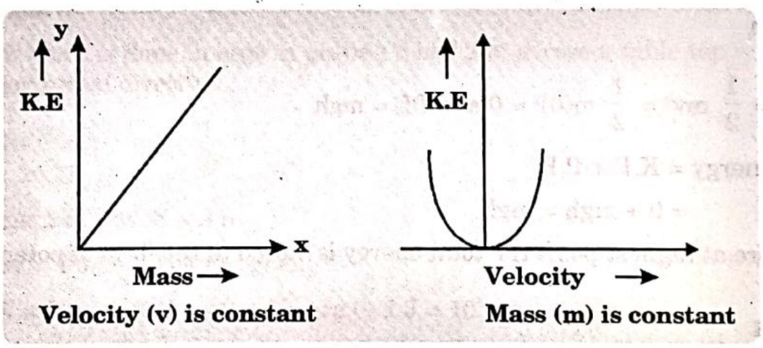
$$K.E = m \times \frac{v^2 - 0^2}{2S} \times S$$

$$\therefore K.E = \frac{1}{2} mv^2$$

$$\therefore \text{Kinetic energy} = \frac{1}{2} \times \text{mass} \times (\text{velocity})^2$$

The larger the mass of the body greater is the K.E. If the mass of the body is doubled, the K.E is also doubled. If velocity of a body is doubled, then its K.E will be increased by four times.

GRAPHICAL REPRESENTATION OF KINETIC ENERGY



POTENTIAL ENERGY

Energy possessed by an object by virtue of its relative position (or) state.

Potential energy is stored energy that depends upon the relative position of a system.

Examples

1. A spring has a more potential energy when it is compressed or stretched.
2. A ball has more potential energy raised above the ground than it has after falling to the earth.
3. The energy possessed by a stretched bow.
4. The energy possessed by water, stored high up in the dam.

Mathematical Expression for Potential Energy

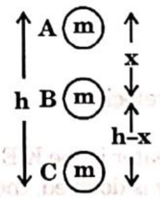
Consider a body of mass 'm' lifted to a height 'h' against gravity. Force applied for lifting the body of mass (m) from A to B = mg.

The workdone (W = mgh) is stored in the form of potential energy.

∴ Potential energy = mgh.

LAW OF CONSERVATION OF ENERGY

Energy can neither be created nor destroyed but it can be transformed from one form of energy to another form. The total energy in the universe remains constant. Consider a body of mass (m) falling freely from height 'h'.



The diagram shows that body of mass (m) at rest at a point A at a height (h) from the ground. It falls freely from A and reach B, at a distance x below. A reaches C the ground via B.

At position A

$$\therefore\ KE = \frac{1}{2}mv^2 = \frac{1}{2}m(0)^2 = 0 \text{ and } PE = mgh$$

Total Energy = K.E + P.E

= 0 + mgh = mgh

Therefore at highest point the total energy is stored in the form of potential energy i.e., mgh.

At position B

$PE = mgh_B = mg(h - x)$

$$KE_B = \frac{1}{2}mv_B^2 = \frac{1}{2}m\,(2gx) \qquad [\therefore\ v^2 - u^2 = 2gs,\ v^2 - u^2 = 2gx, v^2 - (0)^2 = 2gx].$$

Total energy at B = $KE_B + PE_B$ = mgx + mg(h – x) = mgx + mgh – mgx = mgh.

At position C

$$KE_C = \frac{1}{2}mv_C^2 = \frac{1}{2}2mgh = mgh.$$

∴ Total energy at C = $KE_C + PE_C$ = 0 + mgh = mgh.

∴ Total energy is possessed by the object is always constant.

TRANSFORMATION OF ENERGY

According to the law of conservation of energy, energy can be transferred from one form to another form of energy. This is called the transformation of energy.

For example, when a bullet is fired into a target, the entire of the bullet is lost and converted into heat and sound. This energy cannot be utilized further, and so the energy of the bullet is dissipated.

Examples

1. Conversion of Mechanical energy into other forms
2. Conversion of Heat energy into other forms
3. Conversion of Sound energy into other forms
4. Conversion of Electrical energy into other forms
5. Conversion of Magnetic energy into other forms
6. Conversion of Chemical energy into other forms
7. Conversion of Nuclear energy into other forms

SOLVED EXAMPLES

Example 1:

How much work is done in ergs in pulling a box 2 m across a table top with a force of 20 N in horizontal direction.

Solution:

Force F = 20 N

Displacement of Box, S = 2 m

work done = Force × Displacement

$W = 20\ N \times 2\ m = 40\ J = 40 \times 10^7$ erg ($\because 1\ J = 10^7$ erg)

Example 2:

A car weighing 600 kg travels with 72 km h^{-1} stops at a distance of 50 m deccelerating uniformly. What is the force exerted by the brakes? What is the work done by brakes?

Solution:

Mass of the car m = 600 kg

Initial velocity of car = $u = 72\ km\ h^{-1} = 72 \times \frac{5}{18}\ m\ s^{-1} = 20\ m\ s^{-1}$

Final velocity of the car v = 0

Distance covered s = 50 m

W = F × S

F = ma

$$a = \frac{u^2 - v^2}{2s}$$

$$a = \frac{(0)^2 - (20)^2}{2 \times 50} \Rightarrow \frac{0 - 400}{100} = -4 \text{ m s}^{-2}$$

Retarding force = 600 (+ 4) = 2400 N

From formula W = F × s

W = 2400 × 50 = 120 kJ

Example 3:

A man weighing 50 kg supports a man of 20 kg on his hand. What is the work done by him when

(a) he is stationary

(b) he moves a distance of 30 m on a smooth horizontal road.

(c) he moves a distance of 30 m vertically upward

(d) he moves over a distance of 20 m up an inclined plane rising

1 in 10 (g = 9.8 m s^{-2}) (Hint $\sin\theta = \frac{1}{MA}$)

Solution:

m = 50 + 20 = 70 kg

s = 30 m

(a) man is at stationary

W = F × s

W = F × 0 = 0

(b) When he moves a distance of 30 m on smooth horizontal road.

Work done = 0

(c) Distance moved in upward direction = 30 m

W = mgh

= 70 × 9.8 × 30 = 20, 580 J

(d) The body moves up an inclined plane, so work done against gravity is the component mg $\sin\theta$ the inclined plane rises by 1 in 10 ⇒ $\sin\theta = \frac{1}{10} = 0.1$

Work done = mg $\sin\theta$ × S = 60 × 9.8 × 0.1 × 30 = 1764 joules

Example 4:

A car at rest has mass 1000 kg. It is moved by a horizontal force of 50 N on a horizontal surface. Calculate the work done by the force in 8 s

Solution:

Mass of body (m) = 1000 kg

Force (F) = 50 N

Time (t) = 8s

Work done (W) = ?

From equation of motion, $S = ut + 1/2\ at^2$

$S = 1/2\ at^2$ [$\because u = 0$]

From the equation F = ma

$a = \frac{F}{m},\ a = \frac{500}{1000} = 0.05\ m\ s^{-2}$

$\therefore S = 1/2 \times 0.05 \times (8)^2 = 1/2 \times 0.05 \times 64 = 1.6$ m

s = 1.6 m

From formula $W = F \times S$

$W = 50 \times 1.6 = 80$

$\therefore$ The work done by the force in 8 s is 80 J

Example 5:

Calculate the displacement caused by the force in horizontal direction when force of 800 N is acting at an angle of 30^0 to the horizontal and does a work of 80,000 J.

Solution:

Force F = 800 N

angle $\theta = 30^0$

$\text{Cos } 30^0 = \frac{\sqrt{3}}{2} = 0.8660$

Work done (w) = 80,000 J

Displacement (S) = ?

$W = F \times s \cos\theta$

$\therefore S = \frac{W}{FS\cos\theta} = \frac{80,000}{800 \times 0.8660} = 115.47$ m

The displacement caused is 80.83 m

Example 6:

A man pulls 40 kg crate through 20 m across a level floor with a rope which makes 30^0 with the horizontal. He exerts a force of 150 N on the rope. Find the work done.

Solution:

Displacement, S = 20 m

Angle $\theta = 30°$

Force, F = 150 N

Work, W = ?

We know that

$W = F\ S\ \text{Cos}\ \theta$

$= 150\ N \times 20\ m \times \cos 30° = 150 \times 20 \times 0.866\ J = 2.6 \times 10^3\ J$

Example 7:

A force of 100 N displacement an object through 0.2 m and does work of 10 joules. What is the angle between the force and displacement?

Solution:

Force applied (F) = 100 N

Displacement (S) = 2 m

Work done (W) = 10 J

$W = F\ S \cos \theta$

$$\cos\theta = \frac{W}{F \times S}$$

$$\cos\theta = \frac{10}{100 \times 0.2} = \frac{1}{2}$$

$$\therefore \cos\theta = \frac{1}{2} \text{ put } \cos 60^0 = \frac{1}{2}$$

$\therefore \theta = 60^0$

The angle between force and displacement is 60^0

Example 8:

A body does 75 J works in 10 s. What is its power?

Solution:

Work done by a body, W = 75 J

Time, t = 10 s

Power, P = ?

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{W}{t} = \frac{75}{10} = 7.5$$

$P = 7.5\ J\ s^{-1}$ or 7.5 watt

Example 9:

What would be the power of an engine required to lift 9 metric tons of coal per hour from a mine 200 m deep ($g = 9.8\ m\ s^{-2}$)

Solution:

Mass of coal lifted, $m = 90$ metric tons $= 90 \times 10^3$ kg

Depth of mine, $h = 200$ m, $g = 9.8\ m\ s^{-2}$

Time, $t = 1$ hour $= 60 \times 60 = 3600$ s

$$\text{Power} = \frac{\text{Force} \times \text{distance}}{\text{time}} = \frac{mgh}{\text{time}}$$

$$P = \frac{96 \times 10^3 \times 9.8 \times 200}{3600} = \frac{176400 \times 10^3}{3600} = 49 \times 10^3\ W = 49\ kW$$

Example 10:

A motor car weighing 900 kg moves up an incline rising 1 in 49 at the rate of 54 $km\ h^{-1}$. Find the power at which engine is working.

Solution:

Mass of car (m) = 900 kg

$g = 9.8\ m\ s^{-2}$

$$\sin\theta = \frac{1}{49}$$

$v = 54\ km\ h^{-1} = 15\ m\ s^{-1}$

Force $= mg \sin\theta$

Power $= mg \sin\theta \times v$

$$\text{Power} = \frac{1000 \times 9.8 \times 15}{49} = 3000\ J\ s^{-1} = 3000 \text{ watts} = 3\ kW$$

Power = Force × velocity

Force = mg = 90 × 9.8 = 8820 newton

Power = 8820 × 15 watt

Example 11:

A man pulls a lawn roller with a force of 20 kgwt. He applies the force at an angle 60° with ground. Calculate work down in pulling the roller through 10 m. If he takes 1 minute in doing, then, calculate the power developed.

Solution:

Force (F) = mg

$= 20\ kg \times 9.8\ m\ s^{-2} = 196\ N$

distance (S) = 10 m

$\theta = 60°$

time 't' = 1 min = 60 minute

Work done = FS cos θ

$= 196 \times 10 \times 0.5 = 980$ J

$$\text{Power} = \frac{\text{workdone}}{\text{time}} = \frac{w}{t} = \frac{980}{60} = 16.33\ \text{J s}^{-1} = 16.33\ \text{watts}$$

Example 12:

An electric motor of powerating 300 W is used to drive the stirrer in a water bath. If 50% of its energy supplied to the motor is spent in strring the water. Calculate the work done on the water in 25 min?

Solution:

Power of motor, P = 300 W

Power supplied to motor = 50%

Time (t) 25 min = 25 × 60 = 1500 s

Power used on booster by pump = 50% of power supplied

$$= \frac{50}{100} \times 300 = 150\text{W}$$

∴ Net power used on water = 150 W

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

$$150\ \text{W} = \frac{\text{work}}{1500}$$

work = 150 × 1500 = 225 × 10^3 joules

Example 13:

Calculate the kinetic energy of a body of mass 10 kg moving with a velocity 2 m s^{-1}.

Solution:

Mass of the body (m) = 10 kg

Velocity of the body (v) = 2 m s^{-1}

Kinetic energy (K.E) = ?

$$\text{K.E} = \frac{1}{2} mv^2 = \frac{1}{2} \times 10 \times (2)^2$$

$$= \frac{1}{2} \times 10 \times 4 = 20\ \text{joule}$$

∴ The K.E of the body = 20 joule

Example 14:

When the mass and velocity of the body are doubled, what happens to its kinetic energy.

Solution:

Case – I

Mass of body $(m_1) = m$

Velocity $v_1 = v$

Kinetic energy $(K.E)_1 = K$

$$KE_1 = K = \frac{1}{2}mv^2 \ \ldots\ldots \quad (1)$$

Case – II

Doubled mass of the body $(m)_2 = 2m$

Doubled velocity of the body $v_2 = 2v$

Kinetic energy $K_2 = ?$

$$KE_2 = \frac{1}{2}mv_2^2 = \frac{1}{2}\times 2m \times 2u^2 = 4mv^2 \ \ldots\ldots (2)$$

Dividing (II) by (I) we get

$$\frac{K.E_2}{K.E_1} = \frac{K.E_2}{K} = \frac{4mv^2}{\frac{1}{2}mv^2}$$

$KE_2 = 8\,K$

∴ When the mass and velocity of the body are doubled, the kinetic energy becomes 8 times the original.

Example 15:

When the mass of a body is increased by 100% and velocity of a body is decreased by 50%. What is the percentage change in its kinetic energy?

Solution:

$$\text{Mass of body } (m_1) = m + \frac{100}{100}m = 2\,m$$

$$\text{Velocity } (v_1) = v - \frac{50}{100}v = \frac{v}{2}$$

$$K.E = \frac{1}{2}mv^2$$

$$KE_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}(2m)\left(\frac{v}{2}\right)^2 = \frac{mv^2}{4} = \frac{1}{2}KE$$

$$\text{Percentage change in } KE = \frac{KE_1 - KE}{KE}\times 100 = \frac{1}{2}\frac{KE_1 - KE}{KE}\times 100 = 50\%$$

∴ KE of the body decreases by 50%

Example 16:

Two bodies of masses m_1 and m_2 are moving with equal kinetic energies. What is the ratio of their momenta?

Solution:

Let p_1 and p_2 be the momenta of first and second respectively.

Case – I	Case – II
Mass of first body $(m_1) = m_1$	Mass of second body $(m_2) = m_2$
Momentum of first body $= p_1$	Momentum of second body $= p_2$

Ratio of their momentum $= \frac{p_1}{p_2} = ?$

$$K.E. = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mKE}$$

$$\Rightarrow p \propto \sqrt{m} \Rightarrow \frac{p_1}{p_2} = \frac{\sqrt{m_1}}{\sqrt{m_2}} \quad (\because \text{ K.E. is same in the both the cases})$$

$$\therefore \; p_1 : p_2 = \sqrt{m_1} : \sqrt{m_2}$$

Therefore, the ratio of their momentum is $\sqrt{m_1} : \sqrt{m_2}$

Example 17:

A 30 kg child climbs 15 meters up a tree. When he stops to have a look. around, what is the child's potential energy?

Solution:

Mass of the child (m) = 30 kg

Height (h) = 15 metre

Gravitational force (g) = 9.8 m s^{-2}

P.E = mgh = 30 × 9.8 × 15 = 4410 J

Example 18:

A box has a mass of 5.8 kg. The box is lifted from the garage floor and placed on a shelf. If the box gains 145 J of potential energy, how high is the shelf?

Solution:

Mass of the box (m) = 5.8 kg

Potential energy P.E = 145 J

Gravitational force g = 9.8 m s^{-2}

Height of the box h = ?

P.E = mgh

$h = \frac{P.E}{mg} \Rightarrow h = \frac{145}{56.84} = 2.55$ m

$h = \frac{145}{5.8 \times 9.8}$ The height of the shelf is 2.55 m

Example 19:

A man climbs on to a wall that is 3.6 m height and gains 2268 J of potential energy. What is the mass of the mass?

Solution:

Height of the wall = 3.6 m

Potential energy of gained by = 2268 J

Gravitational force (g) = 9.8 m s^{-2}

Mass of the mass (m) = ?

$$P.E = mgh$$

$$M = \frac{P.E}{gh}$$

$$M = \frac{2268}{9.8 \times 3.6} = \frac{2268}{35.28} = 64.28 \text{ kg}$$

$\therefore$ Mass of the mass = 64.28 kg

Example 20:

A bag of rice weighs 200 kg. To what height should it be raised, so that its potential energy may be 9800 J (Take g = 9.8 m s^{-2})

Solution:

Given, mass of the bag, (m) = 200 kg, Potential energy, (P.E) = 9800 J

Height to which it is raised, (h) = ?

Selection of formula : P.E = mgh

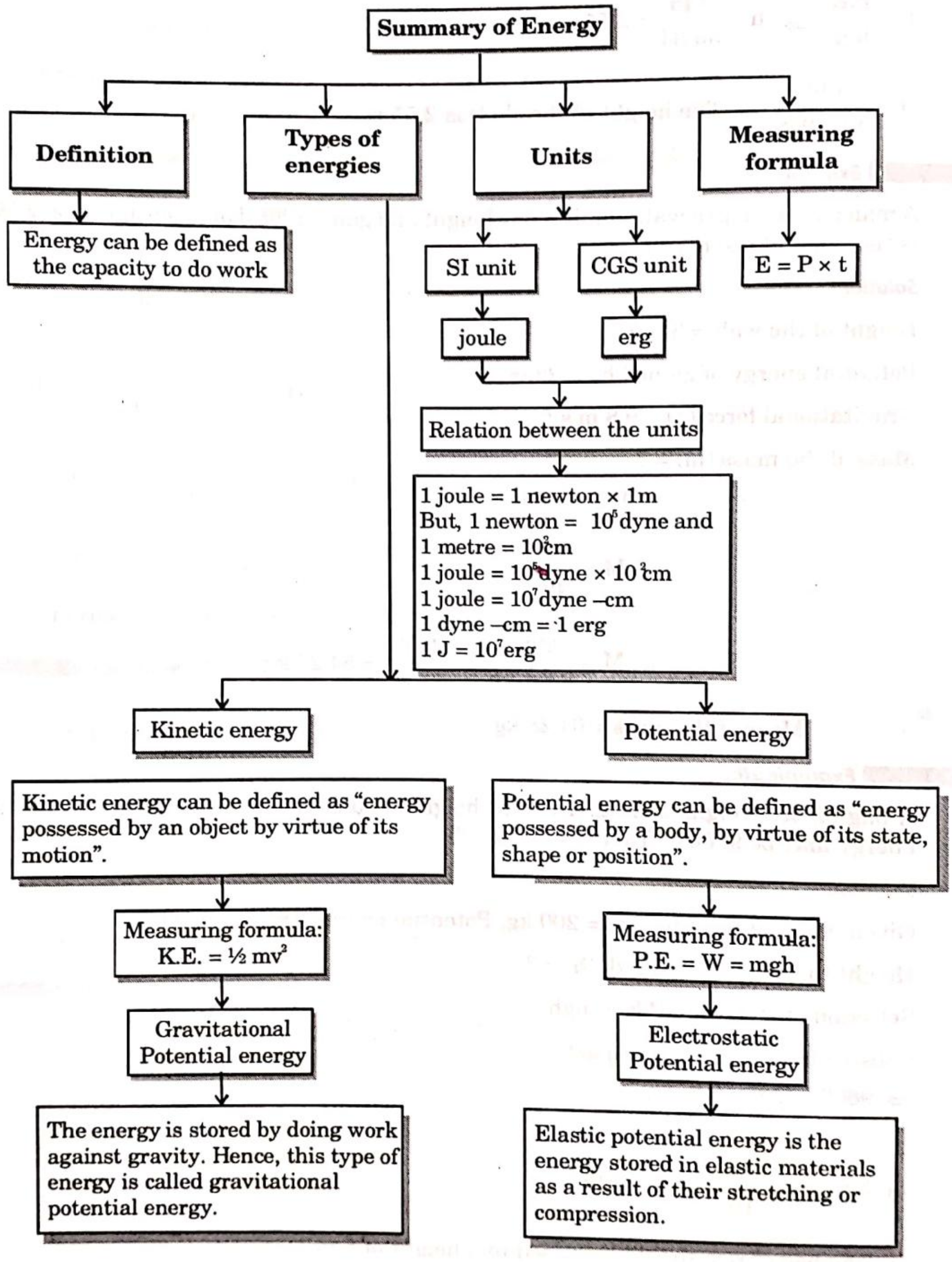
Substituting the values, we get

$\Rightarrow$ 9800 = 200 × 9.8 × h

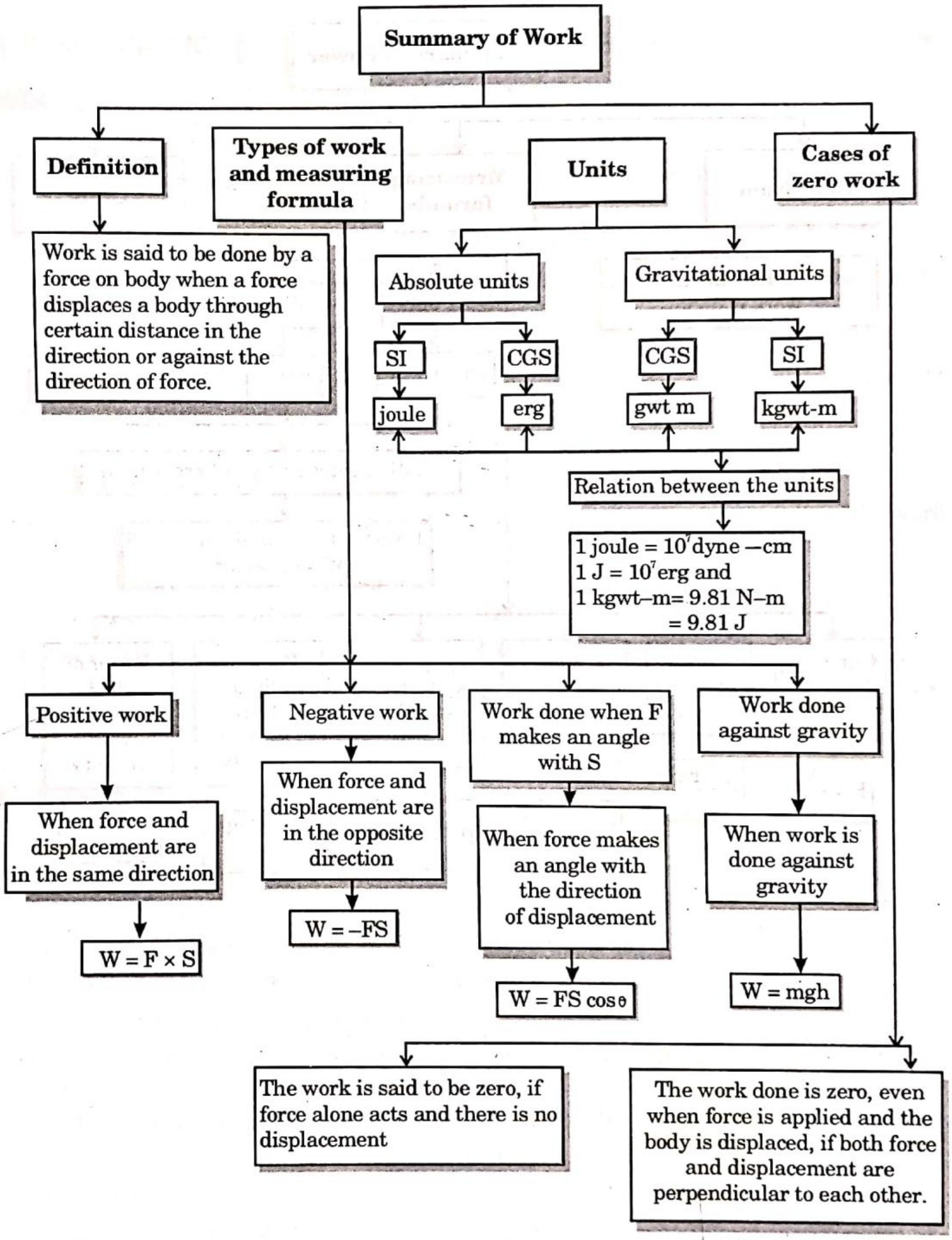
$\Rightarrow h = \frac{9800}{200 \times \frac{98}{10}} \Rightarrow h = 5$ m

$\Rightarrow$ The bag of rice should be raised to a height of 5 m

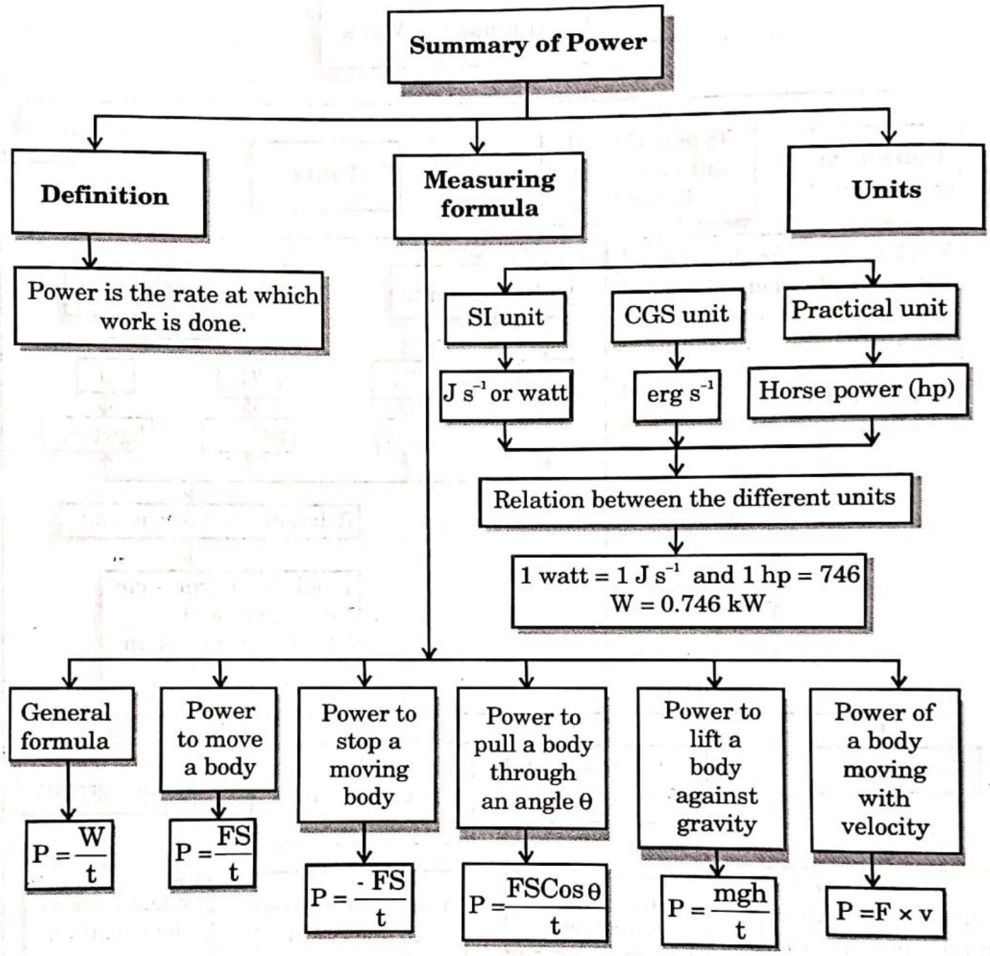
CONCEPT MAP I



CONCEPT MAP II



CONCEPT MAP III



Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. ________ energy is possessed by running water.
2. A tennis ball and an iron ball thrown towards us with the same velocity. Then, tennis ball is ________ to catch as compared to an iron ball.
3. The ratio of SI unit of energy to that of its CGS unit is ________.
4. A 20 kg mass object is being lifted through a height of ________ m when 784 J of work is done on it.
5. One mega watt is ________ times that of one kilowatt
6. If the velocity of a body is tripled, then the KE of the body becomes ________ times that of its initial value.
7. In an heat engine, heat energy is converted into ________.
8. The CGS unit of power is ________.
9. If 1 N of the force displaces the body through 1 m in the direction of force, then the work done is said to be ________.
10. In SI system, the gravitational units of work is ________.
11. A porter carrying a load on his head on a horizontal road does no work against ________.
12. If work done by the net force is zero, work done by the individual forces need ________.
13. If a proton and an electron are brought towards each other, the ________ will decrease.
14. A body at rest cannot have ________ and ________.
15. 1 eV = ________ J.

TRUE OR FALSE

16. 1 kilowatt is about $1\frac{1}{3}$ horse power.
17. If the KE of the body is quadrupled then the momentum of the body doubles.
18. The energy possessed by water stored high up in the dams is KE.
19. A battery converts mechanical energy into electrical energy.
20. A fish swimming in water possess mechanical energy.
21. A boy carrying a box on his head is walking on a level road from one place to another on a straight road is doing no work.
22. The decrease in the PE of a ball of mass 20 kg which falls from a height 25 cm is 98 J.
23. When a cyclist moves on the road, work done by the road on the cycle is negative.
24. Work done is equal to area under the force–displacement graph.
25. Potential energy is stored in a compressed spring.

MATCH THE FOLLOWING

26.

Column A	Column B
A. 1 erg	p. 10^3 W
B. 1 J	q. 980 erg
C. 1 kgwt m	r. 9.8×10^7 ergs
D. 1 kW	s. 6.25×10^{18} eV
E. 1 gwt cm	t. 1 dyne cm

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. If Rahul has done the same amount work in less time compared to Rohan then:
   (A) Rahul has more power (B) Rohan has more power
   (C) both Rahul and Rohan have equal power (D) Rahul has more energy than Rohan
2. A man of mass 60 kg climbs up a 20 m long staircase to the top of a building 10 m high. What is the work done by him? (Take g = 10 m s^{-2}).
   (A) 12 kJ (B) 6 kJ (C) 3 kJ (D) 18 kJ
3. A ball is projected upwards. As it rises, there is increase in its:
   (A) momentum (B) retardation
   (C) kinetic energy (D) potential energy
4. When the mass and speed of a body are doubled, the kinetic energy of the body:
   (A) becomes double (B) becomes four times
   (C) becomes eight times (D) remains unchanged
5. If the momentum of a body is doubled, the kinetic energy is:
   (A) halved (B) unchanged
   (C) doubled (D) increased by four times
6. A mass of the body is halved and its speed is doubled. What happens to the kinetic energy of the body?
   (A) Doubled (B) Becomes four times
   (C) Becomes eight times (D) Remains unchanged
7. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of:
   (A) $\sqrt{2}:1$ (B) $1:4$ (C) $1:2$ (D) $1:\sqrt{2}$
8. If force and displacement of the particle (in direction of force) are doubled. Work should be:
   (A) doubled (B) 4 times (C) halved (D) 1/4 times

9. When the force retards the motion of a body, the work done is:
(A) zero
(B) negative
(C) positive
(D) positive or negative depending upon the magnitude of force and displacement

10. When a force acts on body:
(A) its KE increases (B) its KE decreases
(C) its PE decreases (D) its PE increases

11. A gun fires a bullet with velocity v. Mass of the bullet is m. The mass of the gun is M and it recoils with velocity V. If the kinetic energy of the bullet be E_b and that of gun be E_g, then
(A) $E_b = E_g$ (B) $E_b < E_g$ (C) $E_b > E_g$ (D) $E_b \geq E_g$

12. A body is acted upon by a force which is proportional to the distance covered. If distance covered by denoted by x, then work done by the force will be proportional to :
(A) x (B) x^2 (C) $x^{\frac{3}{2}}$ (D) x^4

13. If a light body and a heavy body have same momentum, then
(A) they have same kinetic energy (B) lighter body have more kinetic energy
(C) heavier body have more kinetic energy (D) cannot be said

14. The power of a pump takes 10 s to lift 100 kg of water tank situated at a height of 20 m is:
(A) 2×10^4 W (B) 2×10^3 W (C) 200 W (D) 1 kW

15. The work done in holding 15 kg suitcase while waiting for a bus for 45 minutes is:
(A) 675 J (B) 40500 J (C) 4500 J (D) zero

MULTIPLE ANSWER QUESTIONS

1. Choose the correct statement from the following:
(A) Kinetic energy of a body is quadrupled, when its velocity is doubled.
(B) Kinetic energy is proportional to square of velocity.
(C) Kinetic energy does not depend on mass of the body.
(D) The change in kinetic energy of a particle is equal to the work done on it by the net force.

2. Choose the correct statement from the following:
(A) One joule of work done uses up one joule of energy.
(B) One watt is the ability to do one joule of work per second.
(C) A worker needs 3200 J energy to raise 40 kg of cement to a height of 8 m.
(D) SI unit of power is watt.

3. A man is climbing a staircase. The energy he uses depends on:

(A) the height of the staircase. (B) the weight of his body.

(C) the time taken to reach the top. (D) the mass of his body.

4. A worker who weighs 600 N carries a load of 100 N through a distance of 5 m. How much energy does he use?

(A) 3.5×10^{10} ergs (B) 3000 J (C) 3500 J (D) 3×10^{10} ergs

5. In which of the following work is being done?

(A) Shopping in the supermarket.

(B) Standing with a basket of fruit on the head.

(C) Climbing a tree to pluck.

(D) Pushing a wheelbarrow of bricks.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of a statement of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** The kinetic energy, with any reference, must be positive.

   Reason: In the expression for kinetic energy, the velocity appears with power 2.

2. **Assertion:** When the momentum of a body is doubled, its kinetic energy increases by 300%.

   Reason: Kinetic energy $= \frac{p^2}{2m}$, where p is momentum of the body.

3. **Assertion:** If a light body and a heavy body possess the same momentum, the lighter body will possess more kinetic energy.

   Reason: The kinetic energy of a body varies as the square of its velocity.

4. **Assertion:** The potential energy stored in a spring is positive, when it is compressed and negative, when stretched.

   Reason: It is in accordance with the sign conventions for positive and negative work.

5. **Assertion:** A man carrying a bucket of water and walking on a rough level road with a uniform velocity does no work while carrying the bucket.

   Reason: The work done on a body by a force (F) in giving it a displacement S is defined as $W = F.S = FS\cos\theta$ where θ is the angle between vectors F and S.

6. **Assertion:** A crane P lifts a car up to a certain height in 1 min. Another crane Q lifts the same car upto the same height in 2 min. Then crane P consumes two times more fuel than crane Q.

   Reason: Crane P supplies two times more power than crane Q.

PARAGRAPH QUESTIONS

Passage - I

I. A car of mass 2,000 kg is lifted up a distance of 30 m by a crane in 1 minute. A second crane does the same job in 2 minutes.

(i) Find the amounts of fuel consumed by two cranes.

(A) 5.88×10^5 J, 5.88×10^5 J (B) 5.88×10^5 J, 2.94×10^5 J

(C) 2.94×10^5 J, 2.94×10^5 J (D) 1.076×10^6 J, 5.88×10^5 J

(ii) The power supplied by first crane is:

(A) 4900 W (B) 9800 W (C) 19.6 kW (D) 980 W

(iii) The power supplied by second crane is:

(A) 4900 W (B) 9800 W (C) 19.6 kW (D) 980 W

SECTION - B

NUMERICAL PROBLEMS

1. Calculate the work done to rise a body of man 30 kg to a height of 50 m ($g = 10$ m s^{-2})
2. A child pulls a toy bus through distance of 8 m on a smooth horizontal floor. The string held in the child is hand makes an angle of 60^0 with horizontal surface. If the force applied by child is 3 N. Calculate the work done by the child in pulling the toy car.
3. An engine of 4.9 kilowatt power is used to pump water from a well 50 meter deep. Calculate the quantity of water in kilolitres which it can pump out in one hour.
4. Calculate the velocity of a body of mass 4 kg possessing KE of 0.02 J
5. If the momentum of a body is increased by 50%, what would be the percentage increase in its kinetic energy?
6. If the kinetic energy of a body increases by 400%, what would be its percentage increase in momentum?
7. What should be the change in velocity of a body, if its mass is increased by four times for the same K.E of the body?

8. A bag of wheat weighs 100 kg. To what height should it be raised, so that its potential energy may be 9800 J ($g = 9.8\ m\ s^{-2}$)

9. Two bodies A and B of equal masses are kept at heights of h and 2h respectively. What will be the ratio of their potential energy?

10. A body of mass 10 kg is projected up with a velocity of 19.6 $m\ s^{-1}$. Find the potential energy at its highest point.

11. A body of mass 10 kg is released from a point where it possesses an energy of 1920.8J. Find the velocity with which it hits the ground.

12. An engine can pump 40,0000 litre of water to vertical height of 35 meters in 5 minutes. Calculate gravitational potential energy of water at given height.

13. Two bodies of same mass possess the same potential energy when they are at a height of 'h' and '4h' on the surface of earth and an unknown planet respectively. What will be weight of a body on the unknown planet, if its weight on earth is 600 N?

CONCEPTUAL QUESTIONS

1. A body is moving in a straight line with a certain velocity. Another body with double the mass and half the velocity of the first, is moving in the straight line. What is the ratio of kinetic energy of second body with the first body?

2. If the mass of a body is changed to n times, then what should be the change in velocity, such that its K.E remains same?

3. Two bodies of mass m_1 and m_2 are moving with equal momentum. What is the ratio of their kinetic energies?

4. If the momentum of a body is numerically equal to its kinetic energy, what is the velocity of the body?

5. Two bodies of masses 'm' and '2m' are thrown with a velocity of 'u' and '3u' from the surface. What is the ratio of their potential energies at the highest point?

6. A lorry and a car moving with the same kinetic energy are brought to rest by the application of brakes, which provide equal retarding forces. Which of them will come to rest in a shorter time?

PREVIOUS CONTEST QUESTIONS — SECTION – C

1. A body of mass 2 kg is thrown up vertically with a KE of 490 J. If the acceleration due to gravity is 9.8 $m\ s^{-2}$, the height at which the KE of the body becomes half of the original value is:

   (A) 50 m (B) 25 m (C) 12.5 m (D) 10 m

2. A motor boat is having a steady speed of 20 $m\ s^{-1}$. If the water resistance to the motor boat is 600 N, then the power is:

   (A) 12 kW (B) 120 kW (C) 9.8 kW (D) 1200 kW

3. The bodies of masses 2m and m have their kinetic energies in the ratio 8 : 1. Then the ratio of their momenta is:

(A) 1 : 1 (B) 2 : 1 (C) 4 : 1 (D) 8 : 1

4. Two bodies of masses 1m and 4m have the same KE. What is the ratio of their momenta?

(A) 2 : 1 (B) 1 : 2 (C) 1 : 4 (D) 4 : 1

5. A body of mass 0.1 kg is dropped from a height of 10 m at a place where $g = 10\ m\ s^{-2}$. Its KE just before its strikes the ground is:

(A) 1 J (B) 1.04 J (C) 3.5 J (D) 10 J

6. If KE of a given particle is doubled, its momentum will be:

(A) doubled (B) tripled

(C) increases by $\sqrt{2}$ times (D) remains unchanged

7. If the velocity of a car is tripled its KE is:

(A) doubled (B) tripled

(C) increased by 9 times (D) increase 15 times

8. Two balls of different masses have the same KE. Then the:

(A) heavier ball has greater momentum than the lighter ball.

(B) lighter ball has greater momentum than the heavier ball.

(C) both balls have equal momentum.

(D) both balls have zero momentum.

9. A body of mass 6 kg is under a force of 6 N which causes displacement in it given by $S = \frac{t^2}{4}$ m where 't' is time. The work done by the force in 2 s is:

(A) 12 J (B) 9 J (C) 6 J (D) 3 J

10. If a force F is applied on a body and it moves with a velocity V, the power will be:

(A) F × v (B) F/v (C) F/v^2 (D) $F \times v^2$

BRAIN NURTURES

1. A boy pulls a toy car with a force of 5 N by a string which makes an angle of 30^0 with the horizontal, in order to move the toy by a distance of 2 m is horizontal direction. If the string were inclined at an angle of 60^0 with horizontal, how much pull would be applied along the string in order to move it through the same distance of 2 m.

2. A boy cycles up a hill 50 m high and the mechanical advantage of the hill is 10. The combined mass of the boy and cycle in 160 kg. Find the work done against gravity.

3. A car is moving in a straight line with a certain velocity. Another car with double the mass and half the velocity of the first, is moving in the straight line. What is the ratio of kinetic energy of second car with the first car?

4. When the momentum of a body is doubled. What is the percentage change in its kinetic energy?

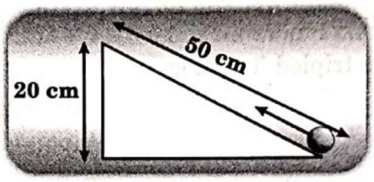
5. If the kinetic energy of a body is doubled, then what is the change in its momentum change?

6. If two bodies of masses '2m' and 'm' have their kinetic energies in the ratio 2 : 1, then find the ratio of their momenta.

7. If two bodies of masses 2m and m have their momenta in the ratio 4 : 1, then find the ratio of their kinetic energy.

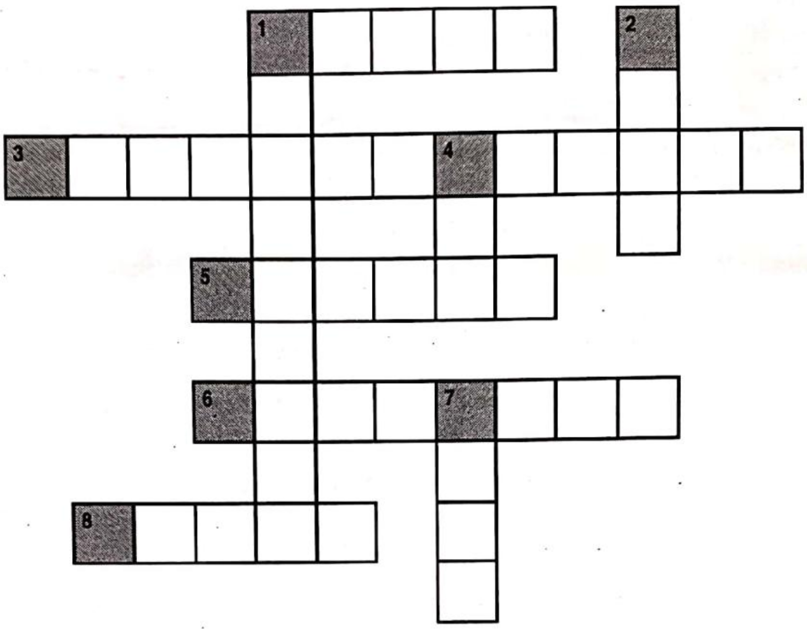
8. A car of mass 1650 kg is moving at a uniform speed of 65 km h^{-1}. On applying brakes its speed is reduced to 20 km h^{-1}. Find the change in K.E.

9. 800 g ball is pulled up a slope as shown in diagram. Calculate the potential energy it gains.



10. A 20 kg ball is thrown upwards with a speed of 6 m s^{-1}. Find its potential energy when it reaches the highest point. Also, find the maximum height it reaches (g = 9.8 m s^{-2}).

CROSSWORD PUZZLE



ACROSS

1 Rate of doing work

3 The work done by a body by virtue of its motion

5 Capacity to do work

6 Thousand watts

8 SI unit of work

DOWN

1 Energy possessed by a stretched bow

2 When the force displaces the body through a certain distance in certain direction

4 CGS unit of KE

7 Joule per second is also called as

Chapter 5

Turning Forces and Equilibrium

Common Misconception	Fact
1. The centre of gravity of an object is always situated within the object itself.	1. The centre of gravity of some objects lies outside the objects. An L–shaped piece of cardboard and a ring have the centre of gravity outside the body.
2. We cannot balance our body well if we stand on one foot because we are not used to this position.	2. We cannot balance our body well on one foot because we are less stable – the centre of gravity is raised and the base area is reduced.
3. If two equal and opposite forces are exerted on a body then net force and net torque acting on the body are zero.	3. If two equal and opposite forces are exerted on a body then net force can be zero whereas net torque acting on the body is non-zero as the body can be rotated.

SYNOPSIS

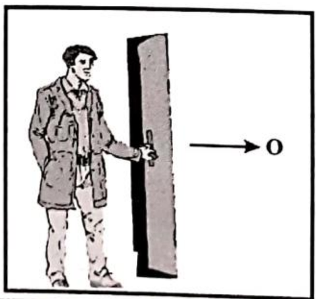
INTRODUCTION

When we pull a door from its outer edge, the door rotates. The whole door is turned or rotated about a fixed axis. So, the force, we apply has a turning effect.

This type of forces which involves turning effect are called turning forces.

MOMENT OF FORCE (TORQUE)

Consider a door fixed at point 'O'



A force 'F' is applied to push the door on application of force, the body rotates or turns about the fixed point (O). This force is unable to displace the body in the direction of force because the body is fixed at point 'O'. Such type of force, is called moment of force or Torque.

Definition

The force that rotates body without displacing it, is called moment of force.

Moment of force is also called Torque which comes from the latin word meaning "To twist". It is denoted by a Greek letter 'τ' (Tau)

Factors affecting the moment of force or turning effect

The turning effect is greater if:

1. the force applied is away from the axis of rotation.
2. the perpendicular distance of the force from the axis of rotation is greater.
3. a greater force would produce a greater turning effect.

Mathematical expression

From above it would be observed that moment of force is directly proportional to the perpendicular distance and applied force.

$\therefore$ moment of force $\propto$ perpendicular distance --------------- (1)

moment of force $\propto$ applied force ------------------------------ (2)

By combining (1) and (2)

τ = K force × perpendicular distance

where 'K' is a constant, with unit value,

Thus,

τ = F × perpendicular distance = F d sin θ

moment of force = Force × perpendicular distance

Mathematical definition of Torque

The moment of a force (or torque) is equal to the product of the magnitude of the force and the perpendicular distance of the line of action of the force, from the axis of rotation.

Units

The SI unit of torque (τ) = Force × perpendicular distance

newton × metre = N–m

Similarly, the CGS unit is dyne–cm

1 N–m = 10^5 dyne × 10^2 cm

1 N–m = 10^7 dyne–cm

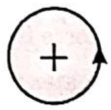
The moment of force is a vector quantity.

CLOCK WISE AND ANTICLOCK WISE MOMENT

If the turning effect on body is clockwise, then the moment of force is called the clockwise moment, which is shown below.

Here, the moment is taken as negative.

If the turning effect on body is anticlockwise, then the moment of force is called the anticlockwise moment, which is shown below.



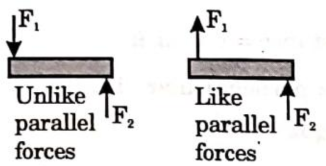
Here, the moment is taken as positive.

Applications of moment of force

1. It is easier to open a door by applying the force at the free end.
2. The hand flour grinder is provided with a handle near its rim.
3. A long spanner is used to loosen a tight nut.

Parallel forces

Forces which are not concurrent and act in opposite direction, and the line of action is not same then such forces are called parallel forces.



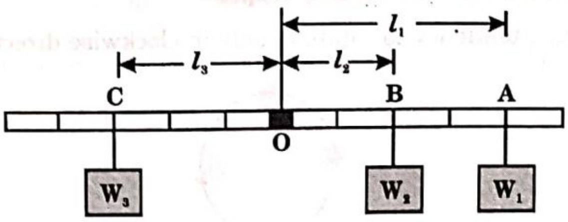
Principle of moment

The principle of moments states that for a body to be in rotational equilibrium, the sum of clockwise torques about any point (which acts as a pivot) must equal to the sum of anti–clockwise torques about that same point.

Sum of clockwise torques = Sum of anti–clockwise torques

Verification of principle of moments

Suspend the metre rule horizontally from its mid–point O, by means of a thread with its other end connected to a fixed support. Now suspend some weights on both sides of the mid–point and adjust their distances in such a way that the scale again becomes horizontal.



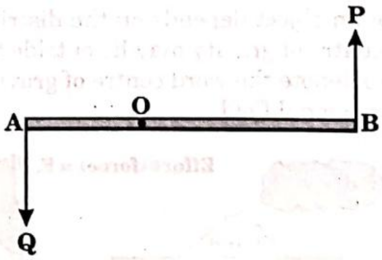
1. Let the weights suspended on the right side of the mid point O be W_1 and W_2 at distance OA = l_1 and OB = l_2 respectively.
2. Let the weight suspended on the left side of the mid point O be W_3 at a distance OC = l_3
3. Total clockwise moment = $W_1 \times l_1 + W_2 \times l_2$
4. Anti–clockwise moment = $W_3 \times l_3$
5. It is found that $W_1 \times l_1 + W_2 \times l_2 = W_3 \times l_3$

Applications of principle of moment

1. To find the mass of an object.
2. To find the mass of metre rule.
3. In simple machines.

COUPLE

Two equal and opposite parallel forces whose lines of action are not the same form a couple.



Arm of couple

Perpendicular distance between two equal and opposite parallel forces is called the arm of couple.

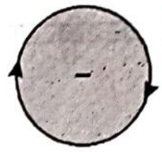
MOMENT OF COUPLE

The product of one of the forces of the couple and arm of the couple is called moment of couple, i.e. Moment of couple = F × d

∴ Moment of couple = Force × Arm of couple

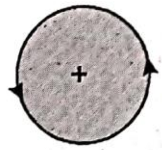
Clockwise and Anticlock wise moment of a couple

If the couple has a tendency to rotate a body in clockwise direction as shown below.



Then its moment is taken as negative.

If the couple has a tendency to rotate a body in anticlockwise direction as shown below.



Then its moment is taken as positive.

Units of moments of couple

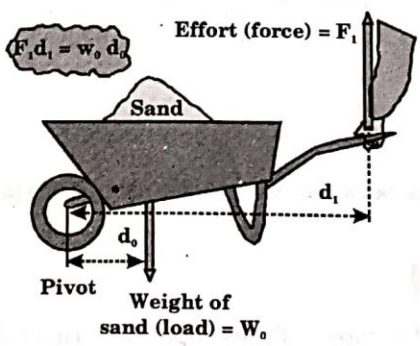
a. In MKS or SI system : newton–metre

b. In CGS system : dyne–cm

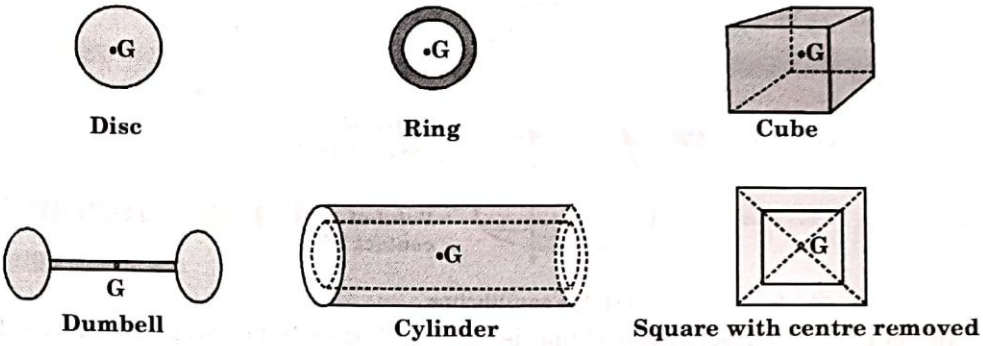
CENTRE OF GRAVITY AND STABILITY

The centre of gravity of an object is defined as the point through which its weight appears to act for any orientation of the object.

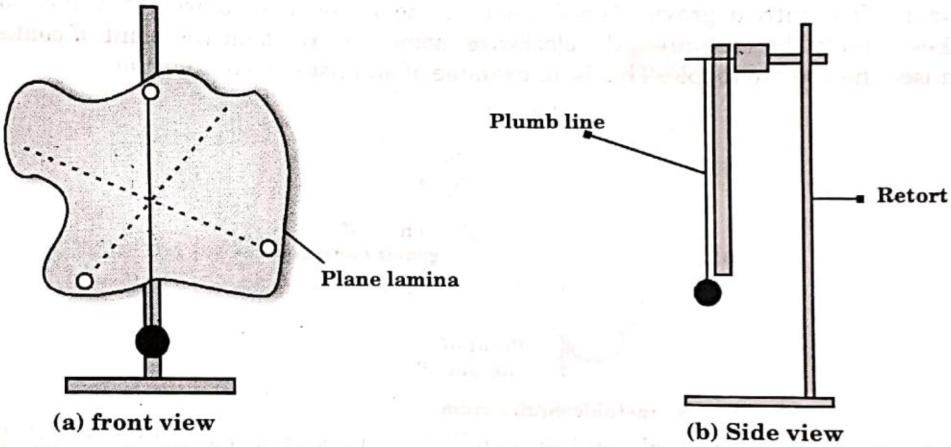
The centre of gravity of an object depends on the distribution of its mass. For certain objects like a ring, the centre of gravity may lie outside the object. Sometimes the term centre of mass is used to denote the word centre of gravity. Both of these will mean the same in a uniform gravitational field.



The centres of gravity of some regular shaped objects



Finding the centre of gravity of an irregular Lamina



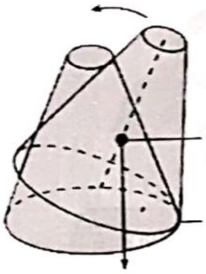
1. Three small holes are made near the edge of the lamina. The holes should be as far apart as possible.
2. The lamina is then suspended freely through one of the holes using a pin and a plumbline is drawn infront of the lamina.
3. The process is repeated with the other holes.
4. The lines of intersection of all the plumblines give the centre of gravity of the lamina.

Stability of an object

Stability refers to the ability of an object to regain its original position after it has been tilted slightly.

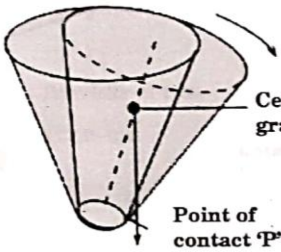
The stability of an object can be better understood by placing a cone shaped object in different positions as shown below and tilting or displacing it slightly.

In figure 1, when the object is tilted slightly, its centre of gravity rises and then falls back again. This is an example of a stable equilibrium. The line of action of weight W of the object lies inside the base area of the object. The applied clockwise moment while tilting the object is counteracted by the anticlockwise moment about the point of contact P of the object with the floor in the tilted position.



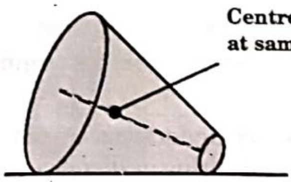
(a) stable equilibrium

In figure 2, the object is placed upside down with the smaller area in contact with the floor. If the object is tilted slightly, it will not return to its original position, but will topple. The centre of gravity falls further. As the line of action of weight W of the object likes outside the base area, the clockwise moment of W about the point of contact P, causes the body to topple. This is an example of an unstable equilibrium.



(b) unstable equilibrium

In figure 3, the object is placed horizontally with its side touching the ground. If the object is rolled or displaced from the original position slightly, it will stay in the new position. The centre of gravity neither rises nor falls but stays at the same level from the ground. The line of action of the reaction R at the point of contact with the ground and the line of action of weight W always coincide. hence, no moment is provided by the weight W about the point of contact to turn the conical object. This is an example of a neutral equilibrium.



(c) unstable equilibrium

The two important factors to increase the stability of an object are:

1. The centre of gravity should be as low as possible.
2. The area of the base should be as wide as possible.

These factors will ensure that the vertical line passing through the centre of gravity of a body will always lie inside the base of the body when it is tilted or inclined.

Examples

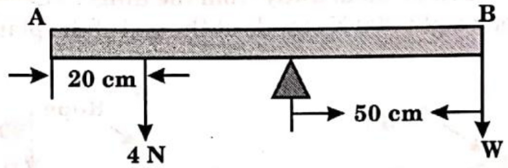
a. Racing cars are designed with low centres of gravity and wide bases.

b. Flower vases, desk lamps, table and pedestal fans, water jugs and various ornamental objects make use of the same principle.

SOLVED EXAMPLES

Example 1:

A uniform metre rule AB is supported at its centre of gravity by a knife–edge. A force of 4 N is applied at a point which is 20 cm from end A of the rule. Calculate the force which must be applied to end B to restore the equilibrium of the rod.



Solution:

Let 'W' be the force applied at end B to restore the equilibrium.

Taking moments about the pivot,

The anticlockwise moment = 4 × 30 (due to 4 N force)

The clockwise moment = W × 50

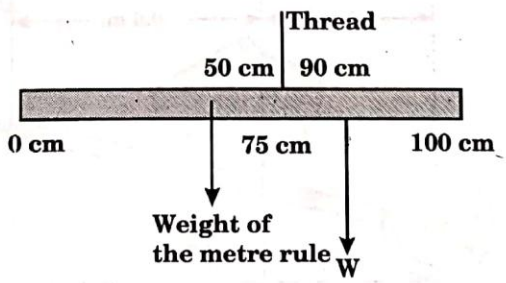
Equating the clockwise and anticlockwise moments

W × 50 = 4 × 30

$$W = \frac{4 \times 30}{50} = 2.4\ N$$

Example 2:

A uniform metre rule which has a mass of 75 g is suspended by a thread at the 75 cm mark and is balanced by a mass of weight W hanging from the 90 cm mark. Calculate the value of W.



Solution:

Since the metre rule is uniform, its centre of mass will be at the middle is 50 cm mark.

Mass of the rule = 75 g = 0.075 kg

Force due to this mass = 0.075 × 10 = 0.75 N, (g = 10 N kg^{-1})

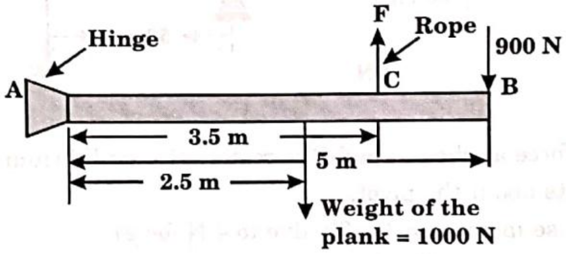
The clockwise moment due to 0.75 N force about the point of the suspension = the anticlockwise moment of W around the same point.

$\therefore 0.75 \times (75 - 50) = W \times (90 - 75)$

$$\therefore W = \frac{0.75 \times 25}{15} = 1.25 \text{ N}$$

Example 3:

A uniform wooden plank AB of 5 m length is hinged at the end A and is supported by a vertical rope at C, which is 3.5 m away from the hinge. The wooden plank has a mass of 100 kg. A painter of weight 900 N stands at the end of the plank at B. Calculate the force F on the rope.



Solution:

The total clockwise moment about the hinge = 1000 × 2.5 + 900 × 5

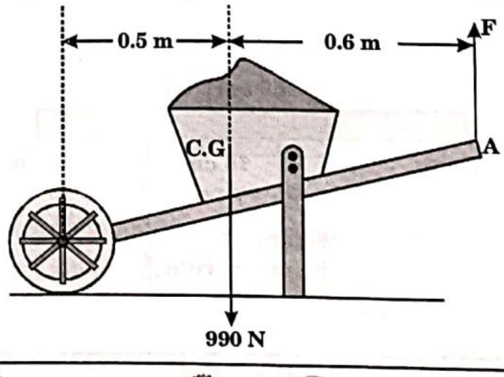
The total anticlockwise moment about the hinge = F × 3.5

Equating the moments F × 3.5 = 1000 × 2.5 + 900 × 5 = 7000

$$\therefore F = \frac{7000}{3.5} = 2000 \text{ N}$$

Example 4:

A wheelbarrow carrying a load of 990 N is as shown in the figure below. What is the minimum force F required to lift up the end A of the wheelbarrow?



Solution:

Taking moments about the fulcrum of the wheel

The clockwise moment = 990 × 0.5

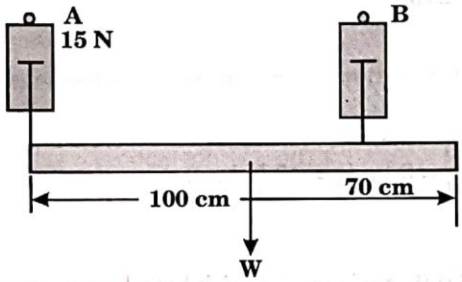
The anticlockwise moment = F × (0.5 + 0.6)

Equating the moments F × 1.1 = 990 × 0.5

$\therefore F = \frac{990 \times 0.5}{1.1} = 450$ N

Example 5:

A uniform metal rod of weight W hands from two spring balances A and B as shown in the figure below. If the reading in the spring balance A is 15 N, calculate the weight of the rod. What will be the reading in the other spring balance?



Solution:

Let 'W' be the weight of the metal rod

Taking moments around the point where the metal rod is attached to spring balance B.

The total clockwise moment = 15 × 70

The total anticlockwise moment = W × 20

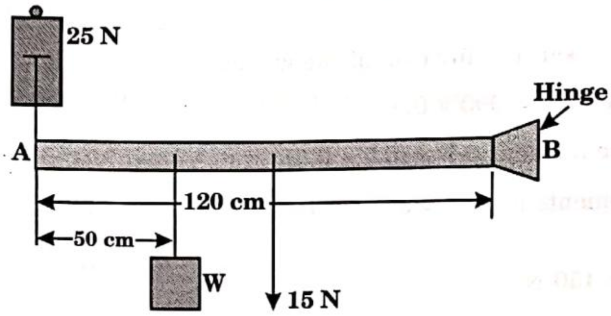
Equating the moments we have W × 20 = 15 × 70

$\therefore W = \frac{15 \times 70}{20} = 52.5$ N = weight of the rod.

The reading in the spring balance B = 52.5 – 15 = 37.5 N

Example 6:

The figure below shows a uniform horizontal metal rod AB of length 1.2 m and weighing 15 N, being pivoted at end B. An object of unknown mass W is hung from the rod at 50 cm from end A. A spring balance attached to end A of the rod shows a reading of 25 N. Find out the weight and mass of the object W.



Solution:

The total anticlockwise moment (about the hinge) = 15 × 60 + W × (120 – 50)

The total clockwise moment = 25 × 120

Equating the moments = 15 × 60 + W × 70 = 25 × 120

∴ 70 W = 3000 – 900 = 2100

$W = \frac{2100}{70} = 30\ N$

The mass of object = $\frac{30}{10} = 3\ kg\ (g = 10\ N\ kg^{-1})$

Example 7:

A man holds a pole of 6.0 ft. horizontally with both hands, one hand at the end, and the other hand at 1.0 ft. from the same end. He just caught a 3 *lb* fish. The pole weighs 2.0 *lb* and its weight can be considered to be concentrated 2.0 ft. from the end near the man's hand. What is the force exerted by each hand?

Solution:

Man uses equal forces by his two hands on the pole. To find the forces used by the man, we have to find clock wise moment and anticlock wise moment.

Clock wise moment produced by two hands about, the balancing point

= F × 2 + F × 1 = 3F × ft .....(1)

Anti clock wise moment produced by the fish of 3 *lb* weight about Balanced point

= 3 × 4 ft = 12 *lb* × ft .....(2)

In the balancing condition, eq. (1) is equal to eq. (2),

3 F × ft = 12 *lb* × ft ⇒ 3F = 12 *lb*

$F = \frac{12\ lb}{3} = 4 lb$

Example 8:

A uniform metre ruler is pivoted at its mid point. A weight of 80 gf is suspended at one end of it. Where should a weight of 160 gf be suspended, to keep the rule horizontal?

Solution:

Let AB be the uniform metre ruler, such that C is its midpoint. The metre ruler is pivoted at C, such that AC = 50 cm and CB = 50 cm. 80 gf weight is suspended near A.

Let D be the point of suspension of 100 gf weight at a distance of x from C, so that the ruler is horizontal.

Left hand side moment,

LHM = $80 \times 80 = 6400$ gf cm .... (1)

right hand side moment,

RHM = $x \times 160 = 160x$ gf cm.............. (2)

To keep the ruler horizontal,

LHM = RHM

$6400 = 160x \Rightarrow x = 40$ cm

$\therefore$ 160 gf is to be suspended at a distance of 40 cm from middle point (or) 60 cm from the end of the ruler.

CONCEPT MAP

TURNING FORCES AND EQUILIBRIUM

Applications: 1. Opening of a door.
2. See-saw
3. A spanner.

Factors affecting:
1. The magnitude of the force perpendicular distance of the line action of the force.
2. The magnitude of the force perpendicular distance of the line action of the force.

Moment of Force Torque): The force that rotates body without displacing it.
τ = F x perpendicular distance
Units : SI: N-m
CGS: dyne-cm

Principles of Moments: If the algebraic sum of moments of all the forces acting on the body is zero, the body is in rotational equilibrium.

RIGID BODY

A body, which does not get deformed under the action of a force.

Force on Rigid bodies
- A Force 'F' acts on it at point called point of action of force.
- An imaginary line passing through the point of action of force, in the direction of force is called line of action of force.

Couple is a set of two equal, parallel and opposite forces.
Since, the forces are opposite and equal in magnitude, the net resultant force is zero. Therefore, it can produce no motion in body, along straight line direction

Moment of Couple: The moment of a couple is equal to the product of either forces and the perpendicular distance, between the line of action of both forces.

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. __________ is the tendency of a force to rotate an object about an axis.
2. SI unit of moment of couple is __________.
3. The resultant of two like parallel forces 12 N and 7 N is __________ N.
4. The point through which the total weight appears to act for any orientation of the object is __________.
5. The centre of gravity of a regular shaped objects is at their __________.
6. Ratio of SI unit of torque to its CGS unit is __________.
7. The coordinates of edges of a square are O(0, 0), A(0, 4), B(4, 4), C(4, 0) respectively, the centre of gravity of square is at coordinates __________.
8. CG of a triangular lamina is at its __________.
9. Two rigid objects A, B of same dimensions are applied with forces in the ratio 4 : 9 respectively. If the perpendicular distance of the force from the axis of rotation of two objects is same then turning force is greater in __________.
10. In a stable equilibrium, the line of action of weight of the object less __________ the base area of the object.

TRUE OR FALSE

11. The centre of gravity depends on the acceleration due to gravity at the given place.
12. The increase in base area leads to decrease in stability of an object.
13. The spanner with a longer handle can tighten nuts and bolts with less effort.
14. At rotational equilibrium, sum of clockwise moments equals to sum of anti–clockwise moments.
15. A couple produces motion in a straight line.
16. Self balancing toys have curved and heavy base area.
17. A cone resting on its side is an example for neutral equilibrium.
18. The position of centre of gravity of the pot before filling it with water will be at its base.
19. A couple can never be replaced by a single force.
20. To produce pure rotation moment of force need to be applied.

MATCH THE FOLLOWING

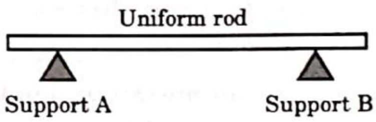
21.

Column A	Column B
A. Torque	p. Wide base area
B. Couple	q. Opening a door
C. CG of circle	r. Opening a tap
D. CG of triangle	s. Intersection of medians
E. Stability	t. Intersection of diameters

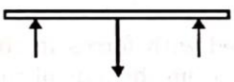
FURTHER PRACTICE

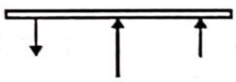
MULTIPLE CHOICE QUESTIONS

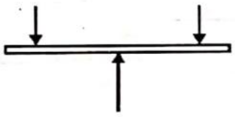
1. A uniform heavy rod is resting on support A and support B as shown.

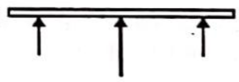


Which of the following shows the correct forces acting on the rod?

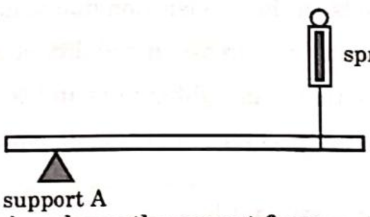
(A) 

(B) 

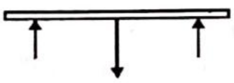
(C) 

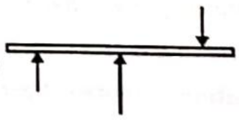
(D) 

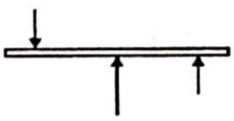
2. A uniform heavy rod is being kept in equilibrium by support A and a spring balance as shown.



Which of the following shows the correct forces acting on the rod?

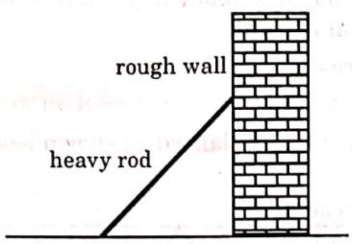
(A) 

(B) 

(C) 

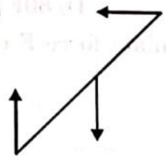
(D) 

3. A uniform heavy rod is being kept in equilibrium by leaning against a rough wall and standing on a smooth floor as shown.

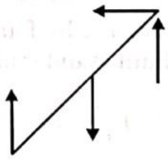


Given that the floor is perfectly smooth, which of the following shows the correct forces acting on the rod?

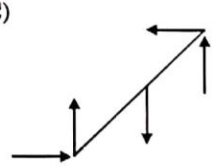
(A)



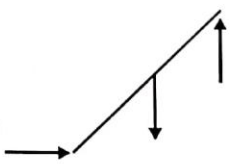
(B)



(C)



(D)



4. When a body is at rest, it is obeying:
(A) principle of conservation of energy
(B) principle of moments
(C) ohm's law
(D) newton' s second law

5. Which of the following instruments make use of principle of moments during operation?
(A) Rule
(B) Vernier calipers
(C) Spring balance
(D) Simple balance

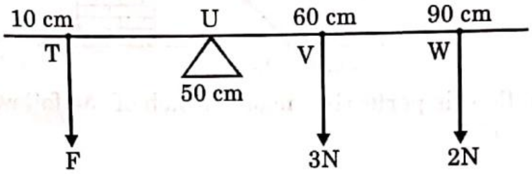
6. An object will not turn when:
(A) the forces are acting on it at different positions
(B) every forces is creating different turning effects
(C) every moment has the same amplitude
(D) all the forces are acting at its centre of gravity

7. Which of the following quantities is zero, when a uniform object is being supported at its centre of gravity?
(A) Mass
(B) Weight
(C) Force
(D) Moment

8. An object is said to be equilibrium when:
   1. there is no resultant force acting on the object.
   2. the total clockwise moments about any point is equal to the total anti-clockwise moments about the same point.
   3. the object has no energy

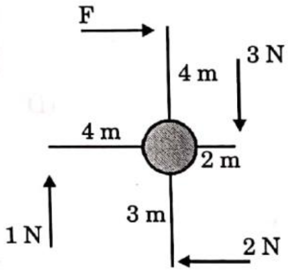
   (A) 1 only (B) 2 only (C) 1 and 2 only (D) 1, 2 and 3

9. A uniform beam of 1 m is being balanced as shown below. What is the moment of force F about point W?



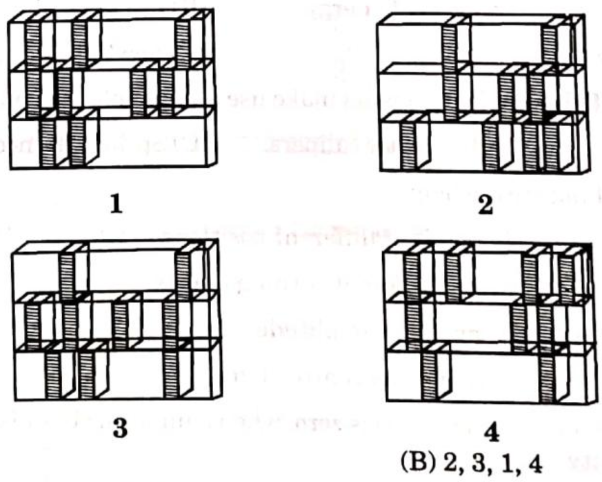
   (A) 0 N cm (B) 40F N cm (C) 50F N cm (D) 80F N cm

10. A windmill is pushed by four external forces as shown. Calculate force F required to make the windmill stand still.



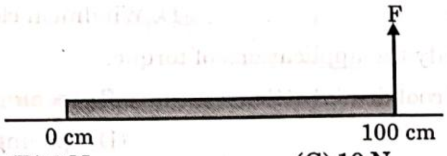
   (A) 2 N (B) 4 N (C) 6 N (D) 16 N

11. Arrange the following bookshelves in descending (decreasing) order of stability?



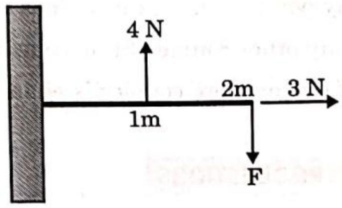
   (A) 1, 4, 2, 3 (B) 2, 3, 1, 4
   (C) 4, 1, 3, 2 (D) 2, 3, 4, 1

12. A 1 m long uniform beam of 2 kg mass is being lifted vertically up by a force F at the 100 cm mark. What is the minimum force to do so?



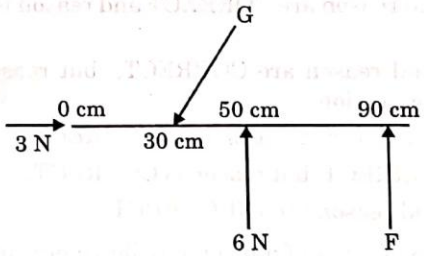
(A) 1 N (B) 2 N (C) 10 N (D) 20 N

13. A uniform beam of 2 m is being fixed to a wall and loaded by the forces shown below. Given that the beam is at equilibrium, calculate force F.



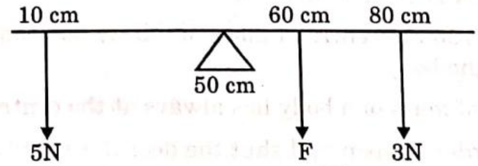
(A) 2 N (B) 4 N (C) 7 N (D) 8 N

14. A 1 m long uniform beam is being balanced as shown below. Calculate force G.



(A) 3.0 N (B) 4.5 N (C) 5.0 N (D) 6.0 N

15. A 1 m long uniform beam is being balanced as shown. Calculate the force F.



(A) 2 N (B) 3 N (C) 7 N (D) 11 N

MULTIPLE ANSWER QUESTIONS

1. Which of the following sports uses the turning effect of forces?

(A) Cycling (B) Swimming (C) Badminton (D) Hockey

2. Which of the following playground equipment make use of the turning effect of forces?

(A) See-saw (B) Slide (C) Swing (D) Toy horse

3. Which of the following objects is/are in equilibrium?

(A) A sleeping cat (B) A flask resting on a table

(C) A rocking see-saw (D) Winding a clock

4. In the following identify the applications of torque:

(A) opening the lid of cool drink bottle. (B) opening the lid of a tin.

(C) opening the door. (D) opening the screw cap of a bottle.

5. Which of the following is/are the properties of moment of a couple?

(A) It tends to produce pure rotation.

(B) It is different about any point in the plane of lines of action of the forces.

(C) It can be replaced by any other couple of the same moment.

(D) The resultant of set of two or more couples is equal to the sum of the moments of the individual couples.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** The centre of mass of a body may lie where there is no mass.

Reason: Centre of mass of a body is a point, where the whole mass of the body is supposed to be concentrated.

2. **Assertion:** The position of centre of mass of a body does not depend upon shape and size of the body.

Reason: Centre of mass of a body lies always at the centre of the body.

3. **Assertion:** It is harder to open and shut the door if we apply force near the hinge.

Reason: Torque is maximum at hinge of the door.

4. **Assertion:** A sphere cannot roll on a smooth inclined surface.

Reason: For a smooth inclined surface force of friction is equal to zero.

5. **Assertion:** To unscrew a rusted nut, we need a wrench with longer arm.

Reason: Wrench with longer arm reduces the torque of the arm.

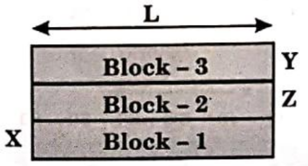
6. **Assertion:** The centre of mass of uniform triangular lamina is centroid.

Reason: Centroid is centre of symmetry of mass of the triangular lamina.

PARAGRAPH QUESTIONS

Passage - I

I. Three identical blocks of length L are stacked together as shown. The blocks 2 and 3 are slided towards the right.



(i) Find the maximum horizontal distance between side X of block one and side Y of block three before any of the block topples?

(A) 1.5 L (B) 1.75 L (C) 2.25 L (D) 1.25 L

(ii) Find the maximum horizontal distance between side X of block one and side Z of block two before any of the block topples?

(A) 1.4 L (B) 1.75 L (C) 1.25 L (D) 2.3 L

SECTION - B

NUMERICAL PROBLEMS

1. A force of 8 dyne with moment arm 125 cm long, rotates a body in clockwise direction. Find its torque.

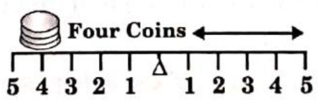
2. A force of 1875 dyne acts on a rigid body, such that perpendicular distance between fulcrum and point of application of force is 20 cm. Calculate moment of force.

3. Calculate the force that produces a moment of force of 2100 dyne-cm, when the perpendicular distance between point of application of force and turning point is 60 cm.

4. The moment of force of 8 N about a point P is 4 N m. Calculate the distance of point of application of the force from the point P.

5. A uniform rule is pivoted at its mid point. A weight of 50 gf is suspended at one end of it. Where should a weight of 100 gf be suspended, to keep the rule horizontal?

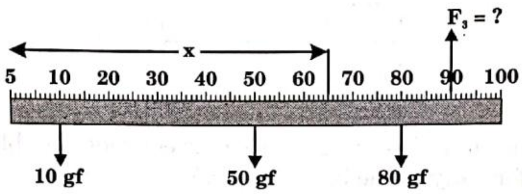
6. The diagram below shows a lever of uniform mass, supported at the middle point. Four coins of equal masses are placed at mark 4 on the left hand side. Where should be the 5 coins of same mass, as that of previous coins should be located?



7. Calculate the force required to lift a load of 60 N, placed at a distance of 3 m, from the fulcrum. The effort force is applied at a distance of 6 cm from the fulcrum.

8. Where should be the uniform rod of length 10 m and weight 100 N is balanced with a weight of 100 N at extreme point?

9. A uniform metre scale has two weights of 10 gf and 8 gf suspended at the 10 cm and 80 cm marks respectively. If the metre scale itself weights 50 gf, find where must the weight be, so that the metre scale stays balanced?



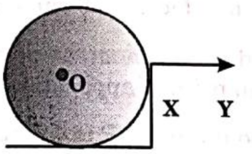
10. A force of 1600 dyne acts on a rigid body, such that the perpendicular distance between force and turning point is 40 cm. Calculate the moment of force.

11. A force of 525 N, produces a moment of force of 420 N-m. Calculate the shortest distance between the point of application of force and the turning point.

12. Two persons A and B carry a load of 1000 kg by hanging it on a pole, supported on their shoulders. If *A* can exert a force 4 times as much as B and the pole is 2.5 m long, where should the load be suspended?

CONCEPTUAL QUESTIONS

1. The diagram below shows a heavy roller with its axle at O, which is to be pulled on a pavement XY, by applying a minimum possible force. Draw the diagram, showing the direction in which the force should be applied.



2. The iron door of a building is x m broad. It can be opened by applying a F_1 N force at the middle of the door. Calculate the least force which can open the door. Where should this force be applied?

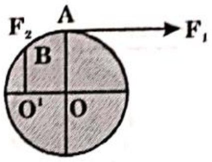
3. Which produces a greater moment, a force of 10 N with a lever arm of 3 m or a force of 8 N with a lever arm of 4 m?

4. A mechanic can open a nut by applying F N force, while using a lever handle of h cm length. What should be the length of the handle required if he wants to open it, by applying a force of only (2F/3) N?

5. The wheel shown in the diagram, has a fixed axle passing through O. The wheel is kept stationary under the action of

(i) A horizontal force F_1 at A and

(ii) A vertical force F_2 at B. Show the direction of F_2 in the diagram. Which is the greater force? Find the ratio between the forces. Given: AO = x cm, BO' = 2x cm and O'O = 3x cm.



6. Suppose the resulting torque on a body is (i) zero (ii) not zero. What is the effect of the acting torques on the body in the two cases?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. The unit of torque is:

(A) $N\ m^{-1}$ (B) N m (C) $N\ m^{-2}$ (D) $N\ m^2$

2. If F is force and r is radius, then torque is:

(A) $\vec{r} \times \vec{F}$ (B) $\vec{r}.\vec{F}$ (C) $|r||F|$ (D) r/F

3. A bicycle tyre in motion has:

(A) linear motion only (B) rotatory motion only

(C) linear and rotatory motion (D) vibratory motion only

4. A uniform metre scale balances horizontally on a knife edge placed at 55 cm mark. When a mass of 25 g is supported from one end, then the mass of the scale is:

(A) 200 g (B) 225 g (C) 350 g (D) 275 g

5. The principle involved in the construction of beam balance is:

(A) principle of moments (B) principle of inertia

(C) principle of superposition (D) principle of velocity

6. A couple always tends to produce:

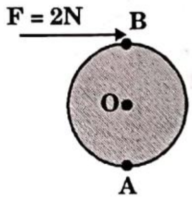
(A) linear motion (B) rotatory motion

(C) both linear and rotatory motion (D) vibratory motion

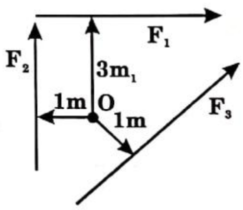
BRAIN NURTURES

1. A wheel of diameter 2 m is shown with axle at 'O'. A force F = 2 N is applied at B in the direction as shown in figure.

   Calculate the moment of force about (i) centre 'O', and (ii) point A.

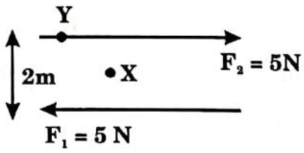


2. F_1, F_2 and F_3 are three forces as shown. The point O is in the same plane. F_1 = 4 N, F_2 = 4 N and F_3 = 6 N.



   (i) Which force has the least moment about 'O'?
   (ii) Which force has the greatest moment about 'O'?
   (iii) Which force has positive moment?
   (iv) Which force has negative moment?

3. The following diagram shows two parallel, opposite and coplanar forces F_1 and F_2, each of magnitude 5 N, with their lines of action separated by a distance of 2 m. A point X lies midway between F_1 and F_2, while a point Y lies on F_2. Calculate the total moment of these forces about (i) X, and (ii) Y. State the effect produced by the forces about the point X.

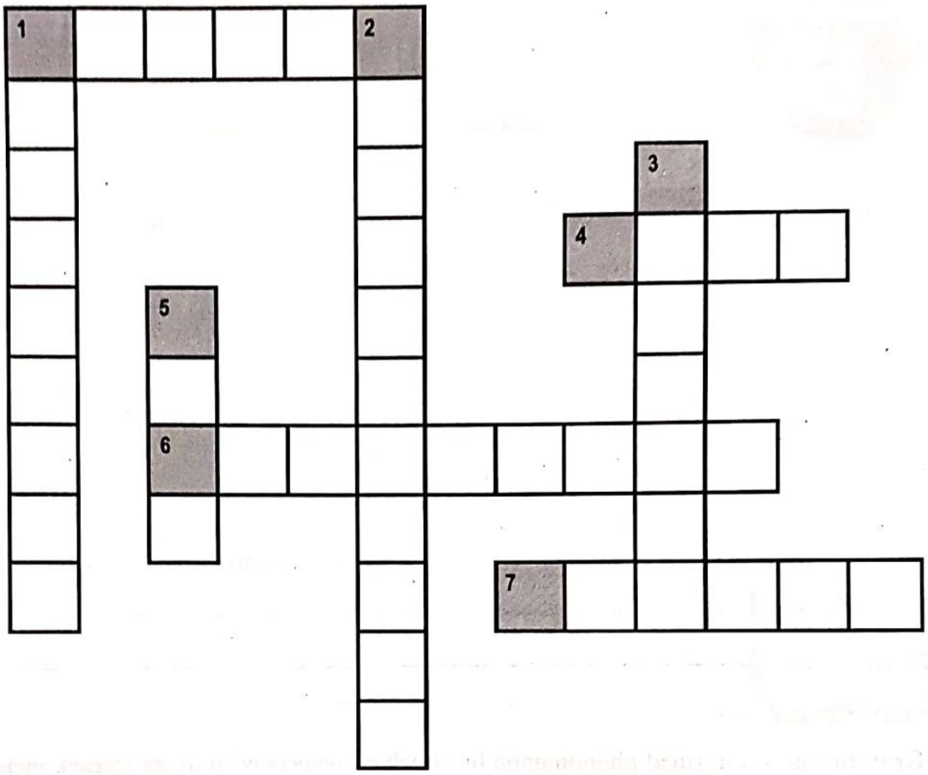


4. A uniform metre scale is balanced at 40 cm mark, when weighs of 25 gf and 10 gf are suspended at 5 cm mark and 75 cm mark respectively. Calculate weight of metre scale.

5. AB is a metre scale, with forces action as shown. Its mass of 100 g. Calculate the algebraic sum of their moments about A.

6. A metre rule is pivoted at its mind point A. 0.6 N weight is suspended from one end. How far from the other end must at 1.00 N weight be suspended for the rule to balance?

CROSSWORD PUZZLE



ACROSS

1 Two equal, parallel, unlike forces whose line of action is not same

4 Racing cars are built with low CG and wide base

6 The ability of an object to regain its original position after it has been disturbed

7 The force that rotates a body without displacing it

DOWN

1 The moment that is taken as negative

2 Sum of clockwise moments is equal to sum of anticlockwise moments when the body is in rotational

3 The turning effect is greater if the perpendicular distance of the force from the axis of rotation is

5 The centre of gravity of an object depends on the distribution of its

Chapter 6

Gravitation

Common Misconception	Fact
1. The value of acceleration due to gravity (g) at poles and equator is mainly affected by angular rotation of the earth.	1. The value of (g) at poles has no effect with rotational motion of the earth but the value of (g) varies at other places.
2. Gravity increases with height and it cannot exist without air; it requires a medium to act through.	2. Gravity is the force of attraction between two or more massive objects. The force of gravity depends upon the masses involved and the distance between them. The force of gravity acts at a distance (contact is not required) and is in-dependent of intervening medium.

SYNOPSIS

INTRODUCTION

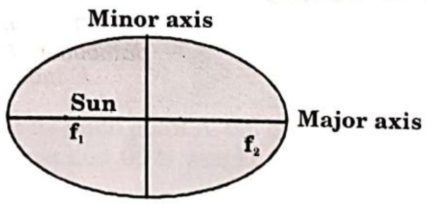
GRAVITATION

Gravitation is a natural phenomenon by which all objects with mass attract each other, and is one of the fundamental forces of physics. It is responsible for keeping the earth and the other planets in their orbits around the sun; for keeping the moon in its orbit around the earth, for the formation of tides and for various other phenomena that we observe. Gravitation is also the reason for the very existence of the earth, the sun, and most macroscopic objects in the universe; without it, matter would not have coalesced into these large masses and life, as we know it, would not exist.

KEPLER'S LAW OF MOTION

Law of orbits

All planets move around the sun, in an elliptical orbits with the sun located at one of its focii.



f_1, f_2 – focii, r – semi major axis

Law of areas

The line joining the sun to any planet known as radius vector sweeps out equal areas in equal time intervals.

(or)

The areal velocity of the radius vector joining the sun and a planet is constant. (It is a consequence of law of conservation of angular momentum (L) (where L = mvr).

Law of periods

The square of the period of revolution of a planet around the sun varies directly as the cube of the semi–major axis of its elliptical path.

$$T^2 \propto R^3 \text{ or } \frac{T^2}{R^3} = \text{constant}$$

NEWTON'S UNIVERSAL LAW OF GRAVITATION

Every particle of matter in the universe exerts an attractive force on every other particle, the force being directly proportional to the product of their respective masses and inversely proportional to the square of the distance of their separation. The force of attraction always acts along the line joining the two particles.

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r^2} \Rightarrow F = G\frac{m_1 m_2}{r^2}$$

Where 'G' is called the 'Universal gravitational constant' and is equal to 6.67×10^{-11} N m^2 kg^{-2}

Characteristics of G

1. It does not depend on the medium between two bodies.
2. It does not depend on the masses of the bodies.
3. It does not depend on the distance between the bodies.

   Suppose if $m_1 = m_2 = 1$ kg and r = 1 m

   then $F = G\frac{1 \times 1}{1}$ or G = F

   Therefore "universal gravitational constant is numerically equal to the force of attraction between unit masses placed at unit distance apart."

Units of G

From equation $F = G\frac{m_1 m_2}{r^2}$ or $G = F \times \frac{r^2}{m_1 m_2}$

Units of force are newtons (N), masses m_1 and m_2 are in kg and distance 'r' is in meters (m).

∴ Unit of G in SI units is N m^2 kg^{-2}

Value of G

Cavendish was the first scientist to measure the value of G experimentally in 1798. Two heavy gold balls were suspended near each other by strong threads. The force between the gold balls was measured. Knowing the force, masses of the gold balls and distance between them, the value of G was calculated using Newton's gravitational formula.

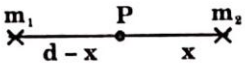
The experimental value of G was found to be $G = 6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}$

Thus the force of gravitation between two masses of 1 kg each kept 1 m apart will be

$$F = G \times \frac{1 \times 1}{1} = G = 6.67 \times 10^{-11} \text{ newtons}$$

When two point objects are kept apart by certain distance if the net gravitational force is zero at a point (p) which lie in between them and distance of the point (P) is given by the formula.

$$\boxed{\frac{m_1}{(d-x)^2} = \frac{m_2}{x^2}}$$



If $m_1 > m_2$ then $(d - x) > x$ i.e., the point at which resultant gravitational field is zero lie in between them and closer to the object of smaller mass.

ACCELERATION DUE TO GRAVITY (g)

The uniform acceleration produced by a freely falling body under the gravitational pull of the earth.

$g = 9.8\ m\ s^{-2} = 980\ cm\ s^{-2}$

Relation between 'g' and 'G'

$$g = \frac{GM}{R^2} = G\rho\frac{4}{3}\pi R$$

S.No.	Acceleration due to gravity (g)	Universal gravitational constant 'G'
1.	Acceleration of a freely falling body due to earth's gravitational attraction is called acceleration due to gravity of earth with the distance towards the centre of earth.	It is the force of attraction between two unit masses by a unit distance of separation.
2.	It is a vector quantity.	It is a scalar quantity.
3.	Its value is constant at a given place but changes from place to place.	It is universal constant.
4.	SI unit of acceleration due to gravity 'g' is $m\ s^{-2}$	SI unit of universal gravitational constant is $N\ m^2\ kg^{-2}$

Relation between g_{earth}, g_{moon} and g_{sun}

$$g_{earth} = 6g_{moon} = \frac{1}{7}g_{sun}$$

Therefore the acceleration due to gravity on the surface of moon is one sixth that on the earth. Acceleration due to gravity of sun is approximately 7 times the acceleration due to gravity on the earth.

Factors influencing the g

The value of g varies from place to place because of the change in the following factors below

(a) Altitude

Let acceleration due to gravity on the surface of a planet of mass 'M' and radius 'R' be 'g' and at a height 'h' be 'g_h'

Then, $g = \frac{GM}{R^2}$, $g_h = \frac{GM}{(R+h)^2}$

$$\frac{g_h}{g} = \frac{R^2}{(R+h)^2} \Rightarrow g_h = g\left(\frac{R}{R+h}\right)^2$$

$$\Rightarrow g_h = g\left(1+\frac{h}{R}\right)^{-2}$$

For heights close to surface of earth i.e., $h << R$

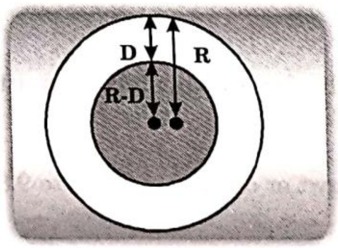
$$\Rightarrow \frac{g_h}{g} = \left(1+\frac{h}{R}\right)^{-2} \approx 1-\frac{2h}{R}$$

$$\Rightarrow g_h \approx g\left(1-\frac{2h}{R}\right)$$

(b) Depth

Assuming earth to be a sphere of uniform density ρ

$$M = \frac{4}{3}\pi R^3 \rho$$



$$g = \frac{GM}{R^2} = \frac{G\left(\frac{4}{3}\pi R^3\rho\right)}{R^2} = \frac{4}{3}\pi G\rho R$$

If body is taken to a depth d below earth's surface then

$$g_d = \frac{GM^1}{(R-d)^2} = \frac{G\left[\frac{4}{3}\pi(R-d)^3\rho\right]}{(R-d)^2}$$

$$g_d = \frac{4}{3}\pi G\rho(R-d)$$

$$\frac{g_d}{g} = \frac{R-d}{R} = 1-\frac{d}{R}$$

$$g_d = \left(1-\frac{d}{R}\right)g$$

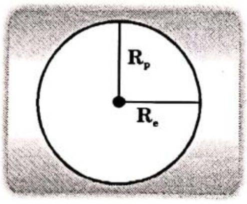
(c) At poles and equator

Earth is not a perfect sphere. It is bulged at equator and flattened at poles.

Hence, $R_{equatorial} > R_{poles}$

But $g \propto \frac{1}{R^2}$

$\therefore$ g is maximum at poles and minimum at equator.



R_e= Radius at equator
R_p= Radius at poles

MASS (m)

It is one of the fundamental property of the body. The mass of the body is the quantity of matter contained in it. S.I unit of mass is kilogram. It is a scalar quantity.

The mass of the body is constant and does not change from place to place. The mass of a body cannot be zero.

WEIGHT

The weight of a body is the force with which it is attracted towards the centre of the earth. It is a vector quantity.

$\therefore$ W = mg

S.I unit is newton. One kgwt or one kgf is equal to 9.8 newtons

Weightlessness

If apparent weight of a body is zero then the body is under weightlessness. Consider a satellite moving in a circular orbit has a radial acceleration.

$$a = \frac{v_o^2}{r} = \frac{GM}{r^2}$$

The apparent weight of a person inside an artificial revolving satellite

$$W_{app} = m(g^{I} - a) = m\left(\frac{GM}{r^2} - \frac{GM}{r^2}\right) = 0$$

i.e apparent weight of a body in a satellite is zero and is independent of radius of the orbit.

ORBITAL VELOCITY

The velocity required for an object to revolve around any planet in circular orbit is called orbital velocity. It is denoted by 'v_0'.

Expression for Orbital Velocity

Orbital velocity to Earth $= v_0 = \sqrt{gR}$

$$= \sqrt{9.8 \times 6.4 \times 10^6}$$

$$= 7919.5 \text{ m s}^{-1} = 7.9195 \text{ km s}^{-1}$$

$$\cong 7.92 \text{ km s}^{-1}$$

$\therefore$ The orbital velocity of Earth $= 7.9 \text{ km s}^{-1}$

1. The orbital velocity does not depend on the mass of a satellite.
2. If the velocity of satellite is less than orbital velocity, it will fall back to Earth. But if the velocity of a satellite is greater than the orbital velocity, it will get lost into space.

ESCAPE VELOCITY

When a body is projected vertically upwards from the surface of earth with a great velocity beyond the gravitational pull of the earth. It goes higher i.e., it never returns and escapes into space.

The velocity required for a body to escape into space from earth's gravity is called escape velocity.

Expression of Escape Velocity

$$V_e = \sqrt{2gR}$$

Therefore, escape velocity $= \sqrt{2} \times$ orbital velocity

SOLVED EXAMPLES

Example 1

Two spheres of masses 100 kg and 900 kg each of radius 10 m and 20 m respectively. Find gravitational force acting between them.

Solution:

The formula to be used is $F = \frac{Gm_1m_2}{d^2}$. It is applicable for all point objects.

In the problem given sphere are to be replaced by point objects of same mass placed at their centre (assuming uniform density). So, distance between them will be 30 m. Then

$$F = \frac{6.67 \times 10^{-11} \times 100 \times 900}{30 \times 30} = 6.67 \times 10^{-9}\ N$$

Example 2

The gravitational force acting between point objects m_1 and m_2 separated by a distance 'd' is 'F'. What will be the force of gravitation between them if

(A) one mass is increased by 100%

(B) each mass is tripled ?

(C) each mass is quadrupled and distance between them is halved ?

(D) mass of each body is increased by 40% and the distance between them is decreased by 25% ?

Solution:

Given $F = \frac{Gm_1m_2}{d^2}$ -------------------- (1)

(a) Final mass of one object is $m_1 + \frac{100}{100} m_1 = 2\,m_1$

Then $F' = \frac{G2m_1m_2}{d^2} = 2F$

(b) Final mass of objects are $(3m_1)\,(3m_2)$

Then $F' = \frac{G(3m_1)(3m_2)}{d^2} = 9F$

(c) Final mass of objects are $(4m_1)\,(4m_2)$ and final distance is $\left(\frac{d}{2}\right)$

Then $F' = \frac{G(4m_1)(4m_2)}{\left(\frac{d}{2}\right)^2} = 64F$

(d) Final mass of each object is $m_1 + \frac{40}{100}m_1 = \frac{14m_1}{10}; \left(\frac{14m_2}{10}\right)$

Final distance between the masses is = $d - \frac{25}{100}d = \frac{75}{100}d = \frac{3d}{4}$

Then, $F' = \frac{G\left(\frac{14}{10}m_1\right)\left(\frac{14}{10}m_2\right)}{\left(\frac{3d}{4}\right)^2} = \frac{Gm_1m_2}{d^2} = \frac{14}{10}\times\frac{14}{10}\times\frac{16}{9}F = \frac{3136\ F}{900}$

Example 3

Gravity at any depth below the surface of the earth is $g' = g\left(1-\frac{d}{R}\right)$ for all. Acceleration due to gravity at a height 'h' above the earth is $g' = g\left(1-\frac{2h}{R}\right)$ for h<<R and $g' = g\left(\frac{R}{R+h}\right)^2$ for any height 'h'. 'd' (R = 6400 km; 'g' is gravity on earth and g' is gravity at specified position)

(a) Find height where the gravity is same as at a depth 20 km

(b) Find height where the gravity is same as at a depth 4800 km

Solution:

(a) 15 km is a small depth. So, formula to be used is $g' = g\left(1-\frac{2h}{R}\right)$ and $g' = g\left(1-\frac{d}{R}\right)$;

Then $g' = g\left(1-\frac{d}{R}\right) = g\left(1-\frac{2h}{R}\right) \Rightarrow 2h = d \Rightarrow h = \frac{d}{2} = \frac{20}{2} = 10$ km

(b) Depth 4800 km is large. So, formula to be used is $g' = g\left(\frac{R}{R+h}\right)^2$ and $g' = g\left(1-\frac{d}{R}\right)$

Then $g' = g\left(1-\frac{d}{R}\right) = g\left(\frac{R}{R+h}\right)^2$

$\Rightarrow 1 - \frac{4800}{6400} = \left(\frac{6400}{6400+h}\right)^2$

$\frac{16}{64} = \left(\frac{6400}{6400+h}\right)^2 \Rightarrow \frac{1}{2} = \left(\frac{6400}{6400+h}\right) \Rightarrow 2\times 6400 = 6400 + h \Rightarrow h = 6400$ km

Example 4

A body weighs 900 N on the earth. Find its weight on a planet whose

(a) density is $\frac{1}{3}$rd the density of earth; radius is $\frac{1}{4}$th that of the earth.

(b) mass is $\frac{5}{4}$th of mass of earth; radius is $\frac{3}{2}$rd that of the earth.

Solution:

Recall the formula for weight $W = mg = m\left(\frac{GM}{R^2}\right) = m\left(g\left(\frac{4}{3}\pi R\right)\rho\right)$ where 'M' denotes mass of earth; 'R' denotes radius of earth; 'ρ' denotes density of earth.

(a) Given $900\text{ N} = mG\left(\frac{4}{3}\pi R\right)\rho = m\left(\frac{GM}{R^2}\right)$

$$W_1 = mG\frac{4}{3}\pi\left(\frac{R}{4}\right)\left(\frac{1}{3}\right)\rho = mG\left(\frac{4}{3}\pi R\right)\rho\left(\frac{1}{4}\times\frac{1}{3}\right)$$

$$= 900 \times \frac{1}{4}\times\frac{1}{3} = 75\text{ N}$$

(b) On the planet, $W_2 = \frac{mG\left(\frac{5}{4}M\right)}{\left(\frac{3R}{2}\right)^2} = m\left(\frac{GM}{R^2}\right)\left(\frac{5}{9}\right) = \frac{900\times 5}{9} \Rightarrow W_2 = 500\text{ N}$

Example 5

Calculate the force of gravitation between two bodies weighing 50 kg and 10 kg kept at a distance 5 meters apart. If the distance between them is increased by 5 m then find the percentage change in force. ($G = 6.67\times 10^{-11}\text{ N m}^2\text{ kg}^{-2}$).

Solution:

Using Newton's formulae, $F = G\frac{m_1 m_2}{r^2}$

$\therefore G = 6.67\times 10^{-11}\text{ N m}^2\text{ kg}^{-2}$, $m_1 = 50$ kg, $m_2 = 10$ kg, $r = 5$ m

$$\therefore F = 6.67\times 10^{-11} \times \frac{50\times 10}{5\times 5} = 13.34 \times 10^{-10}\text{ N}$$

$r' = (r + 5)\text{ m} = 10\text{ m (or) } 2r$

$$\therefore F' = \frac{Gm_1m_2}{(r')^2} = \frac{Gm_1m_2}{(2r)^2} = \frac{F}{4}$$

Percentage change in force $= \frac{F' - F}{F}\times 100 = \frac{\frac{F}{4} - F}{F}\times 100 = -75\%$

Hence force decreases by 75%.

Example 6

At what height from the surface of the earth will the value of g we reduced by 64 % from the value at the surface.

Solution :

Let h be the height at which the value of the g will get reduced by 64 %. $\therefore g' = \frac{36}{100}g$

Such a large decrease in the value of g will occur at a very large height. $g\frac{R^2}{(R+h)^2} = \frac{36}{100}g$

or $\frac{R}{R+h} = \frac{6}{10}$ or $h = \frac{4R}{6} = 4266.7$ km

Example 7

A satellite of mass 500 kg is in an orbit 100×10^6 m from the centre of the earth. The mass of the earth is 6.0×10^{24} kg. What is the force of attraction on the satellite by the earth? What is the force of attraction on the earth by the satellite?

Solution:

Applying Newton's law of gravitation

$$F = \frac{GMm}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times (6.0 \times 10^{24}) \times 500}{(100 \times 10^6)^2} = 20.0 \text{ N}$$

The force of attraction on the earth by the satellite is also 20 N

Example 8

What will be the gravitational force between two bodies if

(a) the distance between them is doubled?

(b) the distance between them is halved?

Solution:

Force of gravitation $F = G\frac{m_1 m_2}{r^2}$

(a) When the distance is doubled, R = 2r

$$\therefore F_1 = G\frac{m_1 m_2}{R^2} = G\frac{m_1 m_2}{4r^2} = \frac{1}{4}G\frac{m_1 m_2}{r^2} \text{ but } F = G\frac{m_1 m_2}{r^2}$$

$$\therefore F_1 = \frac{1}{4}F$$

Gravitational force becomes one fourth, when the distance is doubled.

(b) When the distance between the bodies is halved, $R = \frac{1}{2}r$

$$\therefore\ F_2 = G\frac{m_1m_2}{R^2} = G\frac{m_1m_2}{\left(\frac{1}{2}r\right)^2} = 4G\frac{m_1m_2}{r^2} = 4F$$

$\therefore\ F_2 = 4F$

Gravitational force becomes four times when the distance is halved.

Example 9

Calculate the force of gravitation between two bodies weighing 50 kg and 10 kg kept at a distance 5 meter apart. ($G = 6.67 \times 10^{-11}$ N m² kg⁻²).

Solution:

$m_1 = 50$ kg

$m_2 = 10$ kg

$d = 5$ m.

$F = ?$

$$\therefore\ F = G\frac{m_1m_2}{d^2}$$

$$F = 6.67\times10^{-11}\times\frac{50\times10}{5\times5} = 13.34\times10^{-10}\text{ N}$$

Example 10

Find the force with which two friends having same man of 60 kg and sitting on benches separated by 2 meters, attracts each other.

Solution:

m_1 and $m_2 = 60$ kg

Distance between them $d = 2$ m

Gravitational constant $G = 6.67 \times 10^{-11}$ N m² kg⁻²

Force $F = ?$

From the former $F = G\frac{m_1m_2}{d^2}$

Putting value, we get $F = 6.67 \times 10^{-11} \times \frac{60\times60}{2\times2}$

$$F = 6.67\times10^{-11}\times\frac{3600}{4}$$

$$F = 6.67\times10^{-11}\times900 = 6.67\times9\times10^{-9} = 60.03\times10^{-9}\text{ N}$$

Example 11

The mass of earth is 6×10^{24} kg and that of the moon is 7.4×10^{22} kg. If the distance between earth and moon is 3.84×10^5 km. Calculate the force exerted by the earth on the moon. ($G = 6.7 \times 10^{-11}$ N m² kg⁻²).

Solution:

Mass of earth is $m_1 = 6 \times 10^{24}$ kg

Mass of moon $m_2 = 7.4 \times 10^{22}$ kg

Distance between earth and moon d $= 3.84 \times 10^5$ km

$= 3.84 \times 10^8$ m

Universal gravitational constant $G = 6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}$

Force of the earth on moon F = ?

We know $F = G\frac{m_1 m_2}{r^2}$

putting the values we get

$$F = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 7.4 \times 10^{22}}{(3.84 \times 10^8 m)^2}$$

$$= \frac{6.67 \times 6 \times 7.4 \times 10^{35}}{3.84 \times 3.84 \times 10^{16}} = \frac{296.148}{14.7456} \times 10^{19} N = 2.08 \times 10^{19} N = 2.0008 \times 10^{20} N$$

Force exerted by the earth on the moon

$F = 2.01 \times 10^{20}$ N

Example 12

Calculate the force of gravitation due to earth on a ball of mass 60 kg

Solution:

Mass of earth $= 6 \times 10^{24}$ kg

Radius of earth $= 6.4 \times 10^3$ km = distance

$G = 6.7 \times 10^{-11}\ N\ m^2\ kg^{-2}$

Mass of ball = 60 kg

We know that $F = G \times \frac{m_1 m_2}{d^2}$

Putting the value.

$$F = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 60}{(6.4 \times 10^6)^2} = 588.8 N$$

Example 13

How does the force of gravitation, between two bodies change when the distance between them is reduced to half?

Solution:

Case – I

Mass of the 1st body before change = m_1

Mass of the 2^{nd} body before change = m_2

Distance between them before change = d

Case – II

Mass of the 1^{st} body after change = m_1

Mass of 2^{nd} the body before change = m_2

Distance between them after change = d/2

As we know $F = G\dfrac{m_1m_2}{d_1^2}$

Applying this equation to both cases.

$$F_1 = \frac{Gm_1m_2}{(d)^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$F_2 = \frac{Gm_1m_2}{(d/2)^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Dividing the equation (2) by (1) then

$$\frac{F_2}{F_1} = G\frac{m_1m_2}{(d)^2} / \frac{Gm_1m_2}{\left(\frac{d}{2}\right)^2}$$

$$\frac{F_2}{F_1} = \frac{Gm_1m_2}{Gm_1m_2} \times \frac{(d)^2}{(d/2)^2}$$

$$\frac{F_2}{F_1} = \frac{(d)^2}{\left(\frac{d}{2}\right)^2} = 4$$

Force becomes 4 times

CONCEPT MAP

Gravitation

It is the phenomenon by which all objects with mass attract each other

- **Newton's of Universal law of gravitation** → Every particle of matter in the universe exerts an attractive force on every other particle, the force being directly proportional to the product of their respective masses and inversely proportional to the square of their separation. The force of attraction always acts along the line joining the two particles.
  Formula : $F = G\frac{m_1 m_2}{r^2}$
  → G is equal to the force of attraction between unit masses placed at unit distance apart.
  SI units is Nm^2kg^{-2}
  $G = 6.67 \times 10^{-11} N\,m^2 kg^{-2}$
- **Acceleration due to gravity (g)** → The uniform acceleration produced by a freely falling body under the gravitational pull of the earth. $g = 9.8\ ms^{-2} = 980\ cm\ s^{-2}$
  → **Factors affecting**
  - **Altitude:** $g_h = \frac{GM}{(R+h)^2}$
    $g_h = g\left(1 - \frac{2h}{R}\right)$ $h << R$
  - **Depth** : $g_d = \left(1 - \frac{d}{R}\right)g$
  - g is maximum at poles and minimum at equator.
- **Mass** is the quantity of matter contained in it. S.I unit of mass is kilogram
  → **weight of** a body is the force with which it is attracted towards the centre of the earth.
  ∴ $W = mg$
  S.I unit is newton
- **Kepler's law of motion**
  - All planets move around the sun, in an elliptical orbit with the sun located at one of its focii.
  - The line joining the sun to any planet, known as radius vector sweeps out equal areas in equal time intervals.
  - The square of the period of revolution of a planet around the sun varies directly as the cube of the semi-major axis of its elliptical path.
- **Orbital Velocity** → The velocity required for an object to revolve a round any planet in circular orbit is called orbital velocity.
  $V_o = \sqrt{gR}$
- **Escape Velocity** → The velocity required for a body to escape into space from earth's gravity is called escape velocity.
  $V_e = \sqrt{2gR}$

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. Two satellites of identical masses orbit the earth at different heights. The ratio of their distances from the centre of earth is d : 1 and the ratio of the acceleration due to gravity at those heights is g : 1. Then the ratio of their orbital velocities is ________.
2. Newton's inverse square law is deduced from Kepler's ________ of planetary motion.
3. The acceleration due to gravity on the surface of a planet, whose mass and diameter are double that of the earth, is ________ times the acceleration due to gravity on the surface of the earth.
4. Every planet revolves around the sun in an ________ orbit with the sun at one of its focii.
5. The orbital velocity is independent of ________ of orbiting body.
6. The ratio of SI unit of G to its CGS unit is ________.
7. The mass of a body can never be ________.
8. 1 kgf = ________ dynes
9. The value of g is ________ at poles.
10. When a body is at a depth 'd' from the earth surface its distance from the centre of the earth is ________.
11. The atmosphere is held to the earth by ________.
12. If F is the force between two bodies of masses m_1 and m_2 at certain separation, then the force between $\sqrt{2}\, m_1$ and $\sqrt{3}\, m_2$ at same separation is: ________.
13. The direction of the force is along the line joining the ________ of the two bodies.
14. The place where the value of 'g' is unaffected by the increase (or) decrease in the speed of rotation of the earth about its own axis is ________.
15. Universal gravitational constant is ________ of the intervening medium.

TRUE OR FALSE

16. Any two bodies in the universe attract each other.
17. The weight of a body on the surface of moon is $\frac{1}{6}$th of that on the earth's surface. It is because acceleration due to gravity on the surface of moon is six times that on the surface of the earth.
18. Acceleration due to gravity becomes half at a depth of half the radius of the earth.
19. Mass of a body remains constant anywhere in the universe.
20. As the distance of the planet from the sun increases, the period of revolution decreases.
21. As planet moves around the sun it sweeps equal areas in equal intervals of time.

22. Gravitational force can be repulsive.
23. The orbital velocity is nearly 0.707 times that of escape velocity.
24. If a heavenly object like an asteroid or a planetoid revolving around the sun moves into an orbit of smaller radius, its speed increases.
25. The maximum heights reached by the bodies that are vertically projected with the same velocity on the surface of the moon and the earth are same.

MATCH THE FOLLOWING

26.

Column A	Column B
A. g_h	p. minimum
B. g_d	q. $g\left(1-\frac{2h}{R}\right)$
C. $g_{equator}$	r. $\frac{GM}{R^2}$
D. g_{poles}	s. $g\left(1-\frac{d}{R}\right)$
E. g	t. maximum

27.

Column A	Column B
A. Orbital velocity	p. 1.67 m s^{-2}
B. Escape velocity	q. 9.8 m s^{-2}
C. G	r. $\sqrt{2gR}$
D. g_{earth}	s. $\sqrt{gR}$
E. g_{moon}	t. 6.67×10^{-11} N m^2 kg^{-2}

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. If R is the radius of earth, the height at which the weight of a body becomes 1/4 its weight on the surface of earth is:
(A) 2R (B) R (C) R/2 (D) R/4

2. If the earth shrinks half in radius its mass remaining the same, the weight of an object on earth will change:
(A) decreases by 50% (B) increases by 50%
(C) decreases by 25% (D) increases by 300%

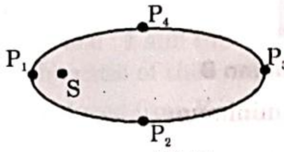
3. A body weighs 72 N on the surface of earth. What is the gravitational force on it due to earth at a height equal to half the radius of the earth from the surface?

(A) 72 N (B) 28 N (C) 16 N (D) 32 N

4. Where will it be profitable to purchase one kilogram sugar?

(A) At poles (B) At equator (C) At 45° latitude (D) At 40° latitude

5. The figure shows a planet in elliptical orbit around the sun S. The kinetic energy of the planet will be maximum when the planet is at:



(A) P_1 (B) P_2 (C) P_3 (D) P_4

6. If mass of a body is M on the earth surface, then the mass of the same body on the moon's surface is:

(A) M/6 (B) zero (C) M (D) none

7. As we go from equator to the poles, the value of g:

(A) remains the same (B) decreases

(C) increases (D) decreases upto altitude of 45°

8. A body weighs 700 N on the surface of the earth. What is its weight on the surface of a planet whose mass is 1/7 th of that of earth and radius is 1/2 times of earth?

(A) 400 N (B) 300 N (C) 700 N (D) 500 N

9. Which of the following statements is true ?

(A) g is same at all places on the surface of earth.

(B) g has its maximum value at the equator.

(C) g is less at the earth's surface than at a height above it or a depth below it.

(D) g is greater at the poles than at the equator.

10. A simple pendulum has a time period T_1 when on the Earth's surface, and T_2 when taken to a height R above the Earth's surface, where 'R' is the radius of the Earth. The value of $\frac{T_2}{T_1}$ is:

(A) 1 (B) $\sqrt{2}$ (C) 0.5 (D) 2

11. At a place, value of 'g' is less by 1% than its value on the surface of the Earth (Radius of Earth, R = 6400 km). The place is:

(A) 64 km below the surface of the earth

(B) 64 km above the surface of the earth

(C) 30 km above the surface of the earth

(D) 32 km below the surface of the earth

12. The radius in kilometres to which the present radius of the earth (R = 6400 km) is to be compressed so that the escape velocity is increased to 10 times is:

(A) 6.4 (B) 64 (C) 640 (D) 4800

13. The mass and diameter of a planet are two times those of Earth. If a seconds pendulum is taken to it, the time period of the pendulum in seconds is:

(A) $\frac{1}{\sqrt{2}}$ (B) $\frac{1}{2}$ (C) 2 (D) $2\sqrt{2}$

14. A body is projected up with a velocity equal to $\frac{3}{4}$ th of the escape velocity from the surface of the Earth. The height it reaches is (Radius of Earth is R).

(A) $\frac{10R}{9}$ (B) $\frac{9R}{7}$ (C) $\frac{9R}{16}$ (D) $\frac{10R}{3}$

15. The gravitational force with which the earth attracts the moon:

(A) is less than the force with which the moon attracts the earth.

(B) is equal to the force with which the moon attracts the earth.

(C) is greater than the force with which the moon attracts the earth

(D) varies with the phases of the moon.

16. The value of g at a place increases with:

(A) decrease in the latitude of the place (B) increase in the latitude of the place

(C) increase in the altitude of the place (D) none of the above

17. The distances of two planets (neptune and saturn) from sun are 10^{13} m and 10^{12} m respectively. The ratio of time periods of the planets is:

(A) 100 : 1 (B) $1 : \sqrt{10}$

(C) $\sqrt{10} : 1$ (D) $10\sqrt{10} : 1$

18. The escape velocity from the earth is 11 km s^{-1}. The escape velocity from a planet having twice the mass and twice the radius will be:

(A) $(11\times\sqrt{12})$ km s^{-1} (B) 11 km s^{-1}

(C) $\frac{11}{2}$ km s^{-1} (D) $(11\times\sqrt{2})$ km s^{-1}

19. Two bodies of masses 2 kg and 8 kg are separated by a distance of 9 m. Then the point where the resultant gravitational field is zero is at a distance of:

(A) 6 m from 8 kg (B) 3 m from 8 kg (C) 6 m from 2 kg (D) 4.5 m from each mass

20. A body falls through a distance 'h' in certain time on the earth. Then if the same body is related on another planet having mass and radius twice as that of the earth, the distance through which it falls in the same time is:

(A) h/2 (B) 2h (C) h (D) 4h

MULTIPLE ANSWER QUESTIONS

1. Choose the correct statement (s). The acceleration due to gravity 'g' decreases if
   (A) we go down from the surface of the earth towards its centre
   (B) we go up from the surface of earth
   (C) we go from the equator towards the poles on the surface of the earth
   (D) the rotational velocity of the earth is increased
2. Two planets A, B have their radii in the ratio 2 : 5 and densities in the ratio 1 : 6 respectively.
   (A) The ratio of the acceleration due to gravity on them is 1 : 15.
   (B) For the same volume of planets, mass of planet A is greater than that of planet B.
   (C) A body weighs 15 times more on planet B than on planet A.
   (D) Planet B have greater volume than planet A.
3. If a body is projected with speed less than escape velocity the body:
   (A) can reach a certain height and may fall down following a straight line path.
   (B) can reach a certain height and may fall down following a parabolic path.
   (C) may orbit the earth in a circular orbit.
   (D) may orbit the earth in an elliptical orbit.
4. Which of the following statements are correct about a planet rotating around the sun in an elliptical orbit?
   (A) Its kinetic energy is constant (B) Its angular momentum is constant
   (C) Its areal velocity is constant (D) Its time period is proportional to r^3.
5. The escape velocity from a planet of mass (M), radius (R) and acceleration due to gravity (g) is given by:
   (A) $2\sqrt{\frac{GM}{R}}$ (B) $\sqrt{2gR}$ (C) $\sqrt{\frac{2gM}{R}}$ (D) $\sqrt{\frac{2GM}{R}}$

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statements of an Assertion and a Reason. Use the following key to choose the appropriate answer.

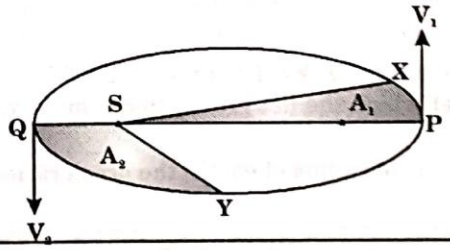
(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.
(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.
(C) If assertion is CORRECT, but reason is INCORRECT.
(D) If assertion is INCORRECT, but reason is CORRECT.
(E) If both assertion and reason are INCORRECT.

1. **Assertion:** Smaller the orbit of the planet around the sun, shorter is the time it takes to complete one revolution.
   Reason: According to Kepler's third law of planetary motion, square of time period is proportional to cube of mean distance from sun.
2. **Assertion:** The universal gravitational constant is same as acceleration due to gravity.
   Reason: Gravitational constant and acceleration due to gravity have same units.
3. **Assertion:** The value of acceleration due to gravity does not depend upon mass of the body.
   Reason: Acceleration due to gravity is a constant quantity.
4. **Assertion:** If earth suddenly stops rotating about its axis, then the value of acceleration due to gravity will become same at all the places.
   Reason: The value of acceleration due to gravity is independent of rotation of the earth.
5. **Assertion:** The difference in the value of acceleration due to gravity at pole and equator is due to difference in the latitude of the place.
   Reason: The value of acceleration due to gravity is minimum at the equator and maximum at the poles.
6. **Assertion:** A planet moves faster, when it is closer to the sun in its orbit and vice versa.
   Reason: Orbital velocity for an orbiting planet is constant.
7. **Assertion:** Earth has an atmosphere but the moon does not.
   Reason: Moon is very small in comparison to earth.
8. **Assertion:** Two different planets can have same escape velocity when their masses and diameter are same.
   Reason: Escape velocity is given as $\sqrt{2gR}$
9. **Assertion:** When distance between two bodies is doubled and also mass of each body is also doubled, gravitational force between them remains the same.
   Reason: According to Newton's law of gravitation, force is directly proportional to mass of bodies and inversely proportional to square of the distance between them.
10. **Assertion:** The escape velocity from the surface of Jupiter is less than that from earth's surface.
    Reason: The radius of Jupiter is smaller than earth.

PARAGRAPH QUESTIONS

Passage - I

I. The figure shown below is an elliptical orbit along which a planet revolves round the sun. Let the velocity of planet at P and Q positions be V_1 and V_2 respectively.



(i) As the planet revolves from point P to point Q, the velocity of the planet.

(A) increases (B) decreases

(C) remains same (D) equal in magnitude and opposite in direction

(ii) The possible relationship between magnitudes of "V_1" and "V_2" is:

(A) $V_1 > V_2$ (B) $V_1 < V_2$ (C) $V_1 = V_2$ (D) Both (A) and (C)

(iii) If the time taken by the planet to move from position P to X and Q to Y is equal then the ratio of A_1 to A_2 is:

(A) greater than one (B) less than one

(C) equal to one (D) data insufficient

SECTION – B

NUMERICAL PROBLEMS

1. At the surface of a certain planet, acceleration due to gravity is one quarter of that on earth. A brass ball is transported on this planet, then find the percentage change in its weight.

2. Two spheres each of mass 10^5 kg and radius 10 m are kept in contact. Find force of gravitation acting between them.

3. Find the gravitational attraction between the two atoms in a hydrogen molecule. Given that $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, mass of a hydrogen atom = 1.67×10^{-27} kg and distance between the two atoms = 1°A.

4. The force of gravitation between two point objects each of mass 'm' kept apart by a distance 'a' is 'F'. Find force of gravitation between them

(a) If mass of one of each object is increased by 25% (other factors are kept same).

(b) If distance of each object is increased by 50% (other factors are kept same).

5. A body weighs 160 N on the earth. Find its weight on the other planet whose

(a) Mass is $\frac{1}{4}$th mass of earth and radius $\frac{1}{3}$rd that of the earth.

(b) Mass $\frac{5}{2}$ times mass of earth and radius $\frac{4}{5}$ times that of earth.

6. The distance between earth and moon is about 3.8×10^5 km. At what point (s) will the net gravitational force of earth–moon system be zero? [Given mass of earth is 81 times the moon's mass). (Hint : Assume a body of unit mass at null point]

7. Two point object of masses 10^4 kg, 10^6 kg are 1.2×10^3 m apart. Find distance of point from smaller mass at which the net gravitational force due to them will be zero.

8. At what depth (interms of radius of earth) the acceleration due to gravity will be: $\frac{2g}{5}$?

9. At what height (interms of radius of earth) the acceleration due to gravity will be:

(a) $\frac{g}{2}$? (b) $\frac{4g}{9}$? (c) $\frac{g}{100}$?

10. A body weighs 100 N at a distance $\frac{R}{4}$ from centre of earth. Find its weight at height of 9 R from the surface of earth (R – Radius of earth).

11. Two persons having mass 50 kg each, are standing such that the centre of gravity are 1 m apart. Calculate the force of gravitation and also calculate the force of gravity on each. (Take $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, mass of earth $M = 6 \times 10^{24}$ kg, Radius of earth $R = 6.4 \times 10^6$ m)

12. If the attractive force between two bodies of mass M_1 and M_2 and situated at a distance R is F, then find the force F' between them at distance (R + d).

13. The acceleration due to gravity on the planet A is 8 times the acceleration due to gravity planet A. A man jumps to a height of 1.5 m on the surface of A. What is the height of jump by the same person on the planet B ?

CONCEPTUAL QUESTIONS

1. Suppose gravitational force between two masses were to be given by $F = k\frac{\sqrt{m_1m_2}}{d^3}$ where k is some constant, two equal masses attract each other with a certain force when the distance is d. If each of the masses is doubled, than what value the distance between them must be maintained for the force to remain the same as earlier?

2. Gold is weighed with a spring balance. It is profitable to sell gold at poles than at equator Comment.

3. Common balance reading on earth of an object is 'X' and the spring balance reading is 'Y'. The set up is transferred to moon. What reading does the common balance and spring balance give?

4. Between the earth and the sun gravitational force of attraction exists then why does not the earth fall into the sun?

5. If the diameter of earth becomes two times its present value and its mass remains unchanged; then how would the weight of an object on the surface of the earth be affected?

6. On the surface of earth, the weight of a body is about 9.8 N kg^{-1}. Justify the statement.

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. R' and 'r' are the radii of the Earth and Moon respectively, ρ_e and ρ_m are the densities of the Earth and Moon respectively. The ratio of acceleration due to gravity on the surface of the Earth to the Moon is:

(A) $\frac{R}{r}\cdot\frac{\rho_e}{\rho_m}$ (B) $\frac{r}{R}\cdot\frac{\rho_e}{\rho_m}$ (C) $\frac{r}{R}\cdot\frac{\rho_m}{\rho_e}$ (D) $\frac{R}{r}\cdot\frac{\rho_m}{\rho_e}$

2. Value of 'g' is:

(A) maximum at poles (B) maximum at equator

(C) same everywhere (D) minimum at poles

3. If the acceleration due to gravity g at the earth 's surface is 9.8 m s^{-2} and mass of earth is 80 times that of moon and radius of earth 4 times that of moon, the value of g at the moon's surface will be approximately

(A) 4 m s^{-2} (B) 1.96 m s^{-2} (C) 27 m s^{-2} (D) 16 m s^{-2}

4. If the radius of the earth were to shrink by 1%, its mass remaining the same, the acceleration due to gravity on the earth's surface would:

(A) decrease by 1% (B) remain unchanged

(C) increase by 1% (D) increase by 2%

5. At what height in km over the earth's pole the free fall acceleration decreases by one percent? (Assume the radius of the earth to be 6400 km).

(A) 32 (B) 64 (C) 80 (D) 1.253

6. The value of g on the earth's surface is 980 cm s^{-2}. Its value at a height of 64 km from the earth's surface is:

(A) 960.40 cm s^{-2} (B) 984.90 cm s^{-2} (C) 982.45 cm s^{-2} (D) 977.55 cm s^{-2}

7. Acceleration due to gravity 'g' and the mean density of the earth 'ρ' are related by the relation where G is the gravitational constant and R_e is the radius of the earth

(A) $\left(\frac{g}{G}\right)\frac{4\pi}{3}R_e^3 = \rho$ (B) $\frac{\left(\frac{g}{G}\right)}{\left(\frac{4\pi}{3}R_e\right)} = \rho$ (C) $\frac{g}{G}\frac{4\pi}{3}R_e^2 = \rho$ (D) $\frac{\left(\frac{g}{G}\right)}{\left(\frac{4\pi}{3}R_e^3\right)} = \rho$

8. The acceleration due to gravity on the surface of earth varies

(A) directly with longitude (B) directly with latitude

(C) inversely with longitude (D) inversely with altitude

9. At a point very near earth's surface, the acceleration due to gravity is g. What will be the acceleration due to gravity at the same point if earth suddenly shrinks to half its radius without any change in its mass?

(A) 2 g (B) 4 g (C) g (D) 3 g

10. A spring balance is graduated on sea level. If a body is weighed with this balance at consecutively increasing heights from earth's surface, the weight indicated by the balance:

(A) will go on decreasing continuously (B) will go on increasing continuously

(C) will remain same (D) will first increase and then decrease

11. If the radius of the earth shrinks by 1.5% (mass remaining same), then the value of acceleration due to gravity changes by:

(A) 1% (B) 2% (C) 3% (D) 4%

12. Mass of moon is 7.34×10^{22} kg. If the acceleration due to gravity on the moon is $1.4\ m\ s^{-2}$, the radius of the moon is $[G = 6.667 \times 10^{-11}\ N\ m^2\ kg^{-2}]$

(A) 0.56×10^4 m (B) 1.87×10^6 m (C) 1.92×10^6 m (D) 1.01×10^8 m

13. The moon's radius is 1/4 that of the earth and its mass 1/80 times that of the earth. If g represents the acceleration due to gravity on the surface of the earth, then on the surface of the moon its value is:

(A) g/4 (B) g/5 (C) g/6 (D) g/8

14. The mass of the moon is about 1.2% of the mass of the earth. Compared to the gravitational force that earth exerts on the moon, the gravitational force the moon exerts on earth

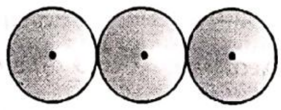
(A) is the same. (B) is smaller.
(C) is greater. (D) varies with its phase.

15. The value of g on the moon is $\frac{1}{6}$ th that on earth. A body weighing 60 kg on the earth, has weight on the moonas

(A) 20 kg (B) zero (C) 360 kg (D) 10 kg

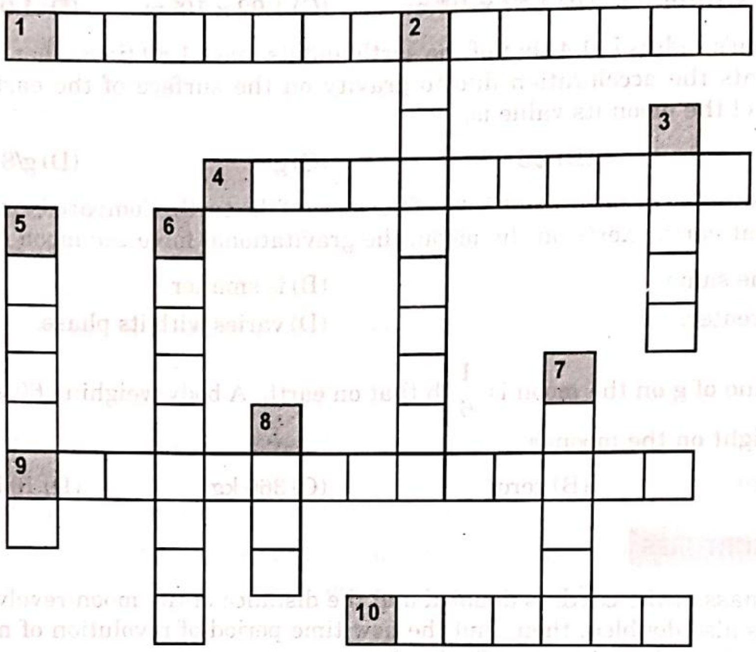
BRAIN NURTURES

1. If the mass of the earth is doubled and the distance of the moon revolving around the earth is also doubled, then, find the new time period of revolution of moon. (Take the present time of revolution as 28 days).
2. If R is the radius of a planet, g is the acceleration due to gravity then find the mean density of the planet.
3. Three uniform spheres each of mass 'm' and radius 'r' are placed in contact as shown. Find net force of gravitation on each sphere.



4. A body of mass 5 kg is cut into two parts of masses (a) $\frac{m}{4};\frac{3m}{4}$ (b) $\frac{m}{7};\frac{5m}{7}$ (c) $\frac{m}{2};\frac{m}{2}$ (d) $\frac{m}{5};\frac{4m}{5}$. When these two pieces are kept apart by certain distance; In which case the gravitational force acting is maximum?
5. Explain, why a tennis ball bounces higher on hills than in plains?
6. Explain, why one can jump higher on the surface of moon than on the earth?
7. According to Newton's law of gravitation, the apple and the earth experience equal and opposite forces due to gravitation. But it is the apple that falls towards the earth and not vice–versa. Why?
8. Imagine a spacecraft going from the earth to the moon. How does its weight vary as it goes from the earth to the moon?

CROSSWORD PUZZLE



ACROSS

1 *The velocity required for an object to revoive around any planet in circular orbit*

4 *The natural phenomenon by which all objects with mass attract each other*

9 *The velocity required for a body to escape into space from earth's gravity*

10 *Earth is bulged at*

DOWN

2 *The shape of orbits in which all planets move around the sun*

3 *The value of g is maximum at*

5 *Escape velocity is $\sqrt{2}$ the orbital velocity, this implies escape velocity is as compared to orbital velocity*

6 *As the altitude increases the value of g*

7 *kgwt is the unit of*

8 *Apparent weight of a body inside an artificially revolving satellite*

Chapter 7

Fluid Pressure

Common Misconception	Fact
1. A block of wood shows a less loss in weight as compared to an iron block of same size both completely submerged in water.	1. No, both show same loss in weight as upthrust depends only on volume of objects but not on its density.
2. Air only exerts pressure when it is moving	2. Air exerts pressure in all directions. The greater the altitude the lower the air pressure.
3. Pressure can be applied on a body.	3. Force can be applied on a body while pressure is an out come of application of force and depends on contact area.

SYNOPSIS

INTRODUCTION

A small iron nail sinks in water, whereas a huge ship of heavy mass floats on water. An astronaut wears a special suit while attempting to travel in space. The reason to all these questions lie in studying and understanding fluid pressure and the principles involved therein.

Matter exists in three states, namely solids, liquids and gases. Solids have a definite shape and size, whether regular or irregular. But liquids and gases do not have a definite shape. But have a common property of 'flowing'; and hence are called 'fluids'. The fluid is a substance that can flow. The interaction of fluids with its surroundings is studied under fluid pressure.

THRUST

Thrust is defined as the force acting on a body normal (perpendicular) to its surface. The unit of thrust is same as the unit of force; i.e., dyne in C.G.S system and newton (N) in SI system. Thrust is also expressed in gravitational units called kgwt (kilogram weight) or kgf (kilogram force). 1 kgwt or 1 kgf = 9.8 N

Similarly, 1 gwt or 1 gf = 980 dyne

Pressure

The force applied normal to the surface of a body exerted per unit area is called pressure.

$$\text{Pressure (P)} = \frac{\text{Thrust(F)}}{\text{area(A)}}$$

Pressure is measured in units of dyne per square cm (dyne cm^{-2}) in C.G.S system and newton per square metre (N m^{-2}) in SI system. One newton per square metre is also known as pascal (Pa)

1 Pa = 1 N m^{-2}

1 N m^{-2} = 10 dyne cm^{-2}

The gravitational unit of pressure is kilogram force per square metre (kgf m^{-2}), which is approximately equal to 10 Pa

1 kgf m^{-2} = 10 Pa

For meterological purposes the unit of pressure is taken as bar.

1 bar = 10^5 Pa

FLUID PRESSURE

The pressure exerted by a fluid is known as fluid pressure.

A fluid exerts pressure in all possible directions. The types of pressure a fluid exerts are vertically downwards, vertically upwards and on the sides of a container. The pressure of the fluid acting sideways is known as its 'lateral pressure'.

Types of fluid pressure

A fluid exerts three types of pressure

(a) downward pressure

(b) upward pressure

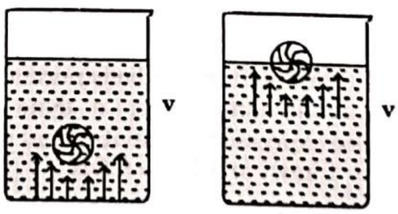
(c) lateral pressure

(a) Fluid Pressure – Downward Pressure

A fluid taken in a vessel exerts pressure on the bottom of the vessel in which it is kept, this pressure is known as downward pressure.

(b) Fluid Pressure – Upward Pressure

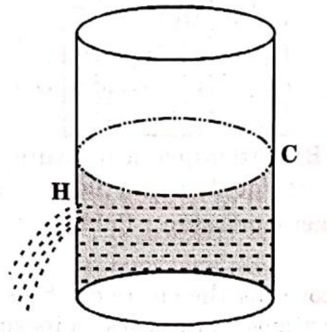
Take a foot ball and immerse it in water in a vessel (V) and leave it. The ball immediately comes up and floats on water. This shows that water (or fluid) exerts pressure in the upward direction.



Upward pressure action on football immersed in water

(c) Fluid Pressure – Lateral Pressure

Take a long cylindrical vessel containing water and make a hole (H) on its wall as shown in the figure. The water comes out with a speed and falls at certain distance. This proves that liquid exerts lateral pressure.

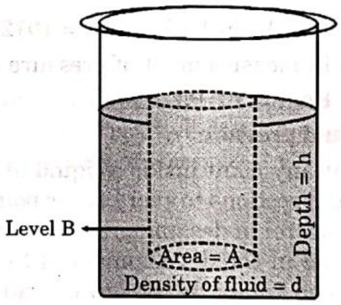


Lateral pressure of water

Mathematical expression for fluid pressure

A beaker is filled with fluid having density 'd'.

Imagine a cylindrical column of liquid with a horizontal area 'A' at a level of 'B' and at a depth 'h' below the surface of the fluid.



Volume of the imaginary column of fluid.

V = Area of cross section × height

V = A × h .... (1)

Thrust on the cylindrical column = Weight of the fluid

= m × g

= (V × d) × g (∴ m = V × d)

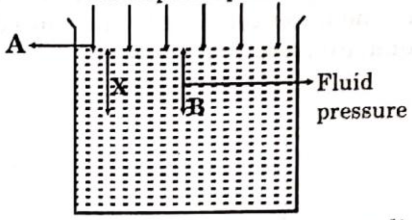
∴ Thrust = (A × h) × d × g [from equation (1)]

But, Pressure = $\frac{\text{Thrust}}{\text{Area}}$

∴ Pressure (P) = $\frac{\text{Ahdg}}{\text{A}}$ = hdg

∴ Pressure due to a fluid column = P = hdg.

Total pressure at a point in a liquid



Total pressure at a point (B) = Atmospheric pressure on liquid surface 'P_A' + in a liquid at a depth 'X' pressure due to liquid column (fluid pressure) above the point 'B'.

Total pressure = Atmospheric pressure + fluid pressure = $P_A + hdg = P_A + xdg$

Atmospheric pressure

The thick blanket of air covering the entire earth's surface is called atmosphere. The pressure exerted by these atmospheric gases on its surroundings and on the surface of the earth is known as atmospheric pressure.

The instrument used for measuring atmospheric pressure is known as barometer.

1 atm is the pressure exerted by a vertical column of mercury of 76 cm (or 760 mm) height.

$\therefore$ 1 atm = 76 cm × 13.6 g cm^{-3} × 9.8 m s^{-2} (using '$h\rho g$' for pressure exerted by a liquid)

= 0.76 m × 13.6 × 10^3 kg m^{-3} × 9.8 m s^{-2} = 101292.8 N m^{-2} or Pa ≈ 1.013 × 10^5 Pa

Other units usually used in measurement of pressure are 'torr' and 'bar'

1 torr = 1 mm of Hg, 1 bar = 10^5 Pa

Pascal law – Transmission of fluid pressure

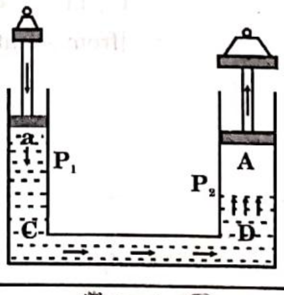
An increase in pressure at any point inside a liquid at rest, is transmitted equally and without any change, in all directions to every other point in the liquid. This is known as Pascal's Law. This law is useful in designing instruments like Bramah press, hydraulic press etc. It is the principle in the development of hydraulic brakes, that are used in automobiles. This law is also known as the law of transmission of fluid pressure.

Hydraulic press or Brahmah press

(a) It is used to compress bales of cotton and straw.

(b) It is used to compress oil seeds for getting oil.

It is consists of a cylinder that contains two pistons, one smaller than the other. The cylinder is filled with a fluid. A force applied to the smaller piston is transferred through the fluid to the larger piston.



Let pressure acting on smaller piston be $P_1 = \frac{W_1}{a}$ and on larger piston be $P_2 = \frac{W_2}{A}$

Since pressure is transmitted equally in all the directions

$$P_1 = P_2 \Rightarrow \frac{W_1}{a} = \frac{W_2}{A} \Rightarrow W_2 = \frac{A}{a}W_1$$

∴ "In a hydraulic press we can multiply a small thrust applied into a big thrust, by making the ratio of area of cross sections very large".

Upthrust or buoyant force

When a body is immersed in a fluid completely or partly, the body experiences an upward force by the fluid. This upward force exerted by the fluid on the immersed body is known as 'upthrust' or 'buoyant force'. The property of a fluid to exert buoyant force on an object immersed in it is known as 'buoyancy'.

Archimedes' Principle

When a body is partially or completely immersed in a fluid at rest, it experience an upthrust which is equal to the weight of the fluid displaced by it.

Due to the upthrust, acting on the body, it apparently loses a part of its weight and the apparent loss of weight is equal to the upthrust.

Thus, for a body either partially or completely immersed in a fluid, upthrust = weight of the fluid displaced = apparent loss of weight of the body.

Relative density

Often density of a substance is compared with the density of water at 4° C. This ratio is called the relative density. Thus "relative density of a substance is defined as ratio of density of the substance to density of water at 4° C".

Mathematically, relative density (R.D) = $\frac{\text{Density of substance}}{\text{Density of water at } 4°\text{C}}$

Relative density of a solid substance = $\frac{\text{Weight of the solid in air}}{\text{Apparent loss of weight of the body in water}}$

Relative density of a solid soluble in water =

$$\frac{\text{Weight of the solid in air}}{(\text{Apparent loss of weight of the body in a liquid})} \times (\text{relative density of the liquid})$$

Relative density of a liquid = $\frac{\text{Apparent loss of weight of a body in liquid}}{\text{Apparent loss of weight of the same body in water}}$

Laws of floatation

1. The weight of a floating body in a fluid is equal to the weight of the fluid displaced by the body.
2. The centre of gravity of the floating body and the centre of buoyancy are in the same vertical line.

Characteristics of a floating body

The following are the characteristics of a floating body in a fluid.

1. Weight of a floating body = upthrust or buoyant force = Apparent loss of weight of the body in the fluid.
2. The net force acting on a body floating in a fluid is zero.
3. The apparent weight and apparent density of a body floating in a fluid is zero.

SOLVED EXAMPLES

Example 1:

A cylinder of certain mass is held in vertical position. If the height of the cylinder is 10 cm and radius of cross–section is 4 cm such that the pressure acting on its bottom surface is 21560 N m^{-2}, then find the mass of the cylinder?

Solution:

Given,

Pressure = 21560 N m^{-2}, radius of cross section = 4 cm

$\therefore$ Area of cross–section = $\pi r^2 = \pi\left(16\times10^{-4}\right)\,m^2$

$$\text{Pressure} = \frac{\text{weight}}{\text{Area of cross section}}$$

$$21560 = \frac{m(9.8)}{\pi\left(16\times10^{-4}\right)}$$

$$m = \frac{21560\times16\times10^{-4}\times\pi}{9.8} = 1106\times10^{-4}\times100 = 11.06\text{ kg}$$

Example 2:

The ratio of height of a mercury column in a barometer at a place to the height of the liquid column at the same place are 1 : 4. Find the density of the liquid.

Solution:

Since Atmospheric pressure is same

Pressure due to mercury column = Pressure due to height of the liquid column

$P_1 = P_2$

$h_1d_1g = h_2d_2g$

$$\frac{h_1}{h_2} = \frac{d_2}{d_1}$$

$h_1 : h_2 = 1 : 4$

$$\therefore \frac{1}{4} = \frac{d_2}{13.6} \Rightarrow d_2 = \frac{13.6}{4} = 3.4\text{ g cm}^{-3}$$

Example 3:

An alloy made of two metals Au and Cu weighs 200 gwt in air and 160 gwt in water. If densities of metals Au and Cu are 20 g cm^{-3} and 4 g cm^{-3}, then find the percentage of mass of each metal present.

Solution:

Mass of alloy in air = 200 gwt, Mass of alloy in water = 160 gwt

Apparent loss in weight of alloy = 200 – 160 = 40 gwt

∴ Weight of water displaced = 120 gwt

Volume of water displaced $= \frac{W}{d} = \frac{40}{1} = 40\ cm^3$

Let mass of metal Au be x g and mass of metal Cu is (200 – x) g, V = 40 cm^3

$\therefore V_{Au} = \frac{x}{20};\ V_{Cu} = \frac{200-x}{4}$

Total volume = $V_{Au} + V_{Cu}$

$40 = \frac{x}{20} + \frac{(200-x)}{4} \Rightarrow 40 = \frac{x+1000-5x}{20} \Rightarrow 40 \times 20 = 1000 - 4x \Rightarrow 4x = 200$

∴ x = 50 g

$m_{Au} = 50$ g; $m_{Cu} = (200 - 50) = 150$ g

Mass percentage of Au $= \frac{50}{200} \times 100 = 25$, Mass percentage of Cu $= \frac{150}{200} \times 100 = 75$

Example 4:

A hollow metal of mass 180.6 g contains cavity of volume 2.5 cm^3. This metal when placed in water displaces 24 cc of water. Find the specific gravity of metal.

Solution:

Let density of metal be ρ

Weight of metal = 180.6 g

∴ Actual volume of metal = (180.6/ρ) cm^3

Volume of cavity = 2.5 cm^3

Volume of ornament = volume of liquid displacement (d)

= 24 cm^3

Volume of cavity = volume of displaced – actual volume

$2.5 = 24 - \frac{180.6}{\rho} \Rightarrow \frac{180.6}{\rho} = 24 - 2.5 \Rightarrow \frac{180.6}{\rho} = 21.5$

$\rho = 8.4\ g\ cm^{-3}$

∴ Specific gravity of metal = 8.4

Example 5:

A block of wood floats in a liquid of density 0.8 g cm^{-3} with one fourth of its volume submerged. In oil the block floats with 60% of its volume submerged. Find the density of (a) wood and (b) oil

Solution:

(a) For floating bodies,

Weight of floating body = upthrust due to liquid

$$V \times \rho_{wood} = V_{immersed}\, \rho_{liquid}$$

$$V\, \rho_{wood} = \frac{1}{4} V(0.8)$$

$\rho_{wood} = 0.2$ g cm^{-3} (or) 200 kg m^{-3}

(b) For floating body in oil,

Weight of floating body = upthrust due to oil

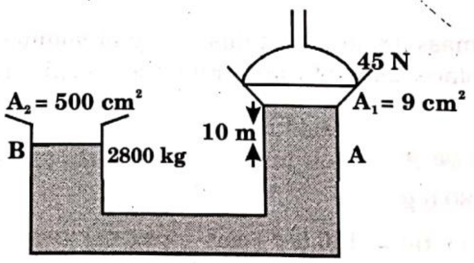
$$V \times \rho_{wood} = V_{immersed}\, \rho_{oil}$$

$$V \times 200 = 0.6\, V\, \rho_{oil}$$

$$\rho_{oil} = \frac{200}{0.6} = \frac{1000}{3} \text{ kg m}^{-3}$$

Example 6:

In the arrangement shown below, a block of 2800 kg is in equilibrium on applying a force of 45 N. Find the density of the liquid?



Solution:

The total pressure acting on side A = $\frac{F}{A_1} + h\rho g = \frac{45}{9\times10^{-4}} + (10\times\rho\times9.8)$ Pa

Pressure acting on side B = $\frac{2800\times9.8}{500\times10^{-4}}$ Pa

According to Pascal's law,

Pressure acting on side A = Pressure at side B

$$5 \times 10^4 + 98\rho = \frac{28}{5} \times 10^4 \times 9.8$$

$$98\rho = 5.6 \times 10^4 \times 9.8 - 5 \times 10^4$$

$$98\rho = (54.88 - 5) \times 10^4$$

$$\rho = 49.88 \times 10^4$$

$$\rho = 0.5089 \times 10^4 \text{ kg m}^{-3} = 5089 \text{ kg m}^{-3}$$

Example 7:

At what depth in an ocean will a bubble of air have one fourth the volume it will have on reaching the surface? (Atmospheric pressure = 76 cm of Hg and density of Hg = 13.6 g cm^{-3})

Solution:

Let volume of bubble on the surface of water be V

Volume of bubble inside = $\frac{V}{4}$

Pressure P at surface = 76 cm of Hg

Let depth of bubble inside = h cm

$\therefore$ Pressure of bubble inside water = $\left(76 + \frac{h}{13.6}\right)$ cm of Hg

Given, P_1 = 76 cm of Hg, $V_1 = V$

$$P_2 = \left(76 + \frac{h}{13.6}\right) \text{cm of Hg}, \; V_2 = \frac{V}{4}$$

According to Boyle's law,

$$P_1V_1 = P_2V_2$$

$$(76)\,V = \left(76 + \frac{h}{13.6}\right)\left(\frac{V}{4}\right)$$

$$76 = \frac{76}{4} + \frac{h}{13.6 \times 4}$$

$$\frac{h}{13.6 \times 4} = 57$$

$$h = 3100.8 \text{ cm}$$

Example 8:

A metal cube is found to float in a liquid of density 2 g cm^{-3} with $\frac{1}{2}$ cm of its vertical side above the liquid. On placing a weight of 144 g over its top, it just submerges in the liquid. Find the specific gravity of the metal cube?

Solution:

Let 'a' be the side of cube.

Case(i) Volume submerged (V) = $a^2\left(a-\frac{1}{2}\right)cm^3$

For floating body,

Upthrust = weight of the cube

$V\rho_l g = V_{cube}\rho_{metal}\, g$

$$a^2\left(a-\frac{1}{2}\right)(2)=a^3\,\rho_{metal}$$

$$\rho_{metal}=\frac{2}{a}\left(a-\frac{1}{2}\right)=\frac{(2a-1)}{a}\text{ g cm}^{-3}$$

Case (ii) When cube is fully submerged,

$$a^3(2)g=a^3\rho_{metal}\,g+144\,g$$

$$2a^3-2a^3+a^2=144$$

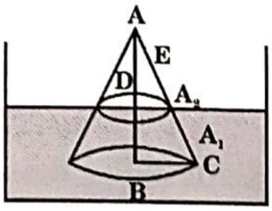
$$a=\sqrt{144}=12\text{ cm}$$

$$\therefore\ \rho_{metal}=\frac{(2a-1)}{a}=\frac{(2)(12)-1}{12}=\frac{24-1}{12}=\frac{23}{12}\text{ g cm}^{-3}$$

Specific gravity of metal cube = $\frac{23}{12}$

Example 9:

A cone of height 16 cm and volume 2948 cm^3 floats in a liquid of density 3.2 g cm^{-3} such that its base lies below the surface of the liquid. If the area of cross section of conical region above the liquid surface is 6 cm^2, find the density of the cone.



Solution:

Volume of cone = $\frac{1}{3}\pi r^2 h = \frac{1}{3}Ah$

$\Rightarrow 2048 = \frac{1}{3}A_1(16)$

$A_1 = 384\ cm^2$

Volume of conical portion above the surface of liquid = $\frac{1}{3}A_2h_2 = \frac{1}{3}\times 6\times h_2$

Consider $\triangle ABC$ and $\triangle ADE$ they are similar,

Hence, $\frac{AB}{AD} = \frac{BC}{DE}$

$\frac{h_1}{h_2} = \frac{r_1}{r_2} (\because AB = h_1, AD = h_2)$

But, $\frac{r_1}{r_2} = \sqrt{\frac{\pi r_1^2}{\pi r_2^2}} = \sqrt{\frac{A_1}{A_2}}$

$\therefore \sqrt{\frac{A_1}{A_2}} = \frac{h_1}{h_2}$

$\sqrt{\frac{384}{6}} = \frac{16}{h_2} \Rightarrow 8 = \frac{16}{h_2} \Rightarrow h_2 = 2\ cm$

$\therefore V_2 = \frac{1}{3}\times A_2h_2$

$= \frac{1}{3}\times 6\times 2 = 4\ cm^3$

$V_{immersed} = V_1 - V_2 = 2048 - 4 = 2044\ cm^3$

According to law of flotation,

Weight of floating body = upthrust

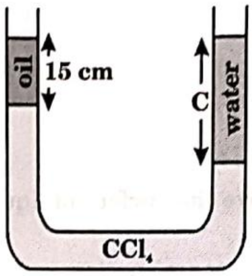
$V_0 d_0 g = V_{imm} d_l g$

$2048\ d_0 = 2044 \times 3.2$

$d_0 = 3.193\ g\ cm^{-3}$

Example 10:

A 'U' tube contains oil, carbon tetrachloride and water as shown in the figure. The density of oil is 0.8 g cm^{-3} and that of carbon tetrachloride is 1.6 g cm^{-3}. If oil and water surfaces are at the same level, find the height of the water column.



Solution:

$$5\,(0.8)\,g + (h - 15)\,1.6\,g = h_1\,g + (h - h_1)\,1.6\,g$$

$$1.6\,h + 12 - 24 = h_1 + 1.6\,h - 1.6\,h_1$$

$$-12 = -0.6\,h_1$$

$$h_1 = \frac{120}{0.6} = 20 \text{ cm}$$

CONCEPT MAP

FLUID PRESSURE

Pressure
Force per unit area of the surface.
$\text{Pressure(P)} = \frac{\text{force}}{\text{area}}$, Units : Pa, dyne cm^{-2}

Thrust: Force acting on a body normal to its surface. SI unit is newton and CGS unit is dyne

Upthrust: The upward force exerted by the fluid on the immersed body is known as 'upthrust'

Archimede's principle: When a body is wholly or partially immersed in a liquid, it experiences an upward thrust equal to the weight of liquid displaced by the body

Laws:
1. Weight of a floating body
   = upthrust or buoyant force
   = Apparent loss of weight of the body in the fluid
2. The centre of gravity and the centre of buoyancy lie in the same vertical line.

Pressure in fluids
- **Fluid:** A substance which has an ability to flow is called fluids.
- **Fluid pressure:** Pressure exerted by fluid is called fluid pressure

Types of fluid pressure
- Down ward pressure
- Upward pressure
- Lateral pressure

Atmospheric pressure
The ocean of air above earth is called atmosphere and pressure exerted by it is atmospheric pressure.

Measurement → Atmospheric pressure is measured by Barometer.
Principle: To use atmospheric pressure to balance vertical column of a liquid to minimum.

Factors affecting:
1. Height
2. Temperature

Uses of atmospheric pressure:
1. Straw pipe
2. Syringe
3. Bicycle pump
4. Ink filled fountain pens
5. Parachute

Transmission of pressure (Pascals law): Pressure is transmitted in equal magnitude in all directions through an incompressible fluid.

Applications of Pascal's law:
1. Hydraulic brakes
2. Hydraulic press

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. The force acting on a body normal to its surface is _________.
2. It is easier to fix a sharp nail than a blunt nail for the same force applied, this is because of difference in their _________.
3. The CGS unit of pressure is _________.
4. The pressure of the fluid acting sideways is known as its _________.
5. As the height of the liquid column increases, the pressure exerted by a liquid at a point _________.
6. Two liquids A and B are taken in two separate identical containers to the same height of the column then the pressure exerted by the two liquids in their respective containers is _________.
7. The SI unit of atmospheric pressure is _________.
8. The pressure exerted by a mixture of atmospheric gases on its surroundings and on the surface of the earth is known as _________.
9. _________ is an instrument used to measure the atmospheric pressure.
10. The commonly used barometric liquid in a barometer is _________.
11. Lifting automobiles in service stations is based on the principle of _________.
12. The property of a fluid to exert buoyant force on an object immersed in it is known as _________.
13. When a body is partially or completely immersed in a fluid at rest, it experiences _________ which is equal to the weight of the fluid displaced by it.
14. The ratio of density of the substance to density of water at 4 °C is known as _________.
15. The mass of a body is 4 kg and its volume is 500 cm^3, then its relative density is _________.

TRUE OR FALSE

16. Pressure at a point in a liquid is inversely proportional to the height of the liquid column.
17. The CGS unit of pressure is 10 times greater than the MKS unit of pressure.
18. A fluid exerts pressure in all possible directions.
19. A barometric liquid having high density produces a shorter column of liquid.
20. As the vertical height from mean sea level increases, the atmospheric pressure decreases.
21. One atmospheric pressure at sea level is equal to 760 cm of Hg.

22. Pascal's law states that an increase in pressure at any point inside a liquid at rest is transmitted equally and without any change, in all directions to every other point in the liquid.
23. Hydraulic press is used in the extraction of oil from oil seeds.
24. The upward force exerted by the floating body on the fluid is known as upthrust.
25. If the weight of the body is equal to the weight of the fluid displaced by it, the net force acting on the body is zero.

MATCH THE FOLLOWING

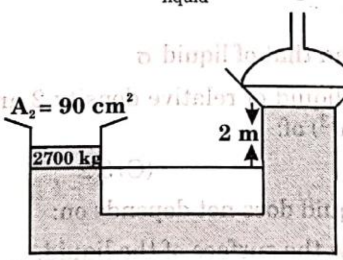
26.

Column A	Column B
A. 1 N m^{-2}	p. 10^{-5} bar
B. 1 gwt	q. 10 dyne cm^{-2}
C. 1 torr	r. 10 Pa
D. 1 pascal	s. 0.1 cm of Hg
E. 1 kgf m^{-2}	t. 980 dyne

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. A nurse applies a force of 3.8 N to the syringe's piston of radius 0.9 cm. Find the increase in pressure of the fluid in the syringe?
   (A) 14.927 kPa (B) 469.13 Pa (C) 46.9 mPa (D) 422 Pa
2. A rectangular tank of 6 m long, 2 m broad and 2 m deep is full of water, the thrust acting on the bottom of the tank is:
   (A) 23.52 × 10^4 N (B) 23.52 N (C) 11.76 × 10^4 N (D) 3.92 × 10^4 N
3. In the arrangement shown below a block of mass 2700 kg is in equilibrium on applying a force F. The value of force F if d_{liquid} = 0.75 g cm^{-3} is



   (A) 147 N (B) 300 N (C) 153 N (D) 918 N
4. The size of an air bubble rising up in water:
   (A) decreases (B) increases
   (C) remains same (D) may increase or decrease
5. A solid cylinder of density 800 kg m^{-3} floats in water. The percentage volume of solid cylinder outside the water is:
   (A) 10 (B) 80 (C) 50 (D) 20

6. As we move upwards, the atmospheric pressure:
(A) increases (B) decreases (C) remains same (D) cannot be said

7. The specific gravity of a solid with respect to a liquid is $\frac{4}{5}$ and specific gravity of a liquid with respect to water is $\frac{10}{9}$, then specific gravity of solid with respect to water is:
(A) $\frac{18}{25}$ (B) $\frac{8}{9}$ (C) 0.56 (D) 1.8

8. A cube of wood floats in water, with 42% of its volume is submerged, then the density of the wood is:
(A) 42 g cm^{-3} (B) 0.42 g cm^{-3} (C) 0.58 kg m^{-3} (D) 600 g cm^{-3}

9. When a body is weighed in a liquid the loss in its weight is equal to:
(A) weight of liquid displaced by the body.
(B) weight of water displaced by the body.
(C) the difference in weights of body in air and liquid.
(D) the upthrust of liquid on the body.

10. If a sample of metal weighs 210 g in air, 180 g in water and 120 g in a liquid:
(A) RD of metal is 3 (B) RD of metal is 7
(C) RD of liquid is 7 (D) RD of liquid is (1/3)

11. When a body of density ρ and volume V is floating in a liquid of density σ:
(A) its true weight is $V\sigma g$
(B) loss in its weight is $V\sigma g$
(C) its apparent weight is zero
(D) its density ρ is greater than that of liquid σ

12. Equal masses of water and a liquid of relative density 2 are mixed together, then the mixture has a density (in g cm^{-3}) of:
(A) 2/3 (B) 4/3 (C) 3/2 (D) 3

13. Pressure at a point inside a liquid does not depends on:
(A) the depth of the point below the surface of the liquid.
(B) the nature of the liquid.
(C) the acceleration due to gravity at that point.
(D) the shape of the containing vessel.

14. Two stretched membranes of area 2 cm^2 and 3 cm^2 are placed in a liquid at the same depth. The ratio of the pressure on them is:
(A) 1 : 1 (B) 2 : 3 (C) 3 : 2 (D) $2^2 : 3^2$

15. A dam for water reservoir is built thicker at the bottom than at the top because:
(A) pressure of water is very large at the bottom due to its large depth.
(B) water is likely to have more density at the bottom due to its large depth.
(C) quantity of water at the bottom is large.
(D) variation in value of g.

16. A tank 5 m high is half filled with water and then is filled to the top with oil of density 0.85 g cm^{-3}. The pressure at the bottom of the tank, due to these liquids, is:
(A) 1.85 g (B) 89.25 g dyne cm^{-2} (C) 462.5 g dyne cm^{-2} (D) 500 g dyne cm^{-2}

17. A piston of cross–sectional area 100 cm^2 is used in a hydraulic press to exert a force of 10^7 dyne on the water. The cross sectional area of the other piston which supports an object having a mass of 2000 kg is:
(A) 100 cm^2 (B) 10^9 cm^2 (C) 2×10^4 cm^2 (D) 2×10^{10} cm^2

18. Two pieces of metal when immersed in aliquid have equal upthrust on them; then:
(A) both pieces must have equal weights (B) both pieces must have equal densities
(C) both pieces must have equal volumes (D) both are floating to the same depth

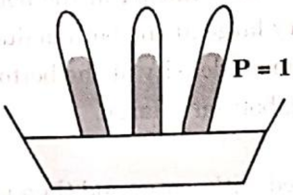
19. An iron ball is weighed in air and then in water by a spring balance:
(A) its weight in air is more than in water
(B) its weight in water is more than in air
(C) its weight is same both in air and water
(D) its weight is zero in water

20. A body weighs 40 g in air. If its volume is 10 cc, in water it will weigh:
(A) 30 g (B) 40 g
(C) 50 g (D) data insufficient

MULTIPLE ANSWER QUESTIONS

1. If a body floats with $\left(\frac{p}{q}\right)^{th}$ of its volume in above the surface of water, then the relative density of the body is:
(A) $\frac{q+p}{q}$ (B) $1-\frac{p}{q}$ (C) $\frac{q-p}{q}$ (D) $\frac{p}{q}$

2. Choose the correct statement among the following:
(A) The upper surface of a stationary liquid is always horizontal.
(B) Pressure of a given liquid is directly proportional to the depth of the liquid.
(C) Pressure at a given depth inside a stationary liquid is different all points in the horizontal plane.
(D) Pressure at a point in a fluid is inversely proportionally to the density of the fluid.

3. 

Based on the figure above, identify the correct statement (s) from the following:

(A) At sealevel, the mercury inside the tube stands upto 76 cm.

(B) The pressure exerted inside a liquid is same at all points along the horizontal plane.

(C) The vertical height of the liquid column is independent of the shape and size of the tube.

(D) The height of barometric liquid column is independent of nature of liquid used.

4. Choose the correct statement among the following:

(A) The upthrust of a floating body is in upwards direction and is equal to the weight of the liquid displaced.

(B) The upthrust is directly proportional to the density of the liquid in which the solid is immersed.

(C) The upthrust is directly proportional to the volume of the fluid displaced by a solid.

(D) The total lateral pressure acting on an immersed object on one side is equal and in same direction to the total lateral pressure acting on the other side.

5. Choose the wrong statement among the following:

(A) The pressure at a point in a fluid is directly proportional to the depth of the point from the surface.

(B) The pressure at a point is independent of acceleration due to gravity.

(C) The pressure at a point is directly proportional to the area of cross section.

(D) The pressure at a point is proportional to the density of the fluid.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of a statement of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** The pressure at the bottom of two tanks of different area of cross sections are equal if they contain same liquid to same height.
   Reason: Pressure of a liquid is hdg and is independent of shape and width of the container.

2. **Assertion:** A balloon filled with hydrogen stops rising after it has attained a certain height in the sky.
   Reason: As height increases, density of air decreases resulting in increase of buoyant force.

3. **Assertion:** A wooden cube when placed in two liquids of different densities the height of the cube above the liquid is different.
   Reason: Volume immersed depends on the density of liquid.

4. **Assertion:** To float, a body must displace liquid whose weight is equal to the actual weight.
   Reason: The body will experience no net downward force in that case.

5. **Assertion:** The force surface of a liquid at rest, under gravity, in a container is always horizontal.
   Reason: The forces acting on a fluid at rest have to be normal to the surface.

6. **Assertion:** Pascal's law is the working principle of a hydraulic lift.
   Reason: Pressure is thrust per unit area.

7. **Assertion:** The blood pressure in humans is greater at the feet than at the brain.
   Reason: Pressure of a liquid is hdg.

8. **Assertion:** Pressure is a vector quantity.
   Reason: Pressure depends on force which is a vector quantity.

9. **Assertion:** A floating body must displace liquid whose weight is equal to the actual weight of the body.
   Reason: A body floats when upward thrust is equal to its actual weight.

10. **Assertion:** A piece of ice floats in water. The level of water remains unchanged when the ice melts completely.
    Reason: According the Archimede's principle, the loss in weight of a body in the liquid is equal to the weight of the liquid displaced by immersed part of the body.

PARAGRAPH QUESTIONS

Passage - I

I. A certain block weighs 22 N in air. It weighs 17 N when immersed in water. When immersed in another liquid it weighs 18 N

(i) Calculate the relative density of the block.

(A) 5 (B) 4.4 (C) 5.5 (D) 3

(ii) Calculate the relative density of the other liquid.

(A) 0.8 (B) 0.67 (C) 0.2 (D) 1

(iii) Find the volume of the block?

(A) 500 cc (B) 400 cc (C) 300 cc (D) 200 cc

SECTION - B

NUMERICAL PROBLEMS

1. A cylinder of mass 5 kg is held in vertical position. If the height of the cylinder is 6 cm and radius of cross section is 4 cm then find the pressure acting on its bottom surface.

2. The height of a mercury column in a barometer at a place is 74 cm. If a liquid of density 5.44 g cm^{-3} is used then find the height of the liquid column.

3. The press plungers of a bramah (hydraulic) press is 40 cm^2 in cross–section and is used to lift a load of mass 800 kg. What minimum force will be required to be applied on the pump plunger if its cross–sectional area is 0.02 m^2 ?

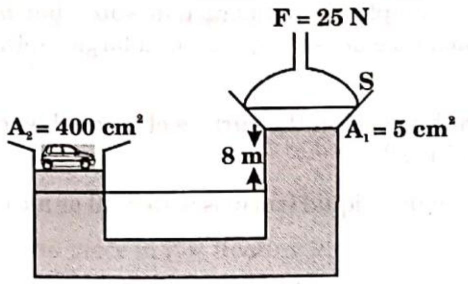
4. A wooden cube is found to float in a liquid of density 1.2 g cm^{-3} with $\frac{1}{4}$ cm of its vertical side above the liquid. On keeping a weight of 67.5 g over its top it just submerges in the liquid. Find the specific gravity of wooden cube.

5. At what depth in an ocean will a bubble of air have one fifth the volume it will have on reaching the surface? (Atmospheric pressure = 76 cm of Hg and density of Hg = 13.6 g cm^{-3})

6. A ping pong ball has a volume V and density $\frac{1}{7}$th that of liquid. What force would be required to hold it completely submerged under liquid?

7. An ornament weighs 60 g in air while it weighs only 56.5 g in water. The ornament is assumed to be mixed with copper while preparing it. Find the amount of copper mixed, the specific gravities of gold and copper are 20 and 10 respectively.

8. In the arrangement shown, a car of certain mass 'm' is in equilibrium by applying a force of 25 N. If the density of liquid taken is 0.9 cm^{-3}, then find the mass of the car.



9. When equal volumes of two liquids are mixed, the specific gravity of the mixture is 4. When equal masses of the same two liquids are mixed the specific gravity of the mixture is 3. Find specific gravities of two liquids.

10. (a) If a room has dimensions 3 m × 4 m × 5 m, what is the mass of air in the room if density of air at NTP is 1.3 kg m^{-3}?

    (b) What force does water exert on the base of a house tank of base area 1.5 m^2 when it is filled with water upto a height of 1 m?
    [Density of water is 10^3 kg m^{-3} and g = 10 m s^{-2}]

11. Find the ratio between the depths where the pressures are 3×10^5 N m^{-2} and 5×10^5 N m^{-2}. ($P_A = 10^5$ N m^{-2})

12. A cylinder is made up of a material of relative density 2, with a height 5 cm and area of cross section 5 cm^2. On immersing in a liquid it looses half of its weight. Find the density of the liquid.

13. For a cylinder of density 1.5 g cm^{-3}, buoyant force is 4 N inside a liquid of density d. Find the buoyant force for the same inside a liquid of density 3d.

14. A cube and a sphere are made such that total surface area of the cube is equal to the surface area of the sphere. Find the ratio between the radius of the sphere to the side of the cube if the ratio of the buoyant forces is X :Y.

15. A cylinder is made up of a material of density 1.5 g cm^{-3} is immersed inside a liquid of density 1 g cm^{-3}. State whether the cylinder moves up or not.

CONCEPTUAL QUESTIONS

1. Why does the barometric height reads less at darjeeling than at puri?
2. A piece of ice is floating in a glass vessel filled with water. How much will the level of water in the vessel change when the ice melts.
3. Why sleepers are used below the rails?
4. Why it may be difficult to stop bleeding from a cut in the body at higher altitudes?
5. The sports boot for soccer and hockey have studs on their soles. Why?
6. When a hollow steel ball and a solid steel ball of the same size are submerged in water, do the two experience the same upthrust ?

7. Imagine a body that is completely submerged in water, but whose depth of submergence can be varied. In which case does it experience a larger upthrust, when it is submerged deep or shallow ?

8. Can a block iron float by itself on the surface of a liquid (such as water, oil or mercury) without an external force ?

9. Is the upthrust exerted by a liquid (such as water, oil or alcohol) related to what kind of liquid it is ?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. If a body weighs 60 g in air and 40 g in water then the specific gravity of the body is:

(A) 3 (B) 6 (C) 1.5 (D) 4.5

2. A piece of copper having an internal cavity weighs 261 g in air and 221 g in water. If density of copper is 9 g cc^{-1} then the volume of cavity is:

(A) 5 cc (B) 10 cc (C) 11 cc (D) 22 cc

3. Pressure at a point inside the liquid does not depend upon:

(A) the depth of the point below the surface of the liquid.

(B) the nature of the liquid.

(C) the acceleration due to gravity at that point.

(D) the shape of the containing liquid.

4. The pressure at any point in the liquid is proportional to:

(A) the density of liquid. (B) the depth of point below the surface.

(C) the acceleration due to gravity. (D) all the above

5. A tank 5 m high is half filled with water and then is filled to the top with oil of density 0.85 g cm^{-3}. The pressure at the bottom of the tank, due to these liquids is:

(A) 1.85 g dyne cm^{-2} (B) 89.25 g dyne cm^{-2} (C) 462.5 g dyne cm^{-2} (D) 500 g dyne cm^{-2}

6. The force exerted by water on the base of a tank, of base area 1.5 m^2 when filled with water upto a height of 1 m is (Density of water is 1000 kg m^{-3} and g= 10 m s^{-2}):

(A) 1500 N (B) 15000 N (C) 3000 N (D) 30000 N

7. A block metal weighs 5 N in air and 2 N when immersed in a liquid. The buoyant force is:

(A) 3 N (B) 5 N (C) 7 N (D) zero

8. The apparent weight of wood floating on water if its weighs 100 g in air is:

(A) 400 g (B) 300 g (C) 100 g (D) zero

9. A body is floating in water, its apparent weight is equal to:

(A) actual weight of the body

(B) unity

(C) weight of the body minus weights in liquid

(D) none

10. An ice cube containing a lead piece in it is floating in a vessel of water. As ice melts, the water level will:

(A) fall (B) rise

(C) remains stationary (D) none

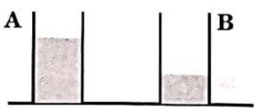
BRAIN NURTURES

1. Two liquids of densities d_1, d_2 are mixed with masses in the ratio 3 : 5, find density of the mixture.

2. Two identical rectangular tanks are connected a small tube at the bottom. The tank A contains a liquid of density 800 kg m^{-3} to height of 30 cm. The tank B contains liquid of density 1600 kg m^{-3}, to a height of 20 cm. The two liquids do not mix.

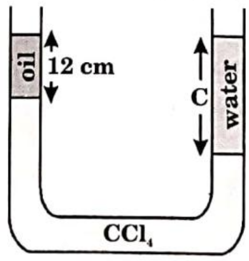
(a) Find the heights of the respective columns, if a small tube connects them at the bottom

(b) Where should a horizontal tube B connected, without causing any flow between the tanks.

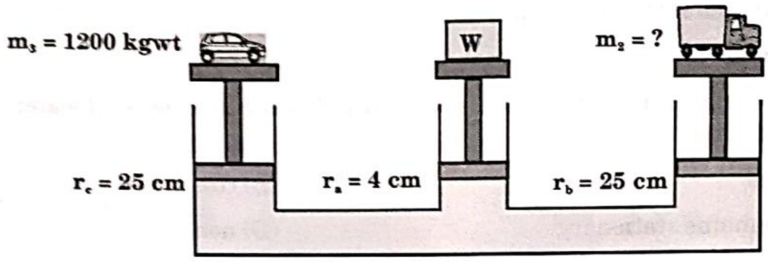


3. A body of mass 716 g and volume 448 cm^3 in put in a liquid of density 1.3 g cm^{-3} will it float or sink?

4. A 'U' tube contains oil, alcohol and water as shown in the figure. The density of oil is 0.6 g cm^{-3} and that of alcohol is 1.6 g cm^{-3}. If oil and water surfaces are at the same level, find the height of the water column.



5. In the figure shown, cylinder 'A' has pump piston, whereas B and C cylinders have lift pistons. If the maximum weight that can be placed on the pump piston is 50 kgwt what is the maximum weight that can be lifted by the piston in the cylinder 'B'. Find the total mechanical advantage. (Take g = 10 m s^{-2}).

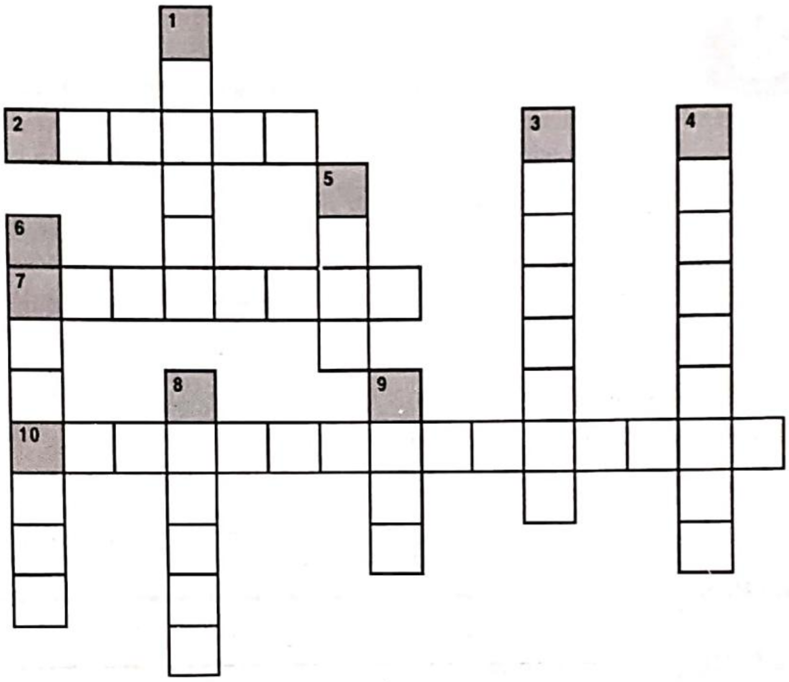


6. Does a long block of wood experience the same upthrust when it lies horizontally than when vertically because its base area is larger in the former orientation than in the latter ?

7. A large homogeneous object sinks in water, it is divided into two parts, one of which is larger than the other. Will both of these parts now sink ?

8. Does a sunk body at the bottom of a vessel experience an upthrust ?

CROSSWORD PUZZLE



ACROSS

2 *Force acting normal to a surface*

7 *Force per unit area*

10 *Ratio of density of substance to density of water at 4^0C*

DOWN

1 *Matter that has ability to flow*

3 *Ratio of CGS unit of density to its SI unit is*

4 *Atmospheric pressure is measured by*

5 *1 mm of Hg*

6 *The upward force exerted by the fluid on the immersed body*

8 *SI unit of pressure*

9 *Net force acting on a floating body*

Chapter 8
Heat

Common misconception	Fact
1. Heat can only be produced by burning things.	1. All forms of energy can be changed to heat energy. For example, rubbing the hands together produces heat energy.
2. 100 cm^3 of water at 100^0 C contain the same amount of heat as 10 cm^3 of water at 100^0 C.	2. Both 100 cm^3 of water and the 10 cm^3 of water are equally hot. But the 100 cm^3 of water contains 10 times more heat than the 10 cm^3 of water.

SYNOPSIS

INTRODUCTION

Heat, a form of energy, which causes a sensation of hotness or coldness. It is also called as a life sustaining energy, that produces a number of effects in material as well as living bodies. The main effects of heat are causing change in temperature, in dimensions, in state and in chemical change.

HEAT AND TEMPERATURE

Heat, when supplied to any body, generally causes change in the temperature of body. Thus, temperature is a physical quantity that measures the degree of hotness or coldness.

THERMAL EQUILIBRIUM

When two bodies at different temperatures are brought in contact with each other, heat energy flows from a body at higher temperature to a body at lower temperature. The net flow of heat energy ceases, when the temperatures of the two bodies become equal. At this stage the two bodies are said to be in thermal equilibrium with each other.

Thus, the two bodies are said to be in the state of thermal equilibrium, when net exchange of heat energy between them is nil. In the state of thermal equilibrium, the two bodies have equal temperatures.

Measurement of temperature

Galileo was the first to construct a thermometer named by him as thermoscope. This works on the principle of property of expansion of gases on heating. Therefore any property of a particular matter (i.e. either a solid or a liquid or a gas) that changes linearly with temperature can be used in the construction of thermometers.

Liquid thermometers

A thermometer that uses the property of expansion of liquids are called liquid thermometers. The liquid used is called thermometric liquid. The choice of this liquid to be used depends on the range of temperatures to be measured.

Generally, mercury and alcohol are used as thermometric liquids. Both these liquids are chosen because of their following properties.

1. Uniform expansion over a wide range of temperature.
2. Good conductor of heat.
3. Low specific heat capacity.
4. Easy availability in pure form.
5. Exerts low vapour pressure.
6. Good sensitivity.

THERMOMETRIC SCALES

There are mainly three kinds of thermometric scales of temperature.

Celsius scale

It is introduced by Celsius. On this scale the melting point of ice and boiling water are calibrated as lower and upper fixed points. On this scale the lower fixed point is equal to 0 °C while upper fixed point is equal to 100 °C.

Fahrenheit scale

This scale was introduced by Fahrenheit. This scale is also defined having its lower and upper fixed points at freezing point of water (32° F) and at the boiling point of water (212° F) with 180 equal divisions.

Kelvin or absolute scale

This scale is known as absolute scale of temperature because when a body loses heat, the average kinetic energy of the molecules decreases and at a certain stage the average kinetic energy of molecules becomes zero. A temperature below this is not possible which is the lowest temperature that is attainable which is equal to absolute zero or zero kelvin.

Mathematical calculation show that, 0 K = – 273 °C

Relation between the three scales

The relation of a given temperature of a substance in different scales is found by equating the ratio of measured length of mercury column to that of total length of mercury column between the respective lower and upper fixed points of each scale as it is always constant for any temperature scale.

$$\therefore \frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273}$$

CLINICAL THERMOMETER

A clinical thermometer is used for measuring the human body temperature. It is calibrated from 95 ^{0}F to 110 ^{0}F. A clinical thermometer is also a mercury thermometer. To measure the body temperature bulb of the clinical thermometer is placed in the mouth of a patient for sometime. The heat given by the body of the patient causes the mercury contained in thermometer to raise. The correct body temperature of a patient can be measured even after removing the thermometer from his mouth by providing a constriction near its bulb. It helps to break the mercury thread such that it does not flow back to the bulb immediately. Clinical thermometer is sterilized using formaldehyde.

THERMAL EXPANSION

It is found that all substances expand on heating and contract on cooling.

Expansion in solids

Most of the solids expand on heating. This thermal expansion takes place in all dimensions i.e. length, breadth and height.

A solid has following types of expansion.

(a) linear expansion (b) superficial (areal) expansion (c) cubical (volume) expansion.

Linear expansion of solids

It is easy to observe the expansion when a long rod is heated. The increase in length depends upon

(i) original length of the rod (ii) increase in temperature

(iii) nature of the substance which the rod is made of.

Let, l_1 = original length of the rod at t_1^{0} C

l_2 = final length of the rod after heating at t_2^{0} C

$l_2 - l_1$ = change in length, $t_2 - t_1$ = change in temperature

Now to quantitatively express the linear expansion in solid a term.

Coefficient of linear expansion (α) is defined as:

$$\alpha = \frac{\text{increase in length}}{\text{original length} \times \text{rise in temperature}} = \frac{l_2 - l_1}{l_1(t_2 - t_1)}$$

The coefficient of linear expansion is defined as the ratio of the increase in length to its original length per 1^0 C rise of temperature.

$$\alpha = \frac{l_2 - l_1}{l_1(t_2 - t_1)} \Rightarrow \Delta l = l_1 \alpha \Delta t \Rightarrow l_2 = l_1(1 + \alpha \Delta t)$$

Unit:

^{0} C^{-1}, $^0F^{-1}$ or K^{-1}

Advantage of thermal expansion

1. A thermostat, used in heaters, geysers, ovens and other such appliances, operates on the principle of expansion.
2. The bimetallic strip which works on the principle of unequal expansion of different metals is used in balance wheels and compensated pendulums.
3. The tremendous force exerted when materials expand or contract due to temperature changes, find practical applications such as riveting, fitting tyres, etc.,

Drawbacks of thermal expansion

1. Structure like railway lines and pipes, when subjected to large temperature changes tend to get deformed.
2. Some materials, such as glassware, break due to strains which results from thermal expansion.
3. Unequal expansion causes cracks in the walls of buildings.

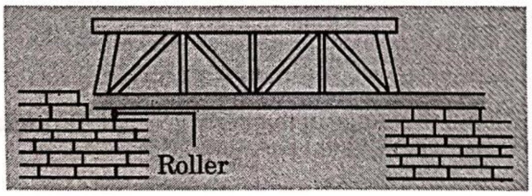
Precautions to guard against expansion (disadvantage of thermal expansion)

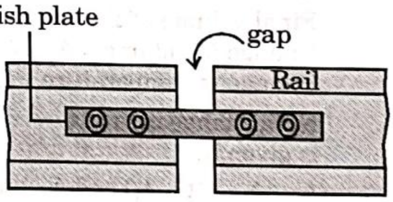
Gaps at joints between rails

Large forces are exerted when a body is heated. The steel rails tend to become deformed (bend or break) due to expansion, spaces or gaps are left behind the rails, or between railway lines at the joints.

Bridges are put on rollers

The ends of steel bridges rest on metal rollers in order to prevent buckling of the structure due to expansion with rise in temperature.





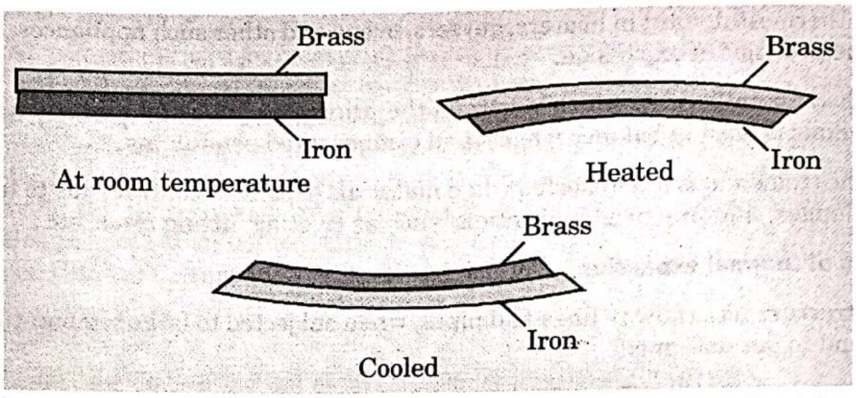
Concrete roads have gaps between sections

Concrete roads laid in small sections. To accommodate expansion, small gaps are left between the sections. These are filled with pitch, or any other suitable material.

Loops at expansion joints of metal pipeline

In industry, the pipes carrying hot water or steam are provided with expansion joints at regular intervals in the form of loops. During changes in temperature, the loops register only a slight change in their curvature and the geometry of the pipe is not disturbed.

Applications of thermal expansion of solids (uses of thermal expansion)



A bimetallic consists of strips of brass and iron of the same length, either welded or riveted together so that on heating they do not slip sideways. On heating, the strip bends in such a way that brass is on the outside and iron is on the inside. This is because brass expands by greater amount when heated through the same rise of temperature. On cooling, the bimetallic strip bends in such a way that brass is on the inner side and iron on the outside. This is because brass contracts by a greater amount and its length decreases by a larger amount than the iron strip for the same range of temperature.

Coefficient of superficial (Aerial) expansion (β)

The coefficient of superficial expansion of a substance is defined as the increase in area per unit original area per degree Celsius rise in temperature is called coefficient of superficial expansion. It is denoted by β.

Mathematical expansion

Initial volume of the solid = A_1 at t_1^0 C
Final volume of the solid = A_2 at t_2^0 C
Change in volume = $A_2 - A_1$
Change in temperature = $t_2 - t_1$

Now, change in area directly proportional to change in temperature and its original area is given by:

$A_2 - A_1 \propto (t_2 - t_1)$ and $A_2 - A_1 \propto A_1$

$\therefore A_2 - A_1 \propto A_1(t_2 - t_1) \Rightarrow A_2 - A_1 = \beta A_1(t_2 - t_1)$

$$\beta = \frac{A_2 - A_1}{A_1(t_2 - t_1)}$$

$$\therefore \text{Coefficient of superficial expansion} = \frac{\text{Increase in area}}{\text{Initial area} \times \text{rise in temp}\left({}^0\text{C}\right)}$$

Units

${}^0C^{-1}$, ${}^oF^{-1}$ or K^{-1}

Coefficient of cubical expansion (γ)

The coefficient of cubical expansion defined as the increase in volume per unit original volume per degree rise in temperature keeping pressure constant.

It is denoted by γ (gamma).

The initial volume of cube = V_1 at t_1^0 C

The final volume of cube = V_2 after heating at t_2^0 C

Change in volume = $V_2 - V_1$

Change in temperature = $t_2 - t_1$

Now, change in volume is directly proportional to change in temperature and to its original volume.

$V_2 - V_1 \propto t_2 - t_1$ (or) Δt

$V_2 - V_1 \propto V_1$

$\therefore V_2 - V_1 \propto V_1(t_2 - t_1)$

$V_2 - V_1 = \gamma V_1(t_2 - t_1)$

$$\gamma = \frac{V_2 - V_1}{V_1(t_2 - t_1)}$$

Units and coefficient of cubical expansion

$^0C^{-1}$, $^oF^{-1}$ or K^{-1}

Relation between coefficient of linear, superficial, cubical expansion

(1) Coefficient of superficial expansion = 2 × coefficient of linear expansion

$$\beta = 2\alpha$$

(2) Coefficient of cubical expansion = 3 × coefficient of linear expansion

$$\gamma = 3\alpha$$

(3) Coefficient of cubical expansion = $\frac{3}{2}$ × coefficient of superficial

$$\gamma = \frac{3}{2}\beta$$

$$\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$$

Thermal expansion of liquids

A liquid has a definite volume but it has no definite shape. Therefore only volume expansion is considered.

Coefficient of apparent expansion

It is defined as the apparent increase in volume of the liquid per unit its original volume for 1 °C rise in temperature.

Therefore, coefficient of apparent expansion of the liquid is given by

$$\gamma_a = \frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Coefficient of real expansion

It is defined as the real increase in volume of the liquid per unit its original volume for 1 °C rise in temperature.

The coefficient of real expansion of the liquid is given by

$$\gamma_r = \frac{\text{real increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

It can be proved that, $\gamma_r = \gamma_a + \gamma_g$

Where γ_g is coefficient of cubical expansion of glass (material of the containing vessel).

Variation of density of solids and liquids with temperature

When a given mass of a solid or a liquid is heated, its volume increases. Accordingly, the density of a solid or a liquid decreases on heating.

$\rho' = \rho(1 - \gamma\Delta t)$ Where, ρ' and ρ are the densities of the solid (or the liquid) at temperatures t_1 and $t_1 + \Delta t$.

Anomalous expansion of water

The expansion of water when it is cooled from 4 °C to 0 °C, is known as anomalous expansion of water. Hence, water has its least volume or maximum density at 4 °C.

Most substances expand when heated, but water is a most unusual liquid in this respect.

TRANSMISSION OF HEAT

The heat energy flows from a body at higher temperature to a body at lower temperature. The flow of heat energy between a hot and a cold body can take place by three different processes namely conduction, convection and radiation.

CONDUCTION

In this process, heat energy flows from one molecule to another molecule of a solid without their actual movement. For example, when one end of an iron is heated, the other end becomes hot.

Good and bad conductors of heat

When heat energy flows easily through a given substance by conduction, it is said to be a good conductor of heat. All metals are good conductors of heat, silver being the best followed by copper and aluminum.

Among non–metals, graphite is a good conductor of heat. When a substance does not allow heat energy to pass through it easily then it is called a bad conductor of heat.

Among solids, glass, wool, rubber, plastic etc., are bad conductors. Except mercury, all other liquids are bad conductors of heat.

All gases are bad conductors. In bad conductors, heat energy does not flow easily because they do not contain a large number of free electrons.

Applications of good conductors

1. Cooking vessels are made of metals so that heat is conducted through them and passes onto the food.
2. Mercury is used as thermometric liquid because it is a good conductor of heat.
3. Automobile radiators use tubes made of copper as it is a good conductor of heat. Being a good conductor, it absorbs the heat from the hot water in the engine and transmit it to the surroundings.

   For the same reason, air conditioners and refrigerators use copper tubes.
4. The heat is passed onto the solder through the tip of soldering iron which is made of copper as copper is a good conductor of heat.

Applications of bad conductors

1. We wear woolen clothes and use blankets in winter as they contain large amount of trapped air which is a bad conductor of heat and therefore does not allow heat energy to flow outward from our body. Thus, our body stops losing heat and we feel warm.
2. The gap between double walls of an ice box is filled with glass, wool, which is a bad conductor of heat. It prevents the heat from flowing in so that ice does not melt.
3. The handles of appliances like pressure cooker, electric iron, electric ovens, etc., are made of bad conductors of heat such as wood or plastic or ebonite so that while handling them, the heat is not conducted from the hot vessels to our hands.
4. The pipes carrying steam from boiler are covered with asbestos or glass wool to prevent loss of heat due to conduction.

CONVECTION

In fluids, the heat energy flows by the process called convection. It is mode of transmission of heat due to movement of molecules from one place to another place.

Applications of convection

In liquids

Ocean water in the tropical regions becomes hot and moves towards cold polar regions, giving rise to hot ocean currents.

The circulation of water in car radiators takes place due to convection current.

In gases

Ventilation is a process by which continuous circulation of air inside the room is maintained due to formation of convection current.

The sea and land breezes are formed due to convectional currents of air.

A wind is formed when convection current is set up in air due to unequal heating of earth.

RADIATION

It is process of heat transfer from hot body to cold body without heating the intervening medium. Radiant energy does not require any material medium for its transmission. Heat radiation is a form of electromagnetic radiation like light rays and travels with a velocity of 3×10^8 m s^{-1}

Application of heat radiation

Shining surfaces are good reflectors of heat and so the roofs of factories are painted white.

SOLVED EXAMPLES

Example 1:

A mercury thermometer is transferred from melting ice to a hot liquid. If the mercury level rises to $\frac{7}{10}$th of the distance between two fixed points. Find the temperature of the liquid in centigrade and fahrenheit scales.

Solution:

Let distance between two fixed points be y.

The rise in mercury level when dipped in hot liquid = $\frac{7}{10}y$

$\therefore$ Temperature of liquid in

Celsius scale = $\frac{\text{rise in level of mercury}}{\text{total distance between two fixed points}} \times 100$

$$= \frac{7y}{10(y)} \times 100 = 70\,°C$$

$\therefore$ Temperature of liquid in Fahrenheit Scale =

$$\left(\frac{\text{rise in level of mercury}}{\text{total distance between two fixed points}} \times 180 + 32\right)$$

$$= \frac{7y}{10(y)} \times 180 + 32 = 126\,°F + 32\,°F = 158\,°F$$

Example 2:

Convert each of the following temperature in °F to the celsius and kelvin scale 68 °F, 5 °F, 176 °F

Solution:

Formula: $\frac{F-32}{180} = \frac{K-273}{100}$

(i) F = 68⁰ F = K = ?

$$\frac{68^0 - 32}{180} = \frac{K-273}{100} \Rightarrow \frac{36}{180} = \frac{K-273}{100} \Rightarrow \frac{4}{20} = \frac{1}{5} = \frac{K-273}{100}$$

$100 = 5(K-273) \Rightarrow 100 = 5K - 1365 \Rightarrow 100 + 1365 = 5K \Rightarrow 1465 = 5\,K \Rightarrow$

$$K = \frac{1465}{5} = 293$$

(ii) F = 5⁰ F K = ?

$$\frac{5-35}{180} = \frac{K-273}{100} \Rightarrow \frac{-27}{180} = \frac{K-273}{100} \Rightarrow \frac{-3}{20} = \frac{K-273}{100} \Rightarrow -300 = 20\,K - 5460$$

$$-300 + 5460 = 20K \Rightarrow 5160 = 20K \Rightarrow \frac{5160}{20} = K \qquad \Rightarrow K = 258\,K$$

(iii) F = 176 K = ?

$$\frac{176-32}{180} = \frac{K-273}{100} \Rightarrow \frac{144}{180} = \frac{K-273}{100} \Rightarrow 144 \times 100 = 180(K-273)$$

$$14400 = 180\,K - 49140 \Rightarrow 50540 = 180\,K \Rightarrow K = \frac{50540}{180} = 353\,K$$

Example 3:

If the temperature of a body in both celsius scale and fahrenheit scale are equal. Calculate its temperatures.

Solution:

Formula: $\frac{C}{100} = \frac{F-32}{180} = C = F = ?$

$$\frac{C}{100} = \frac{C-32}{180} \Rightarrow 180\,C = 100\,C - 3200 \Rightarrow 180\,C - 100\,C = -3200 \Rightarrow 80\,C = -3200$$

$$\Rightarrow C = \frac{-3200}{80} = -40^0 \quad \therefore 40^0\,C = -40^0\,F$$

Example 4:

The body temperature of a patient in 104 °F. Calculate his body temperature in celsius scale.

Solution:

$$\frac{C}{100} = \frac{F-32}{180} \Rightarrow C = \frac{100[F-321]}{180} = \frac{100(101-32)}{180} = \frac{100 \times 69}{180} = 38.3^0\,C$$

Example 5:

Calculate the normal temperature of human body in celsius scale if it is 98.4 ⁰F in Fahrenheit scale.

Solution:

Formula: $\frac{C}{100} = \frac{F-32}{180}$

$F = 98^0\ F\ ;\ C = ?$

$C = \frac{100(98.4-32)}{180} = \frac{100 \times 66.4}{180} \Rightarrow \frac{6640}{180} = 36.88^0 C$

$98.4^0\ F = 36.88^0 C$

Example 6:

If maximum temperature of town is 45° C. Calculate the corresponding temperature in Fahrenheit scale.

Solution:

$\frac{C}{100} = \frac{F-32}{180}$

$C = 45^0\ = F = ?$

$\frac{45}{100} = \frac{F-32}{180} \Rightarrow \frac{9}{100} = \frac{F-32}{180} \Rightarrow 9 \times 180 = 20[F-32] \Rightarrow 1620 = 20\ F - 640$

$\Rightarrow 1620 + 640 = 20\ F \Rightarrow 2260 = 20\ F \Rightarrow F = \frac{2260}{20} = 113^0 F \qquad \therefore 45^0\ C = 113^0\ F$

Example 7:

A brass rod of length 30 cm is joined to a copper rod of length 60 cm. The two rods are of the same thickness and at initial temperature of 20 °C. What is the change in length of the combined rod, when the same is heated to 160 °C. Coefficients of linear expansion of brass and copper are $1.9 \times 10^{-5}\ °C^{-1}$ and $1.7 \times 10^{-5}\ °C^{-1}$ respectively.

Solution:

For brass rod: $\alpha = 1.9 \times 10^{-5}\ °C^{-1}$

$l_1 = 30$ cm; $\Delta T = 160 - 20 = 140\ °C$

The length of the brass rod at 160 °C is given by $l_2 = l_1(1 + \alpha \Delta T)$

$= 30 \times (1 + 1.9 \times 10^{-5} \times 140) = 30.0798$ cm

For copper rod: $\alpha^{|} = 1.7 \times 10^{-5}\ °C^{-1}$

$l_1^{|} = 60$ cm; $\Delta T^{|} = 160 - 20 = 140\ °C$

The length of the steel rod at 160 °C is given by:

$l_2^{|} = l_1^{|}(1 + \alpha^{|} \Delta T) = 60 \times (1 + 1.7 \times 10^{-5} \times 140) = 60.1428$ cm

Therefore, the length of the combined rod at 160 °C,

$l_2 + l_2^{|} = 90.2226$ cm

As the length of the combined rod at 20 °C is 30 + 60 i.e., 90 cm,

The change in length of the combined rod at 160 °C = 90.2226 – 90 = 0.2226 cm

Example 8:

A metal beam is 6000 mm long at a temperature of 22 °C. On a hot day, the temperature rises to 42 °C. What is the change in the length of the beam due to thermal expansion? (Take $\alpha_{metal} = 1.6\times10^{-5}$ °C^{-1})

Solution:

Here, l_1 = 6 m; ΔT = 42 – 22 = 20 °C;

$\alpha = 1.6\times10^{-5}$ °C^{-1}

If l_2 is length of the beam at 40 °C, then

$l_2 = l_1(1+\alpha\Delta T) = 6 \times (1 + 1.6 \times 10^{-5} \times 20)$

$= 6 \times (1 + 3.2 \times 10^{-4}) = 6.00182$ m

Therefore, increase in length of the beam,

$\Delta l = l_2 - l_1 = 6.00182 - 6 = 0.00182$ m (or) 1.82 mm

Example 9:

The base of an iron saucepan has a diameter of 20 cm at 15 °C. What will be the increase in the area of the base of the scaucepan when it is filled with boiling water? Given coefficient of linear expansion of iron = 12×10^{-6} per °C.

Solution:

Diameter of the base of the iron saucepan = 20 cm

Radius of the base = 20/2 = 10 cm.

Initial area of the base = $A_1 = \pi r^2 = \pi \times 10^2$ sq cm

Increase in area of the base = $A_2 - A_1$ = ?

Initial temperature of the iron saucepan = t_1 = 15 °C

Final temperature of the iron saucepan = t_2 = 100 °C

Change in temperature = $t_2 - t_1$ = 100 – 15 = 85 °C

Coefficient of linear expansion of iron α = 12×10^{-6} per °C

Coefficient of area expansion of iron = $\beta = 2\alpha = 2 \times 10^{-6}$ per °C = 24×10^{-6} per °C

We know, $A_2 - A_1 = A_1 \times \beta \times (t_2 - t_1)$

$\Rightarrow A_2 - A_1 = \pi \times 10^2 \times 24 \times 10^{-6} \times 85 = 0.6404$ cm^2

Therefore, the required increase in area is 0.6404 cm^2

Example 10:

The cubical expansivities of benzene and wood are 1.2×10^{-3} °C^{-1} and 1.5×10^{-4} °C^{-1}, their densities at 0 °C are 9×10^2 kg m^{-3} and 8.8×10^2 kg m^{-3} respectively. At what temperature will wood just sink in benzene?

Solution:

Wood will just sink in benzene, when at a temperature, say θ °C, its density becomes equal to that of benzene.

Now, density of benzene at θ °C, $\rho = \rho_0(1-\gamma\theta)$

Here, $\rho_0 = 9\times10^2$ kg m^{-3}, $\gamma = 1.2\times10^{-3}$ °C^{-1}

$\therefore \rho = 9\times10^2(1-1.2\times10^{-3}\theta)$

Also, density of wood at θ °C, $\rho' = \rho_0'(1-\gamma'\theta)$

Here, $\rho_0' = 8.8\times10^2$ kg m^{-3} ; $\gamma' = 1.5\times10^{-4}$ °C^{-1}

$\therefore \rho' = 8.8\times10^2(1-1.5\times10^{-4}\theta)$

At θ °C, $\rho = \rho'$

$\therefore 9\times10^2(1-1.2\times10^{-3}\theta) = 8.8\times10^2(1-1.5\times10^{-4}\theta)$

$9 - 9\times1.2\times10^{-3}\,\theta = 8.8 - 8.8\times1.5\times10^{-4}\,\theta$

$(9\times1.2\times10^{-3} - 8.8\times1.5\times10^{-4})\,\theta = 9 - 8.8$

$$\theta = \frac{0.2}{9\times1.2\times10^{-3} - 8.8\times1.5\times10^{-4}} = \frac{0.2}{0.0108 - 0.0132} = -\frac{0.2}{0.0024} = 83.3\ °C$$

Example 11:

Why is pyrex or borosil is used to make laboratory equipment?

Solution:

It is used to make special glasses as they have low coefficient of linear expansion. As a result, these are less likely to break under such conditions. However, it is not break–proof when the temperature changes very rapidly.

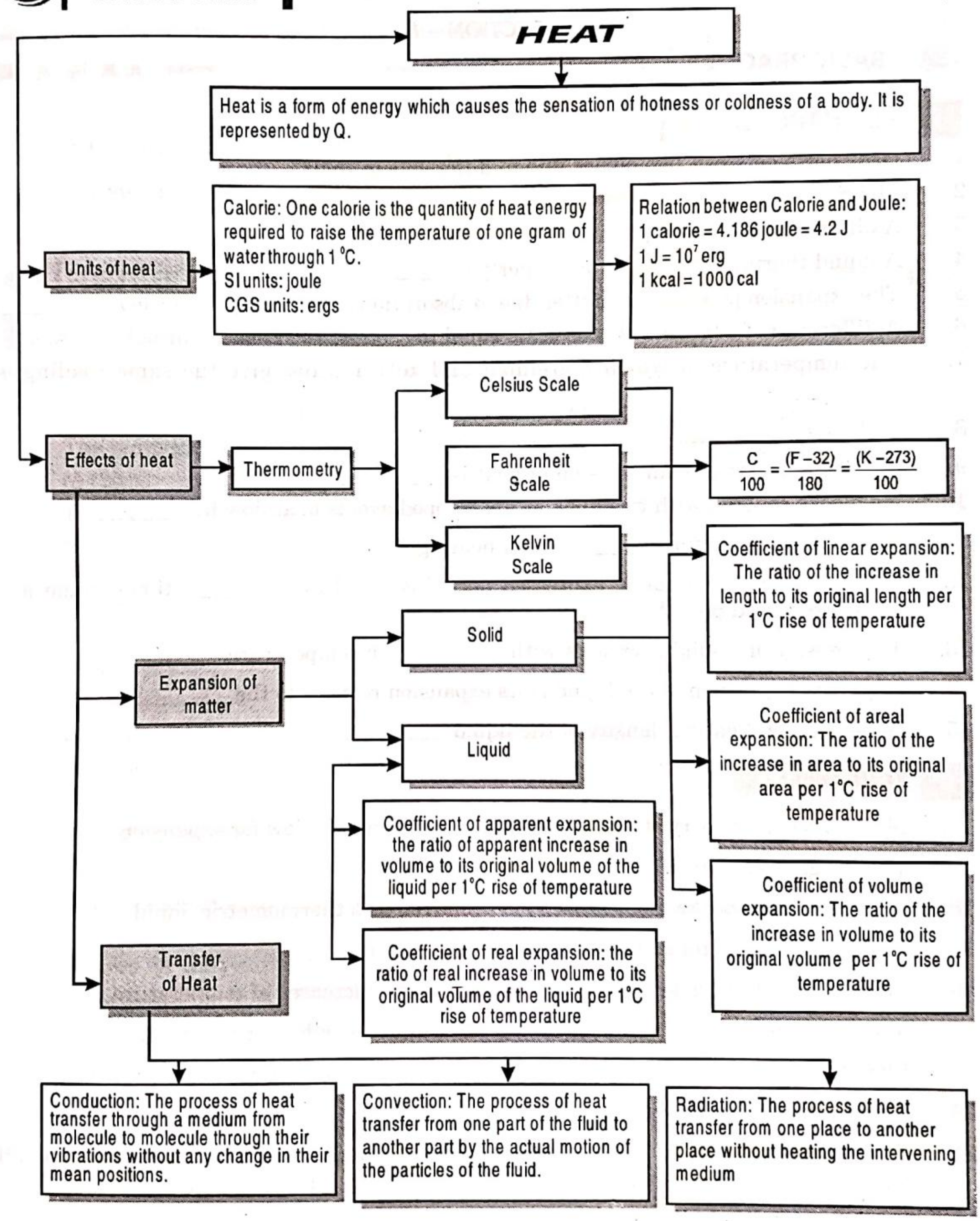
Example 12:

Why is it desirable to have cooking vessels blackened at their bottom and with shining sides?

Solution:

The cooking utensils are blackened at the bottom so that heat energy is absorbed rapidly and have shining sides so that the absorbed heat is not radiated.

CONCEPT MAP


HEAT
Heat is a form of energy which causes the sensation of hotness or coldness of a body. It is represented by Q.
Units of heat
Calorie: One calorie is the quantity of heat energy required to raise the temperature of one gram of water through 1 °C.
SI units: joule
CGS units: ergs
Relation between Calorie and Joule:
1 calorie = 4.186 joule = 4.2 J
1 J = 10^7 erg
1 kcal = 1000 cal
Effects of heat
Thermometry
Celsius Scale
Fahrenheit Scale
Kelvin Scale
$\frac{C}{100} = \frac{(F-32)}{180} = \frac{(K-273)}{100}$
Expansion of matter
Solid
Liquid
Coefficient of linear expansion: The ratio of the increase in length to its original length per 1°C rise of temperature
Coefficient of areal expansion: The ratio of the increase in area to its original area per 1°C rise of temperature
Coefficient of volume expansion: The ratio of the increase in volume to its original volume per 1°C rise of temperature
Coefficient of apparent expansion: the ratio of apparent increase in volume to its original volume of the liquid per 1°C rise of temperature
Coefficient of real expansion: the ratio of real increase in volume to its original volume of the liquid per 1°C rise of temperature
Transfer of Heat
Conduction: The process of heat transfer through a medium from molecule to molecule through their vibrations without any change in their mean positions.
Convection: The process of heat transfer from one part of the fluid to another part by the actual motion of the particles of the fluid.
Radiation: The process of heat transfer from one place to another place without heating the intervening medium

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. Heat flows between two bodies due to difference in their ________.
2. The SI unit of temperature is ________.
3. A difference of 1 °C is ________ as the difference of 1 K.
4. A liquid thermometer uses the property of ________ of liquids.
5. The expansion produced in matter due to absorption of heat energy is called ________.
6. A difference of 1 °C on a celsius scale equal to ________ °F on a Fahrenheit scale.
7. The temperature at which fahrenheit and kelvin scales give the same reading is ________.
8. $\alpha : \beta : \gamma =$ ________.
9. The faster mode of transmission of heat is ________.
10. Ice blocks covered with rice husk as air trapped avoids heat flow by ________.
11. A hole in a metal plate ________ on heating.
12. The numerical value of α expressed per °C is equal to ________ times numeric value expressed per °F.
13. The density of a solid decreases with ________ in temperature.
14. Apparent expansion of the liquid is its expansion relative to the ________.
15. Generally, on heating density of the liquid ________.

TRUE OR FALSE

16. Metal pipes that carry steam are provided with bend to allow for expansion.
17. 10 °C is greater than 10 °F.
18. A liquid of low specific heat capacity is preferred as a thermometric liquid.
19. Radiation of heat from a body can never be stopped.
20. The coefficient of linear expansion decreases with increases of temperature.
21. Most of the heat transfer that is taking place on the earth is by radiation.
22. Ebonite handles would not permit heat to be conducted from hot utensil to hand.
23. Water contracts on freezing.
24. To keep the volume of empty space in a vessel containing a liquid constant at all temperatures, the expansions of vessel and liquid should be the same.
25. Kelvin is the standard temperature scale.

MATCH THE FOLLOWING

26.

Column A	Column B
A. Conduction	p. Areal expansion
B. Convection	q. Cooking vessels
C. Radiation	r. Linear expansion
D. Expansion in length	s. Land and sea breezes
E. Expansion in area	t. No intervening medium

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. 120 °C equivalent to:
(A) 390 K (B) 248 °F (C) 153 K (D) 184 °F

2. The temperature of a room is 77° F. What would it be on the Celsius scale?
(A) 25 °C (B) 45 °C (C) 60 °C (D) 350 °C

3. The temperature of liquid hydrogen is 20 K. What is this temperature on the Fahrenheit scale?
(A) 495.4 °F (B) –423.4 °F (C) –108.56 °F (D) –487.4 °F

4. One heating metal plate having two holes at certain separation the distance between the centres of the holes:
(A) increases (B) decreases
(C) remains same (D) cannot be said

5. Iron or steel is used in reinforcement in concrete because:
(A) concrete has high coefficient of expansion than iron or steel
(B) concrete has low coefficient of expansion than iron or steel.
(C) both have nearly equal coefficient of expansions.
(D) iron or steel is a good conductor of heat.

6. Crucibles are made of mixture of quartz and silica since the linear coefficient of expansion is:
(A) zero for that mixture. (B) infinity for that mixture.
(C) negative for that mixture. (D) positive for that mixture.

7. It is hotter at the same distance over the top of a fire than it is on the side of it mainly because:
(A) heat is radiated upwards
(B) air conducts heat upwards
(C) convection takes more heat upwards
(D) conduction, convection and radiation all contribute significantly in transferring heat upwards.

8. Ventilators are provided at the top of room:
(A) to bring oxygen for breathing.
(B) so that sunlight may enter the room.
(C) to maintain convectional currents to keep the air fresh in the room.
(D) to provide an outlet for carbon dioxide.

9. Which of the following statements are not true?
(A) Size of degree is smallest on celsius scale.
(B) Size of degree is smallest on fahrenheit scale.
(C) Size of degree is equal on celsius and kelvin scale.
(D) None of the above

10. Two thermometers are used to record the temperature of a room. If the bulb of one is wrapped in wet hanky:
(A) the temperature recorded by both will be same.
(B) the temperature recorded by the wet–bulb thermometer will be greater than that recorded by the other.
(C) the temperature recorded by dry–bulb thermometer will be greater than that recorded by the other
(D) none of the above

11. When a metal rod is heated it expands because:
(A) the size of its atoms increases.
(B) the distance among its atoms increases.
(C) atmospheric air rushes into it.
(D) the actual cause is still unknown.

12. When a strip made of iron (α_1) and copper $\alpha_2 (> \alpha_1)$ is heated:
(A) its length does not change.
(B) it gets twisted.
(C) it bends with iron on concave side.
(D) it bends with iron on convex side.

13. If the length of a cylinder on heating increases by 2%, the area of its base will increase by:
(A) 0.5% (B) 2% (C) 1% (D) 4%

14. There are two spheres of same material and radius. One is solid and the other is hollow. If they are heated to the same temperature the expansion of:
(A) solid sphere is more.
(B) hollow sphere is more.
(C) solid and hollow spheres are equal.
(D) solid is outwards while that of hollow inwards.

15. Water is filled in a glass beaker at room temperature and the beaker is heated. The level of water in the beaker:
(A) rises (B) does not change at all
(C) first rises and then falls (D) first falls and then rises

MULTIPLE ANSWER QUESTIONS

1. Two rods of same material and same mass have different lengths. When they are heated:
   (A) through same rise in temperature, longer rod expands more.
   (B) through same rise in temperature, shorter rod expands more.
   (C) if same quantity of heat is supplied, longer rod expands more.
   (D) if same quantity of heat is supplied, shorter rod expands more.
2. Identify the correct statements from the following:
   (A) When hot water is poured in a thick walled glass tumbler suddenly it develops cracks because of unequal expansions of the surfaces.
   (B) For the use of hot liquids thin walled glass containers are preferred.
   (C) A steel disc is fixed tightly in a hole in a brass plate. The disc can be separated by cooling.
   (D) Bimetallic strip works on the principle of unequal expansions.
3. Identify the correct statements from the following:
   (A) The apparent expansion of liquid depends on the expansion of material of the con tainer.
   (B) The real expansion of the liquid depends on the density of the liquid.
   (C) The expansion of liquid with respect to the container is called the apparent expansior.
   (D) The expansion of water is uniform.
4. Choose the correct statement from the following:
   (A) 50 °C is equal to 122 °F.
   (B) A clinical thermometer cannot be sterilized using boiling water.
   (C) Unequal expansion causes cracks in the walls of the buildings.
   (D) Graphite is a bad conductor of heat.
5. Choose the correct statement from the following:
   (A) Woollen clothes keep the body warm in winter as air is the bad conductor of heat.
   (B) Shining surfaces are good reflectors of heat.
   (C) Heat radiations travel with speed of light.
   (D) The SI unit of coefficient of cubical expansion is K^{-1}

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statements of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** When a hot substance is mixed with a cold substance, then the temperature of hot substance gradually decreases.

   Reason: Heat always flows from a body of high temperature to the body of low temperature.

2. **Assertion:** The melting point of ice and boiling point of water are taken as the LFP and UFP of all the thermometer scales.

   Reason: Thermometer works on the principle of thermal expansion of liquids.

3. **Assertion:** A brass disc is just fitted in a hole in a steel plate. The system must be cooled to loosen the disc from the hole.

   Reason: The coefficient of linear expansion for brass is greater than the coefficient of linear expansion for steel.

4. **Assertion:** The temperature at which centrigrade and fahrenheit thermometers read the same is $-40°$.

   Reason: There is no relation between fahrenheit and centigrade temperature.

5. **Assertion:** Two thin blankets put together are warmer than a single blanket of double the thickness.

   Reason: Thickness increases because of air layer enclosed between the two blankets.

PARAGRAPH QUESTIONS

Passage - I

I. Two copper rods P, Q of thickness in the ratio 2 : 5 are taken.

(i) If both the rods P, Q of lengths 10 cm are heated to same temperature rise, then the ratio of the linear expansions of P to that of rod Q is:

(A) 2 : 5 (B) 5 : 2 (C) 1 : 1 (D) 4 : 1

(ii) If rods P, Q of same length are supplied with 200 J of heat energy then greater expansion is possible in:

(A) rod P (B) rod Q

(C) both have same expansions (D) none of the rod expands

SECTION – B

NUMERICAL PROBLEMS

1. What temperature reading on the fahrenheit scale is five times the reading on the celsius scale?

2. The fundamental intervals of two thermometers X and Y are 70° and 140° respectively. Their ice points are 10° and 0° respectively. If Y reads 90°. What would X read?

3. Calculate the temperature on celsius scale whose value is half the absolute reading?

4. The temperature of a body changes from 15 °C to 75 °C. What is the corresponding change in (a) Fahrenheit scale (b) kelvin scale?

5. A faulty thermometer has its fixed points marked as 10° and 90°. The temperature of a body as measured by the faulty thermometer is 61°. Find the correct temperature of the body on celsius scale.

6. A brass rod of length 40 cm is joined to a copper rod of length 50 cm. The two rods are of the same thickness and at initial temperature of 40 °C. What is the change in length of the combined rod, when the same is heated to 280 °C. Coefficients of linear expansion of brass and copper are 1.9×10^{-5} °C^{-1} and 1.7×10^{-5} °C^{-1} respectively.

7. A steel beam is 5 m long at a temperature of 20 °C. On a hot day, the temperature rises to 40 °C. What is the change in the length of the beam due to thermal expansion?

8. What should be lengths of steel and copper rod, so that the length of steel rod is 5 cm longer than the copper rod at all temperatures? (α for copper = 1.7×10^{-5} °C^{-1} and α for steel = 1.1×10^{-5} °C^{-1}).

9. An iron tyre is to be filled onto a wooden wheel 100 cm in diameter. The diameter of the tyre is 5 mm smaller than that of the wheel. How much should the temperature of the tyre be increased for this purpose? (α for iron = 12×10^{-6} °C^{-1}).

10. A metal rod has the length of 50 cm at 20 °C. When it is heated to 95 °C, its length becomes 50.06 cm. Find the length of the rod at 0 °C.

11. A brass rod and a steel rod are both measured at 0 °C and their lengths found to be 120 cm and 120.2 cm respectively. At what temperature are their lengths equal?

    ($\alpha_{brass} = 12 \times 10^{-6}$ °C^{-1}, $\alpha_{steel} = 17 \times 10^{-6}$ °C^{-1})

12. A metal is heated from 0 °C to 500 °C and its density reduces to 1/1.027 of its original density. Determine the coefficient of linear expansion for this metal, considering it constant for the given range of temperature.

13. A circular sheet of copper of radius 35 cm is at 20° C. On heating, its area increases by 14.5 cm^2. If coefficient of linear expansion of copper is 1.7×10^{-5} °C^{-1}, find the temperature to which the sheet was heated.

14. The density of mercury is 13.6 g cm^{-3} at 0 °C and its coefficient of cubical expansion is 1.82×10^{-4} °C^{-1}. Calculate the density of mercury at 50 °C.

15. The coefficient of volume expansion of mercury is 5.4×10^{-4} °C. What is the fractional change in its density for a 80 °C rise in temperature?

CONCEPTUAL QUESTIONS

1. A metal ball is heated through a certain temperature. Out of mass, radius, surface area and volume, which will undergo largest percentage increase and which one the least?
2. Why is it wrong in taking the melting point of ice and the boiling point of water as standard fixed points (as was originally done in the celsius scale)?
3. Why are cold storages constructed with double walls?
4. Why are glass tumblers made of thin glass?
5. Why are teapots kept with shining surfaces?
6. What is the effect of rise in temperature on the density of mercury in a barometer and hence its reading?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. The temperature at which the reading of Fahrenheit thermometer will be double that of a centigrade thermometer is:

   (A) 160 °C (B) 180 °C (C) 32 °C (D) 100 °C

2. When a metal sphere is heated, maximum percentage increase occurs in its:

   (A) density (B) surface area (C) radius (D) volume

3. Two copper rods of same length, but of different diameters of cross section are given same amount of heat. Assuming no heat losses:

   (A) thick rod expands more.

   (B) thin rod expands more.

   (C) both rods expand equally.

   (D) for large quantities of heat thick rod expands more and thin rod expands more for small quantities of heat.

4. The brass disc fits tightly in a hole in a steel plate to loose the disc from hole:

   (A) we should cool the system (B) we should heat the system

   (C) we should apply external force (D) it cannot be separated

5. Which of the following statement is wrong?

   (A) Bimetal is used in metal thermometer.

   (B) Bimetals are used to generate electricity.

   (C) Bimetals relays are used to open or close electric circuits.

   (D) Bimetal is used in thermostats for regulating heating or cooling of rooms.

6. If a bimetallic strip is heated it will:

(A) bend towards the metal with lower thermal expansion coefficient.

(B) bend towards the metal with higher thermal expansion coefficient.

(C) twist itself into a helix.

(D) have no bending.

7. An aluminium rod (length l_1 and coefficient of linear expansion α_A) and a steel rod (length l_2 and coefficient of linear expansion α_B) are joined together. If the length of each rod increased by the same amount when their temperatures are raised by t°C, then $l_1 / l_2 + l_2$ is:

(A) α_A / α_B (B) α_B / α_A (C) $\alpha_B / \alpha_A + \alpha_B$ (D) $\alpha_A / \alpha_A + \alpha_B$

8. When a liquid is heated its density:

(A) decreases

(B) increases

(C) does not change

(D) decrease or increases depending upon the pressure to which it is subjected.

9. The surface water in a lake is going to freeze. Now the temperature of water at the bottom is:

(A) 274 K (B) 227 K (C) 100 K (D) 0 K

10. On heating a liquid of coefficient of cubical expansion 'α' in a container having coefficient of linear expansion on '$\alpha/3$', the level of liquid in the container will:

(A) rise (B) fall

(C) will remain almost stationary (D) it is difficult to say

11. By increasing the temperature of a liquid is:

(A) volume and density decrease

(B) volume and density increase

(C) volume increases and density decreases

(D) volume decreases and density increases

12. Sun's heat reaches the earth by the process of:

(A) conduction (B) convection (C) radiation (D) scattering

BRAIN NURTURES

1. The boiling point of turpentine on Fahrenheit scale is double its value on Celsius scale. If the boiling point of tar on Celsius scale is 140° more than that of turpentine on same scale, find the boiling point of tar on kelvin scale.

2. An accurate celsius scale and faulty Fahrenheit thermometer read 65 °C and 154 °F respectively when placed in a hot liquid. Find the error in the latter.

3. A mercury thermometer is transferred from melting ice to a hot liquid. If the mercury rise by $\frac{4}{5}$th of the distance between the two fixed points, then the temperature of the liquid in centrigrade and Fahrenheit scales.

4. Iron rims are heated red hot before planting on cart wheels. Why?

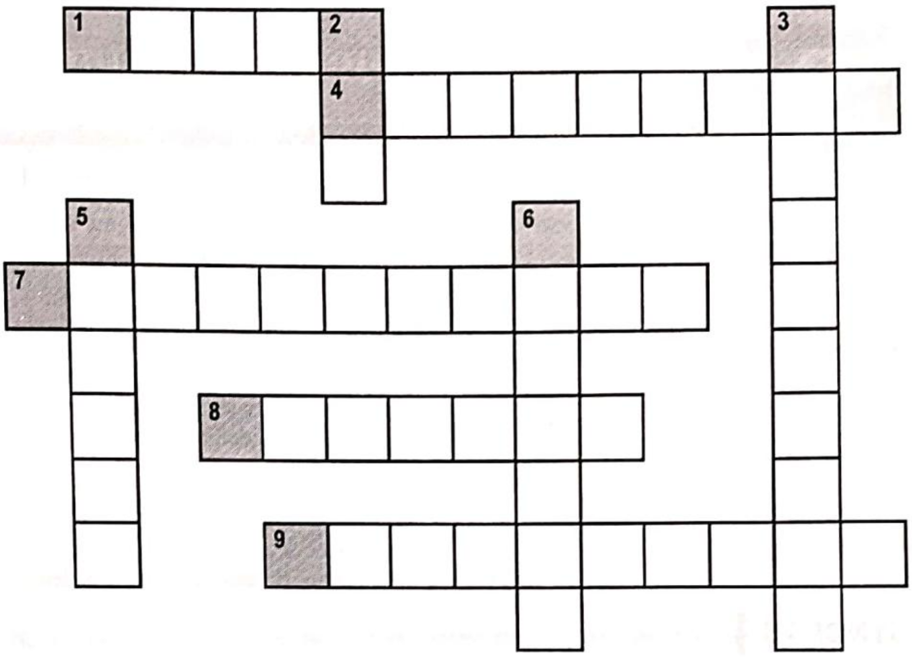
5. A circular piece is cut from a flat metal sheet. The sheet is, then, placed in a furnace. Will the size of hole become larger or smaller? Explain.

6. An ungraduated thermometer of uniform bore is attached to a centimeter scale and is found to read 10 cm in melting ice, 30 cm in boiling water and 16 cm in a liquid. Find temperature of the liquid.

7. Explain how the different forms of heat losses are minimized in a thermos flask.

8. A bimetallic strip is formed out of two identical strips, one of copper and the other of brass. The coefficients of linear expansion of the two metals are α_C and α_B ($\alpha_B > \alpha_C$). On heating the bimetallic strip through temperature ΔT, the strip bends into an arc of a circle. Find the radius of curvature of the strip.

CROSSWORD PUZZLE



ACROSS

1 SI unit of heat

4 Process of heat transfer from one place to another place without heating the intervening medium

7 Degree of hotness or coldness on heating

8 On heating matter

9 Process of heat transfer from one part of the fluid to another part by the actual motion of the particles of the fluid

DOWN

2 10^{-1} joule equals to one

3 Process of heat transfer through a medium from molecule to molecule through their vibrations

5 Absolute scale of temperature

6 Fundamental interval of celsius scale

Chapter 9

Wave Motion and Sound

Common Misconception	Fact
1. Sound is produced when one object collides with another.	1. Sound is produced by a vibrating body.
2. Sound travels in straight line.	2. Sound is a longitudinal wave motion and travels in all directions.
3. During propagation of sound wave the material of the medium also gets transferred.	3. A wave does not transfer material from one place to another. It only transfers energy.

SYNOPSIS

INTRODUCTION

In our daily life, we observe certain motions that repeat in a fixed interval of time. These motions are termed as periodic motion. A few of them are a vibrating spring, motion of a diving board, motion of hands of a clock, motion of earth around the sun etc., In these periodic motions some bodies move to and fro or back and forth which are called oscillatory motion. The oscillations produced by the vibrations or oscillations of a wave results in formation of waves. A wave is one way of transferring the energy without any matter.

WAVE

A wave is a periodic disturbance produced in a material medium due to the vibrating motion of the particles of the medium.

Examples

1. Drop a pebble in a trough containing water you can observe number of ripples (or) waves on the surface of water travelling in forward direction.

2. Strike a tuning fork against a solid surface and then bring the vibrating fork near the surface of water contained in another trough.

Characteristics of waves

1. Wave motion is only a disturbance which is produced in the medium by the repeated periodic motion of the particles of the medium.
2. When wave propagates, it is only the disturbance which travels forward. The medium itself does not move as a whole, along the wave. The particles simply vibrate about their mean position.
3. Wave motion is possible only in that medium which possesses the properties of elasticity and inertia.
4. When a wave is transmitted in a medium, energy is transferred from one particle to another without actual physical transfer of matter.
5. The velocity of the wave is constant in a homogeneous medium (i.e., a medium having constant density throughout). But , the velocity of particle keeps on changing.

TYPES OF WAVES

Waves are classified into two groups on the basis of requirement of medium for the propagation of waves. They are mechanical waves or elastic waves, electromagnetic waves.

Mechanical or elastic waves are classified into two types based on their direction of propagation as transverse waves and longitudinal waves.

TRANSVERSE WAVE

If the particles of the medium vibrate perpendicular to the direction of the propagation of the wave then the wave is called transverse wave.

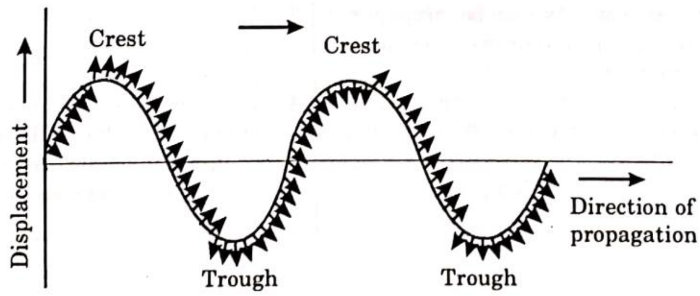
Example

1. Waves on the surface of water.
2. Waves on a long stretched rubber tube.

Crests and troughs of a transverse wave

- ***Crest***

The part of a transverse wave which is above the line of zero disturbance of the medium.



Trough

The part of a transverse wave which is below the line of zero disturbance of the medium.

Longitudinal waves

A wave in which the particle of the medium vibrate up and parallel to the direction of wave is longitudinal wave.

Examples

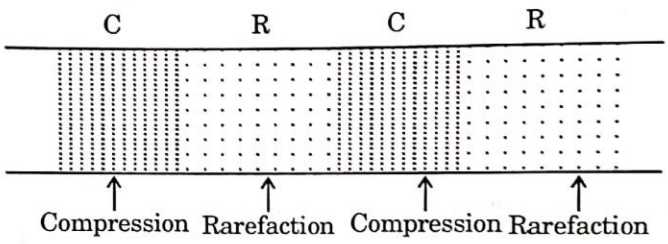
1. Sound waves in air.
2. Waves in spiral spring.

Longitudinal waves can travel through all media i.e. solids, liquids and gases.

Compression and Rarefactions of a longitudinal wave

Compression

The part of a longitudinal wave having particles of the medium higher than their normal density is called a compression.



Rarefaction

The part of a longitudinal wave in which the density of the particles of the medium is lesser than the normal density is called a rarefaction.

Difference between transverse waves and longitudinal waves

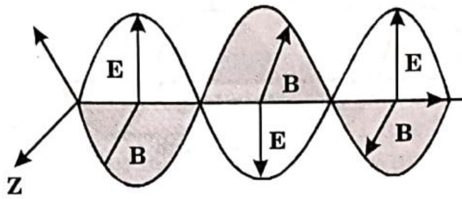
Transverse Waves	Longitudinal Waves
1. In transverse waves, the particles of the medium vibrate at right angles to the direction of wave.	1. In longitudinal waves, the particles of the medium vibrate parallel to the direction of wave.
2. Transverse waves consist of crests and troughs.	2. Longitudinal waves consist of compressions and rarefactions.
3. Transverse waves can be propagated only though a solid or over the surface of a liquid but not in a gas.	3. Longitudinal waves can be propagated through solids, liquids, as well as gases.
4. In transverse waves, the distance between the two consecutive crests or between the two consecutive troughs is equal to one wavelength.	4. In longitudinal waves, the distance between the two successive compressions or between the two successive rarefactions is equal to one wavelength.

ELECTROMAGNETIC WAVES

Electromagnetic waves consists of periodically varying electric (E) and magnetic (B) fields, which are at right angles to each other and in planes normal to the direction of propagation of the wave. These waves are transverse waves and does not require medium.

For example light waves, X rays, gamma rays, radio waves, micro waves etc.,

Travel through Vacuum also



Mechanical Waves	Electro magnetic waves
1. These require a medium for their propagation. 2. They are produced due to the to and fro motion of particles of the medium about their mean position. 3. Speed of mechanical wave is low. For example: The speed of sound wave in air is 330 m s^{-1} 4. They can be either longitudinal. (on transverse) 5. They have low frequency and high wave length.	1. They do not require medium for their propagation. 2. They are produced due to the vibrations (or) variations of electric and magnetic fields. 3. Speed of electromagnetic waves is high. Speed of light wave is 3×10^8 m s^{-1} is vacuum. 4. They are always transverse waves in nature. 5. They have high frequency and short wave length.

Some Terms of Wavemotion

Phase

Phase is that which gives the state of the vibrating particle as regards its position and direction of motion.

Phase difference

The difference in phases of two particles of the medium at same instant or the difference in phases of the single particle at different instants is called phase difference. The phase difference between any two consecutive particles vibrating in same phase is equal to 2π radians

Path difference

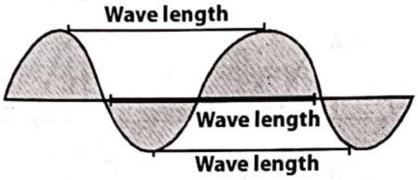
The distance between the two particles of the medium in the direction of propagation of wave is known as path difference.

Time period (T)

Time period is the time taken by a vibrating particle to complete one vibration is called the time period. Its SI unit is second

Wave length (λ)

It is the distance between any two adjacent crests or troughs, compressions or rarefactions. The distance between any two adjacent points on a wave vibrating with same phase.



Amplitude (A)

The maximum displacement of each particle from its mean position of medium during the propagation of wave is called amplitude of the wave.

Frequency (ν)

It is defined as the number of vibrations per second. The units of frequency are cycles per second or hertz

$$\nu = \frac{1}{T}$$

Velocity

The distance travelled by a wave in 1 second is called the velocity of the wave. S.I unit of velocity is m s^{-1}. $V = \nu\lambda$

SOUND

Sound is a form of energy which is emitted by a vibrating body. It travels in the form of waves and causes the sensation of hearing. Sound wave are mechanical in nature and hence cannot travel through vacuum. For example vibrations in a stretched rubber band produces sound, plucking the wire of sitar produces sound.

Speed of Sound in Solids, Liquids and Gases

Sound travels with different speeds in different media. The speed of sound in solids is maximum, less in liquids and the least in air or gases i.e., $v_{solid} > v_{liquid} > v_{gas}$

Velocity of Sound in Solids

When a longitudinal wave passes through a solid (thin rod), the elasticity concerned is the young's modulus. The velocity (V) of sound is given by

$$v = \sqrt{\frac{Y}{d}}$$

Where Y is the young's modulus of the solid and 'd' is the density of the solid.

Velocity of Sound in Gases

The expression for finding velocity of sound in gases was formulated by Newton. He assumed that when sound waves travel in a gas, the condensations and rarefactions take place in the gas under isothermal conditions, thereby no appreciable changes in temperature is noticed. Accordingly Newton gave the formula for velocity of sound in a gas as

$$v = \sqrt{\frac{E}{d}}$$

Where, E is the isothermal bulk modulus and 'd' is the density of the gas. The theoretical value of velocity of sound using Newton's formula is 280 m s^{-1}. But the experimental value obtained from various experiments is 331 m s^{-1}. Later on this was explained by Laplace. According to Laplace, when sound waves travel through air, there are compressions and rarefactions in the particles of the medium. Whenever there is a compression, particles come near to each other and are heated up. If there is a rarefaction, the particles move apart and there is fall in temperature. Therefore, the temperature does not remain constant during the propagation of sound and the process is not isothermal but adiabatic. From an adiabatic process $PV^{\gamma} = \text{Constant}$, where γ is the ratio of specific heats of the gas and $E = \gamma P$. Accordingly, the velocity of sound in a gas is given by:

$$V = \sqrt{\frac{\gamma P}{d}}$$

FACTORS AFFECTING VELOCITY OF SOUND IN A GAS

Effect of temperature on the velocity of sound

The velocity of sound in a gas is directly proportional to the square root of absolute temperature T.

$$\therefore\ V \alpha \sqrt{T}$$

Therefore, as the temperature of a gas increases, the velocity of sound in it also increases.

If V_0 is the velocity of sound in air at 0 °C and V_t is the velocity at t°C, then

$$V_t = V_0\left(1 + \frac{t}{546}\right)$$

Pressure

For a perfect gas, the general equation of a gas is

$$Pv = nRT \Rightarrow P = \left(\frac{nM}{v}\right)\frac{RT}{M}$$

$$\Rightarrow P = \rho\left(\frac{RT}{M}\right) \text{ or } \boxed{\frac{P}{\rho} = \frac{RT}{M}}$$

If temperature of a gas is kept constant then the ratio $\frac{P}{\rho}$ remains constant. So velocity of sound in a gas is independent of pressure as long as temperature remains constant.

Density

Assuming all other conditions are kept constant for different gases, the velocity of sound is inversely proportional to square root of the density of a gas.

$$V \alpha \frac{1}{\sqrt{\rho}}$$

Under similar conditions of pressure and temperature the ratio of speed of sound in any two gases of same atomicity will be $\frac{V_1}{V_2} = \sqrt{\frac{M_1}{M_2}}$ where M_1, M_2 denote molecular masses of the two gases.

Nature of gas

$V \alpha \sqrt{\gamma}$ when pressure, density and temperature of a gas are kept constant. The value of γ depends on atomicity of gases.

CLASSIFICATION OF SOUNDS

Based on frequency, Longitudinal waves can be classified as :

1. Audible range 2. Infrasonics and 3. Ultrasonics

Audible range

The range of frequencies that people with normal hearing can detect is called the audible range. For young people this is usually between 16 Hz to 20,000 Hertz. Thus, the normal hearing range or the range of human audibility is 20 Hz to 20,000 Hz.

Infrasonic Sound

Some vibrations produce sounds below the normal hearing range. These are known as infrasonic sounds (below 20 Hz). Earthquakes, underground nuclear explosions, and tides, all produce infrasonic sounds.

Ultrasonic Sound

Vibrations above the normal hearing range produce ultrasonic sounds (above 20,000 Hz). Many animals like bats, dolphins, dogs produce and hear such sounds.

Application

1. ***Investigation of Structure of Matter***

   Sending ultrasound through bulk of matter and studying the variation in their velocity inside it, valuable information regarding the constitution of complex molecules can be obtained.

2. ***Cleaning***

   Dirty odd shaped parts, spiral tubes, electronic components are placed in a cleaning solution and ultrasonic waves are passed through it. Due to high frequency vibrations particles of dirt get detached and drop out. The objects are thoroughly cleaned.

3. ***Detection of Flaws (Cracks) in Metals***

   Ultrasound is sent through the metallic structure. They pass through unobstructed matter if the structure is homogeneous. In case of a crack inside the structure the ultrasound will be reflected back towards observer and it receives. Existence of reflection, confirms existence of a crack. Due to high frequency and short wavelength, even fine cracks can be detected.

4. ***Depth of Seas and Oceans***

   Ultrasound oscillator producing waves of frequency 40 kHz is provided inside ships. An ultrasound receiver is also provided inside the ship.

   The transmitter oscillator transmits the waves towards bottom. The reflected waves are received by the receiver. A recorder finds the time interval (t). Knowing velocity (v) of ultrasound through sea water, the depth (d) can be calculated as $d = \frac{vt}{2}$.

   A similar mini arrangement can be used for finding the depth of liquid level in a tank without opening its cover.

5. ***Sound Ranging***

   A special equipment called Sonar is used for this purpose.

6. ***Emulsions of Immiscible Liquids***

   When a strong beam of ultrasound is passed through a liquid, it is heated to a very high temperature. This fact is utilized in preparing homogeneous stable emulsion of immiscible liquids. Ultrasound treated honey does not crystallize.

7. ***Medical and Biological Effects***

   a. When ultrasound is passed through a body part having muscular pain or rigid joints, their high frequency vibrations produce soothing effect and relieve the pain.

   b. Ultrasound sent through brain cures a mental patient.

   c. A newly developed technique of three dimensional photographs with the help of ultrasound (ultrasonography) is being used by the physicians to locate the exact position of an eye tumour and its removal giving normal vision to the patient.

   d. Harmful insects are killed by exposing them to ultrasound.

REFLECTION OF SOUNDS

A wave while passing from one medium comes back to the same medium after striking the second medium, resulting in reflection of wave is said to take place. During reflection of sound, the incident angle $\angle i$ = reflected angle $\angle r$.

Applications of Reflection of Sound

1. ***Megaphone***

   Megaphone is a device used to address public meetings. It is a horn-shaped. When we speak through megaphone, sound waves are reflected by the megaphone. These reflected sound waves are directed towards the people without much spreading.

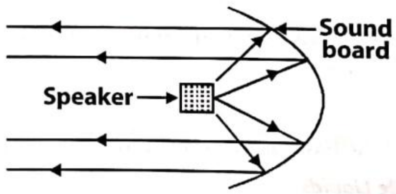
2. ***Hearing Aid***

   Hearing aid is used by a person who is hard of hearing. The sound waves falling on hearing aid are concentrated into a narrow beam by reflection. This narrow beam of sound waves is made to fall on the diaphragm of the ear. Thus, diaphragm of the ear vibrates with large amplitude. Hence, the hearing power of the person is improved.

3. ***Sound Boards***

   Sound boards are curved surfaces (concave) which are used in big hall to direct the sound waves towards the people sitting in a hall. The speaker is placed at the focus of the sound board.

   Sound waves from the speaker are reflected by the sound board and these reflected waves are directed towards the people.



ECHO

Echo is the sound heard after reflection from a rigid obstacle (such as a cliff, a hillside, wall of a building, etc.) is called an echo. For example Echo is produced when you shout into a well, inside an empty hall or inside a dome, Echo is also produced on a hill side, near a valley.

Condition for the Formation of Echoes

a. The minimum distance between the source of sound and the reflecting body should be 17 m.

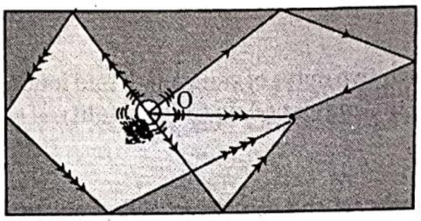
b. The wavelength of sound should be less than the height of the reflecting body.

c. The intensity of sound should be sufficient so that it can be heard after reflection.

d. Extended surfaces or obstacle of large size reflect sound waves. These surfaces need not be smooth or polished.

REVERBERATION

If sound is produced by a source 'S' in a closed enclosure as shown in the figure (35), the observer of sound 'O', can hear the sound directly coming from the source and also reflected from the roof or walls of the enclosure. If the reflections are multiple, the observer continues to hear the sound even after the source of sound has stopped producing the sound.



Reverberation

This persistence of sound in a closed enclosure, due to continuous reflections at the walls or the floor or the ceiling of the enclosure, even after the source has stopped producing sound is known as 'reverberation'.

Acoustics of buildings

In theatres, auditoriums, big halls etc the reverberation of sound is a common problem. Due to this the music or the speech rendered becomes uninteresting or unintelligible. The reverberation of sound can be optimised by taking certain precautions while the theatres are being constructed.

(1) The wall of the hall should be covered with some absorbing material like wallpaper or the walls should be painted to make it rough.

(2) There should not be any concave reflectors in the halls.

(3) The stairs, seats should be covered with absorbing materials.

(4) The windows, doors etc., should be provided with thick curtains, or windows should be provided with double or triple doors.

CHARACTERISTIC OF SOUND

Loudness

Loudness is the characteristic of a sound which distinguishes a feeble sound from a loud sound of the same frequency.

Factors affecting the loudness of sound

1. Loudness increases with the amplitude of vibrating body.
2. Loudness increases with the increase in surface area of vibrating bodies.
3. Loudness decreases with the increase in distance from the source of sound.

Pitch

Pitch is the effect produced in the ear due to the sound of some particular frequency. Pitch depends upon the frequency of a vibrating body i.e., the higher the pitch, the more is the frequency and the lower the pitch, the less is the frequency. The voice of woman is more shrill than the voice of a man. The shrill sound is called high pitch sound, whereas a soft or less shrill sound is called low pitch sound.

Factors affecting the pitch of sound

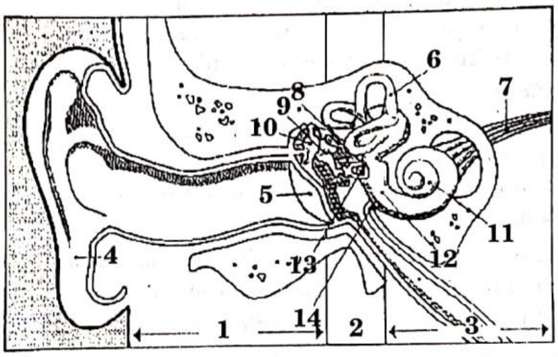
1. It depends upon the frequency of a vibrating body.
2. Higher frequency produces shrill sound and lower frequency produces bass or flat sound.
3. Small lengths of vibrating air columns produce high pitched sound and vice versa.
4. Pitch of sound increases with the decrease in thickness or the length of vibrating wires.

Quality of sound or timbre

The property due to which two notes of same pitch and loudness produced by two different vibrating bodies can be distinguished, is called quality of sound.

HUMAN EAR

Like the human eye gives us the sensation vision or sight, the human ear is a sense organ enabling us to heat the sounds produced in the surroundings.



1. Outer Ear	2. Middle Ear	3. Inner Ear
4. Pinna	5. Ear Drum	6. Semi Circular Canal
7. Nerve Injuetia	8. Stirrup	9. Anvil
10. Hammer	11. Cochlea	12. Basilar Membrane
13. Oval Window	14. Round Window	

The human ear as shown in the figure here is divided into three parts - the outer ear, the middle ear and the inner ear. The pinna of the outer ear helps in diverting these compression/ rarefactions to the eardrum through the ear canal or auditory canal which too is a part of the outer ear. The eardrum, also known as tympanic membrane forms the gateway to the middle ear. It is lightly stretched membrane of about 0.8×10^{-4} thick.

The thin and delicate ear drum has another delicate bone attached to it, which is the first of the three bones constituting the middle ear. The first, called the hammer, is in contact with the eardrum at one end and the anvil, the second bone at the other end.

The compressions and rarefactions of the external sound make the ear drum to vibrate and these vibrations are conveyed through anvil to the third bone called the stirrup which is in contact with the oval window leading to the inner ear. The middle ear is connected to the throat through the eustachian tube for equalising the pressure on either side of the eardrum.

The inner ear consists of the spiral shaped cochlea containing a fluid. The minute vibrations of the oval window coming from the outer and middle ears agitate this fluid causing the hair-like projections on a membrane in the cochlea to vibrate. The resonant vibrations of the hair-like structures generate signals in the auditory nerve connected to the brain to be interpreted as sounds with corresponding frequencies.

SOLVED EXAMPLES

Example 1

What is the distance travelled by sound in air when a tuning fork of frequency 256 Hz. completes 25 vibrations ? The speed of sound in air is 343 m s^{-1}.

Solution :

Data : $v = 343\ m\ s^{-1}$ $n = 256\ Hz$ $d = ?$

$v = n\lambda$

$$\therefore \lambda = \frac{343}{256} = 1.3398\,m$$

Wavelength is the distance travelled by the wave one complete vibration of the tuning fork.

$\therefore$ Distance travelled by sound wave in 25 vibrations = $25 \times 1.3398 = 33.49$ m

Distance travelled by sound wave is 33. 49 m

Example 2

Ultrasonic sound of frequency 100 kHz emitted by a bat is incident on a water surface. Calculate the wavelength of reflected sound and transmitted sound ? (speed of sound in air 340 m s^{-1})

Solution :

$n = 100\ kHz = 10^5\ Hz$, $v_a = 340\ m\ s^{-1}$, $v_W = 1486\ m\ s^{-1}$; $\lambda_a = ?. \lambda_w = ?$

Wavelength of reflected sound $\lambda_a = \frac{v_a}{n}$

$$\lambda_w = \frac{340}{10^5} = 3.4 \times 10^3\ m$$

Wavelength of transmitted sound $\frac{\lambda_a}{\lambda_w} = \frac{v_a}{n} \times \frac{n}{v_w}$

$$\lambda_w = \frac{1486}{10^5} = 1.486 \times 10^{-2}\ m$$

Example 3

Find the ratio of speed of sound in hydrogen to the speed of sound in oxygen at 1270 K.

Solution :

velocity of sound in a gas $v = \sqrt{\frac{\gamma RT}{M}}$ since hydrogen and oxygen are diatomic γ value is

same $\therefore V \alpha \frac{1}{\sqrt{M}}$ (at same temperature)

$$\frac{V_{H_2}}{V_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} \Rightarrow \frac{V_{H_2}}{V_{O_2}} = \sqrt{\frac{32}{2}} = 4:1$$

Example 4

Two waves x and y are taken such that the distance between their corresponding second and fifth crests of two waves are in the ratio 2:7. The ratio of velocities of waves x and y are 3:1. Find the wave that has a greater time period.

Solution :

The distance between second crest and fifth crest is 3λ.

$$\frac{3\lambda_X}{3\lambda_Y} = \frac{2}{7} \text{ (given) and } \frac{V_X}{V_Y} = \frac{3}{1}$$

$$\text{But, } \frac{V_X}{V_Y} = \frac{\lambda_x}{\lambda_y} \times \frac{T_y}{T_x} \Rightarrow \frac{3}{1} = \frac{2}{7} \times \frac{T_y}{T_x}$$

$$\frac{T_Y}{T_X} = \frac{21}{2}$$

$\therefore$ Wave y has greater time period.

Example 5

The ratio of molecular weight of hydrogen to chlorine is 1: 35 at 300 K. Find the ratio of speed of sound of hydrogen to chlorine at the same temperature.

Solution :

$$\text{Given } \frac{M_{H_2}}{M_{Cl_2}} = \frac{1}{35}$$

At constant temperature.

$$v \alpha \frac{1}{\sqrt{M}}$$

$$\therefore \frac{v_{H_2}}{v_{Cl_2}} = \sqrt{\frac{M_{Cl_2}}{M_{H_2}}} = \sqrt{\frac{35}{1}} = \sqrt{35}:1$$

Example 6

Find the phase difference between a particle at 1st crest and a particle at 4th crest.

Solution :

The distance between 1st crest and 4th crest is equal to three times the wavelength of the wave.

The phase difference of a single wavelength of the wave is 2π.

$\therefore$ Phase difference between particles at first crest and 4th crest = $(2\pi) \times 3 = 6\pi$

Example 7

40 waves passes through a point in 0.5 s at $0\,^\circ C$. The distance between one compression and adjacent rarefaction is 8 m. Find the velocity of the sound wave at 2457 K

Solution :

The distance between one compression and adjacent rarefaction = $\frac{\lambda}{2} = 8\,m$

$\therefore$ wavelength$(\lambda) = 16\,m$

Frequency (ν) = no. of waves / time taken = 40 / 0.5 = 80 Hz

$\therefore$ Velocity of sound at $0\,^\circ C$ = $\nu\lambda$ = (80) (16) = 1280 m s^{-1}

$$V \propto \sqrt{T}$$

$$\therefore \frac{V_1}{V_2} = \sqrt{\frac{T_1}{T_2}}$$

Given $T_1 = 0^\circ + 273 = 273\,K$; $T_2 = 2457\,K$

$$\therefore \frac{V_1}{V_2} = \sqrt{\frac{273}{2457}} \Rightarrow \frac{1280}{V_2} = \frac{1}{3}$$

V_2 = (1280 × 3) = 3840 m s^{-1}

Example 8

The 3rd crest of a transverse wave from its centre of disturbance is 32.4 cm away. The 6th crest of this wave is 75.6 cm from its centre of disturbance.

a) Find the wave length of the wave.

b) If time period of a wave is 0.2 s, what will be the velocity of the wave ?

Solution :

The distance between 6th crest and 3rd crest is equal to three times the wavelength of the wave.

$\therefore 3\lambda = 75.6 - 32.4$

$3\lambda = 43.2 \Rightarrow \lambda = 14.4\,cm$

Given T = 0.2 s

$$\therefore v = \frac{\lambda}{T} = \frac{14.4}{0.2} = 7.2 \text{ cm s}^{-1}$$

Example 9

A tuning fork makes 400 vibrations in two seconds in air. If velocity of sound at 0 °C is 320 m s^{-1} then find the wavelength of the wave emitted at 27 °C.

Solution:

Frequency = $\frac{400}{2} = 200\,\text{Hz}$

Velocity of sound at 0 °C (V_0) = 320 m s^{-1} ; $\lambda_0 = \frac{320}{200} = 1.6\,\text{m}$

velocity of sound at 27° C

$$= \frac{V_0}{V_{27}} = \sqrt{\frac{T_0}{T_{27}}} = \frac{\lambda_0}{\lambda_{27}}$$ (as frequency do not change with temperature)

$$\sqrt{\frac{273}{300}} = \frac{1.6}{\lambda_{27}}$$

$$\lambda_{27} = 1.6\sqrt{\frac{300}{273}} = 1.677 \text{ m}$$

Example 10

At what temperature is the velocity of sound in oxygen is equal to half its velocity in chlorine at 42 °C ? The ratio of molecular weights of oxygen and chlorine is (16:35)

Solution :

$$V = \sqrt{\frac{\gamma RT}{M}}$$

For oxygen, $V_{O_2} = \sqrt{\frac{\gamma RT_{O_2}}{M_{O_2}}}$

For chlorine, $V_{Cl_2} = \sqrt{\frac{\gamma RT_{Cl_2}}{M_{Cl_2}}}$

Given $V_{O_2} = \frac{1}{2} V_{Cl_2}$

$$\sqrt{\frac{\gamma RT_{O_2}}{M_{O_2}}} = \frac{1}{2}\sqrt{\frac{\gamma RT_{Cl_2}}{M_{Cl_2}}}$$

$$\Rightarrow \frac{T_{O_2}}{M_{O_2}} = \frac{1}{4}\frac{T_{Cl_2}}{M_{Cl_2}} \Rightarrow \frac{T_{O_2}}{T_{Cl_2}} = \frac{1}{4}\frac{M_{O_2}}{M_{Cl_2}} = \frac{1}{4} \times \frac{16}{35} = \frac{4}{35}$$

$$T_{O_2} = T_{Cl_2} \times \frac{4}{35} = 36 \text{ K}$$

Example 11

The minimum distance between two particles in same phase is 18 cm. If the velocity of the wave is 36 m s^{-1}, then find the time interval after which the given particle undergoes a phase change of π.

Solution :

The minimum distance between two particles in similar phase is its wavelength = 18 cm

$$v = 36 \text{ m s}^{-1}$$

$$\text{Time period} = \frac{\lambda}{v} = \frac{18 \times 10^{-2}}{36}$$

$$0.5 \times 10^{-2} = 5 \text{ ms}$$

Time interval after which the given, particle undergoes a phase change of π is half time period = $\frac{5 \text{ ms}}{2}$ = 2.5 ms

Example 12

A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

Solution :

Distance of the object from submarine, s = 3625 m

Time interval of echo return, t = 5 s

Speed of sound in water, u = ?

The sound travels a total distance 2 s in return journey,

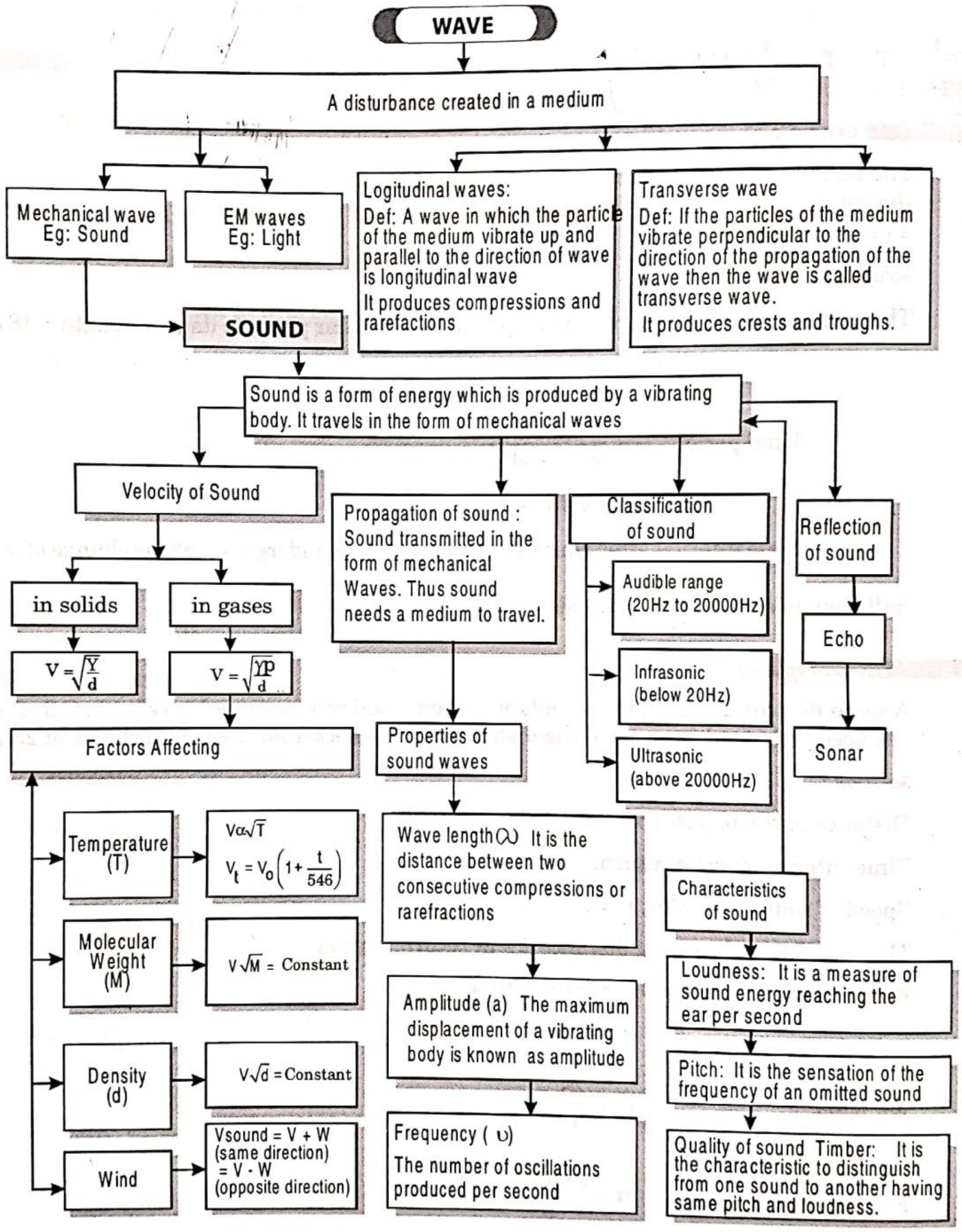
From relation, distance = velocity × time

$$2S = ut$$

We have, $u = \frac{2S}{t}$

Putting values, we get, $u = \frac{2 \times 3625}{5} = 1450 \text{ m s}^{-1}$

CONCEPT MAP


WAVE
A disturbance created in a medium
Mechanical wave Eg: Sound
EM waves Eg: Light
Logitudinal waves: Def: A wave in which the particle of the medium vibrate up and parallel to the direction of wave is longitudinal wave
It produces compressions and rarefactions
Transverse wave Def: If the particles of the medium vibrate perpendicular to the direction of the propagation of the wave then the wave is called transverse wave.
It produces crests and troughs.
SOUND
Sound is a form of energy which is produced by a vibrating body. It travels in the form of mechanical waves
Velocity of Sound
in solids
in gases
$V = \sqrt{\frac{Y}{d}}$
$V = \sqrt{\frac{\gamma P}{d}}$
Factors Affecting
Temperature (T)
$V \propto \sqrt{T}$
$V_t = V_o\left(1 + \frac{t}{546}\right)$
Molecular Weight (M)
$V\sqrt{M}$ = Constant
Density (d)
$V\sqrt{d}$ = Constant
Wind
Vsound = V + W (same direction)
= V - W (opposite direction)
Propagation of sound : Sound transmitted in the form of mechanical Waves. Thus sound needs a medium to travel.
Properties of sound waves
Wave length (λ) It is the distance between two consecutive compressions or rarefractions
Amplitude (a) The maximum displacement of a vibrating body is known as amplitude
Frequency (υ) The number of oscillations produced per second
Classification of sound
Audible range (20Hz to 20000Hz)
Infrasonic (below 20Hz)
Ultrasonic (above 20000Hz)
Reflection of sound
Echo
Sonar
Characteristics of sound
Loudness: It is a measure of sound energy reaching the ear per second
Pitch: It is the sensation of the frequency of an omitted sound
Quality of sound Timber: It is the characteristic to distinguish from one sound to another having same pitch and loudness.

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. S.I. unit of frequency is __________.
2. Loudness of a note increases with the increase in __________.
3. The distance between 1^{st} crest and 7^{th} trough of a transverse wave of wavelength 20 cm is __________.
4. A sound wave travels with a speed of 330 m s^{-1} in air. If the wavelength of the wave is 110 cm, then frequency of the wave is __________.
5. A loaded spring produces __________ waves.
6. The range of the wavelength of audible sound that travels with a velocity of 330 m s^{-1} at 0 °C is __________.
7. The frequency of a sound wave is 250 Hz and its wavelength is 100 cm. The distance travelled by a sound wave in the time taken to produce 100 waves is __________.
8. The shrillness of a sound not depends upon __________.
9. The velocity of sound in oxygen is __________ than in helium.
10. The difficulty to recognise the speakers voice over the telephone is due to __________ of sound.
11. The temperature at which the speed of sound in air becomes double of its value at 0 °C is __________ °C.
12. The variation of speed of sound with temperature is greatest __________.
13. Stethescope works on the principle of __________ of sound.
14. The formula proposed by Newton for velocity of sound in air is based on __________ process.
15. In theatres, big halls etc., the __________ of sound is a common problem.

TRUE OR FALSE

16. Elastic waves need material medium for their propagation.
17. The velocity of sound in a gas is directly proportional to the square root of the temperature of the gas taken in degree celsius.
18. A wave creates disturbance and transmits matter from one place to another.
19. According to Laplace, during the propagation of sound in a gas, an adiabatic change takes place in the medium.
20. Light waves are transverse in nature.
21. Progressive waves are waves originating from a source such that they never return to the source.

22. Sound travels faster in gases when compared to solids and liquids.
23. The velocity of sound is affected by the density of the solid.
24. The direction of the wind affects the velocity of sound.
25. In a longitudinal wave, the density of particles is more at a compression.
26. The sounds having frequency less than 20 Hz are called ultrasonics.
27. During a tsunami, the shock wave originating in the ocean bed propagates as both transverse and longitudinal wave.
28. In a transverse wave, the distance between a crest and the immediate trough is $\lambda / 2$.
29. The ripples in water waves are created by the oscillatory movement of water particles.
30. If the distance between two successive troughs in a transverse wave is 8 cm, then the amplitude of that wave is 5 cm.

MATCH THE FOLLOWING

31.

Column A	Column B
A. Bats	p. $v=\sqrt{\frac{\gamma p}{d}}$
B. Newtons formula	q. Reflection of sound
C. Laplace's formula	r. Sensitive to ultrasonic
D. Sonar	s. $v=\sqrt{\frac{E}{d}}$
E. Reverberation	t. Multiple reflections of sound

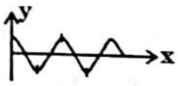
FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. A sound wave has a frequency of 1 kHz and wave length 25 cm, to travel 2.2 km it takes.

(A) $2\frac{3}{7}$ s (B) $80\frac{2}{5}$ min (C) $\frac{5}{4}$ min (D) $8\frac{4}{5}$ s

2. The distance between 2nd crest and 6th trough of a wave shown below is 24 cm. If the wave velocity of the moving crests is 20 m s^{-1}, then frequency of rocking of the boat is:



(A) 24 Hz (B) 20 Hz (C) 375 Hz (D) 240 Hz

3. A source of wave produces 3 crests and 3 troughs in 2 ms, the frequency of the wave is:

(A) 1250 Hz (B) 500 Hz (C) 1000 Hz (D) 750 Hz

4. Human ears can sense sound waves travelling in air having wavelength of ______.

(A) 10^{-3} m (B) 10^{-2} m (C) 1 m (D) 10^{2} m

5. The velocity of sound in a gas is 30 m s^{-1} at 27 °C. What is the velocity of the sound in the same gas at 127 °C ?

(A) 20 m s^{-1} (B) 30 m s^{-1} (C) $20\sqrt{3}$ m s^{-1} (D) 60 m s^{-1}

6. When the pressure of a gas is changed, then:

(A) the density of the gas also changes

(B) the ratio of the pressure to the density remains unaffected

(C) the velocity of the sound remains unaffected.

(D) the value of γ changes

7. If wind blows in a direction opposite to the sound propagation, then the velocity of the sound:

(A) increases (B) decreases

(C) remains constant (D) cannot be determined

8. The persistence of sound in a closed enclosure, due to continuous reflections at the walls, even after the source has stopped producing sound is known as:

(A) the persistence of hearing (B) an echo

(C) reverberation (D) the ultra sounds

9. A.R. Rahman is conducting a musical night in an open auditorium in New York. If two persons, one who is sitting in the auditorium at a distance of 250 m from the stage and the other who is watching the live program on a television set sitting infront of it in Hyderabad, then the person who will hear him first:

(A) person sitting in auditorium (B) person sitting in Hyderabad

(C) both will here at a time (D) cannot be said

10. A wave of frequency 1000 Hz travels between X and Y, a distance of 600 m in 2 seconds. The number of wavelengths there with in distance XY:

(A) 3.3 (B) 300 (C) 180 (D) 2000

11. Human ears can sense sound waves travelling in air having wavelength of:

(A) 10^{-3} m (B) 10^{-2} m (C) 1 m (D) 10^{2} m

12. A 440 Hz sound wave travels with a speed of 340 m s^{-1}. The wavelength of the wave is:

(A) 1.5×10^{5} m (B) 0.77 m (C) 1.3 m (D) 1.1 m

13. Elastic waves in solid are:

(A) transverse (B) longitudinal

(C) either transverse or longitudinal (D) neither transverse nor longitudinal

14. Which of the following statements is wrong?

(A) Changes in air temperature have no effect on the speed of sound.

(B) Changes in air pressure have no effect on the speed of sound.

(C) The speed of sound in water is higher than in air.

(D) The speed of light in water is lesser than in air.

15. In an orchestra, the musical sounds of different instruments are distinguished from one another by which of the following characteristics?

(A) Pitch (B) Loudness (C) Quality (D) Overtones

16. A man standing between two cliffs hears the first echo of a sound after 2 seconds and the second echo 2 seconds after the initial sound. If the speed of sound be 330 m s^{-1}, the distance between the two cliffs should be:

(A) 1650 m (B) 990 m (C) 825 m (D) 660 m

MULTIPLE ANSWER QUESTIONS

1. A mechanical wave will be transverse or longitudinal depending on:

(A) the nature of medium (B) the mode of excitation

(C) frequency (D) amplitude

2. Transverse mechanical wave can travel in:

(A) iron rod (B) hydrogen gas

(C) water (D) stretched string

3. The velocity of sound is affected by change in:

(A) temperature (B) medium

(C) pressure (D) wavelength

4. Bells are made of metal and not of wood because:

(A) metals are elastic than wood

(B) the density of the metal is greater than that of wood

(C) the sound is not conducted by metals but is radiated

(D) wood dampens vibrations faster

5. Which of the following can travel through vacuum?

(A) Light waves (B) Heat waves

(C) X-rays (D) Sound waves

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statements of an Assertion and a Reason.

Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

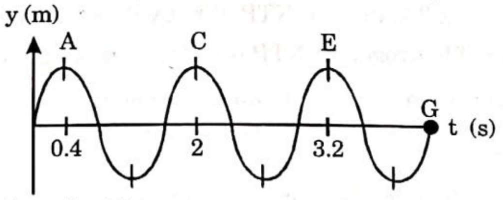
(E) If both assertion and reason are INCORRECT.

1. **Assertion:** Ultrasonic waves are longitudinal waves of frequency greater than 20,000 Hz.
   Reason: The maximum frequency of audible sound waves is 20,0000 Hz.
2. **Assertion:** On a rainy day sound travel slower than on a dry day.
   Reason: When moisture is present in air the density of air increases.
3. **Assertion:** Two persons on the surface of moon cannot talk to each other.
   Reason: There is no atmosphere
4. **Assertion:** Waves produced in a cylinder containing a liquid by moving its piston back and forth are longitudinal waves.
   Reason: In longitudinal waves, the particle of the medium oscillate parallel to the direction of propagation of the wave.
5. **Assertion :** The longitudinal waves are called pressure waves.
   Reason : Propagation of longitudinal waves through a medium involves changes in pressure and volume of air, when compression and rarefaction are formed.

PARAGRAPH QUESTIONS

Passage - I

I. For the wave shown in the figure, the distance between points A and D is 12 m



(i) Find the wavelength of the wave.
(A) 12 m (B) 16 m (C) 8 m (D) 4 m

(ii) Find the time taken by wave to propagate between points A and C
(A) 1.6 s (B) 0.8 s (C) 1.2 s (D) 0.4 s

(iii) Find the velocity of the wave.
(A) 4 m s^{-1} (B) 6 m s^{-1} (C) 10 m s^{-1} (D) 5 m s^{-1}

SECTION – B

NUMERICAL PROBLEMS

1. A man stands in between two cliffs x and y, such that he is at a distance of 66 m from x. When he blows a whistle he hears first echo after 0.4 s and second echo after 1.2 s. Calculate : (i) speed of sound (ii) distance of cliff y from man.
2. Two children are at the opposite end of an iron pipe. One struks the end of the pipe with a stone. Calculate the ratio of the time taken by sound waves in air and in iron to reach the other child. Use speed of sound in (i) air = 344 m s^{-1} and (ii) iron = 5130 m s^{-1}.
3. At what temperature is the velocity of sound in nitrogen is equal to half its velocity in oxygen at 25 °C ? (The ratio of molecular weights of nitrogen and oxygen is 7 : 8)
4. A hollow iron pipe is being hammered heard at the other end at an interval of 0.5s what is the length of iron pipe, if speed of sound in air is 320 m s^{-1} and that in iron is 4320 m s^{-1}?
5. A man fired a bullet against a wall and hears an echo after 2 s. He walks 80 m towards the wall and fired bullet, such that he hears echo after 1 s. Find the distance from wall to the second fired place.
6. The velocity of sound in a medium at a certain temperature is 'V'. If the absolute temperature of the medium is increased by 44 % then find the percentage change in the velocity of the sound.
7. Two rods P,Q are considered such that the young's modulus of elasticity of rod P is twice that of the other while the density of rod Q is eighteen times that of rod P. If a sound wave is allowed to transverse 2 m distance through each rod, then in which case will the sound take lesser time and by how many times ?
8. The velocity of sound through hydrogen is 1400 m s^{-1} at certain temperature. What will be the velocity of sound through a mixture of 2 parts of volume of hydrogen and 1 part of nitrogen at same temperature ?
9. A particle executing SHM takes 4 s to move from one extreme to another extreme position. Find the time period of the particle.
10. A piezo - electric quartz plate is vibrating to produce wavelength of 10^{-2} m. Find the frequency if for quartz $Y = 8 \times 10^{10}$ N m^{-2} and $\rho = 2.65 \times 10^{3}$ kg m^{-3}
11. Speed of sound in air is 332 m s^{-1} at NTP. What will be the speed of sound in hydrogen at NTP if the density of hydrogen at NTP is (1/16) that of air ? (Assume ρ_{air} / ρ_H ; 1.1)
12. Calculate the ratio of the speed of sound in neon to that in water vapours at any temperature. (molecular weight of neon = 2.02×10^{-2} kg $mole^{-1}$ and for water vapours = 1.8×10^{-2} kg $mole^{-1}$)
13. A sound wave travelling in air is made to propagate through a liquid such that the velocity of sound is quadrupled. If the frequency of he sound wave is constant, find the change in the wavelength of the sound wave.
14. Calculate the ratio of the speed of sound in neon to that in water vapour at any temperature. Given that molecular weight of neon gas = $2.02 \times 10^{-2 kg}$ $mole^{-1}$ and molecular weight of watervapour = 1.8×10^{-2} kg $mole^{-1}$.

15. An ultrasonic source emits sound of frequency 220 kHZ in air. If this sound meets a water surface, what is the wavelength of

(a) the reflected sound,

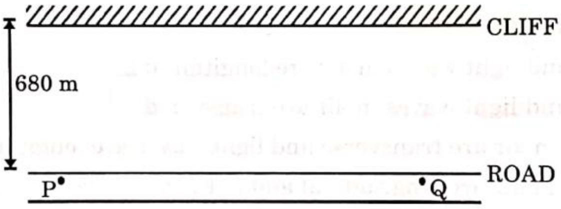
(b) the transmitted sound? (At the atmospheric temperature, speed of sound in air = 352 m s^{-1} and in water = 1.496 m s^{-1})

CONCEPTUAL QUESTIONS

1. If a source of sound and a man are at the same altitude, the sound is heard better in the direction of the wind than in the opposite direction. How can you explain this phenomenon ?

2. A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies ? (Take the speed of sound in air as 344 m s^{-1})

3. A road runs parallel to a vertical cliff at a distance of 680 m as shown in the figure. A truck, standing at P sounded the horn at an instance and the truck driver hears the echo after 4 s. But the sound of the horn was heard twice by a person standing at Q within an interval of 2 s. Give reasons why the person at Q heard the sound twice. Neglecting the wind velocity, Calculate how far the person was from the truck?



4. Distinguish between sound and radio waves of the same frequency.

5. Explain why (a) transverse mechanical waves cannot be propagated in liquids and gases while (b) waves on strings are always transverse.

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. A vibrating body:

(A) will always produce sound

(B) may or may not produce sound if the amplitude of vibration is low

(C) will produce sound which depends upon frequency

(D) none of the above

2. A bomb explodes on the moon. How long will it take for the sound to reach the earth?

(A) 10 seconds (B) 1000 seconds (C) 1 day (D) none of these

3. If you go on increasing the stretching force on a wire in a guitar, its frequency:

(A) increases (B) decreases

(C) remains unchanged (D) none of the above

4. The frequency of a source is 20 kHz. The frequencies of sound wave produced by it in water and air will be:

   (A) same as that of source $\simeq$ 20 kHz (B) > 20 kHz
   (C) < 20 kHz (D) depends upon velocity

5. The velocity of sound in any gas depends upon:

   (A) wavelength of sound only (B) density and elasticity of gas
   (C) intensity of sound waves only (D) amplitude and frequency of sound

6. With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the direction of propagation are:

   (A) energy, momentum and mass (B) mass and momentum
   (C) energy and mass (D) energy and momentum

7. Velocity of sound is maximum in:

   (A) He (B) N_2 (C) H_2 (D) O_2

8. What will be the wave velocity, if the radar gives 54 waves per min and wavelength of the given wave is 10 m?

   (A) 4 m s^{-1} (B) 6 m s^{-1} (C) 9 m s^{-1} (D) 5 m s^{-1}

9. Which of the following statements is correct?

   (A) Both, sound and light waves in air are longitudinal.
   (B) Both, sound and light waves in air are transverse.
   (C) Sound waves in air are transverse and light waves are longitudinal.
   (D) Sound waves in air are longitudinal and light waves are transverse.

10. The distance between two consecutive crests in a wave train produced on a string is 5 cm. If two complete waves pass through any point per second, the velocity of the wave is:

    (A) 10 cm s^{-1} (B) 2.5 cm s^{-1} (C) 5 cm s^{-1} (D) 15 cm s^{-1}

BRAIN NURTURES

1. A rods runs mid between two parallel rows of building. A motorist moving with a speed of 36 km h^{-1}. Sound the horn, find the distance between the two rows of building. When will he hear the echo second time ? Velocity of sound in air is 330 m s^{-1}.

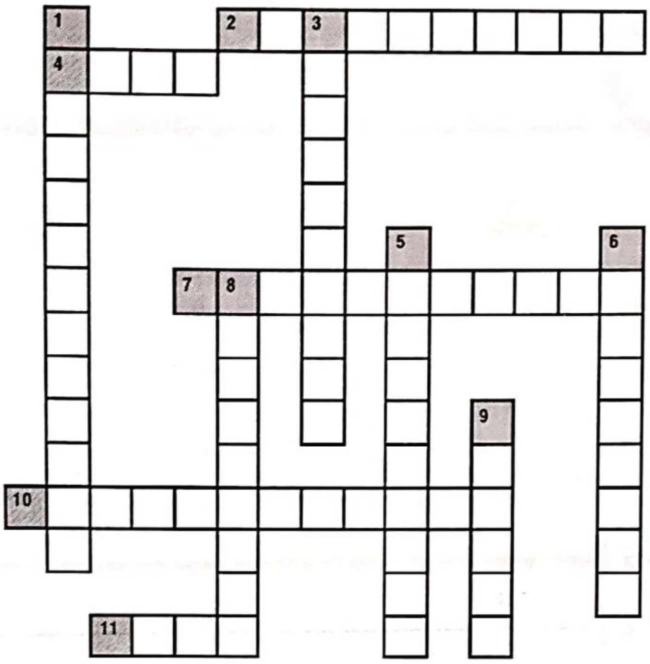
2. A radio direction finder operates in pulse dury. The pulse frequency is f = 1,700 cps and its duration is $\pi = 0.8\mu s$. Determine the maximum and minimum range of this finder.

3. The velocity of sound in a tube containing air at 27 °C and a pressure of 76 cm of mercury is 330 m s^{-1}. What will be its velocity, when the pressure is increased to 100 cm of mercury and the temperature is kept constant?

4. The quality of music from a group of instruments is independent of the listener's distance from the instruments. Why?

5. Does the sound of an explosion travel faster than the sound produced by a humming bee?

CROSSWORD PUZZLE



ACROSS

2 Dolphins are capable of producing and hearing to sounds

4 Produced when we shout with sufficient intensity into a well

7 The part of a longitudinal wave in which the density of the particles of the medium is less than the normal density is

10 waves can travel through all media

11 A periodic disturbance produced in a material medium due to the vibrating motion of the particles of the medium

DOWN

1 The persistence of sound in a closed enclosure, due to continuous reflections at the surface after the source has stopped producing

3 Waves on a long stretched rubber tube is an example of waves

5 Distance between any two adjacent crests or troughs is known as

6 As temperature increases, then velocity of sound

8 Maximum displacement of each particle from its mean position of medium is called

9 Speed of sound is maximum in

Chapter 10

Magnetism

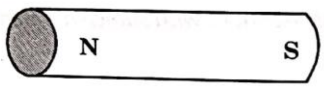
Common misconception	Fact
1. The north pole of a magnet is similar to the north pole of the Earth.	1. The north pole of a magnet is so called because it is always seeking the north pole of the Earth. Since it is attracted by the north pole of the Earth, it has to be a south pole.
2. An object weighs more at the poles than at the equator because the magnetic lines of force are concentrated at the poles.	2. An object weighs more at the poles than at the equator because the poles are nearer to the centre of the Earth.

SYNOPSIS

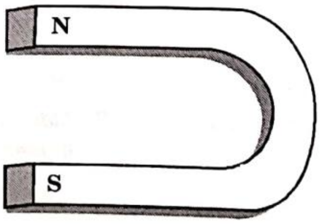
INTRODUCTION

Natural occurring substances which have the property of attracting pieces of iron, cobalt, nickel etc., are called natural magnets. Lodestone is a natural magnet. On rubbing a piece of iron with lode stone, the piece of iron acquires magnetic properties and behaves as a magnet. These type of magnets are known as artificial magnets. There are several other ways of producing artificial magnets.

Bar Magnet



Cylindrical Magnet



Horse shoe Magnet

PROPERTIES OF MAGNET

Attractive property

Magnets attract small pieces of iron seems to be very high in small regions of the magnet. These regions are called magnetic poles.

Directive property

A freely suspended magnet always aligns itself in the north–south direction. This property of magnet is known as directive property.

Law of magnetic poles

Like poles repel each other and unlike poles attract each other.

Since a magnet can attract small pieces of iron or the south pole of another magnet, the attractive property is not a sure test to find out whether the given piece is a magnet or not. Repulsion is a sure test to confirm whether the given piece is a magnet.

Pair property

When we break a magnet each of the pieces will have a North and a South pole at the ends. If we break it further we find that both the pieces formed will have the south and the north poles at its ends. The above phenomenon is observed till we reach a molecular stage. Magnetic poles always exist in pairs and single poles do not exist.

MAGNETIC INDUCTION

Magnetic materials like steel acquire the attractive property, when placed near a magnet. The phenomenon due to which magnetism is produced in a magnetic substance by the mere presence of a magnet near it is called magnetic induction.

The poles formed in the substance in which magnetism is induced are called induction poles.

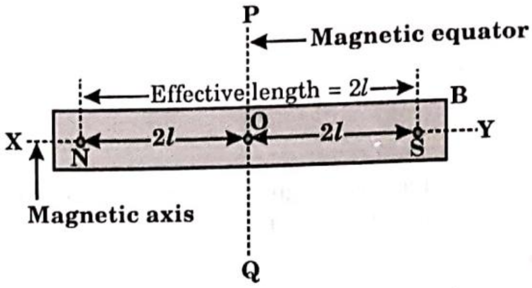
When we bring a magnet near a magnetic substance like a steel rod, the nearer end of the magnetic substance attains an opposite polarity, hence the steel rod gets attracted towards the magnet. Thus, magnetic induction preceedes attraction.

This implies that soft iron is used for making temporary magnets as it loses magnetism easily whereas in case of steel the induced magnetism is not lost easily and is retained for a long time making it useful for preparation of permanent magnets. Hence, the degree of magnetisation in case of steel is less than that of soft iron.

Factors affecting magnetic induction

1. More powerful magnets can produce a high induced magnetism in a magnetic substance.
2. Magnetic induction is inversely proportional to the distance between inducing magnet and the magnetic substance.
3. It also depends upon the nature of magnetic substance.

BAR MAGNET



Given below are few important terms associated with a bar magnet.

1. The geometric ends (A and B) of a bar magnet are called its geometric poles.
2. The property of a magnet to attract small pieces of iron seems to be very high, in small regions at each end of the magnet. These regions are called magnetic poles, these poles lie slightly within the ends of a magnet.
3. A freely suspended magnet aligns itself in the north–south direction. The end of the magnet which points towards the geographic north is called north seeking pole or magnetic north pole and the end which points towards the geographic south is called south seeking pole or magnetic south pole.
4. The line joining the north pole and the south pole of a magnet is called axis of the magnet.
5. The distance (l) between any one of the magnetic poles and the centre of the magnet is called the length of the magnet.
6. The distance between the north pole and the south pole of the magnet is called effective length of the magnet. This is slightly less than the physical length of the magnet and is taken to be equal to $2l$.
7. A vertical plane passing through the magnetic axis of a freely suspended magnet is called its magnetic meridian.
8. An imaginary line passing through the centre of the magnet and perpendicular to the magnetic axis is called the magnetic equator.
9. A vertical plane passing through the magnetic equator of a freely suspended bar magnet is called its equatorial meridian.

POLE STRENGTH (m)

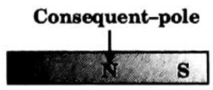
The ability of a pole to attract or repel another pole. Its SI unit is A–m

Consequent – pole and No – pole

There can be magnets with no poles, e.g., a magnetised ring called toroid or solenoid of infinite length has properties of a magnet but no poles.

There can be magnets with two similar poles (or with three poles), e.g., due to faulty magnetisation of a bar, temporarily identical poles at the two ends with an opposite pole of double strength at the centre of bar (called consequent pole) are developed.

Magnet with no poles



Magnet with similar poles
(or with three poles)

MAGNETIC MOMENT (M)

It is defined as the product of pole strength with effective length and direction along the axis of the magnet from south to north pole. Its SI unit is A–m^2

Change in magnetic moment

Due to cutting

a. When a bar magnet is cut into 'n' equal parts parallel to its axis, then pole strength of each piece, $m^1 = \frac{m}{n}$ and magnetic moment of each piece, $M^1 = \frac{M}{n}$

b. When a bar magnet is cut into 'n' equal parts perpendicular to its axis, then pole strength of each piece, $m^1 = m$ and magnetic moment of each piece, $M^1 = \frac{M}{n}$

Due to bending

a. When a bar magnet is bent its pole strength remains same but magnetic length decreases therefore magnetic moment decreases.

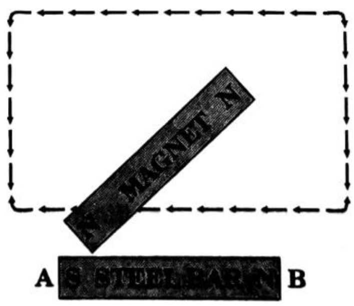
b. When a thin magnetic needle of magnetic moment (M) is bent at the middle, so that the two parts are perpendicular, its new magnetic moment $M^1 = \frac{M}{\sqrt{2}}$

c. When a thin bar magnet of magnetic moment M is bent into an arc of a circle subtending an angle θ at the centre of the circle, the magnetic moment becomes $M^1 = \frac{2M\sin\theta/2}{\theta}$

(θ must be in radians)

METHODS OF MAGNETISATION

Single touch method



a. Keep the steel bar to be magnetized on a wooden table.

b. Take a strong permanent magnet and bring one pole (say North Pole) of the magnet near one end of the steel bar and gently rub from one end to the other as shown in the figure.

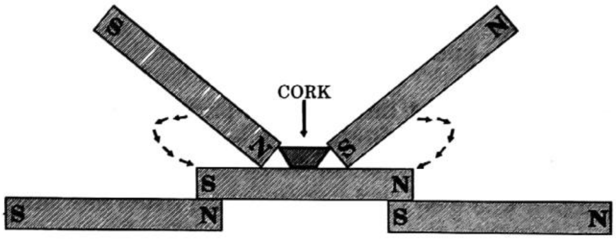
c. Once reached the other end, lift the magnet gently away from the steel bar and again bring it to the starting end.

d. Repeat this process several times.

e. Now the steel bar will be magnetized with the starting end as the north pole and the other end as the south pole.

f. If we start rubbing the steel bar with the south pole of the magnet then the starting end will become the south pole and the other end will be the north pole.

Double touch method



a. Keep the steel bar to magnetized (as shown in the figure) on the top of two permanent magnets.

b. Bring two permanent magnets with opposite poles and touch the middle of the steel bar and rub and move as shown in the figure.

c. Repeat this several times.

d. The end of the steel bar at which south pole of the magnet leaves become the north pole. The end of the steel bar at which the north pole of the magnet leaves becomes the south pole.

Electrical method

a. Keep the steel bar to be magnetized inside a long coil of insulated copper wire.

b. Pass strong direct current through the coil for some time.

c. The specimen of steel bar will get magnetized.

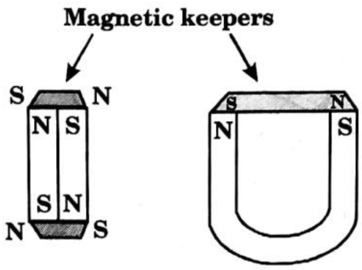
d. The end at which current enters in an anticlockwise direction will become the north pole and the other end becomes the south pole.

METHODS OF DEMAGNETISATION

The process used for destroying the magnetism of a magnet is called demagnetisation. Some of the methods of demagnetisation are rough handling, heating the magnet, by passing high frequency electric current.

Magnetic Keepers

A magnet tends to become weaker with age owing to self–demagnetisation due to poles at the ends which tend to neutralise each other. However, by using pieces of soft iron called keepers, the poles at the ends are neutralised and consequently the demagnetising effect disappears and the magnet can retain its magnetism for a longer period.



MAGNETIC LINES OF FORCE

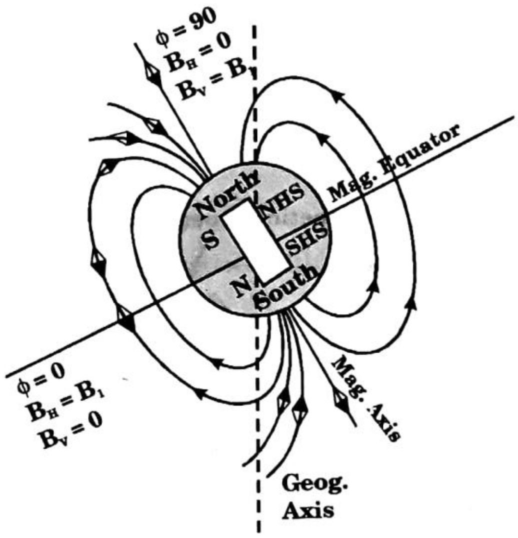
The space around a magnet where its influence can be felt is called the magnetic field. Line of force is an imaginary line along which an isolated north pole kept in a magnetic field tends to move.

Properties of lines of force

1. They are closed, continuous curves.
2. Magnetic lines of force start at the North pole and end at the South pole outside the magnet. Inside the magnet, the lines of force move from the South pole to the North pole.
3. Two lines of force can never meet each other.
4. They are crowded near the poles.
5. The strength of the field is more where the lines of forces are crowded.
6. The lines of force have longitudinal tension and lateral pressure.
7. Magnetic lines of force per unit area gives the intensity of the magnetic field at a point.

TERRESTRIAL MAGNETISM OR EARTH'S MAGNETISM

The study of earth's magnetic field is known as terrestrial magnetism. The earth behaves as a magnetic dipole inclined at a small angle (11.5°) to the earth's axis of rotation with its south pole pointing north.

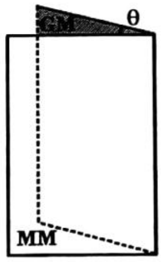


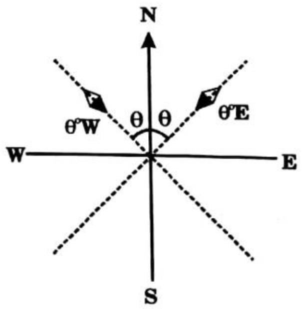
Elements of earth's magnetism

The magnetism of earth completely specified by elements of earth's magnetism viz., angle of dip, declination and horizontal component of earth's magnetic field.

DECLINATION (θ)

At a given place the angle between the geographical meridian and the magnetic meridian is called declination.



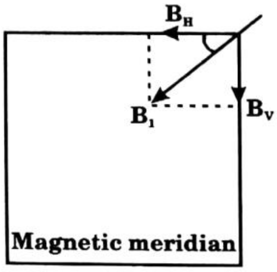


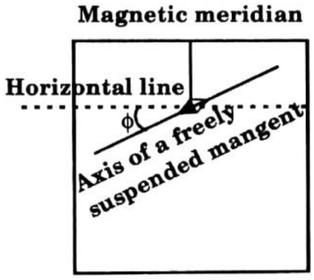
ANGLE OF DIP (φ)

It is the angle which the direction of resultant intensity of earth's magnetic field subtends with horizontal line in magnetic meridian at the given place.

Horizontal component of earth's magnetic field (B_H)

At a given place it is defined as the component of earth's meridian field along the horizontal in the magnetic meridian.





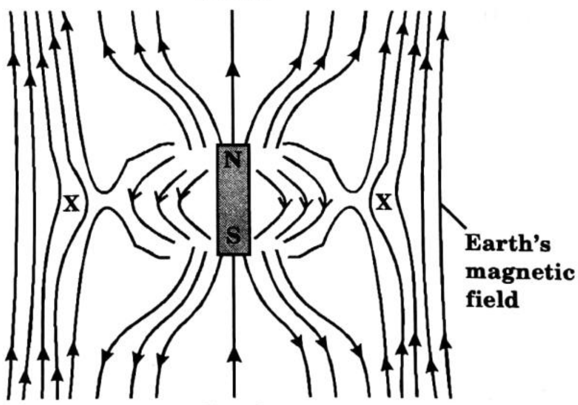
Dip = ϕ

NEUTRAL POINTS

A neutral point is the point at which the resultant of the magnetic field due to magnet and the earth's magnetic field is zero.

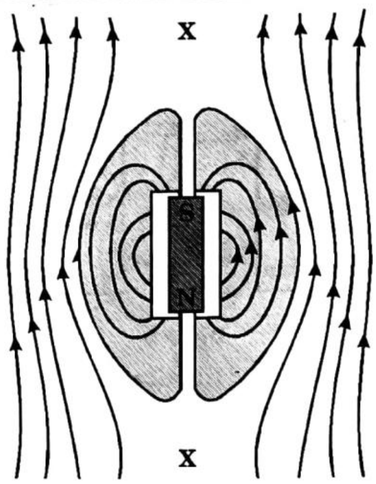
Magnet in the magnetic meridian with its north pole pointing north

When a magnet is placed in the magnetic meridian with its north pole pointing north then due to combined effect of the two fields, the horizontal component of the earth's magnetic field (B_H) and the field produced by the magnet. The neutral points for a bar magnet placed with its axis in the magnetic meridian and N–pole pointing towards the magnetic north is situated in the east–west direction (i.e., on the horizontal line).



Magnet in the magnetic meridian with its south pole pointing north

When a magnet is placed in the magnetic meridian with its south pole pointing north then due to combined effect of the two fields, the horizontal component of the earth's magnetic field (B_H) and the field produced by the magnet. The neutral points for a bar magnet placed with its axis in the magnetic meridian and S–pole pointing towards the magnetic north is situated in the equatorial line.



USES OF MAGNETS

1. The directive property of magnets is used in the construction of a magnetic needle and magnetic compass.
2. Permanent magnets are used in dynamos, electric motors, generators, electron accelerators, door locks etc.,
3. Electromagnets are used widely in electric bells, electric cranes, tape recorders, speakers etc.
4. Magnets are used in separating iron particles from solid mixtures using the method of magnetic separation.

INVERSE SQUARE LAW OF MAGNETISM

Force of attraction or repulsion between the two poles is found to be directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them.

$$F \propto \frac{m_1 m_2}{r^2}$$

$$F = \frac{k m_1 m_2}{r^2}$$

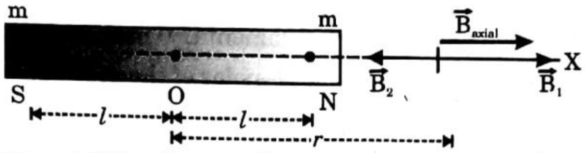
In SI system, $k = \frac{\mu_\circ}{4\pi} = 10^{-7}$ wb $A^{-1}m^{-1}$

Where $\mu_\circ$ = absolute permeability of free space

$$\therefore \; F = \frac{\mu_\circ}{4\pi} \times \frac{m_1 m_2}{r^2}$$

$$F = 10^{-7} \frac{m_1 m_2}{r^2}$$

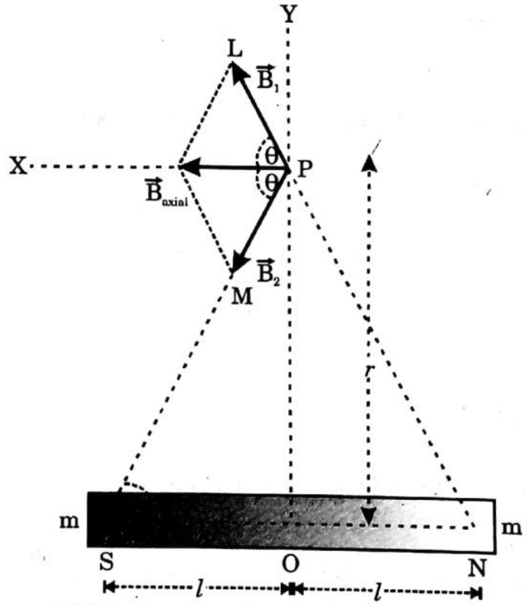
MAGNETIC FIELD ON AXIAL LINE OF A BAR MAGNET



Consider a bar magnet NS, whose each pole is of strength m. Let $2l$ be magnetic length of the magnet and O be its centre. Let P be a point on the axial linen of the magnet at a distance r from the centre O the magnet.

$$\overrightarrow{B_{axial}} = \frac{\mu_o}{4\pi} \times \frac{2\vec{M}r}{\left(r^2 - l^2\right)^2}$$

MAGNETIC FIELD ON EQUITORIAL LINE OF A BAR MAGNET



Consider a bar magnet NS, whose each pole is of strength m. Let 2 l be the magnetic length of the bar magnetic and O be its centre. Let be a point on the equatorial line of the magnet at a distance r from the centre of the magnet.

$$\overrightarrow{B_{equi}} = \frac{\mu_o}{4\pi} \times \frac{\vec{M}}{\left(r^2 + l^2\right)^{3/2}}$$

When bar magnet is very small length for a bar magnet of very small length $l << r$, l^2 can be neglected in comparison to r^2 in equation Therefore, for a very short **bar magnet**,

$$\overrightarrow{B_{equi}} = \frac{\mu_o}{4\pi} \times \frac{\vec{M}}{r^3}$$

EWING'S MOLECULAR THEORY

According to Ewing, the microscopic constituent is a molecule. Every molecule of a magnetic substance behaves as a tiny (elementary) magnet called molecular magnet.

When the iron bar is magnetised all the N–poles of the individual molecules align in one direction and all the S–poles in the opposite direction.

Repetition of the process of magnetisation only allows the maximum alignment among the molecular magnets. This means, the magnetisation of the iron – bar cannot be increased further. This limit of magnetisation of a substance is called "magnetic saturation".

When the magnetised iron – bar is cut into number of smaller and smaller pieces, each piece continues to act as a magnet.

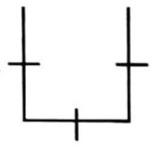
Magnetic poles always exist in pairs.

Magnetism of a magnet can be destroyed by tapering, hammering, heating etc.,

SOLVED EXAMPLES

Example 1

A straight magnetised wire of magnetic moment 'M' is bent as shown. Find final magnetic moment.



Solution :

Given, $M = m \times 2l$

On bending magnet as shown length of each side $= \frac{2l}{3}$

The distance between two poles is length of each side i.e. $\frac{2l}{3}$

$\therefore$ New magnetic moment $M^{I} = m \times \frac{2l}{3} = \frac{M}{3}$

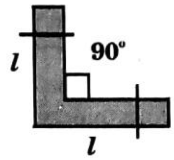
Example 2

A magnetised wire of magnetic moment M is bent at the middle and two parts are at an angle of 90°. Find resultant magnetic moment.

Solution :

Let $M = m \times 2l$

On bending the magnetised wire will be as shown.

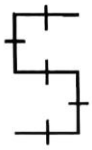


Then, new magnetic length $(2l)' = (2l)' = \sqrt{l^2 + l^2} = \sqrt{2}l$

New magnetic moment $(M)' = m(2l) = m(\sqrt{2}l) \times \frac{2}{2} = \frac{M}{\sqrt{2}}$

Example 3

A straight magnetised wire of magnetic moment 'M' is bent into shape as shown. Find final magnetic moment.



Solution :

Given, $M = m \times 2l$

each side is $\left(\frac{2l}{5}\right)$

The dotted line shown gives the magnet length of this shape $(2l)'$

$$\therefore 2l' = \sqrt{\left(\frac{2l}{5}\right)^2 + \left(\frac{4l}{5}\right)^2} = \sqrt{\frac{20l^2}{25}} = \frac{2l}{5}\sqrt{5}$$

$\therefore$ Final magnetic moment, $M^{|} = m \times 2l' = m \times \frac{2l}{5}\sqrt{5}$

$$M^{|} = \frac{M}{\sqrt{5}}$$

Example 4

A straight magnetised wire of magnetic moment 'M' is bent as shown. Find resultant magnetic moment in each case.

Solution :

Let $M = m \times 2l$

When it is a straight wire on bending as shown in figure it forms equal areas of circle. Let r be the radius of each are then new magnetic length = (2 r) 4 = 8 r ---------------- (1)

From figure, $2l = 4$ (Circumference of each semicircle)

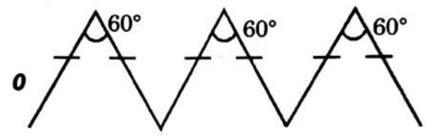
$$2l = 4(\pi r) \text{ ----------- } (2)$$

From (1) and (2), $8r = \frac{4l}{\pi}$

$$M' = m \times 8r = m \times \frac{4l}{\pi} = \frac{2M}{\pi}$$

Example 5

A thin straight magnetised wire of magnetic moment 'M' is bent as shown. Find resultant magnetic moment.



Solution :

Let $M = m \times 2l$

On bending m value remains same.

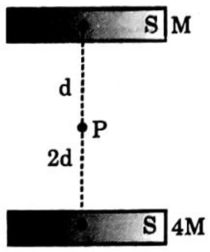
length of each side (s) = $\frac{2l}{6}$

New magnetic length $(l_1) = 3(s) = \frac{3}{6}(2l) = \frac{2l}{2}$

New magnetic moment $M^{|} = m \times l^{|} = m \times \left(\frac{2l}{2}\right) = \frac{M}{2}$

Example 6

Two short bar magnets of magnetic moments M, 4M are arranged as shown. Find magnetic induction at the point 'p'. Also, find magnetic induction at the same point if poles of one magnet are reversed.



Solution :

At P, $B_{\text{due to upper magnet}}(B_1) = \dfrac{\mu_o M}{4\pi d^3}$

$B_{\text{due to low magnet}}(B_2) = \dfrac{\mu_o 4M}{4\pi d^3}$

Since both B_1, B_2 are in same direction.

$B_R = B_1 + B_2$

$$= \frac{\mu_o M}{4\pi d^3} + \frac{\mu_o 4M}{4\pi d^3} = \frac{5\mu_o M}{4\pi d^3}$$

If poles of magnets are reversed.

Then $B_{\text{due to upper magnet}}(B_1) = \dfrac{\mu_o M}{4\pi d^3}$

$B_{\text{due to low magnet}}(B_2) = \dfrac{\mu_o 4M}{4\pi d^3}$

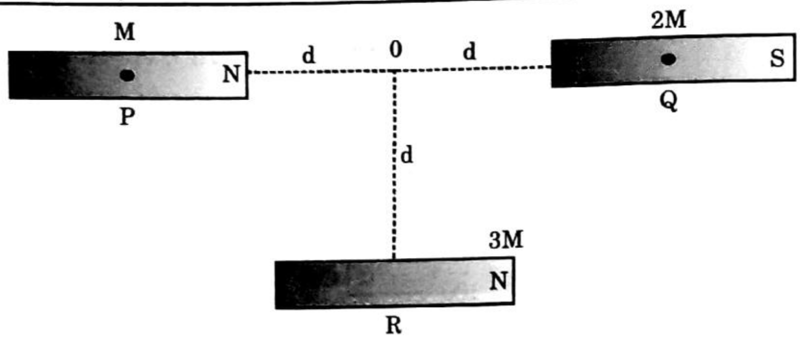
But B_1, B_2 are in opposite direction.

Hence, $B_R = B_2 - B_1$ $(B_2 > B_1)$

$$\frac{\mu_o 4M}{4\pi d^3} - \frac{\mu_o M}{4\pi d^3} = \frac{3\mu_o M}{4\pi d^3}$$

Example 7

Three short bar magnets are arranged as shown. Find resultant magnetic induction at the point θ.



Solution :

The three magnetic inductions at the point '0' are shown in the diagram (b). The resultant magnetic induction $B = B_R + B_Q - B_P$.

So $B = \frac{\mu_0}{4\pi}\frac{3M}{d^3} + \frac{\mu_0}{4\pi}\frac{2(2M)}{d^3} - \frac{\mu_0}{4\pi}\frac{2M}{d^3} = \frac{\mu_0}{4\pi}\frac{5M}{d^3}$

Example 8

A bar magnet of magnetic moment M and pole strength 'm' is cut into 100 similar pieces parallel to the magnetic axis and each piece is cut into 200 similar pieces perpendicular to the magnetic axis. Find magnetic moment similar pieces perpendicular to the magnetic axis. Find magnetic moment and pole strength of smallest piece.

Solution :

Magnetic moment of the magnet decrease when it is cut parallel to the magnetic axis and also perpendicular to the magnetic axis whereas magnetic pole strength decreases only when it is cut parallel to the magnetic axis.

So, magnetic moment of smallest piece $\frac{M}{100 \times 200} = \frac{M}{2 \times 10^4}$

magnetic pole strength of smallest piece $\frac{m}{100}$

Example 9

Two magnetic monopoles are kept apart by certain distance and magnetic force acting is 'F'. If pole strength of one pole is increased by 100 % and another is increased by 100 %, by what percentage distance between them be increased so that magnetic force acting will remain to be 'F'.

Solution :

Coulomb's law $F = \frac{\mu_\circ}{4\pi}\frac{m_1 m_2}{d^2}$

after increase of pole strengths, the final values are

$$m_1' = m_1 + \frac{100}{100}m_1 = 2m_1 ; m_2' = m_2 + \frac{100}{100}m_2 = 2m_2$$

So, $F = \frac{\mu_\circ}{4\pi}\frac{m_1 m_2}{d^2} = \frac{\mu_\circ}{4\pi}\frac{2m_1 \times 2m_2}{d_1^2}$

on simplifying we get

$d_1 = 2d$

so, percentage increase in distance is $\frac{d_1 - d}{d} \times 100 = 100\%$

Example 10

A bar magnet of length of 0.1 m has a pole strength of 50 A m. Calculate the magnetic field at distance of 0.2 m from its centre on (i) its axial line and (ii) its equatorial line.

Solution :

Here, m = 50 A m ; r = 0.2 m; 2 l = 0.1 m or l = 0.05 m

Therefore, M = m (2 l) = 50 × 0.1 = 5 A m^2

(i) $B_{axial} = \frac{\mu_\circ}{4\pi} \times \frac{2Mr}{(r^2 - l^2)^2}$

$$= \frac{10^{-7} \times 2 \times 5 \times 0.2}{(0.2^2 - 0.05^2)^2} \quad = \frac{10^{-7} \times 2 \times 5 \times 0.2}{(0.0375)^2}$$

(ii) $B_{equi} = \frac{\mu_\circ}{4\pi} \times \frac{M}{(r^2 - l^2)^{3/2}}$

$$\frac{10^{-7} \times 5}{(0.2^2 + 0.05^2)^{3/2}} \quad = \frac{10^{-7} \times 5}{(0.0425)^{3/2}} \quad = \frac{5 \times 10^{-7}}{0.00876}$$

CONCEPT MAP

MAGNETISM

Magnets
The objects which have property of attracting certain substances like iron

Properties of Magnets
- Attractive property
- Directive property
- Like poles repel and unlike poles attracts
- Poles always exist in pairs

Types of Magnets
- Natural magnets
- Artificial magnets
  - Temporary magnets
  - Permanent magnets

Inverse square law of magnetism: The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them and acts along the line joining the poles. $F = k\frac{m_1 m_2}{r^2}$

Methods of Magnetisation
- Single touch method
- Double touch method
- Electrical Method

Magnetic lines of force: The path taken by a unit north pole if it is free to move

The Earth as Magnet: The Earth behaves like a huge magnet with its north pole near the geographic south pole and south pole near the geographic north pole.

Neutral point: A point at which the magnetic field induction (B_0) due to a bar-magnet is nullified by the horizontal component of earth's magnetic field induction.

- When N-pole of a bar-magnet points towards geographical N-pole of the earth, the two neutral points lie on the equatorial line of the bar-magnet.
- When S-pole of bar-magnet points towards the goegraphical N-pole of the earth, the two neutral points lie on the axial line of th bar-magnet.

Physical Quantities

Pole Strength: The ability of a pole of a magnet to attract or repel another magnetic pole.
Units:
SI: A-m
MKS: weber

Magnetic moment: Product of pole strength and magnetic length.
$M = m \times 2l$
Units: SI : A-m^2

Magnetic Inducton: The force experienced by a unit north pole placed at that point.
$B = \frac{\mu_0 m}{4\pi d^2}$ Tesla (SI) Gauss (CGS)

- On Axial line: $B_{axial} = \frac{\mu_0}{4\pi} \times \frac{2Mr}{(r^2 - l^2)^2}$
- On equatorial line: $B_{equi} = \frac{\mu_0}{4\pi} \times \frac{M}{(r^2 + l^2)^{3/2}}$

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. The south seeking and is called ___________ pole.
2. Magnetic moment is a vector quantity whose direction is from ___________ pole to ___________ pole.
3. The ___________ drawn at any point on the magnetic lines of force gives direction of magnetic field at that point.
4. At null point the resultant magnetic induction is ___________.
5. The shortest distance joining the magnetic poles of a magnet is known as ___________.
6. The value of μ_o is ___________.
7. Magnetic induction on the axial line due to a short bar magnet is ___________.
8. A unit magnetic pole is that pole which repels an identical pole at 1 metre distance with a force of ___________.
9. If the distance between two unlike poles is doubled then the force of attraction between them becomes ___________ times its original value.
10. The magnetic moment of bar magnet of length 12 cm of magnetic pole strength of 200 mA - m is ___________ A-m^2.
11. To protect an instrument from___________, it is put inside an iron box.
12. SI unit of magnetic induction is ___________.
13. ___________ of a magnet can never be separated.
14. If a bar magnet is cut into two equal parts along the magnetic axis, then the magnetic moment becomes ___________ of the original value.
15. The space around the magnet in which another magnetic pole placed experiences a magnetic force is ___________.

TRUE OR FALSE

16. Magnetic lines of force can never intersect.
17. Magnetic induction due to magnetic monopole is inversely proportional to cube of distance of the point.
18. Magnetic poles are only mathematical assumptions having no real existence.
19. Magnetic induction on the equatorial line of a bar magnet is in the direction of magnetic moment.
20. When a bar magnet is cut parallel to the magnetic axis its pole strength and magnetic moment decreases.
21. Magnetic induction due to a short bar magnet on its axial line is inversely proportional to cube of distance of the point.

22. The ratio of magnetic induction of magnetic field strength in a medium gives magnetic permeability.
23. When a straight magnetised wire of magnetic moment M is bent into a U shape such that all the parts are of equal lengths, then final magnetic moment is M/3.
24. At the magnetic poles of magnet, its attractive power is minimum.
25. The resultant magnetic field at the center of a bar magnet is zero.

MATCH THE FOLLOWING

26.

Column A	Column B
A. Magnetic induction	p. weber
B. Magnetic moment	q. tesla
C. Pole strength	r. H m^{-1}
D. Absolute permeability	s. newton
E. Magnetic force	t. A – m^2

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. The north pole of earth's magnet is near:
(A) geographic north (B) at the centre of earth
(C) geographic south (D) in any direction

2. The magnetic lines of force due to a bar magnet are:
(A) curved lines (B) curved closed loops
(C) concentric circles (D) parallel and straight

3. Choose the correct statement for the following:
(A) Magnetic lines give direction of magnetic field while electric field lines do not.
(B) Electric lines give direction of electric field while magnetic field lines do not.
(C) Electric lines of force are closed curves but not magnetic lines of force.
(D) Magnetic field lines are closed curves but electric field lines are not.

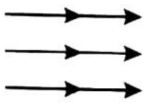
4. A straight magnetised wire of magnetic moment 10 A m^2 is bent into a semi circle. The decrease in the magnetic moment is:
(A) $10\left(\frac{\pi-2}{\pi}\right)$ A m^2 (B) $\frac{20}{\pi}$ A m^2 (C) $\frac{5}{\pi}$ A m^2 (D) 5π A m^2

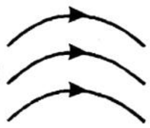
5. The magnetic induction due to a magnetic pole of pole strength 1500 A m at a distance of 50 cm is:
(A) 6×10^{-4} T (B) 12×10^{-4} T (C) 6×10^{-3} T (D) 12×10^{-3} T

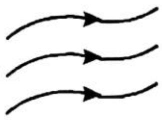
6. A magnetic induction due to a short bar magnetic of magnetic moment 5.4 A m^2 at a distance of 30 cm on the equatorial line is:
   (A) 2×10^{-4} T (B) 2×10^{-5} T (C) 3×10^{-5} T (D) 3×10^{-4} T
7. Two south poles each of pole strength 16 A m are placed at corners P, R of a square PQRS. The pole that should placed at 'Q' to make S as null point is:
   (A) south pole of pole strength 32 A m (B) south pole of pole strength $32\sqrt{2}$ A m
   (C) north pole of pole strength 32 A m (D) north pole of pole strength $32\sqrt{2}$ A m
8. A thin magnetised wire of length 10 cm has a magnetic moment of 0.4 A m^2 is bent such that there is a gap of 2 cm between its ends. Then final magnetic moment is:
   (A) 0.8 A m^2 (B) 0.02 A m^2 (C) 0.08 A m^2 (D) 0.01 A m^2
9. The distance between two magnetic poles is doubled and their pole–strength is also doubled. The force between them:
   (A) increases to four times (B) decreases by half
   (C) remains unchanged (D) increases to two times
10. Magnetic lines of force:
   (A) always intersect.
   (B) are closed curves.
   (C) tend to crowd far away from the poles of a magnet.
   (D) do not pass through vacuum.
11. Two short magnets placed along the same axis with their like poles facing each other will repel each other with a force which varies inversely as:
   (A) distance (B) square of distance
   (C) cube of distance (D) fourth power of distance
12. Earth's magnetic field always has a horizontal component except at:
   (A) magnetic equator (B) magnetic pole
   (C) geographical north pole (D) at an altitude of 45°
13. The angle of dip at a place on the earth gives:
   (A) the horizontal component of the earth's magnetic field.
   (B) the location of geographical meridian.
   (C) the vertical component of the earth's magnetic field.
   (D) the direction of the earth's magnetic field
14. The angle of dip at the magnetic equator is:
   (A) zero (B) 90° (C) 45° (D) 180°
15. The magnetic field of earth is due to:
   (A) magnetic dipole buried at the centre of the earth.
   (B) motion and distribution of some material in and outside the earth.
   (C) induction effect of the sun.
   (D) interaction of cosmic rays with the crust of the earth.

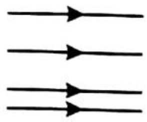
MULTIPLE ANSWER QUESTIONS

1. Which of the following figures depict non uniform magnetic field?

(A) 

(B) 

(C) 

(D) 

2. Choose the correct statement(s) from the following:

(A) Magnetic lines of force appear to converge or diverge at poles.

(B) Magnetic lines of force never intersect each other.

(C) On passing AC through a wire wound around a magnet its strength of magnetism enhances.

(D) A magnet attracts certain other substances through the phenomenon of magnetic induction.

3. Choose the correct statement(s) from the following:

(A) At a neutral point, there cannot be any lines of force.

(B) Magnetic lines of force exist inside every magnetised material.

(C) Soft iron pieces are used as magnetic keepers.

(D) The magnetic moment of a magnet decreases on bending it into a semicircle.

4. Which of the following are vector quantities?

(A) Magnetic moment (B) Magnetic permeability

(C) Magnetic induction (D) Magnetic pole strength

5. A magnet is placed in earth's magnetic field with south pole of the magnet pointing north. At the neutral point:

(A) the earth's magnetic field is zero

(B) the fields of the magnet and the earth are equal and in opposite direction.

(C) the magnet's magnetic field is zero.

(D) the net magnetic field is zero.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of statement of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** Basic difference between an electric lines of force and magnetic lines of force is that former is discontinuous and the latter is continuous or endless.
   Reason: No electric lines of force exist inside a charged body but magnetic lines do exist inside a magnet.
2. **Assertion:** At neutral point, a compass needle point out in any arbitrary direction,
   Reason: Magnetic field of earth is balanced by field due to magnets at the neutral points.
3. **Assertion:** There are two neutral points on a horizontal board when a magnet is held vertically on the board.
   Reason: At the neutral point the net magnetic field due to the magnetic and magnetic field of the earth is zero
4. **Assertion:** Poles of a magnet can never be separated :
   Reason: Since each atom of a magnetic material magnet in itself.
5. **Assertion:** To protect any instrument from external magnetic field, it is put inside an iron body.
   Reason: Iron is a magnetic substance.

PARAGRAPH QUESTIONS

Passage - I

I. A straight magnetised wire of magnetic moment 'M' is bent so that it subtends an angle 'θ' at the centre of the curvature. As shown below:

(i) Find the resultant magnetic moment when $\theta = 60°$.

(A) M/π (B) $2M/\pi$ (C) $3M/\pi$ (D) $\pi/2M$

(ii) Find the resultant magnetic moment when $\theta = 240°$.

(A) $M/4\pi$ (B) $2M/\pi$ (C) $3M/\pi$ (D) $3M/4\pi$

(iii) If the value of θ increases then the magnetic moment value.

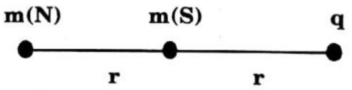
(A) increases (B) decreases

(C) remains same (D) cannot be said

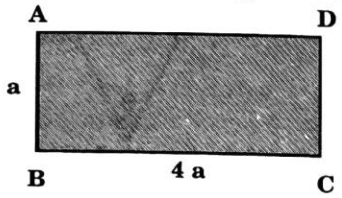
SECTION – B

NUMERICAL PROBLEMS

1. As two points separated by a distance of 15 cm, the ratio of magnetic induction on its axial line is 512 : 125 find distance of the magnet from the first point. (Assume short bar magnet)
2. A magnetised steel wire 31.4 cm long has a pole strength of 0.2 A m. It is then bent in the form of a semicircle. Calculate the magnetic moment of this needle.
3. Two magnetic monopoles are kept apart by a distance 'd'. The magnetic force acting on each pole is 'F'. How much percentage must the distance between the magnetic poles be changed so that the magnetic force acting on each pole be 4F.
4. The magnetic induction due to short bar magnet on its axial line at a distance 'd' is 'B'. What is the magnetic induction due to the same bar magnet on the same line at a distance (a) d/4 ? (b) 4d/5 ?
5. The north poles of pole strengths, m, 9 m are kept apart by certain distance 'd'. Find distance of null point from larger pole.
6. Two magnetic poles each of magnetic pole strength 16 A m are placed at a distance of 2 m apart. Find magnetic force acting on each pole.
7. A bar magnet of magnetic moment 'M' has a magnetic length '2 d'. Find magnetic induction on its equatorial line at a distance '$\sqrt{13}d$'.
8. Magnetic monopoles are arranged as shown. Find resultant magnetic induction at point 'q'.



9. A rectangle has sides of lengths 6 cm and 8 cm. Two magnetic poles each of pole strength 'm' are placed at the ends of one side of smaller length and magnetic force acting between them is 'F'. If they are moved to new positions of same rectangle so that they are diagonally opposite. Find final force acting on each pole.
10. A rectangle with its dimensions is as shown. A magnetic mono pole of pole strength 'm' is placed at the point 'A' and another pole of pole strength '5m' is placed at the point 'B'. The magnetic force acting between them is 'F'. If magnetic pole at the point 'B' is moved to the point 'C', find final magnetic force acting between them.



11. A curved magnet which occupies $\frac{1}{6}$th of a circle of magnetic moment $\frac{30}{\pi}$ A m² is made straight. Find final magnetic moment.
12. If ratio of magnetic induction on the axial line of a long magnet at distances 20 cm and 30 cm is 128 : 27. Find length of the magnet.

CONCEPTUAL QUESTIONS

1. Two identical looking iron bars, A and B are given, one of which is definitely known to be magnetised. How would one ascertain, whether or not both are magnetised ? If only one is magnetised, how does one ascertain which one ?
2. Magnetic lines of force should better be called as field lines. Explain.
3. The earth's core is known to contain iron, but geologists do not regard this as a source of magnetic field. Why ?
4. How does the knowledge of declination at a place help in navigation ?
5. What would be the direction of a compass needle, when placed exactly at the geo-magnetic north pole ?
6. Which direction would a compass point show, if located right on the geomagnetic north or south pole ?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. A bar magnet of magnetic moment 80 units is cut into two halves of equal length, the magnetic moment of each half will be:

   (A) 80 units (B) 40 units (C) 60 units (D) 20 units

2. All magnetic materials lose their magnetic properties when:

   (A) dipped in water (B) dipped in oil
   (C) brought near a piece of iron (D) strongly heated

3. Tesla is the unit of:

   (A) magnetic flux (B) magnetic intensity
   (C) magnetic induction (D) magnetic moment

4. If r be the distance of a point on the axis of a bar magnet from its centre, the magnetic field at this point is proportional to:

   (A) $(1/r)$ (B) $(1/r^2)$ (C) $(1/r^3)$ (D) $(1/r^4)$

5. The magnetic induction at magnetic poles is along:

   (A) vertical only (B) horizontal only
   (C) both (A) and (B) (D) neither (A) and (B)

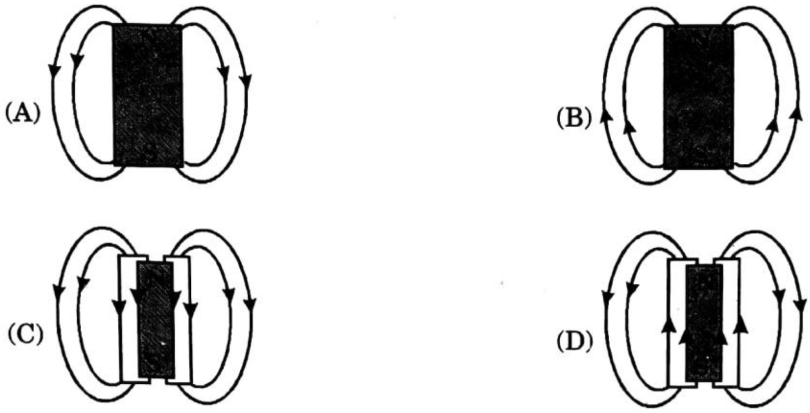
6. A dip needle in a plane perpendicular to magnetic meridian will be:

   (A) vertical (B) horizontal
   (C) at an angle of 4° to the horizontal (D) at an angle of dip to the horizontal

7. Isogonic lines on a magnetic map will have:

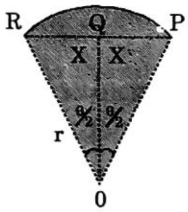
   (A) zero angle of dip (B) zero angle of declination
   (C) the same angle of dip (D) the same angle of declination

8. The magnetic field lines due to a bar magnet are correctly shown is:

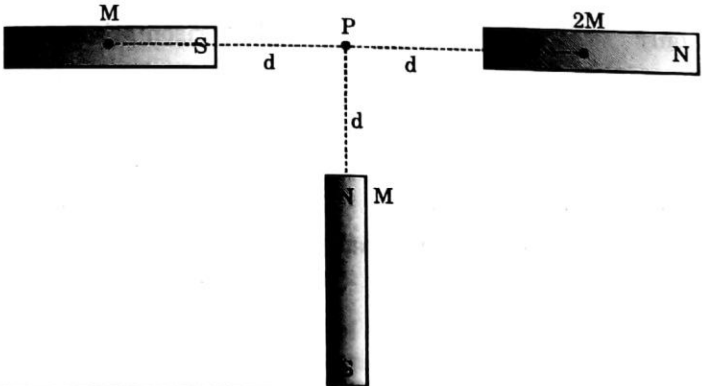


BRAIN NURTURES

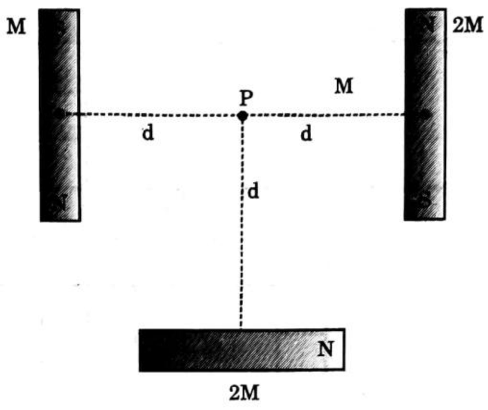
1. A straight magnetised wire of magnetic moment 'M; is bent so that it subtends an angle 'θ' at the centre of the curvature. Find resultant magnetic moment.



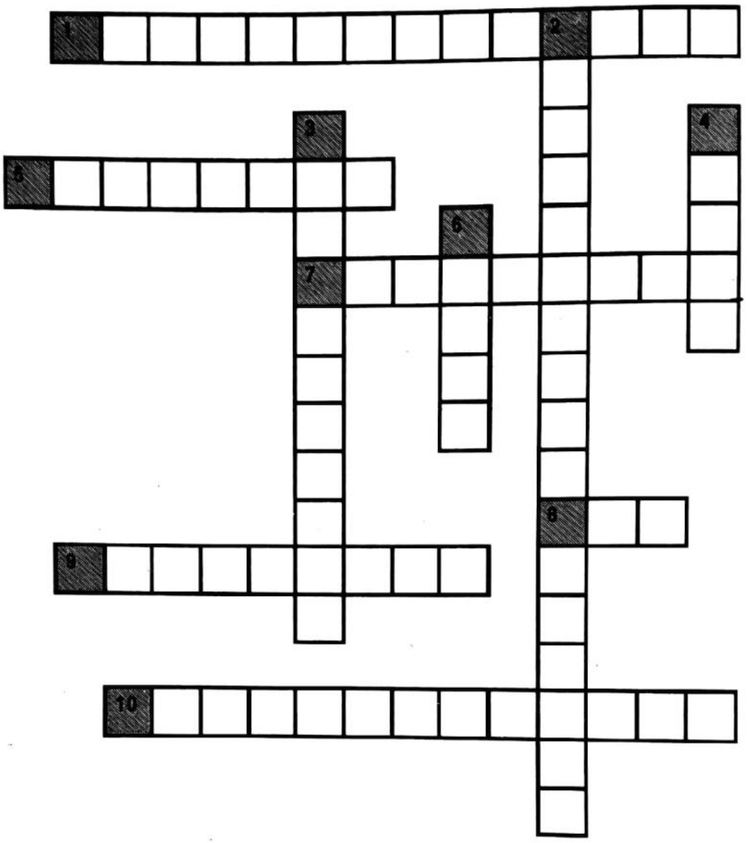
2. Two identical thin bar magnets, each of length L and pole - strength m are placed at right angles to each other, with the N-pole of one touching the south pole of the other. Find magnetic moment of the system.
3. If a compass needle be placed on the magnetic north pole of the earth, then how does it behave ? If a dip needle be placed at the same place, then what will be its behaviour ?
4. Two short bar magnets are arranged as shown. Find resultant magnetic induction at the point 'P' Also, find resultant magnetic induction at the same point 'P' if poles of a magnet of higher magnetic moment are reversed.



5. Three short bar magnets of different magnetic moments are as shown. Find resultant magnetic induction at the point 'P'.



CROSSWORD PUZZLE



ACROSS

1 Product of pole strength and magnetic length

5 Magnetic poles can never be

7 Natural magnet

8 One of the components of earth's magnetic field

9 A point at which the resultant of the magnetic field due to a magnet and the earth magnetic field is zero

10 Space around a magnet where its influence can be felt

DOWN

2 Force experienced by a unit north pole placed at that point

3 The angle between geographic and magnetic meridian

4 MKS unit of pole strength

6 SI unit of magnetic induction

ANSWERS

CHAPTER - 1 MEASUREMENT

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. length
2. joule
3. 25
4. Cd
5. weight
6. 1 mm
7. positive
8. 8.6×10^6
9. 4.6 cm
10. standard
11. 120
12. 4680
13. 200.9
14. 0.02
15. time periods
16. unit
17. 1000
18. zero
19. 0.01 mm
20. 5

True or False

21. True
22. False
23. False
24. True
25. True
26. False
27. True
28. False
29. False
30. False
31. True
32. True
33. False
34. True
35. False

Match the following

36. A – r, B – s, C – q, D – p, E – t

37. A – t, B – s, C – q, D – p, E – r

Multiple Choice Questions

1. B 2. C 3. B 4. A 5. A 6. B 7. B 8. D 9. D 10. D

11. D 12. C 13. A 14. C 15.B 16. A 17. C 18. A 19. A 20. B

Multiple Answer Questions

1. A, B, D 2. A, B, C 3. A, B, C 4. A, B, C 5. A, C, D

Assertion and Reasoning

1. A 2. E 3. A 4. C 5. A 6. A 7. A 8. A 9. C 10. D

Paragraph Questions

(i) A (ii) C (iii) D (iv) B

SECTION – B

Numerical Problems

1. 64 : 9 2. 4.95 mm 3. 68 : 5 4. 0.01 mm 5. 6.5 cm
6. 49.7 cm 7. 100 8. 0.025 mm 9. 8 : 9 10. 1461 days

Conceptual

1. By winding over the circumference of rod and finding its length. 2. $u_2 = \sqrt{\frac{A}{6}}\,u_1$
3. Yes, (3/N) MSD 4. Accuracy decreases 5. Yes 6. No

SECTION – C

Previous Contest Questions

1. A 2. A 3. B 4. B 5. C 6. D 7. A 8. C 9. D 10. C

Brain Nurtures

1. 3.51 cm 2. 5.87 cm 3. 0.8 mm 4. 1.4 mm 5. 140.56 mm^3
6. 43.2 7. 10^4 m

CHAPTER - 2 MOTION IN ONE DIMENSION

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. equal 2. equal to 3. total displacement
4. less than or equal to 5. at rest 6. displacement
7. uniform 8. $\sqrt{\frac{2h}{g}}$ 9. 4H
10. $\sqrt{h_1} : \sqrt{h_2}$ 11. time of flight 12. 90°
13. 20 14. 7 15. 2 m s^{-2}
16. 1 : 1 17. 30 18. acceleration
19. square of the time 20. 1 : 2

True or False

21. False 22. True 23. True 24. False 25. False
26. False 27. True 28. False 29. False 30. True
31. False 32. True 33. False 34. True 35. False

Match the following

36. A – s, B – r, C – t, D – q, E – p
37. A – t, B – q, C – s, D – p, E – r

Multiple Choice Questions

1. B 2. B 3. D 4. C 5. B 6. B 7. A 8. A 9. D 10. C
11. C 12. C 13. C 14. C 15. A 16. B 17. C 18. C 19. B 20. B

Multiple Answer Questions

1. A, C, D 2. A, C 3. A, B 4. B, C, D 5. A, C
6. A, B 7. A, B, D 8. C, D 9. A, B 10. A, D

Assertion and Reasoning

1. A 2. A 3. C 4. D 5. B 6. E 7. A 8. C 9. A 10. E

Paragraph Questions

(i) C (ii) D (iii) D

SECTION – B

Numerical Problems

1. (a) $\frac{\sqrt{2}}{225}$ cm s^{-1} (b) $\frac{1}{225}$ cm s^{-1} 2. 6 m s^{-2}, 7 m s^{-1} 3. 17 : 13
4. 27 : 13 5. 300% 6. 56 m 7. 25 : 49
8. 20 m 9. 125 m 10. 65 m s^{-1} 11. 5 s, 122.5 m
12. 4 s 13. 1 : 9 14. 3.2 m s^{-2}, 40 m; 5 m s^{-2}, 60 m 15. 3 m s^{-1}

Conceptual

1. Yes, straight line 2. No 3. Yes 4. Yes 5. Yes 6 No 7. Yes
8. $\frac{2V_o(V_1+V_2)}{(2V_o+V_1+V_2)}$

SECTION – C

Previous Contest Questions

1. A 2. C 3. C 4. C 5. C 6. B 7. C 8. B 9. B 10. B
11. C 12. A 13. B 14. B 15. A

Brain Nurtures

1. X, uniform speed 2. 45 ms 3. 72V/43 4. $h_1 = h_2$ 5. 1.024 km

CHAPTER - 3 | NEWTON'S LAWS OF MOTION

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. forwards 2. tangentially 3. zero
4. same 5. kg m s^{-1} 6. different
7. mass 8. 5 kg 9. law of conservation of linear momentum
10. inertia 11. motion 12. force
13. backwards 14. reduce to half 15. acceleration

True or False

16. True 17. True 18. False 19. True 20. False
21. True 22. False 23. True 24. True 25. True

Match the following

26. A – s, B – p, C – t, D – r, E – q

Multiple Choice Questions

1. A 2. A 3. B 4. B 5. B 6. B 7. B 8. D 9. A 10. C
11. D 12. C 13. D 14. D 15. C 16. A 17. C 18. A 19. A 20. B

Multiple Answer Questions

1. A, B, C 2. A,B, D 3. A, B 4. A, B 5. A, B, C, D

Assertion and Reasoning

1. D 2. C 3. C 4. A 5. A 6. D

Paragraph Questions

(i) B (ii) A (iii) D

SECTION – B

Numerical Problems

1. $4\ cm\ s^{-2}$
2. $6 \times 10^{-3}\ m\ s^{-1}$
3. (i) $500\ m\ s^{-2}$ (ii) 0.02 s (iii) –10 N s
4. 78 N
5. $4.8\ m\ s^{-2}$
6. 60 N
7. 8 F
8. $16\ m\ s^{-1}$
9. 10 N s
10. 9000 N
11. $2.4\ m\ s^{-2}$
12. 400 N
13. $\left[\dfrac{m_2^2 v^2}{(m_1+m_2)2s}\right]N$
14. $6\sqrt{2}\ m\ s^{-1}$
15. 4

Conceptual

1. Reduces the impact of impulsive force
2. $a \propto \dfrac{1}{m}$
3. $\sqrt{2}$ times the initial momentum
4. horse cannot push in backward direction
5. momentum adds to the effort
6. Table tennis ball is very small
7. Increases the time of impact
8. $a = -\dfrac{F_1}{m}$

SECTION – C

Previous Contest Questions

1. C 2. A 3. B 4. C 5. D 6. C 7. C 8. A 9. D 10. A

Brain Nurtures

1. Due to inertia
2. $3\ kg\ m\ s^{-1}$
3. $\left(-\dfrac{m_1 a}{m_2}\right) m\ s^{-2}$
4. (mxy) N
5. $\left(\dfrac{F}{aV}\right) kg\ m^{-3}$
6. 2 : 3

CHAPTER - 4 WORK, POWER AND ENERGY

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. Kinetic
2. easier
3. $10^7 : 1$
4. 4
5. 1000
6. nine
7. mechanical energy
8. $erg\ s^{-1}$
9. 1 J
10. kgwt–m
11. gravity
12. not be zero
13. potential
14. KE, momentum, energy
15. 1.6×10^{-19}

True or False

16. True 17. True 18. False 19. False 20. True
21. True 22. False 23. False 24. True 25. True

Match the following

26. A – t, B – s, C – r, D – p, E – p

Multiple Choice Questions

1. A 2. D 3. D 4. C 5. D 6. A 7. C 8. B 9. B 10. A
11. C 12. B 13. B 14. B 15. D

Multiple Answer Questions

1. A, B, D 2. A, B, C, D 3. A, B, D 4. A, C 5. A, C, D

Assertion and Reasoning

1. A 2. A 3. B 4. A 5. E 6. A

Paragraph Questions

(i) A (ii) B (iii) A

SECTION – B

Numerical Problems

1. 15 kJ 2. 12 J 3. 36 kilolitre 4. 10^{-2} J 5. 125%
6. 100% 7. 0.5 8. 10 m 9. 1 : 2 10. 1920.8 J
11. 19.6 m s^{-1} 12. 1.37×10^7 J 13. 150 N

Conceptual

1. 1 : 2 2. $V\left[\frac{1-\sqrt{n}}{\sqrt{n}}\right]$ 3. $m_2 : m_1$ 4. 2 m s^{-1} 5. 1 : 9

6. Both comes to rest in same time

SECTION – C

Previous Contest Questions

1. C 2. A 3. C 4. B 5. D 6. C 7. C 8. A 9. C 10. A

Brain Nurtures

1. 6.12 N 2. 784 J 3. 1 : 2 4. 300% 5. $(\sqrt{2}-1)$times
6. 2 : 1 7. 8 : 1 8. – 243375 J 9. 1.568 J 10. 1.84 m

CHAPTER - 5 | TURNING FORCES AND EQUILIBRIUM

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. Torque 2. N m 3. 5 N
4. Centre of gravity 5. Geometric centre 6. $10^7 : 1$
7. (2, 2) 8. Centroid 9. Object B 10. inside

True or False

11. False 12. False 13. True 14. True 15. False
16. True 17. True 18. False 19. True 20. False

Match the following

21. A – q, B – r, C – t, D – s, E – p

Multiple Choice Questions

1. A 2. A 3. B 4. B 5. D 6. D 7. D 8. C 9. D 10. B
11. B 12. C 13. A 14. C 15. D

Multiple Answer Questions

1. A, B, C, D 2. A, C, D 3. A, B, D 4. A, B, C 5. A, B, D

Assertion and Reasoning

1. B 2. D 3. C 4. A 5. C 6. A

Paragraph Questions

(i) B (ii) C

SECTION – B

Numerical Problems

1. 1000 dyne cm
2. 37500 dyne cm
3. 35 dyne
4. 0.5 m
5. 25 cm from mid point
6. At 3.2, on right side
7. 3000 N
8. 2.5 m from the extreme
9. 64.28 cm from the begining
10. 64×10^3 dyne–cm
11. 0.8 m
12. 0.5 m

Conceptual

1. horizontal direction
2. $\frac{2F_1}{x}$
3. 2^{nd} lever
4. $\frac{3h}{2}$ cm
5. F_2 – anticlock wise moment, 1 : 3
6. (i) rotational equilibrium, no effect
   (ii) anticlockwise, $\Sigma\tau = +ve$; clockwise, $\Sigma\tau = -ve$

SECTION – C

Previous Contest Questions

1. B 2. A 3. C 4. B 5. A 6. B

Brain Nurtures

1. (i) 2 N m (ii) 4 N m
2. (i) F_2 (ii) F_1 (iii) F_3 (iv) F_1 and F_2
3. (i) 0 (ii) 10 N m (iii) No effect
4. 52.5 gf
5. 50 gf cm
6. 20 cm

CHAPTER - 6 GRAVITATION

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. $\sqrt{dg} : 1$	2. third law	3. 0.5
4. elliptical	5. mass	6. 100 : 1
7. zero	8. 980	9. maximum
10. (R – d)	11. gravity	12. $\sqrt{6}$ F
13. centres	14. poles	15. independent

True or False

16. True	17. False	18. True	19. True	20. False
21. True	22. False	23. True	24. True	25. False

Match the following

26. A – q, B – s, C – p, D – t, E – r
27. A – s, B – r, C – t, D – q, E – p

Multiple Choice Questions

1. B	2. D	3. D	4. B	5. A	6. C	7. C	8. A	9. D	10. D
11. A	12. B	13. D	14. C	15. B	16. B	17. D	18. B	19. A	20. A

Multiple Answer Questions

1. A, B, D	2. A, C, D	3. A, B, C	4. B, C, D	5. B, D

Assertion and Reasoning

1. A	2. E	3. C	4. C	5. B	6. C	7. B	8. E	9. A	10. E

Paragraph Questions

(i) A	(ii) B	(iii) C

SECTION – B

Numerical Problems

1. 75%
2. 6.67×10^{-3} N
3. 1.86×10^{-44} N
4. (a) 1.5625 F (b) $\frac{4}{9}$ F
5. (a) 360 N (b) 625 N
6. 3.8×10^{7} m
7. 110 m
8. 3/5 R
9. (a) $R(\sqrt{2}-1)$ (b) R/2 (c) 9 R
10. 4 N
11. 1.67×10^{-7} N, 0.48×10^{3} N
12. $F' = \frac{R^2F}{(R+d)^2}$
13. 12 m

Conceptual Questions

1. $\sqrt[3]{2d}$
2. g value increases
3. X, Y/6
4. motion of the earth
5. one fourth of the present value
6. W = M × 9.8 N

SECTION – C

Previous Contest Questions

1. A	2. A	3. B	4. D	5. A
6. A	7. B	8. B	9. B	10. A
11. D	12. B	13. B	14. A	15. D

Brain Nurtures

1. 56 days
2. $\frac{3g}{4G\pi R}$
3. $\frac{5Gm^2}{16r^2}$, 0, $\frac{5Gm^2}{16r^2}$
4. in case (c)
5. g on hills is less
6. g_{moon} is less
7. $a_{apple} >> a_{earth}$
8. Initially decreases then becomes zero and again increases.

CHAPTER - 7 | FLUID PRESSURE

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. thrust
2. area of contact
3. dyne cm^{-2}
4. lateral pressure
5. also increases
6. different
7. pascal
8. atmospheric pressure
9. barometer

10. mercury
11. hydraulic pressure
12. buoyancy
13. an upthrust
14. Relative density of a substance
15. 8

True or False

16. False 17. False 18. True 19. True 20. True
21. False 22. True 23. True 24. False 25. True

Match the following

26. A – q, B – t, C – s, D – p, E – r

Multiple Choice Questions

1. A 2. A 3. D 4. B 5. D 6. B 7. B 8. B 9. D 10. B
11. C 12. B 13. D 14. A 15. A 16. C 17. C 18. C 19. A 20. A

Multiple Answer Questions

1. B, C 2. A, B 3. A, B, C 4. A, B, C 5. A, B, D

Assertion and Reasoning

1. A 2. C 3. A 4. A 5. A 6. B 7. A 8. D 9. A 10. A

Paragraph Questions

(i) B (ii) A (iii) A

SECTION – B

Numerical Problems

1. 0.97×10^4 N m^{-2}
2. 185 cm
3. 39200 N
4. 1.18 g
5. 41.34 cm
6. $\frac{6}{7} V \rho g$
7. 10 g
8. 492 kg
9. [2, 6]
10. (a) 78 kg (b) 1.5×10^4 N
11. 1.2
12. 1 g cm^{-3}
13. 12 N
14. 1 : 6
15. move up

Conceptual

1. darjeeling is at higher altitude
2. no change
3. to increase base area
4. weight of players act over a small area
5. greater difference in blood pressure and the atmospheric pressure
6. submerged volume to be same
7. difference in the upward and downward force 8. Float a block of iron on a beaker of mercury.
8. Yes, $d_l > d_{iron}$
9. Yes

SECTION – C

Previous Contest Questions

1. A 2. C 3. D 4.D 5.C
6. B 7. A 8. D 9. C 10. A

Brain Nurtures

1. $\frac{8d_1d_2}{[3d_2 + 5d_1]}$ 2. (a) $\frac{100}{3}$ cm, $\frac{50}{3}$ cm (b) 10 cm from bottom of the tank 3. Sink
4. 20 cm 5. 1953.12 kgwt, 63(approx) 6. depends on the volume of the object
7. Both the parts of homogenous object will sink 8. Yes

CHAPTER - 8 | HEAT

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. temperatures 2. kelvin 3. same
4. expansion 5. thermal expansion 6. 5/9
7. 574.25 8. 1 : 2 : 3 9. radiation
10. convection 11. expands 12. 9/5
13. increase 14. container 15. decreases

True or False

16. True 17. False 18. True 19. True 20. False
21. False 22. True 23. False 24. True 25. True

Match the following

26. A – q, B – s, C – t, D – r, E – p

Multiple Choice Questions

1. B 2. A 3. B 4. A 5. C 6. A 7. C 8. C 9. B 10. C
11. A 12. C 13. D 14. B 15. D

Multiple Answer Questions

1. A, C 2. A, B, D 3. A, B, C 4. A, B, C 5. A, B, C, D

Assertion and Reasoning

1. A 2. D 3. A 4. C 5. C

Paragraph Questions

(i) C (ii) A

SECTION – B

Numerical Problems

1. 50 °F 2. 55° 3. 273 °C 4. 108 °F, 60 K
5. 70° 6. 0.3864 cm 7. 1.2 mm 8. 14.17 cm (cu), 9.17 cm (steel)
9. 130.82 °C 10. 49.98 cm 11. 57.415 °C 12. 1.8×10^{-5} °C^{-1}
13. 110.8 °C 14. 13.48 g cm^{-3} 15. 0.0414

Conceptual

1. volume, radius 2. impurities effect BP and MP 3. air is a bad conductor
4. glass is a bad conductor 5. shining surfaces are bad radiators 6. increase in reading

SECTION – C

Previous Contest Questions

1. D 2. D 3. D 4. A 5. B 6. A 7. D 8. A 9. B 10. B
11. B 12. C

Brain Nurtures

1. 573 K 2. 5 °F
3. 80 °C, 170 °F 4. due to expansion
5. radius of the circle increases 6. 80 °C
7. different forms of heat lossess 8. $R = \dfrac{d}{(\alpha_B - \alpha_C)\Delta T}$

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. hertz	2. frequency	3. 130 cm
4. 300 Hz	5. longitudinal	6. 16.5 m – 16.5 mm
7. 100 m	8. frequency	9. less
10. poor quality	11. 819	12. in gases
13. multiple reflection	14. isothermal	15. reverberation

True or False

16. True	17. False	18. False	19. True	20. True
21. True	22. False	23. True	24. True	25. True
26. False	27. False	28. True	29. True	30. False

Match the following

31. A – r, B – s, C – p, D – q, E – t

Multiple Choice Questions

1. D	2. C	3. A	4. C	5. C	6. B	7. B	8. C	9. B	10. D
11. C	12. B	13. C	14. B	15. C	16. D				

Multiple Answer Questions

1. A, B	2. A, C, D	3. A, B	4. A, D	5. A, B, C

Assertion and Reasoning

1. A 2. A 3. C 4. A 5. E 6. A

Paragraph Questions

(i) C (ii) A (iii) D

SECTION – B

Numerical Problems

1. 198 m	2. 15 : 1	3. 65.18 K	4. 172.8 m	5. 160 m
6. 20	7. 3 times	8. $350\sqrt{3}\,\text{m s}^{-1}$	9. 0.25π	10. 550 kHz
11. 1328 m s^{-1}	12. 1.055	13. $3\lambda_{air}$	14. 0.944	

15. (a) 1.6×10^{-3} m (b) 6.8×10^{-3} m

Conceptual Questions

1. Sound propagates in a direction perpendicular at each point
2. 17.2 mm – 17. 2 m
3. 1020 m
4. Sound – mechanical wave, radio – EMwave
5. (a) medium need to be elastic (b) string is non stretchable

SECTION – C

Previous Contest Questions

1. C 2. D 3. A 4. A 5. B 6. D 7. C 8. C 9. D 10. A

Brain Nurtures

1. 164.9 m 2. 90 km, 120 m 3. The velocity of sound in a gas is independent of pressure
4. Independent of the frequency 5. same speed

CHAPTER - 10 | MAGNETISM

Summative Exercise

SECTION – A

Basic Practice

Fill in the blanks

1. south 2. i) south, ii) north 3. tangent 4. zero

5. magnetic length 6. $4\pi\times10^{-7}\ \mathrm{H\,m^{-1}}$ 7. $\frac{\mu_0\, 2M}{4\pi d^3}\ N(A-m)^{-1}$ 8. 10^{-7} N

9. 0.25 10. 0.024 A-m² 11. external magnetic field

12. tesla 13. poles 14. half 15. magnetic field

True or False

16. True 17. False 18. True 19. False 20. True
21. True 22. True 23. True 24. False 25. True

Match the following

26. A – q, B – t, C – p, D – r, E – s

Multiple Choice Questions

1. C 2. A 3. D 4. A 5. A 6. B 7. D 8. C 9. C 10. B
11. D 12. B 13. D 14. A 15. B

Multiple Answer Questions

1. B, C, D 2. A, B, D 3. A, B, C, D 4. A, C 5. B, D

Assertion and Reasoning

1. A 2. A 3. C 4. A 5. E 6. A

Paragraph Questions

(i) C (ii) D (iii) B

SECTION – B

Numerical Problems

1. 25 cm 2. 0.04 A m^2 3. decreases by 50% 4. (a) 64 B (b) 125/64 B

5. 3d/4 6. 64×10^{-7} N 7. $\frac{\mu_o M}{4\pi(d^3)(17)^{3/2}}$ 8. $\frac{\mu_o}{4\pi}\frac{m}{r^2}\frac{3}{4}$

9. $\frac{18F}{50}$ 10. F/5 11. 10 A m^2 12. 20 cm

Conceptual

1. an iron bar experiences no force at the middle of a magnet.
2. as magnetic forces perpendicular to magnetic field.
3. high temperature inside the earth.
4. angle between geographic and magnetic meridians.
5. vertical with its north pole downwards and south pole upwards.
6. any direction on the geomagnetic north or south.

SECTION – C

Previous Contest Questions

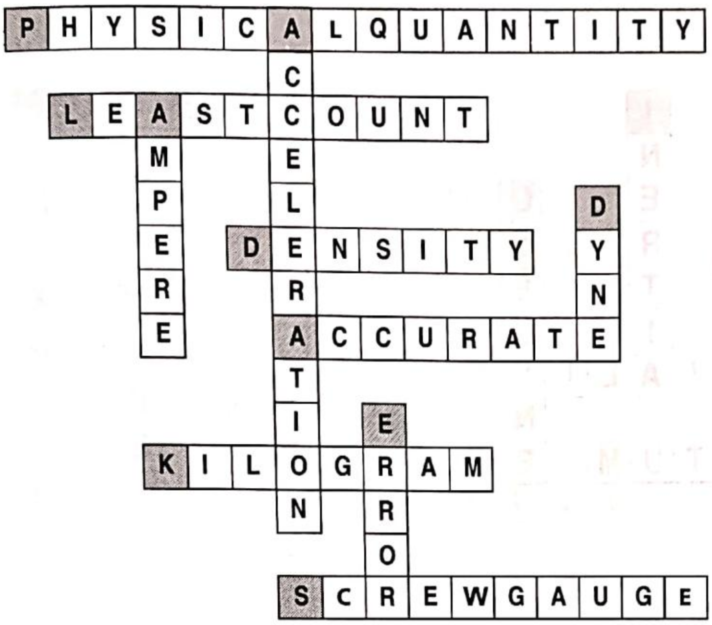
1. B 2. D 3. C 4. C 5. A 6. A 7. D 8. D

Brain Nurtures

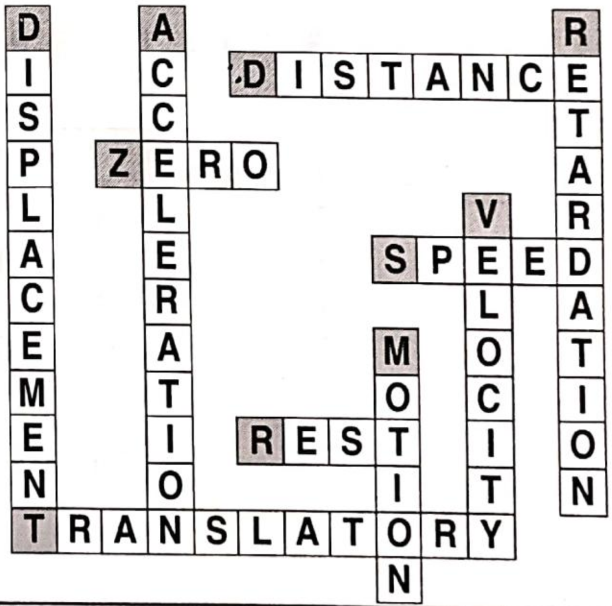
1. $2\left(\frac{M}{\theta}\right)\sin\frac{\theta}{2}$ 2. $\sqrt{2}$ M 3. will come to rest along the vertical

4. $\frac{\mu_o M}{4\pi d^3}\sqrt{8}, \frac{\mu_0 M}{4\pi d^3}\sqrt{40}$ 5. $\frac{\mu_o M}{4\pi d^3}\sqrt{5}$

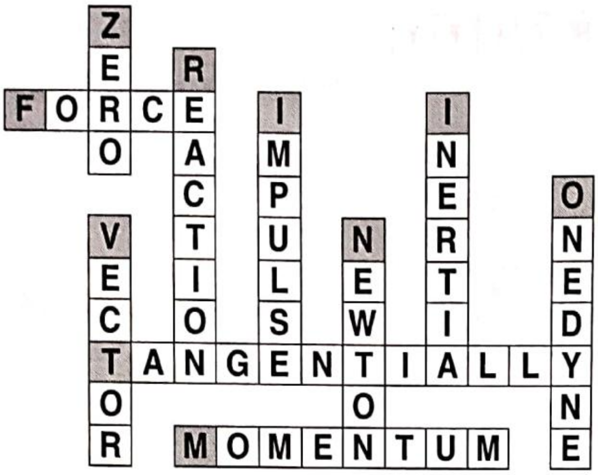
CHAPTER 1 – MEASUREMENT



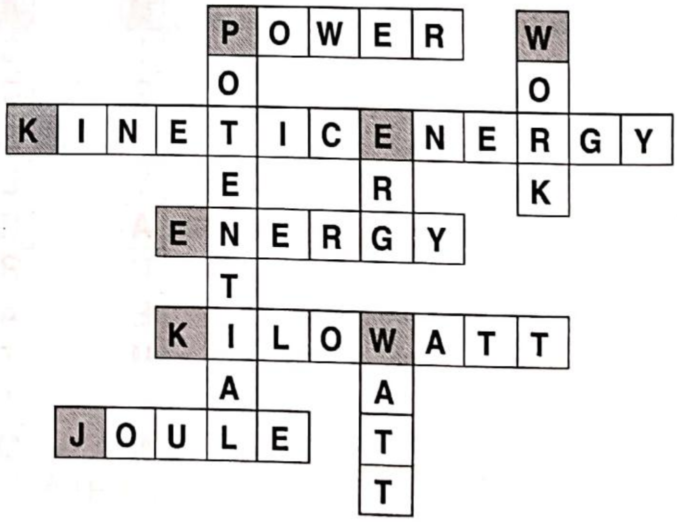
CHAPTER 2 – MOTION IN ONE DIMENSION



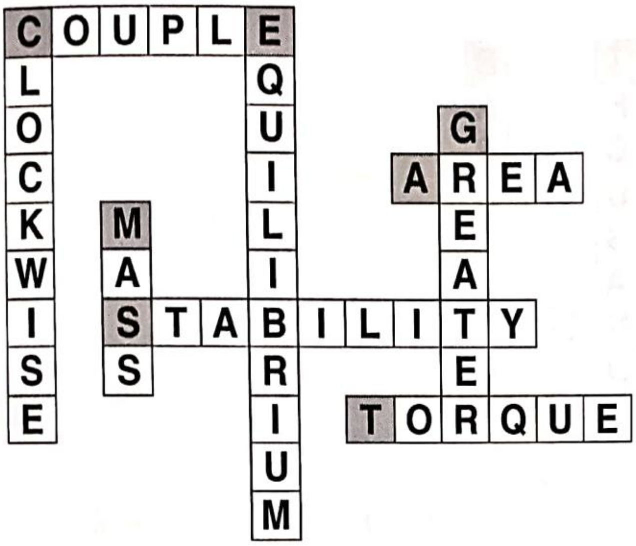
CHAPTER 3 – NEWTON'S LAWS OF MOTION



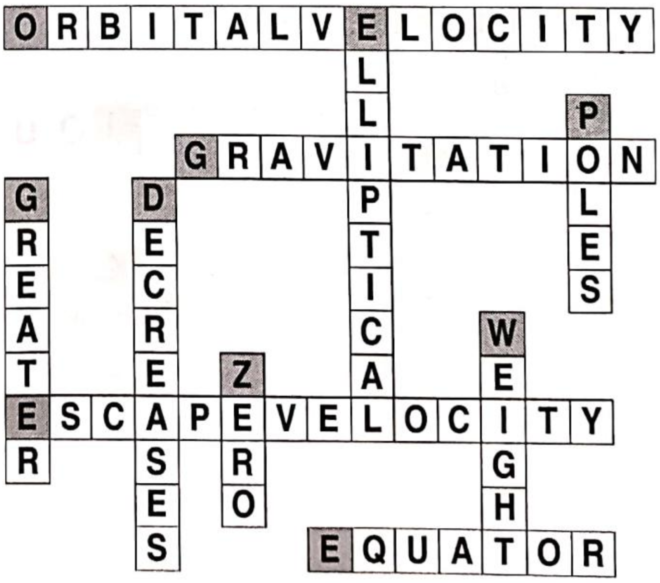
CHAPTER 4 – WORK, POWER AND ENERGY



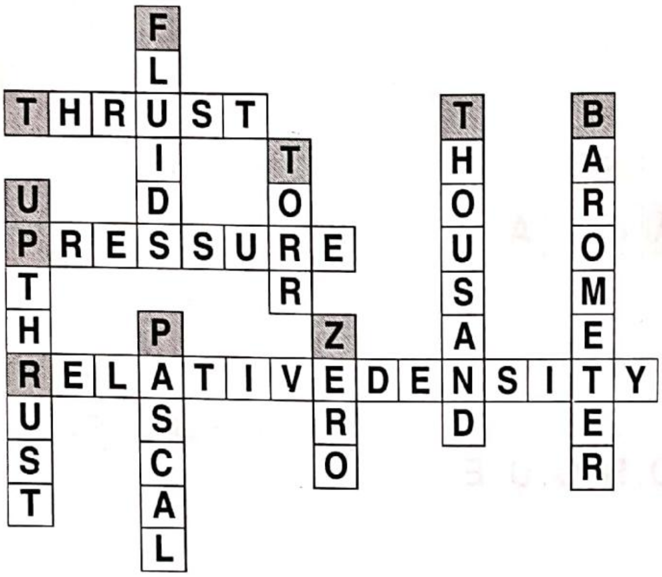
CHAPTER 5 – TURNING FORCES AND EQUILIBRIUM



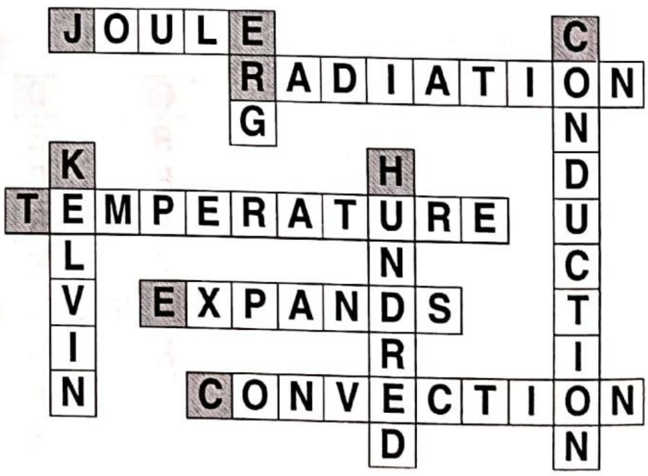
CHAPTER 6 – GRAVITATION



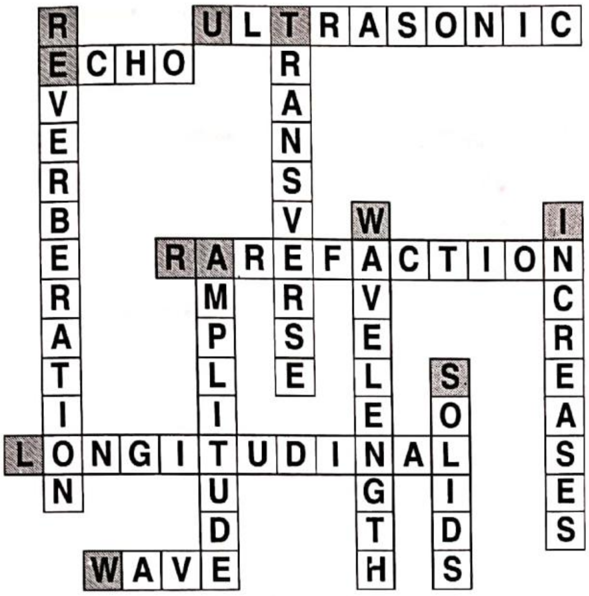
CHAPTER 7 – FLUID PRESSURE



CHAPTER 8 – HEAT



CHAPTER 9 – WAVE MOTION AND SOUND



CHAPTER 10 – MAGNETISM