ENGINEERING PHYSICS - I

I SEMESTER

CONTENTS

UNIT - I

S.I. UNITS & STATICS

Introduction

One of the definitions of physics is 'It is a science of accurate measurement. Since accurate measurement of physical quantities is necessary in the field of engineering and technology for better quality control, the study of physics assumes more importance in any course in Engineering.

1.1 UNITS AND MEASUREMENTS

1.1.1(a) Quantities

The various physical properties of matter and energy are represented by the physical names called as physical quantities.

They are :

1. Fundamental quantities.
2. Derived quantities
3. Supplementary quantities.

(b) S.I. Units

Any physical quantity that can be measured on the basis of well defined small part is known as **unit**.

For the measurment of units three different systems were used. They are

1. fps (or) British system (foot - pound - second)
2. cgs (or) Gaussian system (centimetre - gram - second)
3. mks (or) S.I.system (metre - kilogram - second)

1.1.2. Fundamental quantities

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

E.g. Length, Mass, Time

(a) Fundamental Units & Symbols

The units of fundamental quantities are known as fundamental units. The S.I units and symbols of fundamental quantities are given in the table.

Serial No.	Fundamental quantities	Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Temperature	Kelvin	K
6.	Luminous intensity	candela	cd
7.	Amount of substance	mole	mol

1.1.3. Derived quantities

The physical quantities which are derived from the fundamental quantities are known as ***derived quantities***.

(Eg.) - Area, velocity

Some of the derived quantities are given below :-

1. Area $= \text{length} \times \text{breadth}$ (i.e) $A = l \times b$

$= \text{Length} \times \text{Length} = \text{Length}^2$

2. Volume $= \text{length} \times \text{breadth} \times \text{height}$. (ie.) $V = l \times b \times h$

$= \text{Length} \times \text{Length} \times \text{Length} = \text{Length}^3$

3. Density $= \dfrac{\text{Mass}}{\text{Volume}}$ (i.e) $\rho = \dfrac{M}{V}$

4. Velocity $= \dfrac{\text{displacement}}{\text{time}}$ (i.e) $v = \dfrac{s}{t}$

$= \dfrac{\text{Length}}{\text{Time}}$

5. Acceleration $= \dfrac{\text{change in velocity}}{\text{time}}$ (i.e) $a = \dfrac{v-u}{t}$

$= \dfrac{\text{velocity}}{\text{time}} = \dfrac{\text{Length}}{\text{Time}^2}$

6. Momentum $= \text{mass} \times \text{velocity}$ (ie) $p = mv$

$= \text{Mass} \times \dfrac{\text{Length}}{\text{Time}}$

7. Force $= \text{mass} \times \text{acceleration}$ (i.e) $F = ma$

$= \text{Mass} \times \dfrac{\text{Length}}{\text{Time}^2}$

8. Impulse $= \text{Force} \times \text{time}$ (i.e) $Im = F \times t$

$= \text{Mass} \times \dfrac{\text{Length}}{\text{Time}^2} \times \text{Time} = \text{Mass} \times \dfrac{\text{Length}}{\text{Time}}$

9. Work $= \text{Force} \times \text{displacement}$ (i.e) $W = F \times s$

$= \text{Mass} \times \dfrac{\text{Length}}{\text{Time}^2} \times \text{Length}$

$= \text{Mass} \times \dfrac{\text{Length}^2}{\text{Time}^2}$

10. Energy $= \text{Work} = \text{Mass} \times \dfrac{\text{Length}^2}{\text{Time}^2}$

11. Power $= \dfrac{\text{work}}{\text{time}}$ (i.e) $P = \dfrac{W}{t}$

$= \text{Mass} \times \dfrac{\text{Length}^2}{\text{Time}^3}$

(a) Derived units

The units of derived quantities are known as derived units. The unit of a derived quantity is obtained by the combination of fundamental units. Some of the derived units of S.I. system are given in the table.

Sl.No.	Physical quantity	Unit	Symbol
1.	Area	metre × metre	m^2
2.	Volume	metre × metre × metre	m^3
3.	Density	kilogram/metre^3	kg m^{-3}
4.	Velocity	metre/second	m s^{-1}
5.	Acceleration	metre/second^2	m s^{-2}
6.	Momentum	kilogram-metre/second	kg m s^{-1}
7.	Force	newton	N
8.	Impulse	newton-second	N s
9.	Work, Energy	joule	J
10.	Power	watt	W
11.	Pressure	newton/metre^{2}or pascal	N m^{-2}

1.1.4. Supplementary quantities

In physics, only two physical quantities are used as supplementary quantities.

Sl. No.	Supplementary quantities	Unit	Symbol
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

1.1.5 Dimensional formula

The first capital letters of Length, Mass and Time are the dimensional formula of their respective quantities.

Sl. No.	Fundamental quantities	Dimensional formula
1.	Length	L
2.	Mass	M
3.	Time	T

The dimensional formula of a derived quantity is the combination of the dimensions of fundamental quantities (M,L,T) raised to suitable powers.

The dimensional formula for some derived quantities are derived as follows.

1. Area = Length × breadth = Length × Length
   $= L \times L = L^2$ (or) $L^2 M^0 T^0$

2. Volume = Length × breadth × height
   $= L \times L \times L = L^3$ (or) $L^3 M^0 T^0$

3. Density $= \dfrac{\text{Mass}}{\text{Volume}} = \dfrac{M}{L^3} = M\,L^{-3}$ (or) $M\,L^{-3}\,T^0$

4. Velocity $= \dfrac{\text{Displacement}}{\text{Time}} = \dfrac{L}{T} = L\,T^{-1}$

5. Acceleration $= \dfrac{\text{Change in velocity}}{\text{Time}} = \dfrac{L\,T^{-1}}{T} = L\,T^{-2}$

6. Momentum = Mass × Velocity $= M\,L\,T^{-1}$

7. Force = Mass × accleration $= M\,L\,T^{-2}$

8. Impulse = Force × time $= M\,L\,T^{-2} \times T = M\,L\,T^{-1}$

9. Work = Force × displacement

$$= M\ L\ T^{-2} \times L = M\ L^2\ T^{-2}$$

10. Power $= \frac{\text{Work}}{\text{Time}} = \frac{M\ L^2\ T^{-2}}{T} = M\ L^2\ T^{-3}$

11. Energy = Force × displacement

$$= M\ L\ T^{-2} \times L = ML^2T^{-2}$$

1.1.6 Uses of dimensional formula

The dimensional formula is used to

1) to find which fundamental quantities are related in a derived quantity
2) to find the unit of a physical quantity
3) to discover new laws relating to different physical quantities.

1.1.7. Conventions to be followed in S.I. system

The following conventions to be followed while writing the S.I. unit symbols and numerical values.

1) Names of units begin with small letters.
   e.g. - metre, newton
2) Symbol for unit named after scientist is written by capital letter.
   e.g - N- newton; J - joule
3) Symbol for other units use small letters.
   e.g - m - metre ; kg - kilogram
4) Only the singular form of the unit is to be used
   e.g - kg
5) Don't use full stop at the end of the symbol.
6) Omit degree notation (°) for temperature

   e.g - 273 K

7) Write the derived units in index notation
   e.g - 6m/s as $6ms^{-1}$
8) Express the numerical value in scientific notation
   e.g - Velocity of light = $3 \times 10^8\ ms^{-1}$
9) Use the accepted symbols
   e.g - for ampere A

(a) Merits of S.I. system :

1. The decimals and multiples are in terms of 10
2. Very easy for conversion and calculation
3. Very accurate measurements can be made.

1.1.8. Multiples and sub-multiples of units

The larger and smaller units of some physical quantities in S.I. system can be expressed in multiples and sub multiples of 10 or $\frac{1}{10}$. For example 1 km is 1000m and 1mm is $\frac{1}{1000}$ metre. Some standard prefixes and multiplication factors are given in the table.

Multiplication factor	Prefix	Abbreviation
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d

10^1	deca	da
10^2	hecto	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P

1.1.9 Unit Conversions

(i) Horse Power to Watt

$$\text{Power} = \frac{\text{Energy}}{\text{time}} \Rightarrow \text{Watt} = \frac{\text{Joule}}{\text{second}} \text{ (or) J/s}$$

1 Horse Power = 746 watt (or)

1 Horse Power = 0.746 kilowatt

(ii) Calorie to Joule

1 Calorie = 4.2 joule

1 large calorie = 4.2 kilojoule

1.1.10 Applications of dimensional analysis

Dimensional analysis are used

1) to check the dimensional correctness of a physical equation.
2) to find the value of a physical quantity when convert one system of unit to another.
3) to derive the relation between various physical quantities
4) to find the dimensions and units of dimensional constants.

1.2 STATICS

Mechanics deals with the study of bodies when they are at rest or in motion. It can be divided into statics and dynamics. Statics deals with the equilibrium of a body under the action of two or more forces.

1.2.1 Scalar and vector quantities

(a) Scalar : Physical quantities having only magnitude are called **scalar quantities.**

(e.g) mass, volume, density etc.

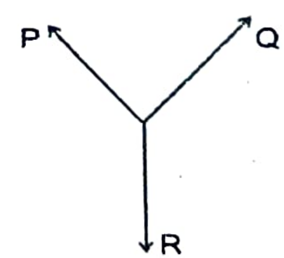
(b) Vector : Physical quantities having both magnitude and direction are called **vector quantities.**

(e.g) velocity, acceleration, force etc.

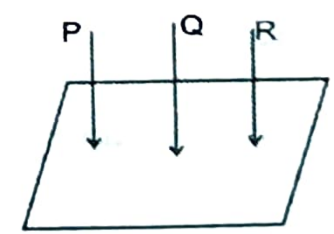
1.2.2. Concurrent forces & coplanar forces.

(a) Concurrent forces : Two or more than two forces acting at a point are called concurrent forces.

(b) Coplanar forces : Two or more than two forces acting on the same plane are called coplanar forces.



Concurrent forces



Coplanar parallel forces

10^1	deca	da
10^2	hecto	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P

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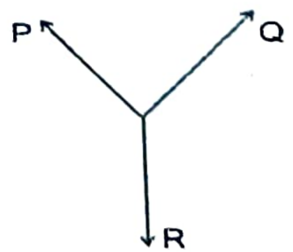
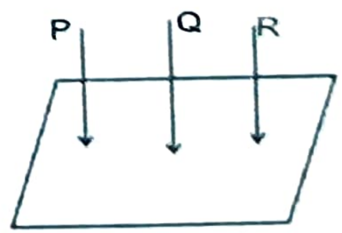
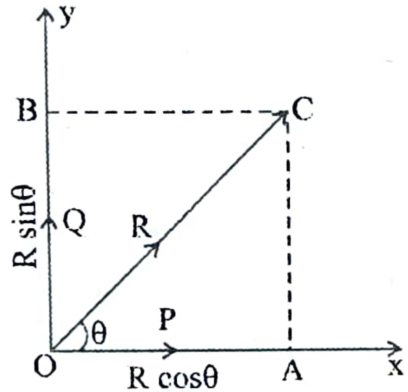


Concurrent forces



Coplanar parallel forces

1.2.3.Resolution of a force into rectangular components



A single force can be replaced by two or more forces is known as components of a force (or) resolution of a force.

Consider a force **R** acting at the point O in between x-axis and y-axis. The magnitude and direction of **R** is represented by OC. Let θ be the angle of inclination of R with x-axis.

Draw a rectangle OACB. The line **OA** represents the horizontal component of the force and **OB** represents the vertical component of the force.

In the ΔOAC, $\cos\theta = \frac{OA}{OC}$ $\therefore$ OA = OC cosθ

But OC = R and OA = P

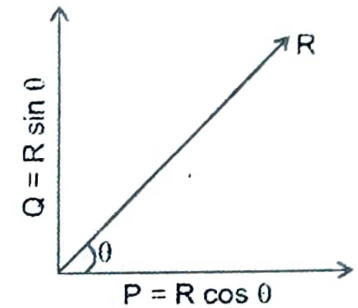
$\therefore$ **The horizontal component** $\boxed{\mathbf{P = R\cos\theta}}$

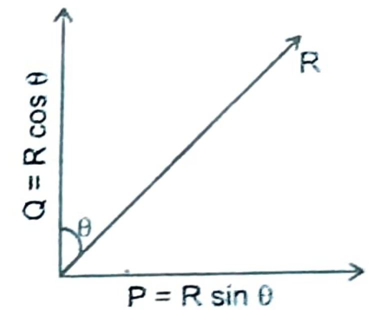
In the Δ OAC, $\sin\theta = \frac{AC}{OC}$ $\therefore$ AC = OC sinθ

But OC = R and AC = OB = Q

$\therefore$ **The vertical component** $\boxed{\mathbf{Q = R\sin\theta}}$

Note : The following figures shows the values of horizontal and vertical components according to the value 'θ'





1.2.4 Resultant and Equilibrant :

(a) Resultant : Resultant is a single force which gives the same effect as that of all other forces acting together.

(b) Equilibrant : Equilibrant is a single force which acting along with the other forces keeps the point in equilibrium.

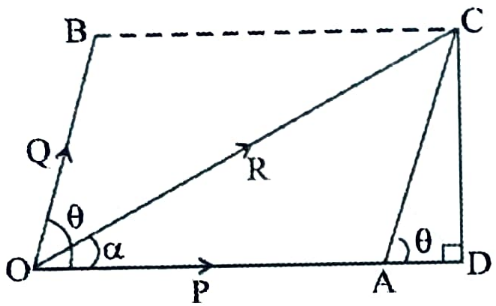
Resultant and equilibrant are equal in magnitude but opposite in direction.

1.2.5. Parallelogram law of forces - Statement

If two forces acting at a point be represented in magnitude and direction by the two adjacent sides of a parallelogram, the resultant is given in magnitude and direction by the diagonal of the parallelogram drawn through the point.

1.2.6. Expression for the magnitude and direction of the resultant of two forces.

Consider two forces **P** and **Q** acting at a point O are represented in magnitude and direction by the two adjacent sides OA and OB. Complete the parallelogram OACB and draw the diagonal OC. Let θ be the angle between them.



To draw right angled triangle ∠ODC extend the line OA upto D. Draw the perpendicular line CD. According to parallelogram law of forces the diagonal OC gives the magnitude and direction of the resultant **R**.

Magnitude

In the right angled triangle ODC

$$OC^2 = OD^2 + CD^2$$

$$= (OA + AD)^2 + CD^2 \qquad (\because OD = OA + AD)$$

$$= OA^2 + AD^2 + 2OA.AD + CD^2$$

$$= OA^2 + AC^2 + 2OA.AD \qquad (\because AC^2 = AD^2 + CD^2)$$

In ΔADC

$$\cos\theta = \frac{AD}{AC} \qquad \therefore AD = AC\cos\theta = Q\cos\theta$$

$$\sin\theta = \frac{CD}{AC} \qquad \therefore CD = AC\sin\theta = Q\sin\theta$$

$$OC^2 = OA^2 + AC^2 + 2OA.AC\cos\theta$$

In figure OC= R, OA = P and OB = AC = Q.

(i.e) $R^2 = P^2 + Q^2 + 2PQ\cos\theta$

$$\boxed{R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}}$$

This is the expression for the **magnitude of the resultant.**

Direction

Let α be the angle between P and R. This gives the direction of the resultant.

In ΔODC, $\tan\alpha = \dfrac{CD}{OD} = \dfrac{CD}{OA + AD} = \dfrac{AC\sin\theta}{OA + AC\cos\theta}$

$$\tan\alpha = \frac{Q\sin\theta}{P + Q\cos\theta}$$

$$\boxed{\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P + Q\cos\theta}\right)}$$

This is the expression for the **direction of the resultant.**

1.2.7. Lami's theorem

(a) Statement : If three forces acting at a point be in equilibrium, then each force is directly proportional to the sine of the angle between the other two forces.

(b) Explanation : Consider a point O is in equilibrium under the action of three forces **P**,**Q** and **R**. If α, β and γ are the angles opposite to P, Q and R, respectively then,

By Lami's theorem.

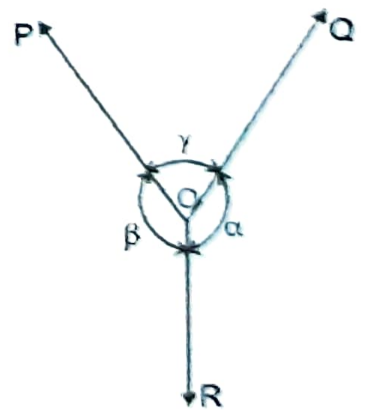
$P \propto \sin\alpha$

$Q \propto \sin\beta$

and $R \propto \sin\gamma$

ie., $\dfrac{P}{\sin\alpha}$ = a constant,

$\dfrac{Q}{\sin\beta}$ = a constant and



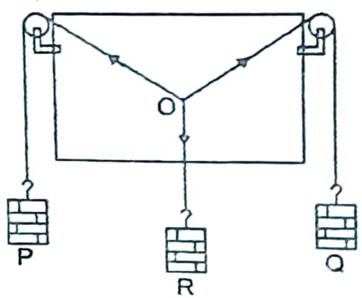
$$\frac{R}{\sin\gamma} = \text{a constant}$$

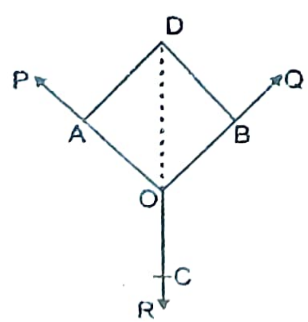
$$\boxed{\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}}$$

1.2.8. Experimental verification of the parallelogram law of forces.

- Two smooth pulleys are fixed at the top two corners of a vertically fixed drawing board.
- From the common knot 'O' weights P & Q are passed over two pulleys and weight R hanged freely.
- Draw the directions and connect the points of the three strings when 'O' is in equilibrium.
- Draw OA, OB, OC for P,Q,R as 50 gm = 1cm
- Choose OA, OB as bases and draw a parallelogram OADB. Connect the diagonal OD. Measure OD, $\underline{|COD}$ and tabulate.
- Repeat the experiment for different values of P,Q,R and tabulate.
- In all cases, it is found that OC = OD and $\underline{|COD} = 180°$.

Hence parallelogram law of forces is verified.



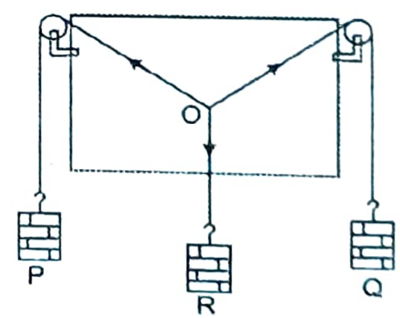


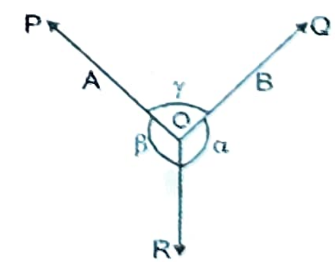
Sl.No.	P	Q	R	OA	OB	OC	OD	∠COD
1								
2								
3								

1.2.9. Experimental verification of Lami's Theorem

- Two smooth pulleys are fixed at the top two corners of a vertically fixed drawing board.
- From the common knot 'O' weights P & Q are passed over two pulleys and weight R hanged freely.
- Draw the directions and connect the points of the three strings when 'O' is in equilibrium.
- Mark and measure the angles α , β , γ and tabulate.
- Repeat the experiment for different values of P,Q,R
- In all cases, it is found that $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$

Hence Lamis theorem is verified.





Sl.No.	P	Q	R	α	β	γ	$\frac{P}{\sin\alpha}$	$\frac{Q}{\sin\beta}$	$\frac{R}{\sin\gamma}$
1									
2									
3									

WORKED EXAMPLES

1) ***If the resultant of two equal forces inclined to each other at 60° is $8\sqrt{3}$N, find the component forces. (Ap. 17)***

Given : $\theta = 60°$ $R = 8\sqrt{3}N$; $P = Q = P$ (say) = ?

Resultant $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$= \sqrt{P^2 + P^2 + 2\,P\,P\cos 60°}$

$R = \sqrt{2P^2 + 2P^2 \times \frac{1}{2}} = P\sqrt{3}$

But $R = 8\sqrt{3}$ $\therefore 8\sqrt{3} = P\sqrt{3}$ $\therefore P = 8N$

2) ***Two forces of magnitudes 4N and 3N respectively, act on a particle at right angles to each other. Find the magnitude of the resultant and the angle of inclination with the first force.***

Here $P = 4N$; $Q = 3N$ and $\theta = 90°$

Resultant $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$= \sqrt{4^2 + 3^2 + 0} = \sqrt{16 + 9}$

$R = 5N$

Let α be the angle between the resultant and the first force

$$\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P + Q\cos\theta}\right)$$

$$= \tan^{-1}\left(\frac{3\sin 90°}{4 + 3\cos 90°}\right) = \tan^{-1}\left(\frac{3}{4}\right)$$

$$= \tan^{-1}(0.75)$$

$\alpha = 36°52'$

3) ***Two forces of 4N and 8N acting at a point with an angle 90° between them. Find the magnitude and direction of the resultant of the forces (Ap. 19)***

Here $P = 4N$; $Q = 8N$ and $\theta = 90°$

Resultant $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$= \sqrt{4^2 + 8^2 + (2 \times 4 \times 8 \times \cos 90°)}$

$= \sqrt{16 + 64} = \sqrt{80}$

$R = 8.94$ N

Direction

$$\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P + Q\cos\theta}\right)$$

$$\alpha = \tan^{-1}\left(\frac{8\sin 90°}{4 + 8\cos 90°}\right)$$

$$= \tan^{-1}\left(\frac{8}{4}\right)$$

$$= \tan^{-1}(2)$$

$$\alpha = 63°26'$$

4) ***If the resultant of two equal forces is $\sqrt{3}$ times a single force, find the angle between the forces (Oct. 16, Ap 17,18)***

Given : Two forces are equal $P = Q$; $R = \sqrt{3}\,P$.

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

$$\sqrt{3}\ P = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

Squaring $3P^2 = P^2 + P^2 + 2P^2 \cos\theta = 2P^2 (1 + \cos\theta)$

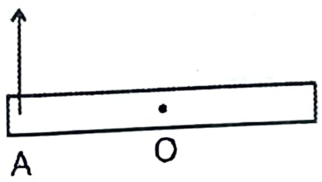
$$2\cos\theta = 1$$

$$\cos\theta = \frac{1}{2} \text{ or } \theta = 60°$$

Angle between the two forces $\theta = 60°$

1.2.10. Moment of a force :

The moment of a force about a point is the rotating effect of the force about that point.



Moment of a force is the product of force and the perpendicular distance from the point to the line of action of the force.

Moment of the force = Force × Perpendicular distance

= F × OA.

1.2.11. Clock wise moments & Anticlock wise moments

If the force F rotates the body in the clockwise direction, the moment is said to be clockwise moment.

If the force F rotates the body in the anticlockwise direction, then the moment is said to be anticlockwise moment.

Conventionally anticlockwise moments are taken as positive and clockwise moments are taken as negative.

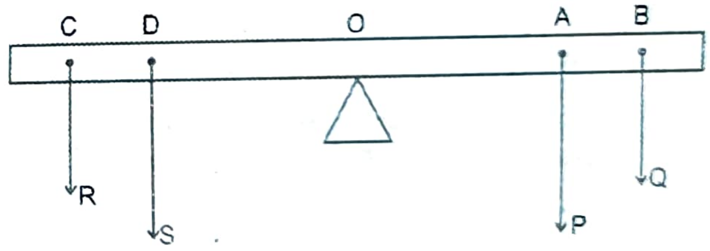
1.2.12. Principle of moments

Statement : *When a rigid body is in equilibrium under the action of number of parallel forces, then the sum of clockwise moments is equal to the sum of anticlock wise moments.*

Explanation :

P, Q, R and S are the forces acting from the point A,B,C and D respectively from a balanced beam.

The clockwise moments are P×OA and Q×OB.



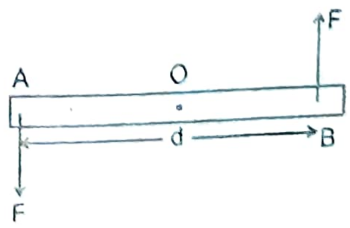
The anti clockwise moments are R×OC and S×OD.

According to the principle of moments,

$$P \times OA + Q \times OB = R \times OC + S \times OD$$

1.2.13. Couple

Two equal unlike parallel forces constitute a couple.



Moment (or) Torque of the couple.

The moment of the couple is the rotating effect of the couple.

Moment of the couple

$$= F \times OA + F \times OB$$

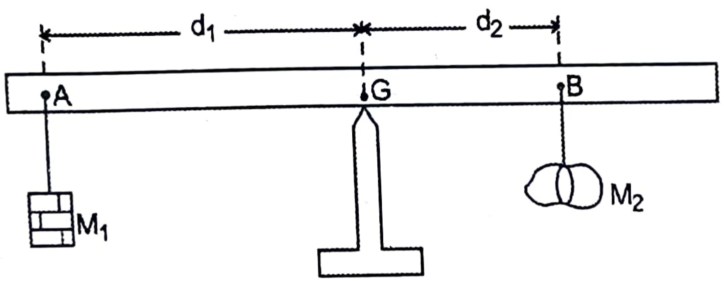
$$= F(OA + OB)$$

$$= F \times AB$$

Definition : *The moment of the couple is the product of one of the forces and the perpendicular distance between the forces..*

Moment of the couple = $F \times AB$

1.2.14. Experiment to determine the mass of a body using Principle of moments.



- A metre scale is balanced horizontaly on a knife edge at the centre of gravity G.
- Known mass M_1 and unknown mass M_2 are suspended on left and right side.
- Adjust the positions of M_1 and M_2 till it reaches the equilibrium position.

- Measure the distances d_1 and d_2 from G and tabulate.
- Repeat the experiment for different values of M_1 and tabulate.

According to Principle of moments

$$M_2 d_2 = M_1 d_1$$

Mass the body $M_2 = \dfrac{M_1 d_1}{d_2}$

Hence we calculate the average value of unknown mass M_2.

Sl. No.	Mass M_1	Distances		$M_2 = \dfrac{M_1 d_1}{d_2}$
		d_1	d_2	
1				
2				
3				

Average =

QUESTIONS

PART A

1. **Define - unit.**

Any physical quantity that can be measured on the basis of well defined small part is known as unit.

2. **Give two examples for fundamental quantities**

Length, mass

3. **Give two examples for derived quantities**

Area, volume

4. **Write the S.Iunit of the following quantities.**

i) momentum	-	kgs^{-1}	
ii) Force	-	N	
iii) Impulse	-	Ns	(Oct. 18)
iv) Work & Energy	-	J	
v) Power	-	W	(Oct. 18)

5. **Write the supplementary quantities**

(i) Plane angle (ii) solid angle

6. **Write the dimensional formula for the following quantities (or) Write the quantities for the following dimensional formulas**

i) Momentum (or) Impulse	-	MLT^{-1} (Oct. 09, Ap.10,14)
ii) Force	-	MLT^{-2}
iii) Work (or) Energy	-	ML^2T^{-2} (Nov-10,12)
iv) Power	-	ML^2T^{-3}

7. **Write the unit conversion for horse power to watt?**

1 Horse Power = 746 watt (1 H.P. = 746 W)

8. **Write the unit conversion for calorie to joule?**

1 Calorie = 4.2 joule (1C = 4.2 J)

9. **Define scalar quantities. Give examples. (Oct.18)**

Physical quantities having only magnitude are called **scalar quantities.**

(E.g) mass, volume, density etc.,

10. **Define vector quantities. Give examples. (Oct. 18)**

Physical quantities having both magnitude and direction are called **vector quantities.**

(Eg) velocity, acceleration, force etc.,

11. **How do we call physical quantities having both magnitude and direction?**

Vector quantities

12. **Define concurrent forces (Oct. 18)**

Two or more than two forces acting at a point are called concurrent forces.

13. **Define coplanar forces.**

Two or more than two forces acting on the same plane are called coplanar forces.

14. **Define resultant.**

Resultant is a single force which gives the same effect as that of all other forces acting together.

15. **Define equilibrant. (Ap.19)**

Equilibrant is a single force which acting along with the other forces keeps the point in equilibrium.

16. How the resultant and equlibrant are formed in parallelogram law of forces?

Resultant and equlibrant are equal in magnitude but opposite in direction.

PART - B

1. What are fundamental quantities? Give examples (Oct. 15, 17)

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

(Eg) Length, Mass, Time

2. What are derived quantities? Give examples

The physical quantities which are derived from the fundamental quantities are known as derived quantities.

(Eg.) Area, Velocity

3. Derive the dimension of formula and S.I. Units for velocity and acceleration.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{time}} = \frac{L}{T} = LT^{-1};$$

$$\text{unit} = \frac{m}{s} = ms^{-1}$$

$$\text{acceleration} = \frac{\text{velocity}}{\text{time}} = \frac{LT^{-1}}{T} = LT^{-2};$$

$$\text{unit} = \frac{ms^{-1}}{s} = ms^{-2}$$

4. Derive the dimensional formula and S.I unit for momentum and force

$$\text{momentum} = \text{mass} \times \text{velocity} = MLT^{-1};$$

$$\text{unit} = kgms^{-1}$$

$$\text{Force} = \text{mass} \times \text{acceleration} = MLT^{-2};$$

$$\text{unit} = kgms^{-2} = N$$

5. Derive the dimensional formula and S.I .Unit for work and power.

$$\text{Work} = \text{Force} \times \text{displacement}$$

$$= MLT^{-2} \times L = ML^2T^{-2};$$

$$\text{unit} = Nm = J$$

$$\text{Power} = \frac{\text{work done}}{\text{time}} = \frac{ML^2T^{-2}}{T}$$

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

$$\text{unit} = \frac{J}{s} = W$$

6. Derive the dimensional formula and S.I unit for energy and impulse.

$$\text{energy} = \text{Force} \times \text{displacement}$$

$$= MLT^{-2} \times L = ML^2T^{-2};$$

$$\text{unit} = Nm = J$$

$$\text{Impulse} = \text{Force} \times \text{time}$$

$$= MLT^{-2} \times T = MLT^{-1};$$

$$\text{unit} = Ns$$

7. Give the supplementary quantities and units. (Ap.16,17,18)

Supplementary quantities	Unit
Plane angle Solid angle	radian stradian

8. **Write the uses of dimensional formula. (Oct.15,16, Ap.18, 19)**

Dimensional formula is used to

1) to find which fundamental quantities are related in a derived quantity
2) to find the unit of a physical quantity.
3) to discover new laws relating to different physical quantities.

9. **Write any three conventions to be followed in writing S.I. Units. (Ap.17,Oct. 18)**

1. Names of units begin with small letters (e.g) metre; newton
2. Omit degree notation (°) for temperature
3. Write the derived units in index notation. e.g. 6m/s as $6ms^{-1}$

10. **Write any two applications of dimensional analysis**

1) to check the dimensional correctness of a physical equation.
2) to derive the relation between various physical quantities.

11. **Write the unit conversion for power from horse power to watt and colorie to joule**

1 horse power = 746 watt

1 calorie = 4.2 joule

12. State **parallelogram law of forces (Apr. 16)**

If two forces acting at a point be represented in magnitude and direction by the two adjacent sides of a parallelogram, the resultant is given in magnitude and direction by the diagonal of the parallelogram drawn through the point.

13. **State Lami's theorem. (Oct. 16, 17,Ap.18)**

If three forces acting at a point be in equilibrium, then each force is directly proportional to the sine of the angle between the other two forces.

$$\frac{P}{\sin \alpha} = \frac{Q}{\sin \beta} = \frac{R}{\sin \gamma}$$

14. **Define moment of a force. (Oct. 18,Ap.19)**

Moment of a force is the product of force and the perpendicular distance from the point to the line of action of the force.

15. **State the principle of moments. (Ap.18**

When a rigid body is in equilibrium under the action of number of parallel forces, then the sum of the clockwise moments is equal to the sum of the anticlockwise moments.

16. **What is couple? (Ap. 16,19)**

Two equal, unlike parallel forces constitute a couple.

17. **Define moment (or) torque of the couple.**

The moment of the couple is the product of one of the forces and the perpendicular distance between the forces.

PART - C

1. Write the conventions to be followed in writing S.I. unit (Oct. 15, Ap. 16,18) (Ans. Sec. 1.1.7)
2. Explain how a vector quantity can be resolved into two rectangular components. (Oct. 16) (Ans. Sec. 1.2.3)
3. Derive expressions for magnitude and direction of the resultant of two forces acting at a point with an acute angle between them. (Ap.16,17, Oct. 16) (Ans:Sec.1.2.6)

4. Describe an experiment to verify parallelogram law of forces (Oct.15,18) (Ans. Sec. 1.2.8)

5. Describe how Lami's theorem is verified in the laboratory. (Ap.16, 17,19,19) (Ans. Sec. 1.2.9)

6. Describe an experiment to determine the mass of the given body using principle of moments (Oct. 16,17,18,Ap.19) (Ans. Sec. 1.2.14)

PROBLEMS

1. Two equal forces acting at a point with an angle of 60° between them. If the resultant force is equal to $20\sqrt{3}$N, find the magnitude of each force. (Ans : 20 N)

2. Find the magnitude and direction of the resultant of two forces 60N and 80N acting at a point with an angle 90° between them. (Oct. 09) (Ans : R = 100N, α = 53°)

3. Find the magnitude and direction of the resultant of two forces 3N and 4N acting of a point, if the angle between the forces is 60°. (Oct.14,18) (Ans :R = 6.08N, α = 34°)

4. Find the magnitude and direction of the resultant of two forces 30N and 40N acting at a point at 90° each other (Oct. 15,19,Ap.19) (Ans : R = 50N, α = 53°)

5. If the resultant of two forces 6N and 8N is 12N. Find the angle between two forces. (Ans : 62°43')

6. If the resultant of two equal forces is $\sqrt{2}$ times a single force, find the angle between them. (Ans : θ = 90°).

UNIT - II

PROPERTIES OF MATTER

2.1 ELASTICITY

2.1.1. Elasticity :

Any body when subjected by an external force undergoes a change in its length, volume or shape. When the deforming force is removed, the body tends to regain its original shape. This property is called **'elasticity'**.

On the basis of elasticity, the bodies are classfied in two types.

i) Elastic bodies

ii) Plastic bodies.

(i) Elastic bodies:

The bodies which regain its original size or shape after the removal of deforming force is called **'elastic bodies'**.

(Ex.) : Steel, Glass, Rubber, Quartz

(ii) Plastic bodies :

The bodies which cannot regain its original size or shape after the removal of deforming force is called **'plastic bodies'**.

(Ex) - Plastic toys, plastic vessels etc.

The opposite of elasticity is plasticity.

2.1.2. Stress

Force acting per unit area is known as stress. The linear stress is the linear force per unit area. If F is the linear force acting on an area A

$$\text{Linear stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Dimensional formula $ML^{-1}T^{-2}$

Unit - Nm^{-2}

2.1.3. Strain

Because of the stress applied a change in the dimension of the body takes place.

The ratio of the change in dimension to the original dimension is called strain.

There are three types of strain. They are

(i) Linear strain (ii) bulk strain and (iii) shearing starin.

(i) Linear strain : The ratio of the change in length to the original length is called **linear starin.**

$$\text{Linear strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{l}{L}$$

(ii) Bulk strain : The ratio of change in volume to the original volume is called **bulk strain.**

$$\text{Bulk or Volume strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{v}{V}$$

(iii) Shearing strain : Shearing strain is the angle turned from the original.

2.1.4. Hooke's Law

(i) Law : *Within the elastic limit of a body, the ratio of stress to strain is a constant.*

Stress α Strain,

(ii) Modulus of elasticity : The **modulus of elasticity** is defined as the ratio of stress to strain.

$$\therefore \boxed{\text{Modulus of elasticity} = \frac{\text{stress}}{\text{strain}}}$$

2.1.5. Elastic limit and Plastic limit.

(i) Elastic limit : The **elastic limit** is the maximum value of the stress applied upto which the body will regain its original size or shape when the stress is removed.

(ii) Plastic limit : The **plastic limit** is the maximum value of the stress applied which do not show the elasticity property when the stress is removed.

2.1.6. Three modulus of elasticity

According to three different types of strain, there are three types of modulus of elasticity. They are

(i) Young's modulus (ii) Bulk modulus and

(iii) Rigidity modulus.

i) Young's modulus (E)

Definition :

The ratio of linear stress to the linear strain is called **Young's modulus**

$$\text{Young's modulus (E)} = \frac{\text{Linear stress}}{\text{Linear strain}}$$

Consider a wire of length **L** and area of cross-section A is subjected to a linear force **F**. If l is the increase in length.

$$\text{Young's modulus (E)} = \frac{F/A}{l/L}$$

If F = Mg and r is the radius of the wire. $A = \pi r^2$

$$\boxed{E = \frac{M\ g\ .\ L}{\pi\ r^2\ l}}\ N/m^2$$

(ii) Bulk modulus (K)

Definition :

The ratio of bulk stress to bulk strain is called **bulk modulus.**

$$\text{Bulk modulus (K)} = \frac{\text{Bulk stress}}{\text{Bulk strain}}$$

Consider a body of volume V subjected to a bulk stress (f/A) If v is the change in volume, then

$$\text{Bulk modulus(K)} = \frac{F/A}{v/V}\ \text{(ie)}\ K = \frac{FV}{Av}$$

$$K = \frac{PV}{v} \qquad \left\{\because \frac{F}{A} = P\right\}$$

(iii) Rigidity modulus (n)

Definition : *The ratio of shearing stress to shearing strain is called the rigidity modulus.*

$$\text{Rigidity modulus (n)} = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

Let F is the tangential force applied on the top surface area A of a cuboid and ϕ is the shearing strain.

$$\text{Rigidity modulus (n)} = \frac{F/A}{\phi} = \frac{F}{A\phi}$$

2.1.7. Poisson's ratio (σ) :

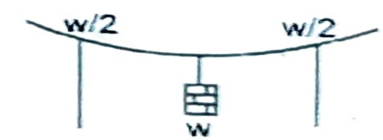
When a force is applied along the length of the wire. The wire elongates along the length but at the same time it contracts radially also.

Definition : *Poisson's ratio is defined as the ratio of lateral strain to linear strain.*

$$\text{Poisson's ratio } \sigma = \frac{\text{lateral strain}}{\text{Linear strain}}$$

2.1.8. Uniform bending and Non-uniform bending of beams

Uniform bending



Non-uniform bending

(i) Uniform bending :

When a beam is bent upwards just to be an arc by the application of load is known as **uniform bending**.

A uniform crosssectional beam is symmertically supported on two knife edges horizontally. Two equal weights are suspended at equal distances from each knife edge outwards. On each knife edge a reaction W is acting upwards.

Here every element of the beam is bent with the same radius of curvature.

Non-uniform bending

When a beam is bent downwards but not like an arc by the application of load is known as **non-uniform bending**.

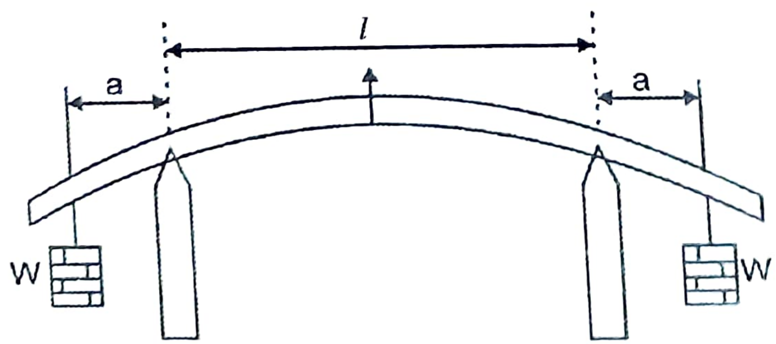
A uniform crossectional beam is symmetrically supported on two knife edges horizontally. A weidht W is hanged at the centre. On each knife edge a reaction W/2 acting upwards.

Here the centre part of the beam bent large. So every element of the beam bent with different radius of curvature.

2.1.9. Determination of Young's modulus by uniform bending

- The beam is symmetrically supported horizontally on two knife edges with a pin fixed vertically at the centre of the beam.
- Two weight hangers each of weight W are suspended at a distance **a** outwards from each knife edge.
- The tip of the pin is focused and the microscope reading is noted.
- The readings are noted in steps of 50gm loading and unloading. From this, the elevation **y** for **M** gm is calculated.
- Distance between two knife edges l and distance **a** are measured.
- The breadth **b** and thickness **d** of the beam are measured using vernier caliper and screw gauge.

Hence the Youngs modulus of the beam is calculated using the formula.



Load	Microscope reading			Elevation for M-gm (y)
	Loading	Unloading	Mean	
W W+50 W+100 W+150 W+200				

2.1.10 Applications of elasticity

The property of elasticity is applied in the following:

1. Steel is used in the design of heavy duty machines.
2. Iron rod is used in the construction of buildings
3. Springs are made of steel
4. The thickness of metallic ropes used in cranes are choosed as per weight
5. In designing of bridges and beams
6. To declare the bridge to unfit after long use.

WORKED EXAMPLES

1) *The length of a wire increases from 1.25m to 1.2508m when a force of 120N is applied. The radius of the wire is 0.5mm. Find the stress, strain and Young's modulus of the material of the wire (Oct. 17)*

Given : $F = 120N$; $r = 0.5\ mm = 0.0005m$

$L = 1.25m$; $l = 1.2508 - 1.25 = 0.0008m$

$= 1.25 \times 10^{?}\ Nm^{-2}$ [illegible]

Young's modulus [illegible] Nm^{-2}

2) A wire of length 2m is stretched by a force of 100N. The area of crossection of the wire is $0.008m^2$ and increase in length is 0.05mm. Calculate the Young's modulus. (Apr. 17)

$d = 1mm$ [illegible] $E = 120 \times 10^{9}\ Pa$

Young's modulus $E = \frac{F L}{A l}$

Elongation $l = \frac{F L}{A E}$

$l = 1.562 \times 10^{?}\ m$

4) A wire 100 cm long and 0.5 mm in diameter becomes 103cm when stretched. If the Young's modulus of the wire is $9.81 \times 10^{10}\ Nm^{-2}$. Calculate the value of the load. (Ap. 09)

Given : $L = 1m$ $l = 0.03m$

$r = 0.25 \times 10^{-3}\ m$ $E = 9.81 \times 10^{10}\ Nm^{-2}$

$F = Mg$

(i) Stress $= \frac{F}{A} = \frac{F}{\pi r^2} = \frac{120}{3.14\,(.0005)^2} = 1.529 \times 10^8\ Nm^{-2}$

(ii) Strain $= \frac{l}{L} = \frac{.0008}{1.25} = 6.4 \times 10^{-4}$

(iii) Young's modulus $E = \frac{stress}{strain} = \frac{1.529 \times 10^8}{6.4 \times 10^{-4}}$

$E = 23.89 \times 10^{10}\ Nm^{-2}$

2) ***A wire of length 2m is stretched by a force of 100N. The area of crossection of the wire is 0.008m² and the increase in length is 0.05mm. Calculate the stress, strain and Young's modulus. (Apr. 17)***

Given : $L = 2m;\ A = 0.008m^2;$

$F = 100N\ ;\ l = 0.05 \times 10^{-3}m$

(i) Stress $= \frac{F}{A} = \frac{100}{0.008} = 12500\ Nm^{-2}$

(ii) Strain $= \frac{l}{L} = \frac{0.05 \times 10^{-3}}{2} = 0.025 \times 10^{-3}$

(iii) Young's modulus $E = \frac{stress}{strain} = \frac{12500}{0.025 \times 10^{-3}}$

$= 5 \times 10^8\ Nm^{-2}$

3) ***A copper wire of 3m length and 1mm diameter is subjected to a tension of 5kgwt. Calculate the elongation produced with wire if Young's modulus is 120G Pa***

Given : $F = 5kg\ wt. = 5 \times 9.81N;\ L = 3m$

$d = 1mm\quad r = 0.5mm$

$r = 0.5 \times 10^{-3}\ m \qquad E = 120 \times 10^9\ Pa$

Youngs modulus $E = \frac{F}{A} \times \frac{L}{l}$

Elongation $l = \frac{F}{A} \times \frac{L}{E}$

$= \frac{5 \times 9.81 \times 3}{3.14 \times (.5 \times 10^{-3})^2 \times 120 \times 10^9}$

$l = 1.562 \times 10^{-3}m$

4) ***A wire 100 cm long and 0.5 mm in diameter becomes 103cm when stretched. If the Young's modulus of the wire is*** 9.81×10^{10} ***Nm⁻², Calculate the value of the load. (Ap. 09)***

Given : $L = 1m\ ;\qquad l = 0.03m$

$r = 0.25 \times 10^{-3}\ m \quad E = 9.81 \times 10^{10}\ Nm^{-2}$

Young's modulus $E = \frac{F}{A} \times \frac{L}{l} = \frac{Mg \cdot L}{\pi r^2 \cdot l} \qquad \{\because F = Mg\}$

$\therefore\ M = \frac{E \times \pi r^2 l}{g \cdot L}$

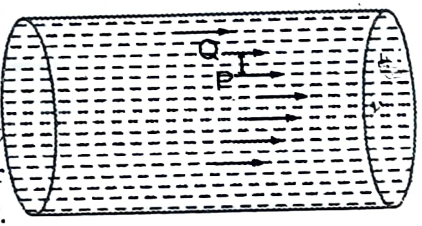
$= \frac{9.81 \times 10^{10} \times 3.14 \times (0.25 \times 10^{-3})^2 \times 0.03}{9.81 \times 1}$

$M = 58.87\ kg$

2.2. VISCOSITY

2.2.1. Viscosity

Consider a liquid flowing over a horizontal solid surface under low pressure. The liquid consists of a number of liquid layers. The layer in contact with the solid surface is at rest and the top most layer has the maximum velocity. The intermediate layers have intermediate velocities.



Consider any two consecutive liquid layers. The lower layer tends to resist the motion of the upper layer due to the tangential frictional forces between them.

This tangential frictional forces that brings the liquid to rest are known as **viscous forces** and this property is known as **viscosity.**

Rain drops falls slowly with uniform velocity due to the viscosity of air.

2.2.2. Co-efficient of viscosity

When the flow of liquid is stream line motion, the tangential viscous force

$F \propto$ area A between the layers

$\propto$ velocity gradient $\frac{dv}{dx}$

(i.e) $F \propto A \cdot \frac{dv}{dx}$

$$F = \eta \cdot A \cdot \frac{dv}{dx}$$

where η is a constant known as co-efficient of viscosity of a liquid.

If $A = 1$ and $\frac{dv}{dx} = 1$ then $F = \eta$

Definition :

The co-efficient of viscosity of a liquid is the tangential force per unit area required to maintain unit velocity gradient.

Dimension and S.I. unit of η

Viscous force $F = \eta \cdot A \cdot \frac{dv}{dx}$ (or) $\eta = \frac{F \cdot dx}{A \cdot dv}$

Substitute the dimensions of F, A and $\frac{dv}{dx}$

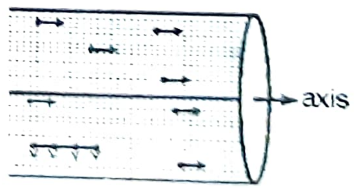
Dimensional formula $= \frac{MLT^{-2} \cdot L}{L^2 \cdot LT^{-1}} = ML^{-1}T^{-1}$

Substitute the units of F, A and $\frac{dv}{dx}$

S.I. unit $= \frac{Nm}{m^2 ms^{-1}} = Nsm^{-2}$

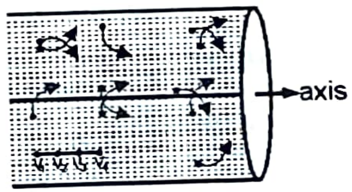
2.2.3. Streamline motion

When a liquid flows under low pressure, the flow of liquid at every point is parallel to the axis of the tube. The velocity of all particles along a line parallel to the axis of the tube are equal. Such motion is called **stream line motion.**



Here the flow of liquid is orderly and velocity is constant. The velocity of liquid will be less than the critical velocity. Velocity is proportional to the pressure.

2.2.4. Turbulent motion



When a liquid flows under high pressure, the flow of the liquid at every point is not parallel to the axis of the tube. The velocity of all particles along a line parallel to the axis of the tube are not equal. Such motion is called **turbulent motion.**

Here the flow of liquid is disorderly and velocity changes. The velocity of liquid will be greater than critical velocity. Velocity is proportional to the square root of pressure.

2.2.5. Difference between streamline motion and Turbulent motion

Sl.No.	Streamline motion	Turbulent Motion
1.	Flow of liquid is orderly	Flow of liquid is zigzag and random
2.	Velocity is constant	Velocity changes
3.	Orderly flow	Disorderly flow
4.	Velocity is below the critical velocity	Velocity is above the critical velocity
5.	Velocity is proportional to the pressure	Velocity is proportional to the square root of pressure

2.2.6. Critical velocity (V_c)

The velocity at which stream line motion stops and turbulent motion begins is called **critical velocity**.

2.2.7. Reynold's number (N_R)

Reynold's number is a number which determines whether the flow of liquid is streamline or turbulent.

$$\text{Reynolds number } N_R = \frac{v_c \rho D}{\eta}$$

where v_c - critical velocity

ρ - density

D - diameter of the pipe

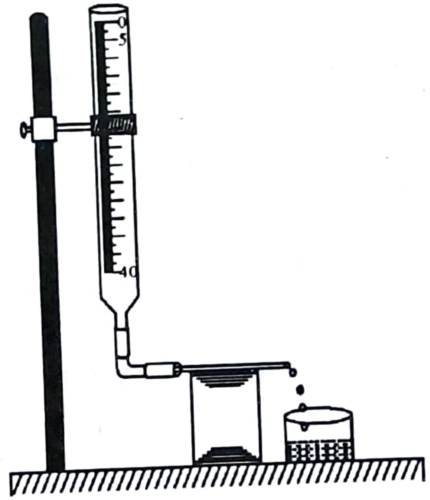
η - Co-efficient of viscosity

- If N_R lies between 0 to 2000, the flow of the liquid is said to be stream line motion.
- N_R is above 3000, the flow is turbulent motion.
- If N_R lies between 2000 to 3000, the flow is neither streamline nor turbulent, it may switch over from one type to another.

2.2.8. Comparison of co-efficient of viscosities of two low viscous liquids - Experiment.

- A cleaned burette is fixed vertically and a capillary tube is connected horizontally by means of a rubber tube.
- The given I liquid of co-efficient of viscosity η_1 is filled in the burette just above zero mark.
- Open the stopper and start the stop clock when the liquid reaches 0cc and the times are noted when it crosses 5,10,15 . . . . 35cc.

- Repeat the experiment for the II liquid of co-efficient of viscosity η_2.
- The time of flow t_1 and t_2 are calculated for 5cc liquid coloumn and hence calculate the average $\frac{t_1}{t_2}$.



The ratio of co-efficient of viscosities of two liquids is calculated using the formula.

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1}{\rho_2} \times \frac{t_1}{t_2}$$

ρ_1 – density of I liquid

ρ_2 – density of II liquid.

Range cc	Time of flow Liquid - I t_1	Time of flow Liquid - Ii t_2	$\frac{t_1}{t_2}$
0 - 5			
5 - 10			
10 - 15			
15 - 20			
20 - 25			
25 - 30			
30 - 35			

2.2.9. Terminal Velocity:

Definition : *The maximum constant velocity acquired by a body while falling freely through a high viscous liquid is called terminal velocity..*

Note : Stokes' formula for

$$\text{Co-efficient of viscosity } \eta = \frac{2\, r^2 g}{9\, v} (\rho - \sigma)$$

If the sphere moves with teminal velocity v and it crosses a distance h. For this the time taken is 't'.

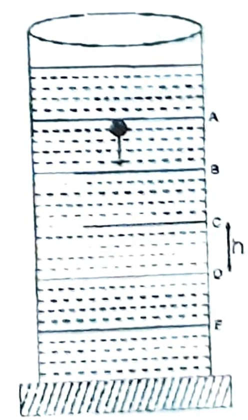
$$\text{Then terminal velocity } v = \frac{h}{t}$$

Substitute the value of v in the above equation

$$\text{Co-efficient of viscosity } \eta = \frac{2\, g\, (\rho - \sigma)\ (r^2\, t)}{9h}$$

2.2.10. Experiment to determine the of co-efficient of viscosity of high viscous liquid by Stokes' method.

- Castor oil is taken in a tall, wide glass jar. Mark AB = BC = CD = DE = h, on outside of the jar.



- Find the radius of the sphere r using screw gauge and drop on the surface of the liquid. Note the time taken 't' to cross the height CD = h using stop clock.
- Repeat the experiment for different radius of balls and calculate the average r^2t
- Note the values of density of sphere ρ, density of castor oil σ and h.

The co-efficient of viscosity of castor oil is calculated using the formula

$$\eta = \frac{2\ g\ (\rho - \sigma)}{9\ h}\ (r^2\ t)$$

Spherical ball	Radius 'r'	r^2	Time taken t	r^2t

Mean :

2.2.11. Practical applications of viscosity

1) It is used to determine the molecular weight of organic liquids.
2) It is used to choose the suitable lubricant for special machines.
3) Viscosity of blood is to be maintained properly to free flow of blood.

2.2.12 Practical applications of Stokes' law

1. To determine the co-efficient of viscosity of liquids
2. To determine the radius of liquid drop
3. It explains the flotation of clouds
4. Separating oil from waste water mixed with oil.
5. A man coming down with the help of a parachute acquires constant terminal velocity.

2.3 SURFACE TENSION

The free surface of a liquid at rest behaves like a stretched elastic membrane under tension with a tendency to minimise its surface area. This property of liquid is known as surface tension.

2.3.1. Surface Tension

***Surface tension** is defined as the force acting per unit length of a line drawn on the surface, acting perpendicular to the line and parallel to the surface.*

$$\text{Surface Tension} = \frac{\text{Force}}{\text{Length}}$$

$$\text{Dimensional formula} = \frac{MLT^{-2}}{L} = MT^{-2}$$

unit – Nm^{-1}

2.3.2. Angle of contact.

The **angle of contact** is defined as the angle inside the liquid between the tangent drawn at the point of contact to the liquid surface and the solid surface.

For water $\theta = 0°$. For mercury $\theta = 138°$.

- Find the radius of the sphere r using screw gauge and drop on the surface of the liquid. Note the time taken 't' to cross the height CD = h using stop clock.
- Repeat the experiment for different radius of balls and calculate the average r^2t
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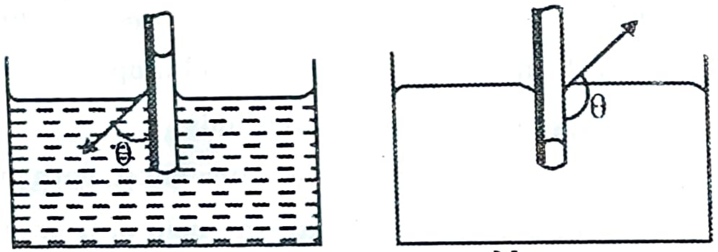


Water   Mercury

2.3.3. Capillary rise and capillary dip (uses)

(i) Capillary rise

When a capillary tube is dipped in water, the water rises up in the tube. This rise is above the free surface of water in the beaker. This is known as capillary rise.

ii) Capillary dip

When a capillary tube is dipped in mercury, the mercury rises in the tube. This rise is below the free surface of mercury in the beaker. This is known as capillary dip.

iii) Capillarity:

The rise of a liquid in a capillary tube is called **capillarity.**

2.3.4. Practical applications (uses) of capillarity

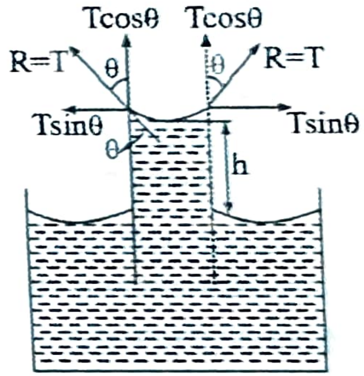
The following incidents are happen because of capillarity.

1) A blotting paper absorbs ink.
2) Oil rises in the cotton wick.
3) A sponge retains water
4) Walls get damped in rainy season.
5) The continous flow of ink from the pen through the nib.
6) Water rises to other parts of the plant

7) Clay soils are wet for long days.

2.3.5. Expression for the surface tension of a liquid by capillary rise method.

A capillary tube of radius **r** is dipped in a liquid of density ρ.



h- Capillary rise
θ - angle of contact
T - Surface tension
R - Reactive force

The horizontal component of reaction = T sinθ

The vertical component of reaction = T cosθ

The horizontal component along the circumference are equal and opposite in direction, so they cancels each other.

Total upward force = $2\pi r T\cos\theta$

Weight of liquid column = $\pi r^2 h \rho g$

$$2\pi r T\cos\theta = \pi r^2 h\rho g$$

$$\boxed{T = \frac{h r \rho g}{2\cos\theta}}$$

For water, angle of contact θ = 0°, cos 0° = 1

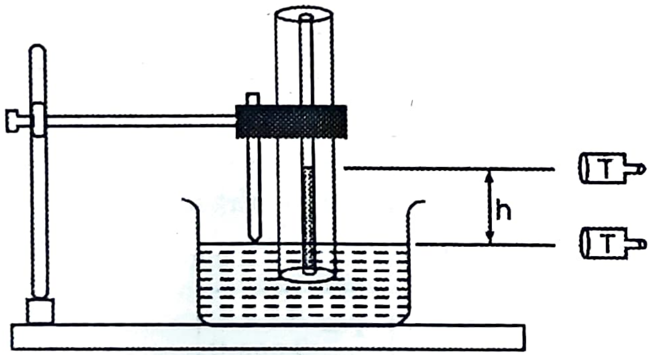
Surface Tension of water $\boxed{T = \frac{h r \rho g}{2}}$

2.3.6. Experiment to determine the surface tension of water : Capillary rise method.

- A cleaned capillary tube is dipped vertically in water. Water rises to a certain height h. Adjust the tip of the pointer just touches the surface of water.

- The travelling microscope is focused for the lower meniscus of the water in the capillary tube is noted as h_1.
- After removing the beaker, the microscope is focussed to the tip of the pointer is noted as h_2.
- The difference between h_1 and h_2 is capillary rise h ($h_1 - h_2 = h$). Find the radius of the capillary tube r using microscope.
- Repeat the experiment for different water levels.

The surface tension of water is calculated using the formula $T = \frac{h r \rho g}{2}$



Sl.No.	Water level (Capillary tube) h_1	Water level (beaker) h_2	Capillary rise $h = h_1 \sim h_2$

2.2.7. Applications of surface Tension

1. Rain drops and other liquid droplets are almost in spherical

2. Small insects like mosquitoes can walk on the surface of water
3. Oil spreads on water surface
4. Dirts on clothes get removed when soaps are added to water.
5. A needle gently placed on water can float.

WORKED EXAMPLES

1. ***A capillary tube of radius 0.04 cm is dipped in water vertically and water rises to a height of 4cm. If the density of water is 1000kgm^{-3}. Calculate the surface tension of water (g = 9.8ms^{-2}) (Ap. 03)***

Given : Radius $r = 0.04 \text{ cm} = .04 \times 10^{-2}$ m

Height $h = 4\text{cm} = 4 \times 10^{-2}$m

Density $\rho = 1000 \text{ kgm}^{-3}$; $g = 9.8 \text{ ms}^{-2}$

$$T = \frac{h r \rho g}{2} = \frac{4 \times 10^{-2} \times .04 \times 10^{-2} \times 1000 \times 9.8}{2}$$

$= 0784 \text{ Nm}^{-1}$

2. ***A liquid of density 1000 kgm^{-3} is contained in a beaker. A capillary tube of diameter 1.00mm is dipped vertically in it. Calculate the rise of liquid in the tube. Surface Tension of the liquid is 72 $\times 10^{-3}$ Nm^{-1}. (Oct. 97)***

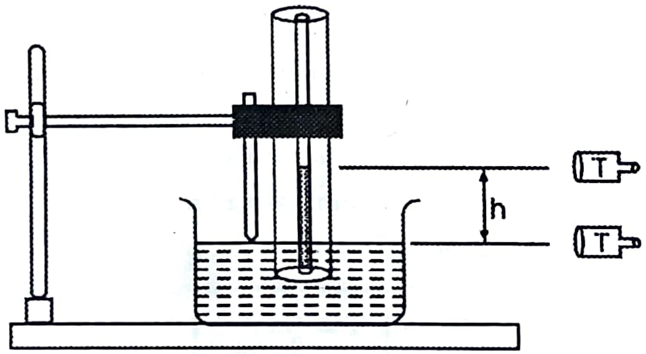
Given : Diameter d = 1mm

$\therefore$ Radius $r = .5\text{mm} = .5 \times 10^{-3}$ m

Density $\rho = 1000 \text{ kgm}^{-3}$

- The travelling microscope is focused for the lower meniscus of the water in the capillary tube is noted as h_1.
- After removing the beaker, the microscope is focussed to the tip of the pointer is noted as h_2.
- The difference between h_1 and h_2 is capillary rise h ($h_1 - h_2 = h$). Find the radius of the capillary tube r using microscope.
- Repeat the experiment for different water levels.

The surface tension of water is calculated using the formula $T = \frac{h r \rho g}{2}$



Sl.No.	Water level (Capillary tube) h_1	Water level (beaker) h_2	Capillary rise $h = h_1 \sim h_2$

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1. A capillary tube of radius 0.04 cm is dipped in water vertically and water rises to a height of 4cm. If the density of water is $1000 kgm^{-3}$. Calculate the surface tension of water ($g = 9.8 ms^{-2}$) (Ap. 03)

Given : Radius $r = 0.04$ cm $= .04 \times 10^{-2}$ m

Height $h = 4cm = 4 \times 10^{-2} m$

Density $\rho = 1000\ kgm^{-3}$; $g = 9.8\ ms^{-2}$

$$T = \frac{h r \rho g}{2} = \frac{4 \times 10^{-2} \times .04 \times 10^{-2} \times 1000 \times 9.8}{2}$$

$= 0784\ Nm^{-1}$

2. A liquid of density $1000\ kgm^{-3}$ is contained in a beaker. A capillary tube of diameter 1.00mm is dipped vertically in it. Calculate the rise of liquid in the tube. Surface Tension of the liquid is $72 \times 10^{-3}\ Nm^{-1}$. (Oct. 97)

Given : Diameter d = 1mm

$\therefore$ Radius $r = .5mm = .5 \times 10^{-3}$ m

Density $\rho = 1000\ kgm^{-3}$

Surface Tension T $= 72 \times 10^{-3}\ Nm^{-1}$

Surface Tension T $= \frac{h\, r\, \rho\, g}{2}$ (or) $h = \frac{2T}{r\, \rho\, g}$

$$= \frac{2 \times 72 \times 10^{-3}}{.5 \times 10^{-3} \times 1000 \times 9.8}$$

$$h = 2.939 \times 10^{-2}\ m$$

---

3. ***A liquid of density 1200 kgm^{-3} and surface tension $214 \times 10^{-3} Nm^{-1}$ rises to a height of 2.4cm in a capillary tube of diameter 0.5mm. Calculate the angle of contact of the liquid with the walls of the capillary tube (Ap. 08)***

Given : Density $\rho = 1200\ kgm^{-3}$

Surface Tension $T = 214 \times 10^{-3}\ Nm^{-1}$

Height $h = 2.4\ cm = 2.4 \times 10^{-2}\ m$

Diameter $d = 0.5\ mm$

radius $r = 0.25\ mm = 0.25 \times 10^{-3}\ m$

$$T = \frac{h\, r\, \rho\, g}{2 \cos\theta}$$

$$\cos\theta = \frac{h\, r\, \rho\, g}{2T} = \frac{2.4 \times 10^{-2} \times 0.25 \times 10^{-3} \times 1200 \times 9.8}{2 \times 214 \times 10^{-3}}$$

$$\cos\theta = 0.1649$$

$$\theta = \cos^{-1}(0.1649)$$

Angle of contact $\theta = 80°30'$

QUESTIONS

PART - A

1. **Define - elasticity**

The property of a material body tends to regain its original size and shape after the removal of the deforming force is called elasticity.

2. **Why springs are made of steel?**

Springs are made of steel because steel has high elasticity.

3. **Define stress (Oct-16, 2000)**

Force acting per unit area is known as stress

4. **Write the dimensional formula and S.I. unit for stress**

Dimensional formula for stress – $ML^{-1}T^{-2}$

Unit - Nm^{-2} (or) pascal

5. **Define linear stress**

The linear stress is the linear force per unit area

6. **Define strain**

The ratio of the change in dimension to the original dimension is called strain.

7. **What are the three types of strain?**

(i) Linear strain (ii) Bulk strain (iii) Shearing strain

8. **Define linear strain**

The ratio of change in length to the original length is called linear strain

9. **Define bulk strain.**

The ratio of change in volume to original volume is called bulk strain.

10. **What are three moduli of elasticity? (Ap.00, Oct.11)**

(i) Young's modulus (ii) Bulk modulus (iii) Rigitidy modulus

11. Why rain drops fall slowly? (oct. 07)

Rain drops falls slowly due to the viscosity of air.

12. Write the dimensional formula and unit for coefficient of viscosity.

Dimensional formula for viscosity = $ML^{-1}T^{-1}$

Unit = Nsm^{-2}

13. Why cannot honey be poured so easily from one vessel into another?

Honey having high coefficient of viscosity

14. What is the angle of contact of water? (Nov. 10)

Angle of contact of water is 0°

15. Write the dimensional formula and S.I unit for surface tension.

Dimensional formula for surface tension = MT^{-2}

Unit = Nm^{-1}

16. Water drops (or) rain drops always exists in the form of a sphere. Why? (Oct. 08, Ap.11)

Due to surface tension of water.

17. Why does oil spread on water?

Due to surface tension of water

18. How do insects run on the surface of water?

Due to surface tension of water

19. What is capillarity?

The rise (or) fall of a liquid inside capillary tube is known as capillarity.

20. Give the reason for the rise of water and fall of mercury in a capillary tube (Oct. 00)

For water the level rises and for mercury the level falls because of surface tension of liquids.

21. Write any two practical applications of capillarity

(i) A blotting paper absorb ink.

(ii) Oil rises in the cotton wick.

PART - B

1. State Hooke's law (Oct. 15)

Within the elastic limit of a body, the ratio of stress to strain is a constant. Stress ∞ strain

2. Define moduus of elasticity

The ratio of stress to starin is called modulus of elasticity.

$$\text{Modulus of elaslicity} = \frac{\text{stress}}{\text{strain}}$$

3. Define elastic limit

The elastic limit is the maximum value of the stress applied upto which the body will regain its original size or shape when the stress is removed.

4. Define plastic limit.

The plastic limit is the maximum value of the stress applied which do not show the elasticity property when the stress is removed.

5. Define young's modulus (Oct. 17)

The ratio of linear stress to linear strain is called young's modulus.

6. Define bulk modulus

The ratio of bulk stress to bulk strain is called bulk modulus.

7. Define rigidity modulus

The ratio of shearing stress to shearing strain is called the rigidity modulus.

8. **Define Poisson's ratio (Ap.16,17)**

Poisson's ratio is defined as the ratio of lateral strain to linear strain.

$$\sigma = \frac{\text{Lateral strain}}{\text{Linear strain}}$$

9. **Write any two applications of elasticity**

   1. Steel is used in the design of heavy duty machines.
   2. Iron rod is used in the construction of buildings

10. **Define viscosity.**

The tangential fricitional force that brings the liquid to rest are known as viscous forces and this property is known as viscosity.

11. **Define coefficient of viscosity of a liquid.**

The coefficient of viscosity of a liquid is the tangential force per unit area required to maintain unit velocity gradient.

12. **What is stream line motion? (Ap.18)**

When a liquid flows under low pressure, the velocity of all particles along a line parallel to the axis of the tube are equal. Such a motion is called stream line motion.

13. **What is turbulent motion?**

When a liquid flows under high pressure, the velocity of all particles along a line parallel to the axis of the tube are not equal. Such a motion is called turbulent motion.

14. **Write the differences between stream line motion and turbulent motion. (Ap.16)**

Sl.No.	Stream line motion	Turbulent Motion
1.	Velocity is constant	Velocity changes
2.	Orderly flow	Disorderly flow
3.	Velocity is below the critical velocity	Velocity is above the critical velocity
4.	Velocity is proportional to pressure	Velocity proportional to square root of pressure

15. **Define critical velocity (Oct. 16,Ap.17)**

The velocity at which stream line motion stops and turbulent motion begins is called critical velocity.

16. **What is the significance of Reynold's number?**

Reynold's number determines whether the flow of liquid is streamline or turbulent.

17. **Define terminal velocity**

The maximum constant velocity acquired by a body while falling freely through a high viscous liquid is called terminal velocity..

18. **Write any two practical applications of coefficient of viscosity**

   (i) It is used to determine the molecular weight of organic liquids.

   (ii) It is used to choose the suitable lubricant for special machines.

19. **Write any two practical applications of Stoke's law**

   1. It explains the flotation of clouds
   2. A man coming down with the help of a parachute acquires constant terminal velocity.

20. Define surface tension of a liquid (Ap.17, Oct.17)

Surface tension is defined as the force acting per unit length of a line drawn on the surface, acting perpendicular to the line and parallel to the surface.

21. Define angle of contact

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

22. Write any two practical applications surface tension.

1. Rain drops and other liquid droplets are almost in spherical
2. Small insects like mosquitoes can walk on the surface of water

PART - 'C'

1. Explain uniform and non-uniform bending of beams (Ans Sec 2.1.8)
2. Describe an experiment to determine the Young's modulus of a beam by uniform bending. (Oct. 15,18Ap.16,19) (Ans. Sec 2.1.9)
3. Explain streamline motion and turbulent motion (Ans : Sec 2.2.3 & 2.2.4)
4. Distinguish between streamline motion and turbulent motion. (Ans : 2.2.5)
5. Describe an experiment to compare the co-efficient of viscosities of two low viscous liquid. (Oct.15, 16,Ap.18) (Ans. Sec. 2.2.8)

6. Describe an experiment to determine co-efficient of viscosity of a high viscous liquid by Stokes' method. (Ap.16,17, Oct. 17,18) (Ans. Sec. 2.2.10)
7. Write the practical applications (uses) of capillarity. (Ans : Sec. 2.3.4)
8. Derive an expression for the surface tension of a liquid by capillary rise method.(Oct.16,17Ap.17,18) (Ans. Sec. 2.3.5)
9. Describe an experiment to determine the surface tension of water by capillary rise method. (Oct. 13, Ap.10, Nov.10) (Ans. Sec. 2.3.6)

PROBLEMS

1. A 4m long aluminium wire with cross sectional area 1.0×10^{-6} m^2 is suspended b a weight of 50N. If the elongation of the wire is 2.5 mm. Calculate the young's modulus of the wire. (Ans : 8×10^{10} Nm^{-2})
2. A wire of length 3cm is stretched by a force of 120N. The area of cross section of the wire is 0.01m2. If the increase in length is 0.075ml. Calculate the stress, strain and youngs modulus. (Oct. 16) (Ans: 12,000N; $2.8x10^{-5}$; $4.8x10^{8}Nm^{-2}$)
3. Calculate the surface tension of water if it rises to a height of 5 cm. in a capillary tube dipped vertically in it. Radius of the capillary tube is 2.94×10^{-4}m (Oct. 06,Ap.19) (Ans : 0.072 Nm^{-1})
4. Calculate the surface tension of water if it rises to a height of 4.2 cm. in a tube dipped in it. Radius of the capillary tube is 3.5×10^{-4}m (Oct.15,18) (Ans: 0.072 Nm^{-1})

5. A capillary tube of 0.45mm diameter is dipped vertically inside a liquid of density 1000 kgm^{-3}. If the rise of the liquid in the tube is 6.4cm. Calculate the surface tension of the liquid (Ap.14) (Ans. 0.07056 Nm^{-1})

6. A capillary tube of bore 0.5mm is dipped vertically in water of surface tension 0.072 Nm^{-1}. Find the height of capillary rise. (Ans : 5.87×10^{-3}m)

7. Whan a capillary tube of diameter 0.6mm is dipped in water, the rise of water in the capillary tube is 49.5mm. If the density of water is 1000kgm–3 and g = 9.81m–2. Calculate the surface tension of water. (Ap.16) (Ans : 0.072Nm^{-1})

UNIT - III

DYNAMICS-I

Introduction :

Dynamics is a branch of mechanics which deals with the motion of bodies. It comes from the Greek word 'dynamis' which means power. In this unit we are going to study the motions like i) straight line motion ii) projectile motion and iii) circular motion and its applications.

3.1 STRAIGHT LINE MOTION

Introduction :

The motion along a straight line is known as straight line motion. The important quantities required to study the motion along a straight line are position, displacement, velocity and acceleration.

3.1.1. Newton's laws of motion :

Sir Issac Newton formulated the laws of motion of the object. They are :

I Law : *Every body continues to be in its state of rest or of uniform motion in a straight line unless compelled by an external force to change the state.*

II Law : *The rate of change of momentum of a body is directly proportional to the force acting on it and it takes in the direction of the force. ($F = ma$)*

III Law : *For every action, there is an equal and opposite reaction.*

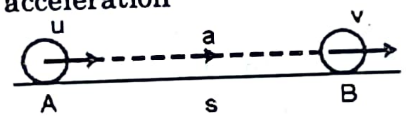
3.1.2. Equations of motion :

(i) For horizontal motion of a body

Here u - initial velocity   v - final velocity

t - time taken   s - displacement

a - acceleration



1) $v = u + at$

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

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

The above three equations are known as equations of horizontal motion of bodies.

ii) For a freely falling body

Here initial velocity $u = 0$ and $a = +g$

(1) $v = gt$

(2) $s = \frac{1}{2}gt^2$

(3) $v^2 = 2gs$

iii) For a body thrown vertically upwards

Here $a = -g$

(1) $v = u - gt$

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

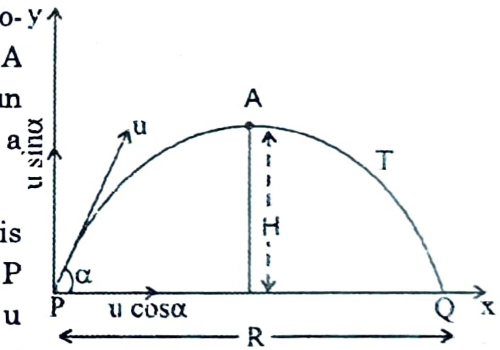
(3) $v^2 = u^2 - 2gs$

3.2 PROJECTILE MOTION

3.2.1. Projectile Motion :

A body is thrown into space with some initial velocity in a particular direction is called **projectile motion.**

(ex) 1. Javelin throw 2. Shot put 3. A stone projected at an angle 4. A bullet fired from a gun 5. Motion of a ball hit by a cricket bat.



Consider a body is projected from the point P with an initial velocity u and an angle α. The point P is called the point of projection and α is the angle of projection. In the figure, H - Maximum height, R - Range, T - Time of flight, PAQ - Trajectory.

The following two assumptions are made in the projectile motion.

1) the acceleration due to gravity is constant throughout the motion.
2) the air resistance to the motion is negligible.

3.2.2. Angle of projection (α)

The angle between the direction of projection and the horizontal plane at the point of projection is called **angle of projection.**

3.2.3. Trajectory

The path described by the projectile is **trajectory.**

3.2.4. Maximum Height (H)

The **maximum vertical displacement** of the projectile from the horizontal plane through the point of projection is called **maximum height**..

3.2.5. Time of flight (T)

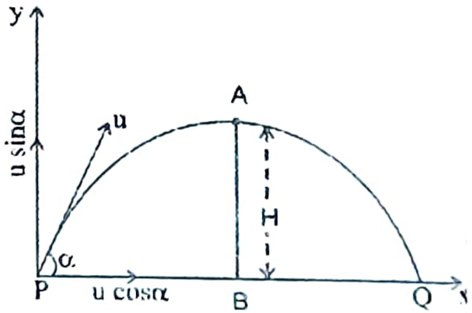
The time taken by the projectile from the instant of projection to the instant when it again reaches the horizontal plane through the point of projection is called the **time of flight**.

3.2.6. Range (R)

The distance from the point of projection and the point where the trajectory meets the plane through the point of projection is **range**.

3.2.7. Expression for Maximum height (H) reached by a projectile.

Let a body be projected with a velocity u and an angle of projection α. The height from the ground to the highest point is the maximum height H (AB=H).



Equation of motion is

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

Here, $u = u \sin\alpha$

$v = 0$

$a = -g$

$s = H$

Substitute the values in the equation

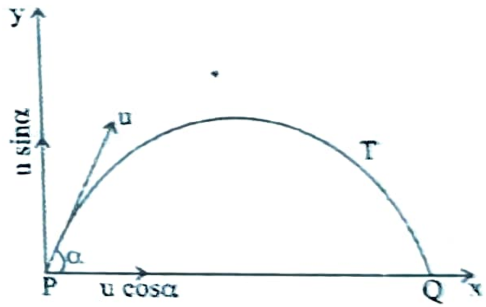
$$0 = u^2 \sin^2\alpha - 2gH$$

$$2gH = u^2 \sin^2\alpha$$

Maximum height $\boxed{H = \dfrac{u^2 \sin^2\alpha}{2g}}$

3.2.8. Expression for Time of flight (T)

Let a body be projected with a velocity u and an angle of projection α. Let T be the time taken by the particle from P to Q.



Equation of motion is

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

Here $s = 0$

$u = u \sin\alpha$

$a = -g$

$t = T$

Substitute the values in the equation

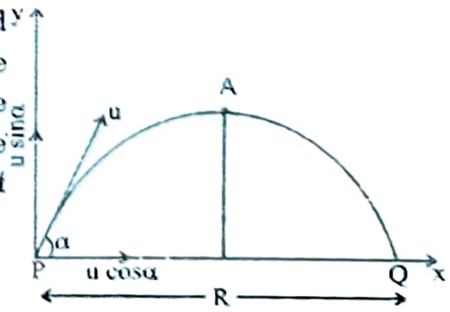
$$0 = u \sin\alpha \,.\, T - ½\, gT^2$$

$$\frac{1}{2} gT^2 = u \sin\alpha T$$

Time of flight $\boxed{T = \dfrac{2u \sin\alpha}{g}}$

3.2.9. Expression for Range (R)

Let a body be projected with a velocity u and an angle of projection α. Range is the horizontal displacement made by the projectile in the time of flight T (ie) PQ = R.



Range = horizontal component of velocity × time offlight

$$R = u\cos\alpha \times T$$

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

$$R = \frac{u^2}{g}\,2\sin\alpha\cos\alpha \quad (\because \sin 2\alpha = 2\sin\alpha\cos\alpha)$$

Range $\boxed{R = \frac{u^2\sin 2\alpha}{g}}$

3.2.10. Condition for Maximum Range (R_{max})

Let a body be projected with a velocity u and an angle of projection α

Range of the projectile $R = \frac{u^2}{g}\sin 2\alpha$

Range is maximum only when sin 2α is maximum.

(i.e) $\sin 2\alpha = 1$

$\sin 90° = 1$

$2\alpha = 90° \quad \therefore \alpha = 45°$

∴ The range is maximum when the angle of projection is 45°.

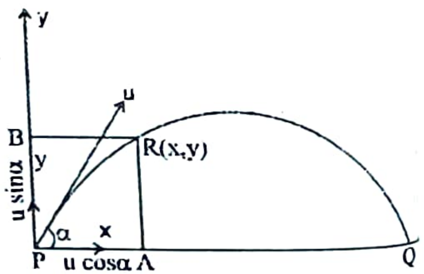
Maximum Range $\boxed{R_{max} = \frac{u^2}{g}}$

3.2.11. The path of the projectile is a Parabola

Consider a body is projected with a velocity u and an angle of projection α.

After 't' sec

The displacement along x axis, $x = u\cos\alpha\, t$



$$\therefore t = \frac{x}{u\cos\alpha}$$

The displacement along y-axis, equation of motion is

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

Here, s= y; $u = u\sin\alpha$; $a = -g$ and $t = \frac{x}{u\cos\alpha}$

Substitute the values in equ (1)

$$y = u\sin\alpha\,\frac{x}{u\cos\alpha} - \frac{1}{2}g\cdot\frac{x^2}{u^2\cos^2\alpha}$$

$$y = x\tan\alpha - \frac{gx^2}{2u^2\cos^2\alpha}$$

The above equation resembles the equation of a parabola $y = ax - bx^2$. Therefore the path of the projectile is also a parabola.

WORKED EXAMPLES

1) ***A body is thrown with a velocity of $49ms^{-1}$ at an angle of projection 45°. Calculate its maximum height, time of flight and range. ($g = 9.8m^{-2}$)***

(Oct.17)

Given : $u = 49ms^{-1}$ $\alpha = 45°$

1) Maximum height $H = \frac{u^2\sin^2\alpha}{2g} = \frac{(49)^2\sin^2(45°)}{2\times 9.8}$

$$H = 61.25\text{ m}$$

2) Time of flight $T = \frac{2u\sin\alpha}{g}$

$$= \frac{2\times 49\times\sin 45°}{9.8} = 7.071s$$

2) Horizontal range $R = \frac{u^2 \sin 2\alpha}{g} = \frac{(49)^2 \sin 90°}{9.8}$

$R = 245$ m

2) *Calculate the velocity of projection for a stone to reach a maximum height of 108m when it is projected with an angle of projection 45°. (Oct. 09)*

Given : H = 108m; $\alpha = 45°$ u = ?

Maximum height $H = \frac{u^2 \sin^2\alpha}{2g}$

$$u^2 = \frac{2gH}{\sin^2\alpha} = \frac{2 \times 9.8 \times 108}{\sin^2 (45°)}$$

$$u = \sqrt{4233} = 65 \text{ m/s}$$

3) *A bullet fired from a gun with velocity 540 kmph strikes the ground at the same level as gun at a distance of 1200 m. Find the angle with the horizontal at which the gun was fired.*

Given : $u = 540 \text{ kmph} = 540 \times \frac{5}{18} = 150 \text{ m/s}$;

R = 1200 m

$$R = \frac{u^2 \sin 2\alpha}{g} \text{ (or) } \sin 2\alpha = \frac{R \cdot g}{u^2}$$

$$\sin 2\alpha = \frac{1200 \times 9.81}{150 \times 150} = \frac{11772}{22500} = 0.5232$$

$$\sin 2\alpha = 0.5232 \quad 2\alpha = \sin^{-1}(0.5232)$$

$$2\alpha = 31°33' \quad \alpha = 15°46$$

3.3. CIRCULAR MOTION

3.3.1. Circular motion

Definition : A body is moving along the circumference of a circle, is called circular motion.

Ex i) Spinning top ii) The motion of a fan blade.

If a particle is in circular motion it has two velocities namely linear velocity v and angular velocity ω.

3.3.2 Angular velocity (ω)

*The angle described by the radius vector is one second is called **angular velocity.***

If, θ is the angle described in t seconds, then

angular velocity $\omega = \frac{\theta}{t}$ radian/second.

3.3.3. Period of revolution (T)

The time taken for one complete revolution is called **period of revolution.**

As the particle completes one revolution, the radius vector describes an angle 2π radian at the centre.

$$\omega = \frac{2\pi}{T} \qquad \therefore \quad T = \frac{2\pi}{\omega}$$

3.3.4 Frequency of revolution (n)

Number of revolutions in one second is called **frequency of revolution.**

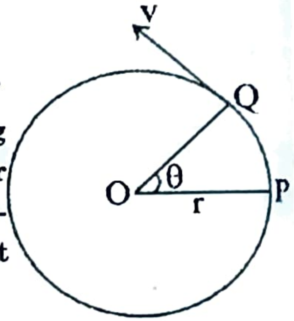
$$n = \frac{1}{T}$$

$$\therefore \quad T = \frac{1}{n}$$

$$\frac{2\pi}{\omega} = \frac{1}{n} \qquad \left\{T = \frac{2\pi}{\omega}\right\}$$

$$\omega = 2\pi n$$

3.3.5 Relation between linear velocity and angular velocity (v = rω).



Consider a particle moving along the circumference of a circle of radius r with linear velocity v and angular velocity ω. Let θ be the angle described in t seconds.

$$\text{Angular velocity } \omega = \frac{\theta}{t}$$

$$\text{Linear velocity } v = \frac{\text{length of the arc PQ}}{\text{time}}$$

$$\text{But arc PQ} = r \cdot \theta$$

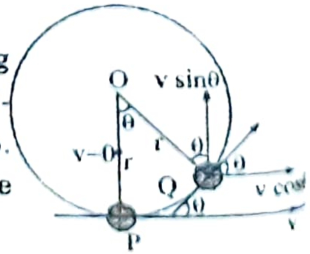
$$v = \frac{r \cdot \theta}{t} = r \cdot \frac{\theta}{t}$$

$$\boxed{v = r\,\omega}$$

3.3.6 Normal acceleration

*The acceleration directed towards the centre of the circle along the radius and perpendicular to the velocity of the particle is known as **normal acceleration**.*

3.3.7 Expression for Normal acceleration



Consider a particle moving along a circular path of radius r with uniform velocity v and angular velocity ω. Let θ be the angle described by the radius vector in t sec.

$$\left.\begin{array}{r}\text{Intially, the velocity component at}\\ \text{P in PO direction}\end{array}\right\} = 0$$

$$\left.\begin{array}{r}\text{After t sec, the velocity component at}\\ \text{Q in PO direction}\end{array}\right\} = v \sin\theta$$

$$\text{Change in velocity} = v\sin\theta - 0$$

$$= v\sin\theta$$

$$\text{Acceleration in vertical direction} = \frac{v\sin\theta}{t}$$

If θ is very small, $\sin\theta = \theta$

$$\text{Normal acceleration } a = \frac{v\cdot\theta}{t} = v\,.\,\omega \quad \left\{\because \omega = \frac{\theta}{t}\right\}$$

$$\text{Normal acceleration } a = v\,\omega$$

$$\text{since } v = r\,\omega \qquad a = r\omega\,.\,\omega = r\omega^2$$

$$\text{since } \omega = \frac{v}{r} \qquad a = v \times \frac{v}{r} = \frac{v^2}{r}$$

$$\boxed{\text{Normal acceleration } \quad a = v\,\omega \ \text{(or)}\ r\omega^2 \ \text{(or)}\ \frac{v^2}{r}}$$

3.3.8. Centripetal force

*For circular motion, a constant force should act on the body, along the radius towards the centre and perpendicular to the velocity of the body. This force is known as **centripetal force**.*

(Eg.) 1) A stone tied to the end of a string whirled in a circular path, the centripetal force is provided by the tension in the string.

2) The moon revolving around the earth, the centripetal force is the gravitational pull of the earth on the moon.

3.3.9. Expression for centripetal force.

Let **m** is the mass of the particle and **a** is the normal acceleration.

According to Newton's II law of motion F = ma

Normal acceleration $a = v\omega$ or $\frac{v^2}{r}$ or $r\omega^2$

Centripetal force $\boxed{F = m v \omega \text{ (or) } \frac{m v^2}{r} \text{ (or) } m r \omega^2}$

3.3.10. Centrifugal force

According to Newton's III law of motion there is an equal and opposite force for centripetal force. This reactive force away from the centre is known as ***centrifugal force.***

Eg. A stone tied to one and of a string is being rotated in a circle, the stone itself exerts an equal and opposite force on the hand. It is due to the centrifugal force.

- Centrifugal force $F = m v \omega$ (or) $\frac{m v^2}{r}$ (or) $m r \omega^2$

The centripetal force and centrifugal force are equal in magnitude but opposite in direction.

3.3.11 Applications of centripetal force and centrifugal force

i) Centripetal force

1) Banking of curved roads
2) Washing machine dryer
3) Cream seperater
4) Motion on a vertical circle
5) Bending of cyclist round a curve

ii) Centrifugal force

1) Centrifuges
2) Centrifugal pumps
3) Watt Governer
4) Centrifugal clutches.

WORKED EXAMPLES

1) ***A ball weighing 1 kg tied to one end of string of length 2m is whirled at a constant speed of 10 ms^{-1} in a horizontal plane. Calculate the centripetal force on the ball.*** *(Ap. 03)*

Given : $m = 1$ kg, $v = 10\ ms^{-1}$, $r = 2m$

$$F = \frac{mv^2}{r} = \frac{1 \times 10 \times 10}{2} = 50\ N$$

2) ***A rope of length 1m can withstand a maximum weight of 10 kg. Now a stone of mass 200 gram is tied to it and it is whirled round in a horizontal circle. Calculate the maximum permissible speed of the stone.*** *(Oct. 95)*

Given : $m = 200$ g $= 0.2$ kg ; $F = mg = 10 \times 9.8$ N

$$F = \frac{m v^2}{r}$$

$$\therefore\ v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{10 \times 9.8 \times 1}{0.2}}$$

$$= 22.14 ms^{-1}$$

3) ***Find the centripetal force on a body of mass 500 gm when it revolves in a circle of radius 1.5 m. The body makes 2 revolutions per second.***

Given : m = 500 gm = 0.5 kg ; r = 1.5 m

Centripetal force $F = m r \omega^2 = m r (2\pi n)^2$

$= 4\pi^2 m r n^2$

$= 4 \times (3.14)^2 \times 0.5 \times 1.5 \times 2^2$

$= 118.4$ N

4) ***A string of length 1.5 m can withstand a maximum weight of 5 kg wt. A body of mass 2 kg is tied to it and whirled round in a horizontal plane. Calculate the possible maximum number of revolutions per minute.*** ***(Ap. 2000)***

Given : F = 5 kgwt = 5 × 9.8 N ; m = 2 kg ; r = 1.5 m

$F = m r \omega^2 \quad \therefore \quad \omega = \sqrt{F/mr}$

$\omega = \sqrt{\dfrac{5 \times 9.8}{2 \times 1.5}} = 4.04$

$n = \dfrac{\omega}{2\pi} = \dfrac{4.04}{2 \times 3.14} \quad \{\omega = 2\pi n\}$

$= 0.643$ / sec.

Revolutions per minute $= 0.643 \times 60$

$= 38.6$

5) ***A ball weighing 0.5 kg and tied to the end of a string is whirled at a constant speed of 10 ms^{-1} in a horizontal plane. If the length of the string is***

one metre, calculate the normal acceleration and tension in the string. ***(Ap. 17)***

Given : m = 0.5 kg   v = 10 ms^{-1} r = 1m

Normal acceleration $a = \dfrac{v^2}{r} = \dfrac{10^2}{1} = 100 \text{ ms}^{-2}$

Tension in the string (centripetal force)

$= \dfrac{m v^2}{r} = ma = 0.5 \times 100 = 50$ N

Applications of circular motion

3.3.12.Banking of curved roads and railway tracks :

(a) Curved Road :

When a motor car moving along a curved road, two forces are acting on the car, one is the weight of the car acting downwards and another is the normal reaction of the weight acting upward. In addition to these forces a horizontal centripetal force is provided by the friction between the track and the tyres of the car towards inner side.

According to Newton's III law of motion, for this centripetal force there is a centrifugal force. This frictional force tries to balance the centrifugal force. If the road is smooth or in horizontal level, the frictional force may not be sufficient to balance centrifugal force and the car may be skid.

(b) Curved railway track :

If a train moving along a curved track, the necessary centripetal force is supplied by the lateral thrust exerted by the flanges of the wheels on the rails. This leads to wear and tear of the tracks and derailment may takes place.

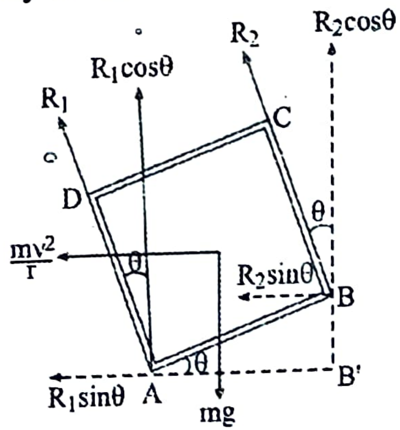
(c) Banking :

The outer rail is raised over the inner rail by a small amount to reduce the wear and tear of the railway tracks and to avoid derailment. This is known as **banking.**

3.3.13 Angle of banking :

The angle through which the outer rail is raised over the inner rail is called **angle of banking.**

3.3.14 Expression for angle of banking of curved railway track



A railway carriage of mass **m** travelling along a curved track of radius **r** with a speed **v**. Let ABCD is the vertical section of a carriage. As the outer rail is raised over the inner rail by an angle θ is known as angle of banking.

Let R_1 and R_2 be the reaction of the inner and outer rails.

Here, (i) the horizontal component of forces $(R_1+R_2)\sin\theta$ gives necessary centripetal force.

$$(R_1 + R_2)\sin\theta = \frac{mv^2}{r} \qquad \text{...... (1)}$$

(ii) the vertical component of forces $(R_1+R_2)\cos\theta$ balances the weight of the carriage.

$$(R_1+R_2)\cos\theta = mg \qquad \text{.......(2)}$$

$$\text{Equ } \frac{(1)}{(2)} \quad \tan\theta = \frac{v^2}{rg}$$

The angle of banking $\boxed{\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)}$

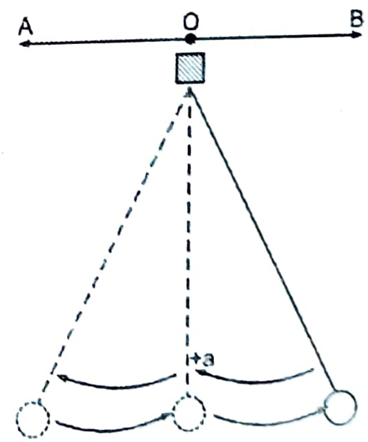
The height of the outer rail over the inner rail.

$BB' = AB\sin\theta.$

3.3.15 Simple Harmonic motion

Definition : *Simple Harmonic motion (S.H.M) is a periodic motion such that its acceleration is always directed towards the mean point and varies as the distance from the point.*

Eg. Oscillations of a simple pendulum



3.3.15. Amplitude of SHM

The maximum displacement from the mean position is called amplitude of S.H.M.

3.3.16. Period of S.H.M.

The time taken for one complete oscillation is **period** of S.H.M.

3.3.17 Frequency of S.H.M.

The number of oscillations in one second is **frequency** of S.H.M.

WORKED EXAMPLES

1) ***A scooter rider negotiates a curve of 100 m radius on a level road with a speed of 72 kmph. Calculate the angle of banking he should make to avoid falling.*** ***(Oct. 01)***

Given : r = 100 m, $v = 72 \text{ kmph} = 72 \times \frac{5}{18} = 20 \text{ ms}^{-1}$

$$\tan\theta = \frac{v^2}{rg} = \frac{20 \times 20}{100 \times 9.8} = 0.4082$$

$$\therefore \theta = \tan^{-1}(0.4082) = 22°12'$$

2) ***A circular railway track of radius 300 m is banked at an angle 10°. Find the safe speed of train.***

Given : r = 300 m $\theta = 10°$

$$\tan\theta = \frac{v^2}{rg}$$

$$v^2 = rg\tan\theta$$

$$v^2 = 300 \times 9.8 \times \tan 10°$$

$$v^2 = 518.4$$

$$v = 22.76 \text{ m/s}$$

3) ***An electric train has travel on a railway track with a bend of radius 120 m with a speed of 45 kmph. Calculate the height through which the outer rail should be raised for safe running of the train if the distance between two rails is 1.6 m ($g = 9.81 \text{ ms}^{-2}$)*** ***(Ap. 95)***

Given : r = 120 m ; $v = 45 \text{ kmph} = 45 \times \frac{5}{18} = 12.5 \text{ ms}^{-1}$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{12.5 \times 12.5}{120 \times 9.81}\right)$$

$$= \tan^{-1}(0.1327) = 7°33'$$

Height through which outer rail should be raised.

$$= AB\sin\theta$$

$$= 1.6 \sin 7°33' = 0.2102 \text{ m}$$

4) ***An aeroplane travelling in a curved path with a speed of 500kmph tilts through an angle of 30° for safe negotiation. What is the radius of the curve?***

Given : $v = 500 \text{ kmph} = 500 \times \frac{5}{18} = 138.89 \text{ ms}^{-1}$

$$\theta = 30° \quad \tan\theta = \frac{v^2}{rg} \text{ (or) } r = \frac{v^2}{\tan\theta\, g}$$

$$r = \frac{(138.89)^2}{\tan 30° \times 9.8} = 3409 \text{ m}$$

Radius of the curve r = 3.409 km

QUESTIONS

PART - A

1. **State Newton's III law of motion**

For every action, there is an equal and opposite reaction

2. **What is meant by projectile motion ?**

A body is thrown with some initial velocity and angle of projection into space, the motion is called projectile motion.

3. **Write any two examples of projectile motion**

1) Javelin throw 2) Motion of a cricket ball.

4. **Define angle of projection. (Ap.16,18)**

The angle between the direction of projection and the horizontal plane at the point of projection is called angle of projection.

5. **Define trajectory of a projectile**

The path described by the projectile is trajectory.

6. **What is the velocity at the maximum height reached by a projectile?**

The velocity of the projectile is zero

7. **What is the condition for maximum range of a projectile? (Oct. 16)**

The range is maximum only when the angle of projection is 45°.

8. **What is circular motion?**

A body is moving along the circumference of a circle is called circular motion.

9. **Define angular velocity (Oct. 15)**

The angle turned by the radius vector in one second is called angular velocity. $\omega = \frac{\theta}{t}$

10. **Define period of revolution. (Ap.16)**

The time taken for one complete revolution is the period of revolution

11. **Write the relation between angular velocity and period of revolution.**

$$\text{angular velocity} = \frac{2\pi}{\text{period of revolution}} \left(\omega = \frac{2\pi}{T}\right)$$

12. **Define frequency of revolution.**

The number of revolutions in one second is known as frequency of revolution

13. **Write the relation between angular velocity and frequency of revolution.**

$$\text{Angular velocity} = 2\pi \times \text{Frequency of revolution}$$
$$\omega = 2\pi n$$

14. **Write the relation between linear velocity and angular velocity.**

$$\text{linear velocity} = \text{Radius vector} \times \text{angular velocity}$$
$$v = r\omega$$

15. **Write the formula for centripetal force.**

$$\text{Centripetal force} = \text{mass} \times \text{linear velocity} \times \text{angular velocity}$$
$$F = mv\omega$$

16. **During circular motion, how the centripetal force and centrifugal force are formed ?**

The centripetal force and centrifugal force are equal in magnitude but opposite in direction.

16. What is banking?

The outer edge of the road is raised over the inner edge is called banking.

PART - B

1. State Newton's laws of motion. (Oct.16,17Ap. 17,19)

I Law : Every body continues to be in the state of rest or of uniform motion in a straight line unless compelled by an external force to change the state.

II Law : The rate of change of momentum of a body is directly proportional to the force acting on it and it takes in the direction of the force. (F = ma)

III Law : For every action, there is an equal and opposite reaction.

2. Write the fundamental equations of motion for a body in horizontal motion. (Oct. 15, Ap.16)

$$v = u + at$$

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

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

3. Write the fundamental equations of motion for a freely falling body. (Ap. 17)

Here $u = 0$ and $a = g$

$$v = gt$$

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

$$v^2 = 2gs$$

4. Write the fundamental equations of motion when a body is thrown vertically upwards.

Here $a = -g$

$$v = u - gt$$

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

$$v^2 = u^2 - 2gs$$

5. Define maximum height of a projectile (Ap.98,10)

The maximum vertical displacement of the projectile from the horizontal plane through the point of projection is called the **maximum height**..

6. Define time of flight of a projectile (Oct.17,18)

The time taken by the projectile from the instant of projection to the instant when it again reaches the horizontal plane through the point of projection is called the time **of flight**.

7. Define range of a projectile

The distance from the point of projection and the point where the trajectory meets the plane through the point of projection is called **range**.

8. Define normal acceleration

The acceleration directed towards the centre of the circle along the radius and perpendicular to the velocity of the particle is known as normal acceleration.

9. Define centripetal force (Oct. 18)

For circular motion, a constant force should act on the body, along the radius towards the centre and perpendicular to the velocity of the body. This force is known as centripetal force.

10. Define centrifugal force.

According to Newton's III law of motion there is an equal and opposite force for centripetal force. This reactive force, away from the centre is known as centrifugal force.

11. Write any two applications of centripetal force.

1) Washing machinedryer 2) Cream seperate

12. Write any two applications of centrifugal force

1) Centrifugal pumps 2) Watts' Governer

13. Why does outer rail is raised over the inner rail along a curved railway track? (Nov. 11)

The outer rail is raised over the inner rail to reduce the wear and tear of the tracks and to avoid derailment.

14. Define angle of banking. (Ap. 17,18 Oct.17)

The angle through which the outer rail is raised over the inner rail is called **angle of banking.**

15. Define simple harmonic motion. Give example (Oct.16,17)

Simple harmonic motion is a periodic motion such that its acceleration is always directed towards the mean point and varies as the distance from the point.

(Eg.) Oscillations of a simple pendulum.

16. Define amplitude of S.H.M (Ap.16)

The maximum displacement from the mean position is amplitude of S.H.M.

17. Define period of S.H.M.

The time taken for one oscillation is period of S.H.M.

18. Define frequency of S.H.M (Oct. 16)

The number of oscillations is one second is frequency of S.H.M.

PART - C

1. Derive an expression for maximum height of a projectile (Oct. 15,16,18) (Ans. sec 3.2.7)
2. Derive an expression for time of flight of a projectile (Oct. 15,16,18) (Ans Sec 3.2.8)
3. Derive an expression for the range of a projectile. (Oct. 09) (Ans. Sec. 3.2.9)
4. Show that the range is maximum when the angle of projection is 45° (Ans : Sec. 3.2.10)
5. Prove that the path of the projectile is a paraola. (Ap.16,17, Oct.16) (Ans: Sec 3.2.11)
6. Derive expressions for normal acceleration and centripetal force of a body executing uniform circular motion. (Oct. 15,16,18,Ap.19) (Ans : 3.3.7 & 3.3.9)
7. Write the applications of centripetal force and centrifugal force. (Ans : Sec. 3.3.11)
8. Explain the banking of curved roads and railway track. (Ans. Sec. 3.3.12)
9. Derive an expression for the angle of banking of a curved railway track. (Ap.16,17,18 Oct.17) (Ans. Sec 3.3.13 & 3.3.14)

PROBLEMS

1. A projectile is thrown with a velociy of 19.6 ms^{-1} at an angle of projection 45°. Calculate its (i) Maximum height (ii) Time of flight and (iii) Range (Ans: 9.8m, 2.828s, 39.2m)
2. A body is thrown at an angle 30° with a velocity of 36kmph. Calculate its (i) time of flight (ii) horizontal range (Ap. 02,19) (Ans:1.02s, 8.837m)

3. A body is projected upwards with a velocity of 108kmph at an angle of 30°. Calculate (i) maximum height (ii) time of flight and (iii) range (Ans: 11.48m, 3.06s, 79.53m)

4. A bullet fired from a gun with a velocity of 80 m/s strikes the ground at the same level as the gun at a distance of 460m. Find the angle of inclination with the horizontal at which the gun was fired. (Ans: α = 22°23′)

5. Calculate the velocity of projection for a stone to reach a maximum range of 400m on the horizontal plane through the point of projection. (Ans : u = 62.61 ms^{-1})

6. A missile is fired at an angle of 40° to hit a target situated at a distance of 100km. Find the velocity of projection of the missile (Ans: 995ms^{-1})

7. A car of mass 500 kg turns in a road of radius 50m with a velocity of 36 kmph. How much centripetal force is required. (Ans : 1000 N)

8. A body of mass 2kg is tied to a string of length 2m revolves in a horizontal circle. If the angular velocity of the body is 5 radian sec^{-1}. Calculate the centripetal force. (Ans : 100N)

9. A body of mass 2kg is tied to one end of a rope of length 1.5m. It is whirled in a horizontal circle with an angular velocity 2π radian per second. Find the centripetal force acting on the body. (Nov. 11) (Ans.118.315N)

10. A body of mass 500gm is tied to one end of a string of length 1m and is whirled in a horizontal circle making two revolutions per second. Calculate the tension in the string. (Oct. 10) (Ans : 78.87N)

11. A body of mass 8kg is revolving in a circle of radius 1m. The centripetal force acting on the body is 72N. Calculate the angular velocity (Ap. 10) (Ans :3 rad/s)

12. A body of mass 5 kg is revolving in a circle of radius 0.6m. The centripetal force acting on the body is 27N. Find angular velocity and linear velocity of the body. (Ans : ω = 3 rad/s, v = 1.8 ms^{-1})

13. An electrtic train has to travel on a railway track with a curve of radius 120m with a speed of 36km per hour. Calculate the angle of banking of rails. (Oct. 18) (Ans : 4°51′)

14. The radius of a railway line at a place where the train is moving with a speed of 72 kmph is 1250m. The distance between the two rails is 1.5m. Find the elevation of the outer rail so that there is no lateral thrust on the rails. (Ans : 1°52′ :0.049m)

15. An electric train has to travel a curved railway line of radius 48m with a maximum speed of 36 kmph. Calculate the angle through which the outer rail should be raised above the inner rail so that there is no lateral thrust on the rails. (Ap.06, Nov. 12) (Ans: 12°)

16. Find the angle that a cyclist makes with the vertical when moving at a speed of 10ms^{-1} along a circular path of radius 30m. (Oct.07) (Ans. 18°53′)

17. At what angle must a railway track with a bend of 320m radius be banked for safe running of a train at a speed of 80kmph. (Ap. 09) (Ans : 8°56′)

18. A train has to travel a curved railway line of radius 120m. with a maximum speed of 54kmph. If the distance between the two rails is 1.6m. Calculate the height through which the outer rail has been raised (g =9.81 ms^{-2}) (Ap. 14) (Ans. 10°49′,0.3m)

UNIT - IV

DYNAMICS - II

4.1 ROTATIONAL MOTION OF RIGID BODY

A "**rigid body**" is one in which the distance between two particles remains unchanged when an external force acting on it. A rigid body is made up of large number of particles . When a rigid body rotating about a fixed axis, its motion is known as **rotatory** motion.

4.1.1. Moment of Inertia of a particle

Definition : The **moment of inertia of a particle** about an axis is the product of the mass of the particle (m) and the square of the distance from the axis (r^2).

Moment of Inertia of the particle = mr^2

4.1.2 Moment of Inertia of a rigid body (I)

The **moment of inertia of a rigid body** about a fixed axis is the sum of the moment of inertia of all particles.

Consider a rigid body rotating about an axis. Let m_1, m_2, m_3 ...... m_n are the masses of the particles and r_1, r_2, r_3 .....r_n are the distances from the axis of rotation.

Moment of Inertia of the rigid body

$$= m_1r_1^2 + m_2r_2^2 + m_3r_3^2 + \ldots + m_nr_n^2$$

$$I = \Sigma mr^2$$

4.1.3. Radius of gyration (K)

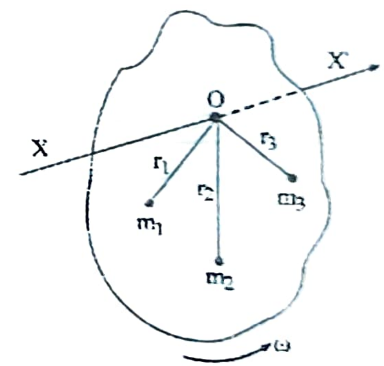
If M is the mass of the whole body and K is the radius of gyration, then moment of inertia of the rigid body $I = MK^2$

Definition : Radius of gyration is the perpendicular distance between the axis of rotation and the point where the entire mass is concentrated.

4.1.4 Expression for Kinetic Energy of a rigid body

Consider a rigid body rotating about a fixed axis XOX'. The rigid body is made up of n number of particles of masses m_1, m_2, m_3......m_n etc and r_1, r_2, r_3......r_n etc are the distances from the axis of rotation.

All particles rotate with the same angular velocity, but the linear velocities are different.



The kinetic energy of the first particle = $\frac{1}{2} m_1 v_1^2$

$$= \frac{1}{2} m_1 r_1^2 \omega^2 \qquad \{\because v_1 = r_1\omega\}$$

The kinetic energy of the whole body is the sum of the kinetic energies of all particles.

$\therefore$ Kinetic energy of the rigid body

$$= \frac{1}{2}m_1r_1^2\omega^2 + \frac{1}{2}m_2r_2^2\omega^2 + \ldots\ldots + \frac{1}{2}m_nr_n^2\omega^2$$

$$= \frac{1}{2}\omega^2(m_1r_1^2 + m_2r_2^2 + \ldots\ldots + m_nr_n^2)$$

$$= \frac{1}{2}\omega^2 \Sigma m r^2 \quad \{\because \Sigma mr^2 = I\}$$

Kinetic energy of the rigid body $= \frac{1}{2} I\omega^2$

$$\boxed{K.E. = \frac{1}{2} I\omega^2}$$

4.1.5 Angular momentum

The moment of linear momentum is known as '**angular momentum**'.

Angular momentum = linear momentum × perpendicular distance

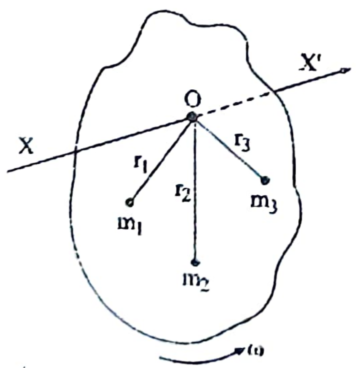
$$= mv \times r$$

Angular momentum $\boxed{L = mr^2\omega}$ $\{\because v = r\omega\}$

4.1.6 Expression for Angular momentum of a rigid body

Consider a rigid body rotating about a fixed axis XOX'. The rigid body is made up of n number of particles of masses m_1, m_2, m_3......m_n and r_1, r_2, r_3......r_n are the distance from the axis of rotation.

All particles rotate with the same angular velocity but the linear velocities are different.



Angular momentum of the first particle

$$= m_1 v_1 \times r_1 = m_1 r_1^2 \omega \qquad \{\because v_1 = r_1\omega\}$$

The angular momentum of the whole body is the sum of the angular momentum of all particles.

The angular momentum of the rigid body,

$$L = m_1 r_1^2 \omega + m_2 r_2^2 \omega + \ldots\ldots + m_n r_n^2 \omega$$

$$= \omega (m_1 r_1^2 + m_2 r_2^2 + \ldots\ldots + m_n r_n^2)$$

$$= \omega \Sigma mr^2$$

$$= \omega I \quad (\because \Sigma m r^2 = I)$$

Angular momentum $\boxed{L = I\omega}$

4.1.7 Law of conservation of angular momentum

The angular momentum of a rigid body rotating about an axis remains constant unless compelled by an external torque.

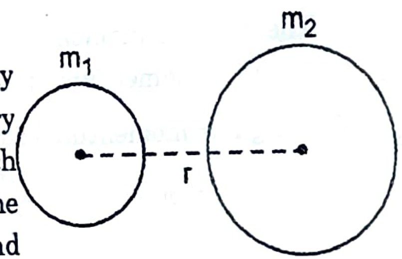
(ie) $I\omega = constant.$

Examples :

1. A ballet dancer can increase her angular velocity by folding her arms, as this decreases the moment of inertia. So the angular momentum remains constant.
2. When the planet is nearer to the sun, its angular velocity increases due to the decrease of its moment of intertia.

4.2 GRAVITATION

4.2.1. Newton's law of gravitation



Statement : Every body in this universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Explanation : Consider two particles of masses m_1 and m_2 are seperated by a distance r. Then the force of attraction F is

$$F \alpha \; m_1 m_2$$

$$F \alpha \; \frac{1}{r^2}$$

$$F \alpha \; \frac{m_1 \; m_2}{r^2}$$

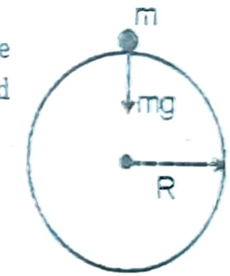
$$F = \frac{G \; m_1 \; m_2}{r^2}$$ where G is known as a gravitational constant

Note :

Let M be the mass and R be the radius of the earth. A body of mass m is placed on the earth.

Gravitional force, $F = \dfrac{G \; M \; m}{R^2}$

4.2.2. Accleration due to gravity on the surface of earth.



Consider a body of mass m is on the surface of the earth. Let M is the mass and R is the radius of the earth.

By Newton's law of gravitation

Gravitational force $F = \dfrac{G \; M \; m}{R^2}$ ... (1)

By Newton's II law of motion, Force $F = m\,g$ ....(2)

Within the atmosphere these two forces are equal.

$$\therefore \quad \frac{G \; M \; m}{R^2} = m \; g$$

$$GM = g \, R^2$$

$\therefore$ Accelerationdue to gravity on the surface of earth $\Big\}$ $\boxed{g = \dfrac{G \; M}{R^2}}$

The above equation says,

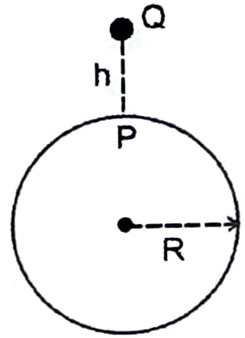
i) g is independent of mass m

ii) g varies with radius R.

iii) at the equator g is slightly least ($g = 9.78 \; ms^{-2}$)

iv) at the poles, g is slightly high ($g = 9.83 \; ms^{-2}$)

4.2.3. Variation of acceleration due to gravity with altitude



Let P be a point on the surface of the earth and Q be a point at an altitude h. Let M be the mass and R the radius of the earth.

Accleration due to gravity at P,

$$g = \frac{G\ M}{R^2} \qquad \ldots (1)$$

Accleration due to gravity at Q,

$$g_h = \frac{GM}{(R + h)^2} \qquad \ldots (2)$$

$$(2) \div (1) \ \frac{g_h}{g} = \frac{R^2}{(R + h)^2} =$$

Expand by Binomial theorem and simplify

$$g_h = g\left[1 - \frac{2\,h}{R}\right]$$

The above equation says,

i) g decreases with increases in height.

ii) when $h = \frac{R}{2}$, g is zero

4.3 SATELLITES

4.3.1 Satellites - Natural & Artificial

The heavenly bodies which revolving the sun in fixed orbit are called **planet**.

Any body which is revolving round a planet is called **satellite**.

The body which revolves around one of the planet naturally is called **natural satellite.** (Eg) Moon

The man made object revolving round the earth or any other planet is called **artificial satellite.**

(Eg)

(i) I R S (Indian Remote sensing Satellite)

(ii) PSLV (Polar Satellite Launching Vehicle)

(iii) GSLV (Geo Synchronous Satellite Launch Vehicle)

4.3.2 Escape Velocity (V_e) - Definition

The minimum velocity required to project upwards a body from the surface of the planet so that it just escapes from the gravitational pull of the planet is called escape velocity.

Escape velocity of earth – 11.2 k.m/s

Escape velocity of moon – 2.5 k.m/s

4.3.3 Expression for escape velocity (V_e)

A body of mass m is projected with escape velocity Ve on the surface of earth. Let M be the mass and R is the radius of the earth.

By Newton's law of gravitation

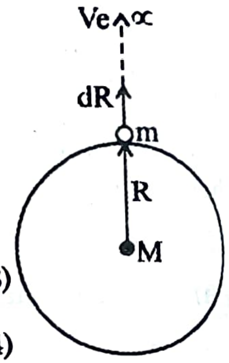
Gravitional force, $F = \frac{GMm}{R^2}$

Work done in carrying the body from the surface of earth to infinity is

$$W = \int_R^{\infty} \frac{GMm}{R^2} dR = \frac{GMm}{R} \qquad \ldots(1)$$

This work done is converted into kinetic energy with escape velocity V_e

$\therefore$ Kinetic energy $= \frac{1}{2} m V_e^2$ ...(2)



Equating the equations (2) and (1)

$$\frac{1}{2} m V_e^2 = \frac{GMm}{R}$$

$$V_e = \sqrt{\frac{2GM}{R}} \quad \text{... (3)}$$

But, $GM = gR^2$ ...(4)

Substituting (4) in (3)

escape velocity $\boxed{V_e = \sqrt{2gR}}$

4.3.4 Orbital Velocity (V_o)

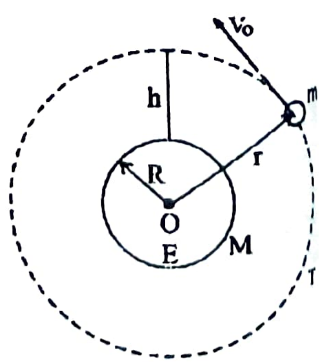
The horizontal velocity with which a satellite rotating around the earth in circular path at pre determined height is called orbital velocity.

4.3.5 Expression for orbital velocity (V_o)

Let M is the mass and R is the radius of the earth. A satellite of mass m revolves around the earth with an orbital velocity V_o. at a height (R + h)

For stable orbital motion of the satellite, the gravitational force is equal to the centripetal force.

Centripetal force = Gravitational force



$$\text{(i.e)} \quad \frac{m V_o^2}{R+h} = \frac{GMm}{(R+h)^2}$$

$$V_o^2 = \frac{GM}{R+h} \quad \text{...(1)}$$

But, $GM = gR^2$ ...(2)

Substitute the equ (2) in (1)

Orbital velocity $\boxed{V_o = \sqrt{\frac{gR^2}{R+h}}}$

If the satellite is at 200km to 300km then R+h = R.

$\therefore$ Orbital velocity $\boxed{V_o = \sqrt{gR}}$

4.3.6 Geo - Stationary satellities

The satellites which appear stationary at a height of 36,000 km above the equator are called Geo-Stationary satellites.

The period of revolution of a satellite around the earth must be equal to the rotational period of the earth (24 hours) about its axis.

The relative angular velocity of the earth and satellite are same. Also these two (earth & satellite) revolves from west to east over the equator. Because of these two reasons the satellite appear stationary to an observer on the earth.

It is used in television and telephone communications. Some television programmes or events occuring in other countries are often transmitted 'live' with the help of these satellites.

For a world wide communication network, three satellites to be parked at 120° intervals each above Atlatic. Pacific and Indian Oceans.

4.3.7 Polar Satellites

The satellites which revolving round the earth in the north-south orbit passing over the poles of the earth are called polar satellites.

These satellites are placed nearly 500 to 800 km above the earth. The period of revolution of the satellites are 102 minutes. The polar orbit remains fixed in space and the earth rotates iside the orbit in the perpendicular direction. As a result, most of the earths surface crosses the satellite in a polar orbit. So, the polar satellites are used for maping and surveying.

4.3.8 Uses of artificial satellites

1. They are used to send radio, television and telephone signals over long distances.
2. They are used in weather monitoring
3. They are used in remote sensing.
4. They are used to navigate ships and aeroplanes.
5. They are used to find the nautral wealths in the earth.
6. They are used in astronomical observation
7. They are used in space research.
8. They are used to study cosmic rays and solar radiations.

WORKED EXAMPLES

1) ***If the radius of the earth is 6400 km and the accleration due to gravity is 9.8 ms^{-2}. Calculate the escape velocity.*** ***(Oct.15,Ap.18)***

Given : $R = 6400 \times 10^3$ m $g = 9.81$ ms^{-2}

Escape velocity $V_e = \sqrt{2gR}$

$$= \sqrt{2 \times 9.81 \times 6400 \times 10^3} = 11{,}205 \text{ ms}^{-1}$$

$$V_e = 11.2 \text{ km s}^{-1}$$

2) ***The escape velocity of the surface of the earth is 11.2 km/s. Find the radius of the earth. (Oct. 07)***

Given $V_e = 11.2$ km/s $= 11200$ m/s

$V_e = \sqrt{2gR}$ $\therefore V_e^2 = 2gR$

$$\therefore R = \frac{V_e^2}{2g}$$

$$R = \frac{11200 \times 11200}{2 \times 9.8} = 6400 \times 10^3\text{m} = 6400\text{km}$$

3) ***Calculate the escape velocity on the surface of the moon taking the radius of the moon to be 2×10^6 m and the acceleration due to gravity on moon is $g = 1.69$ ms^{-2}.*** ***(Ap.08,11, Oct. 13)***

Given : $R = 2 \times 10^6$ m ; $g = 1.69$ ms^{-2}

Escape velocity $V_e = \sqrt{2gR}$

$$= \sqrt{2 \times 1.69 \times 2 \times 10^6}$$

$$= 2600\text{ms}^{-1} = 2.6\text{kms}^{-1}$$

4) ***Calculate the escape velocity for a particle 1000km above the surface of the earth.***

Radius of the earth is 6.4×10^6 m.

Escape velocity $V_e = \sqrt{2gR}$

Where R is the distance between the particle and the centre of the earth.

$$R = 1 \times 10^6 + 6.4 \times 10^6 = 7.4 \times 10^6 \text{ m}$$

$$V_e = \sqrt{2 \times 9.8 \times 7.4 \times 10^6} = 12.04 \times 10^3$$

$$= 12.04 \text{ kms}^{-1}$$

5) *A satellite is revolving round the earth at a height of 300km from the surface of the earth. Given that radius of the earth is 6400km, calculate the orbital velocity of the satellite. (Oct. 10)*

Given : R = 6400 km; h = 300 km

$$\text{Orbital Veloctity } V_0 = \sqrt{\frac{g R^2}{R + h}}$$

$$= \sqrt{\frac{9.8 \times (6400)^2}{6400 + 300}}$$

$$= \sqrt{\frac{401408000}{6700}}$$

$$= \sqrt{59911 \times 10^{+3}}$$

$$\text{Orbital velocity } V_0 = 7.74 \text{ km/s}$$

6) *An artificial satellite revolves around the earth at a distance of 3400 km. Calculate its orbital velocity. Radius of the earth = 6400km; g = 9.8 ms^{-2}.*

Given : $g = 9.8$ ms^{-2}; R = 6400 km ; h = 3400 km

$$\text{Orbital velocity } V_0 = \sqrt{\frac{g R^2}{R + h}}$$

$$= \sqrt{\frac{9.8 \times (6400)^2}{6400 + 3400}}$$

$$= \sqrt{40960 \times 10^3} = 6.4 \text{ km/s}$$

7) *A satellite is revolving round the earth at a distance of 182 km from the surface of the earth. The radius of the earth is 6371km and g is 9.81 ms^{-2}. Calculate the orbital velocity of the satellite. (Apr.12, Oct.14)*

Given : $g = 9.8$ ms^{-2} $R = 6371 \times 10^3$m, $h = 182 \times 10^3$m

$$V_o = \sqrt{\frac{g R^2}{R + h}} = \sqrt{\frac{9.81 \times (6371 \times 10^3)^3}{6371 \times 10^3 + 182 \times 10^3}}$$

V_o = .7795 ms^{-1} (or) 7.795 kms^{-1}

QUESTIONS

PART - A

1. **What is a rigid body?**

   A rigid body is one in which the distance between two particles remains unchanged when an external force acting on it.

2. **Write the relation between moment of inertia of a body and radius of gyration (Ap. 07)**

   $$I = MK^2$$

3. **Give the formula for moment of inertia of a rigid body. (Oct. 07)**

   Moment of inertia of a rigid body $I = \Sigma mr^2$

4. **Give the expression for Kinetic energy of a rigid body;.**

   Kinetic energy of rigid body = $\frac{1}{2} I\omega^2$

5. **Define angular momentum**

   The moment of linear momentum is known as angular momentum.

6. **Give the expression for angular momentum of a rigid body**

   Angular momentum of rigid body $L = I\omega$

7. **What will happen to angular momentum when there is no external torque acting on a rotating body?**

Angular momentum remains constant

$$I\omega = \text{constant}$$

8. **Give an example for law of conservation of momentum.**

Ballet dancer

9. **What is a satellite?**

Any body which is revolving round a planet is called satellite.

10. **Give an example for natural satellite**

moon

11. **Give an example for artificial satellite**

IRS, PSLV

12. **Expansion of IRS, PSLV, GSLV**

IRS	-	Indian Remote sensing Satellite
PSLV	-	Polar Satellite Launching Vehicle
GSLV	-	Geo Synchronous Satellite Launch Vehicle

13. **What is the value of escape velocity of earth?**

Escape velocity of earth is 11.2 km/s.

PART - B

1. **Define moment of intertia of a particle (Oct. 16, Ap. 17)**

The moment of inertia of a particle about an axis is the product of the mass of the particle and the square of the distance from the axis. (ie) mr^2

2. **Define moment of inertia of a rigid body**

The moment of inertia of a rigid body about a fixed axis is the sum of the moment of inertia of all particles.

$$I = \Sigma mr^2$$

3. **Define radius of gyration** **(Ap.16,18)**

Radius of gyration is the perpendicular distance between the axis of rotation and the point where the entire mass is concentrated.

4. **State the law of conservation of angular momentum** **(Oct.15, 18 Ap.16)**

The angular momentum of a rigid body rotating about an axis remains constant unless compelled by an external torque. (i.e) $I\omega$ = constant

5. **State Newton's law of gravitation.(Ap.16, 18Oct.17)**

Every body in this universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$F = \frac{G \cdot m_1 m_2}{r^2}$$

6. **Define - artificial satellite**

The man made object revolving around the earth or any other planet in fixed orbit is called artificial satellite.

(Eg) IR satellites

7. **Define escape velocity** **(Oct.15)**

The minimum velocity required to project upwards a body from the surface of the planet so that it just escapes from the gravitational pull of the planet is called escape velocity.

8. **Define orbital velocity** **(Ap.17)**

The horizontal velocity with which a satellite rotating around the earth in circular path at predetermined height is called orbital velocity.

9. **What is meant by geo-stationary satellites?**

The satellites which appear stationary at a height of 36,000 km above the equator are called Geo-Stationary satellites.

10. **Some satellites appears stationary to an observer on earth. Why?**

The relative velocity of earth and satellite are the same. Also these two revolves from west to east. So, it appears stationary.

11. **What is meant by polar satellites?**

The satellites which revolving round the earth in the north-south orbit passing over the poles of the earth are called polar satellites.

12. **Write any two uses of artificial satellities.** **(Oct. 15,16,17,18, Ap.19)**

1. It is used in weather monitoring.
2. It is used in remote sensing
3. It is used to navigate ships and aeroplanes.

PART - C

1. Derive an expression for kinetic energy of a rigid body rotating about an axis. (Oct.16,18 Ap.17,19) **(Ans. Sec.4.1.4)**

2. Derive an expression for angular momentum of a rigid body rotating about an axis. (Oct. 15,17 Ap.16,18) **(Ans. Sec.4.1.6)**

3. Derive an expression for acceleration due to gravity on the surface of earth (or) Acceleration due to gravity on the surface of the earth differs. How? (Oct. 16,Ap.19) **(Ans. Sec.4.2.2)**

4. Derive an expression for the variation of acceleration due to gravity with altitude. (Oct. 15,17 Ap.16,17) **(Ans.Sec. 4.2.3)**

5. Derive an expression for escape velocity of a body (Oct.16,18) **(Ans. Sec. 4.3.3)**

6. Derive an expression for escape velocity of an artificl satellite. (Ans ; 4.3.5)

7. Explain geo stationary and polar satellites **(Ans: Sec.4.3.6 & 4.3.7)**

8. Write the uses of artificial satellites. **(Ans :Sec.4.3.8)**

PROBLEMS

1. Calculate the escape velocity on the surface of the planet Mars taking the radius of Mars is 3392km and acceleration due to gravity 3.72 ms^{-2} (5.02kms^{-1})

2. Calculate the escape velocity of a particle 850km above the surface of earth. Given radius of earth = 6.4×10^6m and g = 9.81 ms^{-2} (Oct. 08) (11.92 kms^{-1})

3. A remote sensing satellite is revolving round the earth at a height of 325 km from the surface of the earth. Given that the radius of the earth is 6400km. Calculate the orbital velocity of the satellite ($g = 9.8\ ms^{-2}$) (Ap.09)

(Ans : $7.726\ kms^{-1}$)

4. A satellite is revolving in circular orbit at a height of 1000km from the surface of the earth. Calculate the orbital velocity. The radius of the earth is 6400km.

(Oct. 17) (Ans : 8.515 km/s)

5. An artificial satellite is revolving around the earth at a height of 30km above the surface of the earth. Find the orbital velocity. Radius of the earth is 6371 km and $g = 9.8\ ms^{-2}$ (Ans : 7.883 km/s)

UNIT - V

SOUND & MAGNETISM

5.1. SOUND

Introduction

Sound is produced due to the vibrations of the body. These vibrations are transferred to the air medium and reach our ear, The diaphram of the ear vibrates with equal vibrations. Hence we are able to hear the sound

Properties of Sound

1. Sound cannot travel in vacuum
2. A medium is necessary for propagation
3. It travels in the form of wave motion
4. Velocity of sound in air is $333ms^{-1}$

5.1.1. Audible range, Infrasonics and ultrasonics.

The number of vibrations made in one second is known as frequency of the sound. Its unit is hertz (Hz). According to frequency the sounds are divided into three types. They are:

i) Audible range :

Normal human ear can hear sound of frequencies ranging from 20Hz to 20,000 Hz. This is called audiable range of frequency.

ii) Infrasonics

Sound waves of frequency below 20Hz are called infrasonics.

iii) Ultrasonics

Sound waves of frequency more than 20,000Hz are called ultrasonics.

(Eg) Bats produce ultrasonic wave.

5.1.2 Wave motion

There are two types of wave motion.

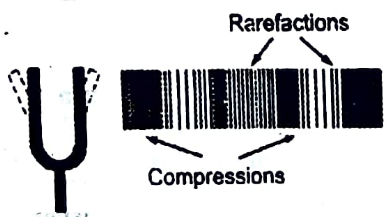
i) Longitudinal wave motion

ii) Transverse wave motion.

i) Longitudinal wave motion:

i) Longitudinal wave motion :

If the particles of the medium vibrate parallel to the direction of propagation of the wave, the wave is known as longitudinal wave.



(Ex.) (i) The propagation of sound in air or gas.

(ii) The propagation of sound inside the liquid.

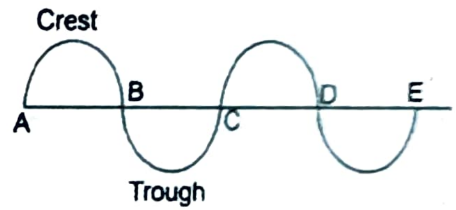
- The longitudinal waves travel in a medium in the form of compressions and rarefactions.
- The place where the particles of the medium crowded together are called compressions.
- The places where the particles spread out are called rarefactions.

ii) Transverse wave motion :

If the particles of the medium vibrate perpendicular to the direction of propagation of the wave, the wave is known as transverse wave.

(Ex) (i) Waves produced on the surface of water.

(ii) Waves travelling along a rope.



- The transverse waves travel in a medium in the form of crests and troughs.
- Crests are points having maximum upward displacement.
- Troughs are points having maximum downward displacement.

5.1.3 Differences between longitudinal and transverse wave motion

	Longitudinal Wave	Transverse Wave
1.	Particles of the medium vibrate parallel to the propogation of sound	Particles of the medium vibrate perpendicular to the propogation of sound
2.	Compressions and rarefactions are formed	Crests and troughs are formed
3.	Travels through solid, liquid and gas.	Travels through solid and on liquid surfaces.
4.	Can be reflected, refracted and diffracted but not polarised.	Can be reflected, refracted, diffracted and also polarised.
5.	Distance between two successive compressions or rarefactions is called wave length.	Distance between two successive crests or troughs is called wave length.

5.1.4. Progressive waves

If a wave travels continuously in a medium without any disturbance, is called progressive wave.

5.1.5 Amplitude, wavelength, period and frequency of a wave - Definitions

Amplitude :

The maximum displacement of a particle about their mean position is called **amplitude**.

Wave length (λ):

The wavelength is the distance between two consecutive particles of the medium which are in the same state of vibration.

Time Period (T) :

The time period of a wave is the time taken by the wave to travel a distance equal to its wave length.

Frequency (n) :

The frequency is the number of vibrations in one second.

5.1.6 Derivation of v = n λ

Let n is the frequency and λ, the wave length of the wave,

$$\text{Time taken for one oscillation (T)} = \frac{1}{n} \text{ second.}$$

$$\text{Distance travelled} = \lambda$$

$$\text{Velocity (v)} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

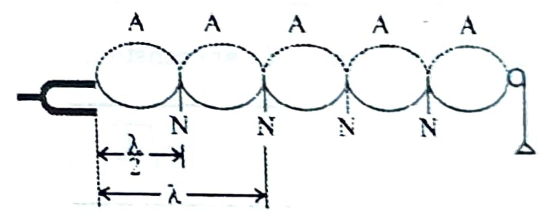
$$v = \frac{\lambda}{T} = \frac{\lambda}{1/n} = n\lambda$$

$$\boxed{v = n\,\lambda}$$

This is the relation between v, n and λ

5.1.7. Stationary or Standing Waves :

- When a progressive waves strikes against a hard surface, it gets reflected. The reflected wave superimposes on the incident wave to form stationary wave.
- When two identical waves having equal wavelength and amplitude travel in opposite directions they superimpose on each other forming stationary wave.
- A stationary wave formed by a vibrating string (PQ) is as shown in the figure.



- In a stationary wave, at certain points the particles of the medium are at rest, such points are called *nodes*.
- At certain other points the displacement of the particles is maximum, such points are called *antinodes*.

5.1.8. VIBRATIONS

a) Free vibrations :

If a body is set to vibrate and let free, it vibrates with its natural frequency are called free vibrations.

(Eg) (i) Vibrations of a tuning fork

b) Forced vibrations

If a vibrating tuning fork is placed on a body, the vibrations produced by the body with the tuning fork is called forced vibrations.

c) Resonance :

When the frequency of the forced vibration is equal to the natural frequency of the body, the body vibrates with maximum amplitude. This phenomenon is called resonance.

5.1.9 Laws of vibration in stretched strings :

When a stretched string vibrates,the frequency

(i) $n \propto \frac{1}{l}$ *when T and m are constants*

ii). $n \propto \sqrt{T}$ when l and m are constants

iii) $n \propto \frac{1}{\sqrt{m}}$ when T and l are constants

Frequency of the string $\boxed{n = \frac{1}{2l}\sqrt{\frac{T}{m}}}$

l - length of the vibrating segment

T - Tension

m - linear density

Note :

Frequency of the stretched vibrating string $\boxed{n = \frac{1}{2l}\sqrt{\frac{T}{m}}}$

l - length of the vibrating segment

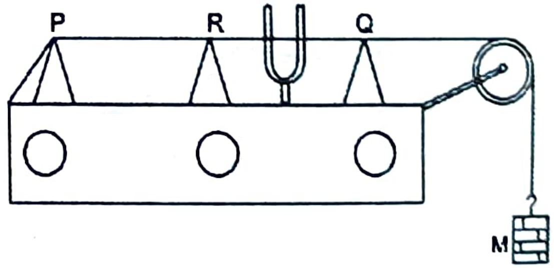
T - Tension = Mg

m - linear density

Then, Frequency $\boxed{n = \frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}}$

5.1.10 Determination of frequency of a tuning fork using Sonometer.

- A thin wire is stretched on a hollow wooden box with one end to the nail and the other end to the weight hanger. It passes over the knife edges P,Q,R and pulley.
- Add M kg weight to the hanger and a small paper rider is placed between two knife edges.
- Excited tuning fork is placed on the wooden box. Adjust the distance between the knife edges till the paper rider falls down due to resonance. Measure the length of the vibrating string 'l'.
- Repeat the experiment for different loads and the average $\frac{M}{l^2}$ is calculated.
- Measure the radius of the string r using screw gauge and calculate linear density m($m = \pi r^2 \rho$)



S.No.	Load M	Vibrating length l	l^2	$\frac{M}{l^2}$

The frequency of the tuning fork

$$\boxed{n = \frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}\ \text{Hz}}$$

WORKED EXAMPLES

1. ***A sonometer wire is loaded with a mass of 2kg. The linear density of the wire is 2×10^{-3} kgm^{-1}. When an exited tuning fork is placed on the sonometer box, the resonating length is found to be 15.4 cm. Find the frequency of the tuning fork.***

Given : $M = 2kg$; $m = 2 \times 10^{-3}$ kgm^{-1}; $l = 15.4 \times 10^{-2}$ m

$$\text{Frequency } n = \frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}$$

$$= \frac{1}{2}\sqrt{\left(\frac{2}{(.154)^2}\right)\left(\frac{9.8}{2 \times 10^{-3}}\right)}$$

$$= \frac{1}{2}\sqrt{413221} = 321 \text{ Hz}$$

2. ***A wire 50 cm long and mass 6.5×10^{-3} kg is streched so that it makes 80 vibrations per second. Find the stretching tension.***

$l = 50cm = 0.5m$; mass $= 6.5 \times 10^{-3}$ kg; $n = 80$

$$\text{Linear density} = \frac{\text{mass}}{\text{length}}$$

$$m = \frac{6.5 \times 10^{-3}}{0.5} = 13 \times 10^{-3} \text{ kg/m}$$

$$\text{Frequency} \quad n = \frac{1}{2l}\sqrt{\frac{T}{m}} \text{ (or) } n^2 = \frac{1}{4l^2} \cdot \frac{T}{m}$$

$$\text{Tension } T = 4\, l^2\, mn^2$$

$$= 4 \times 0.5 \times 0.5 \times 13 \times 10^{-3} \times 80 \times 80$$

$$= 83.2 \text{ N}$$

3. ***A wire of length 1m and mass 12×10^{-3} kg is stretched by a tension of 200N. Calculate the Frequency of vibration.***

Given

$l = 1m$ $\qquad M = 12 \times 10^{-3}$

$T = 200N$ $\qquad n = ?$

$$\text{linear density } m = \frac{\text{mass}}{\text{length}}$$

$$m = \frac{12 \times 10^{-3}}{1}$$

$$m = 12 \times 10^{-3} \text{ kgm}^{-1}$$

$$\text{Frequency of vibration } n = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

$$= \frac{1}{2 \times 1}\sqrt{\frac{200}{12 \times 10^{-3}}}$$

$$n = 64.4 \text{ Hz}$$

5.1.11 Acoustics of buildings (Architectural acoustics)

Acoustics of building deals with design and construction of buildings.

The following points should be consider for the good acoustic properties.

1) The sound heard by the audience in any part of the hall must be sufficiently loud.

2) The quality of speech and music must be unchanged.

3) The successive sound must be clearly heard.

4) Outside noise must be completly eliminated.

5) There should not be any vibrations due to resonance.

To achieve the above properties, the following factors should be considered while designing a building.

(i) Echo (ii) Reverberation (iii) Reverberation time.

i) Echo :

The first reflected sound is known as echo. If the time interval between the direct sound and reflected sound is $\frac{1}{15}$ second the echo is clearly heard. During speeches the echo produced confusion, so it is not desirable. But in music echo is desirable.

ii) Reverberation :

The reverberation is the multiple reflection of sound from the walls, floor and ceiling of a hall.

Reverberation is heard for a small time with low intensity of sound. After it becomes inaudible.

iii) Reverberation time

The time required for the intensity of sound produced by the reverberation to die out is known as reverberation time.

For a good quality of loudness an optiuin reverberation time must be maintained.

To minimise this effect, Sabine derived a formula for the reverberation time.

$$\boxed{T = \frac{0.16\,V}{\alpha\,A}} \text{ seconds}$$

where V - Volume of the hall

α - Co-efficient of absorption of sound energy

A - total sound absorbing area.

T will be minimised by increasing the value of α.

To reduce the above defects.

1) Number of doors and windows should be increased.

2) Use curtains and floor carpets.

3) The roofs and walls are covered with sound absorbing materials.

5.1.12 Co-efficient of absorption of sound energy.

The co-efficient of absorption of sound energy of a surface is defined as the ratio of the sound energy absorbed by the surface to the total sound energy incident on the surface.

5.1.13 Noise pollution

The human environment is polluted by unwanted noise is known as noise pollution.

Types :

i) Air born noise ii) Structure borne noise iii) Inside noise.

Effects :

1) It produce mental fatigue and irritation

2) It reduces the efficiency of work.

3) It lowers the quality of sleep.

4) Strong noise leads to hearing impaired

Control measures

1) Construct the building without echo and reverberation.
2) Construct the industries, airport and railway station outside the city.
3) Use noise free new machines.
4) Use vibrating mounts, leather washers and sound filters in noise machines.
5) Use air plug and muffs while working inside the factories.

5.1.14 Doppler effect and Applications

Doppler effect : The phenomenon of the apparent change in frequency of sound during the relative motion between a wave source and its observer.

Applications :

The doppler effect principle is used in the following.

1. Sirens 2. Satellite communication 3. Radar 4. Sonar
5. Medical imaging and blood flow management
6. To track storms by meteorologists
7. To diagnose heart problems
8. Radar gun is used to check the speed of oncoming vehicles

5.1.15 Uses of Ultrasonic waves

Sound waves of frequency more than 20,000Hz are called ultrasonics.

1) Ultrasonics are used to detect the cracks and defects inside metalcasting.

2) They are used to drill holes in glass and steel.
3) Ultrasonic echoes are used to view soft tissues and organs which are invisible to X-rays
4) Ultrasonic waves are used to remove kidney stones, cure cancer, to remove joint and muscular pain.

5.1.16 SONAR

- The word SONAR stands for

  SOund NAvigation and Ranging
- It is a device used for finding the distance and nature of object under the ocean using ultrasonic waves.
- The device in a ship produce and sent out ultrasonic beams into the sea.
- The nature and depth of object are analysed by the reflected ultrasonic waves from the objects.
- It is used to estimate the depth of seas and to locate submarines, icebergs, hills under the sea.

5.2 MAGNETISM

The word 'magnetism' is derived from the name of the mineral ore called 'magnetite' found in Magnesia. Magnetite has the property of attracting small pieces of iron. Magnetite is available in nature so it is called natural magnet. Artificial magnet can be prepared from iron or steel materials.

5.2.1. Magnetic field

The space around the magnet in which the magnetic lines of force act is called magnetic field.

5.2.2. Pole strength (P) :

Pole strength of a magnet is the force acting on the pole when it is placed in a uniform magnetic field of unit intensity.

Unit is ampere-metre (Am)

Unit Pole : A unit pole is defined as a pole which repel a similar pole placed one metre apart with a force of 10^{-7} newton.

5.2.3. Magnetic moment (m)

Magnetic moment of a magnet is the product of the pole strength and length of the magnet.

Magnetic moment $m = P \times 2l$

Unit is ampere-metre^2 (Am^2)

5.2.4. Magnetic induction (B)

The magnetic induction or magnetic flux density is defined as the total number of magnetic lines of force passing through unit area of cross-section.

Unit is weber/m^2 ($Wb\text{-}m^{-2}$)

5.2.5. Intensity of magnetic field (H)

The intensity of the magnetic field at a point in a magnetic field is defined as the force experienced by a unit north pole placed at that point.

Unit is ampere/metre (Am^{-1})

5.2.6 Magnetic permeability (μ)

Magnetic permeability is the ratio of the magnetic induction to the intensity of magnetic field at a point.

Unit is henry/metre (Hm^{-1})

5.2.7. Intensity of Magnetisation (M)

Intensity of magnetisation of a magnet is defined as the magnetic moment per unit volume of the magnet.

Intensity of magnetisation M

$$= \frac{\text{Magnetic moment (m)}}{\text{Volume of the magnet (V)}}$$

Unit is ampere/metre (Am^{-1}).

If m is the magnetic moment, l is the length, b is the breadth, and h is the thickness of a bar magnet, then the volume of the magnet $V = l\,b\,h$.

Intensity of magnetisation $\boxed{M = \frac{m}{V} = \frac{m}{l\,bh}}$

5.2.8 Hysteresis

When a rod of iron or steel is kept inside a solenoid through which a current is passed, the rod gets magnetised. As the strength of the current is increased the magnetism induced in the rod also increases upto a certain level. Then the induced magnetism is not increased for further increase of magnetising field. Now the rod is said to be saturated.

If the magnetising field is gradually decreased to zero, the induced magnetism does not reduced to zero. There is some residual magnetism in the specimen.

Definition : *The lagging of the induced magnetism behind the magnetising field is known as* ***hysteresis.***

5.2.9 Retentivity, coercivity and magnetic saturation

i) Retentivity (or) residual magnetism :

Retentivity is intensity of magnetisation retained in the specimen when the magnetising field is reduced to zero.

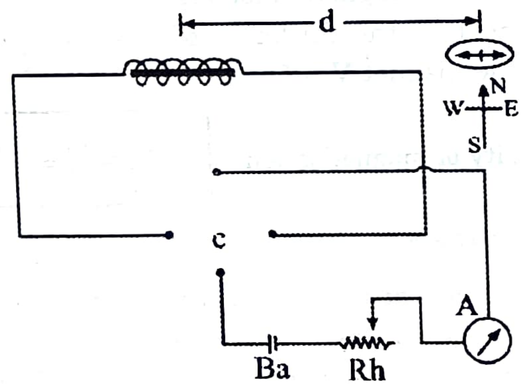
ii) Coercivity (or) coercive force :

Coercivity is the reverse magnetising field given in the specimen when the magnetising field is reduced to zero.

iii) Saturation :

The stage when there is no further increase in the induced magnetism on increasing the magnetising field is known as **'saturation'**..

5.2.10. Experiment to draw the Hysteresis loop.



The experimental arrangement is as shown in the figure. The specimen in the form of rod is placed inside the solenoid and the deflection magnetometer in tan A postion.

i) Magnetising field $H = \frac{NI}{l}$

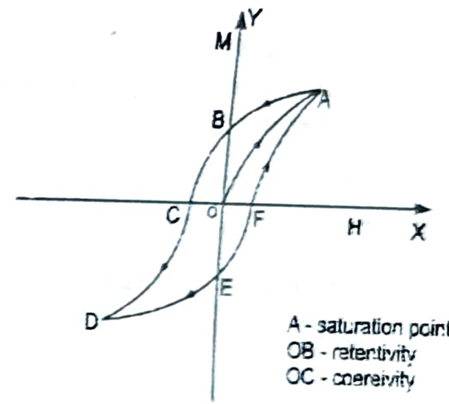
ii) Intensity of magnetisation $M = k \tan \theta$

where N - no of turns in the solenoid

I - current

l - length of the solenoid

θ - angle of delection



- The circuit is closed. The values of M and H are calculated for corresponding currents. A graph is drawn as H along X-axis and M along Y-axis.
- The value of H increases correspondingly M also increases upto the point A. The curve OA is obtained. A is the ***saturation point***.
- The value of M decreases, H also decreases and the curve AB is obtained. Here H = 0. M = OH is ***rententivity***.
- Then change the direction of current using commutator. The value of H increases in opposite direction correspondingly M decreases. The curve BC is obtained. Here M = 0, H = OC is ***coercivity***.
- Continue the process further, the curves CD, DE, EF and FA is obtained.

The specimen is taken through a cycle of magnetisation the hystersis loop ABCDEFA is obtained.

5.2.11 Selection of magnetic materials for permanent and Temporary magnets (or) uses of hysterests loops

The hysteresis loops are very useful for the selection of temporary and permanent magnets.

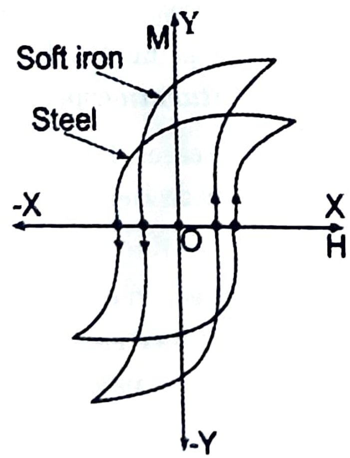
Properties of temporary magnets :

1) Large retentivity

2) Small coercivity

3) Minimum energy loss.

Soft iron possesses the above properties. So soft iron is selected to prepare temporary magnets. The soft iron is used as a core material for transformers. A.C. motors and dynamos.



Properties of permanent magnets :

1) Small retentivity

2) Large coercivity

3) High energy loss (Not important)

Steel possesses the above properties. So, steel is selected to prepare permanent magnets.

5.2.12 Types of magnetic materials and their applications

There are three types of magnetic materials

1) Dia magnetic substances

2) Para magnatic substances

3) Ferro magnetic substances

1) Dia magnetic substances

Definition : When the material is placed in a magnetic field which repells the magnetic field lines are known as dia magnetic substances.

(Eg.) Copper, Zinc, Bismuth)

Application : They are used for magnetic levitation, where an object will be made to float in are above a strong magnet.

(Eg.) Maglev train (Magnetic levitated train)

2) Para magnetic substances :

Definition : When the material is placed in a magnetic field which attracts the magnetic field lines are known as para magnetic substances.

(Eg.) Aluminium, titanium

Application : Targetting of these nonoparticules enables identification of specific organs and tissues.

3) Ferro magnetic substances

Definition : When the material is placed in a magnetic field which strongly attracts the magnetic field lines are known as ferro magnetic substances.

(Eg.) Iron, Nickel, Cobalt

Application : They are used in magnetic recording devices such as for cassette tapes, floppy disc for computer. The magnetic stripe on the back of credit cards

WORKED EXAMPLES

1) *The moment of a bar magnet is 0.6 Am^2 and its volume is 3×10^{-5} m^3. Calculate the intensity of magnetisation of the magnet.* *(Oct.15)*

Given : Moment of the magnet, $m = 0.6\ Am^2$

Volume of the maget, $V = 3 \times 10^{-5}\ m^3$

Intensity of magnetisation, $M = \frac{m}{V} = \frac{0.6}{3 \times 10^{-5}}$

$$M = 0.2 \times 10^5\ Am^{-1}$$

2) *The length, breadth and thickness of a bar magnet are 150mm, 20mm and 10mm respectively. Calculate the intensity of magnetisation if the magnetic moment is 9×10^{-6} Am^2.*

Given : $l = 150mm = 150 \times 10^{-3}m$

$b = 20mm = 20 \times 10^{-3}m$

$h = 10mm = 10 \times 10^{-3}m$ and $m = 9 \times 10^{-6}\ Am^2$

$$M = \frac{m}{V} = \frac{m}{lbh} = \frac{9 \times 10^{-6}}{150 \times 10^{-3} \times 20 \times 10^{-3} \times 10 \times 10^{-3}}$$

$$= 0.3\ Am^{-1}$$

3) *The length, breadth and thickness of bar magnet are 30cm, 2cm and 1cm respectively. Calculate the intensity of magnetisation if its magnetic moment is 6×10^{-6} Am^2.* *(Oct. 04)*

Given : $l = 30cm = 30 \times 10^{-2}m.$

$b = 2cm = 2 \times 10^{-2}m$

$h = 1mm = 1 \times 10^{-2}$ m and $m = 6 \times 10^{-6}\ Am^2$

$$M = \frac{m}{V} = \frac{m}{lbh} = \frac{6 \times 10^{-6}}{30 \times 10^{-2} \times 2 \times 10^{-2} \times 1 \times 10^{-2}}$$

$$= 0.1\ Am^{-1}$$

QUESTIONS

PART - A

1. Write any two properties of sound.

1) Sound cannot travel in vacuum

2) It travels in the form of waves.

2. Can sound waves propagate in vacuum?

Sound waves cannot propagate in vacuum

3. What is the velocity of sound in air ?

Velocity of sound in air 330 m/s

4. What is audible range ? **(Oct. 16)**

Normal human ear can hear sound of frequencies ranging from 20Hz to 20,000 Hz. This is called audible range.

5. What are infrasonics ?

Sound waves of frequency below 20Hz are called infrasonics.

6. What are ultrasonics?

Sound waves of frequency more than 20,000 Hz are called ultrasonics.

(Eg.) Bats produce ultrasonic waves.

7. What are the two types of waves motion?

(i) Longitudinal wave motion

(ii) Transverse wave motion

8. **Give an example of longitudinal wave motion**

The propagation of sound in air

9. **Give an example of transverse wave motion**

Waves produced on the surface of water

10. **Define amplitude**

The maximum displacement of a particle about their mean position is called amplitude

10. **Define frequency**

The frequency is the number of vibrations in one second.

12. **Write the relation between frequency, wavelength and velocity of a wave?**

Velocity = frequency × wavelength ($v = n\lambda$)

13. **What is the use of sonometer? (Oct. 11)**

It is used to find the frequency of a tuning fork

14. **Why the paper rider is thrown out in a sonometer experiment? (Oct. 09)**

Resonance occurs between the vibration of the string and the vibration of tuning fork. So it falls down.

15. **What are the important factors to be considered in acoustics of building (Oct. 08, Ap.17)**

(i) echo (ii) Reverberation (iii) Reverberation time

16. **Define echo**

The first refection of sound is echo

17. **Write the Sabine's formula for reverberation time**

$$T = \frac{0.16\ V}{\alpha\ A}$$

T - Reverberation time
V - Volume of Hall
α - Co-efficient of absorption of sound energy
A - total sound absorbing area

18. **Define noise pollution.**

The human environment polluted by unwanted noise is known as noise pollution.

19. **Expand the acronym SONAR.**

SOund NAvigation and Ranging

20. **Define magnetic field**

The space around the magnet in which the magnetic lines of force act is called magnetic field.

21. **Why does energy loss occur during hysteresis? (Oct. 06)**

During the cycle of magnetization and demagnetization of specimen energy is spent. This energy appears as the loss of energy.

22. **Write the uses of hysteresis loop.**

It is used in the selection of magnetic materials for permanet and temporary magnets.

23. **Which material is used to prepare temporary magnet?**

Soft iron

24. **Which material is used to prepare permanet magnet?**

Steel

25. **Write the types of magnetic materials**

Para, dia and ferro magnetic substances

PART - B

1. Define longitudinal wave. Give example (Oct.15,17,Ap.16)

If the particles of the medium vibrate parallel to the direction of propagation of the wave is known as longitudinal wave.

(Eg.) Propagation of sound in air

2. Define transverse wave. Give example. (Ap-16, Oct.17)

If the particles of the medium vibrate perpendicular to the direction of propagation of the wave is known as transverse wave.

(Eg) Waves produced on the surface of water.

3. Define wave length of a wave (Ap-16)

The wavelength is the distance between two consecutive particles of the medium which are in the same state of vibration.

4. Define stationary wave

When a progressive wave strikes against a hard surface, it gets reflected. The reflected wave superimposes on the incident wave, stationary waves are formed.

5. What are free vibrations? (Oct. 17)

If a body is set to vibrate and let free, it vibrates with its natural frequency are called **free vibrations.**

(Eg) Vibrations of a tuning fork

6. What are forced vibrations? (Oct. 17)

If a vibrating tuning fork is placed on a body, the vibrations produced by the body with the tuning fork is called forced vibrations.

(Eg) A vibrating tuning fork is kept on the table

7. Define resonance (Ap.18)

When the frequency of the forced vibration is equal to the natural frequency of the body, the body vibrates with maximum amplitude. This phenomenon is called resonance.

8. State the laws of vibrations instretched strings. (Oct. 15,16,17)

When a stretched string vibrates,the frequency

(i) $n \propto \frac{1}{l}$ *when T and m are constants*

ii) $n \propto \sqrt{T}$ when l and m are constants

iii) $n \propto \frac{1}{\sqrt{m}}$ when T *and* l are constants

Frequency of the string $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$

l - length of the vibrating segment

T - Tension

m - linear density

9. Define reverberation (Ap.18)

The reverberation is the multiple reflection of sound from the walls, floor and ceiling of the hall.

10. Define reverberation time

The time taken by the sound to fall in intensity to one millionth of the original sound is called reverberation time.

11. Define coefficient of absorption of sound energy

The coefficient of absorption of sound energy of a surface is defined as the ratio of the sound energy absorbed by the surface to the total sound energy incident on the surface.

12. Write the 'Doppler effect'

The phenomenon of the apparent change in frequency of sound during the relative motion between a wave source and its observer.

13. Write any two applications of doppler effect

1) Radar 2) Sonar 3) Sirens

14. Write any two applications of ultrasonic waves.

1) Ultrasonics are used to detect the cracks and defects inside metalcasting.

2) They are used to drill holes in glass and steel.

15. Define pole strength. (Ap. 16)

Pole strength of a magnet is the force acting on the pole when it is placed in a uniform magnetic field of unit intensity.

16. Define magnetic moment (Oct.16,18 Ap. 17)

Magnetic moment of a magnet is the product of the pole strength and length of the magnet.

17. Define magnetic induction

The magnetic induction (or) magnetic flux density is defined as the total number of magnetic lines of force passing through unit area of cross section.

18. Define intensity of magnetic field.

The intensity of the magntic field at a point is defined as the force experienced by a unit north pole placed at that point.

19. Define magnetic permeability.

Magnetic permeability is the ratio of the magnetic induction to the intensity of magnetic field at a point.

20. Define intensity of magnetisation (Oct.16, 17,18)

The magnetic moment per unit volume of the magnet is known as intensity of magnetisation.

$$\text{Intensity of Magnetisation} = \frac{\text{magnetic moment}}{\text{volume of the magnet}}$$

21. Define hysteresis (Nov. 11)

The lagging of the induced magnetism behind the magnetising field is known as hysteresis.

22. Define retentivity (Oct. 15, Ap.17)

Retentivity is the intensity of magnetisation retained in the specimen when the magnetising field is reduced to zero..

23. Define coercivity (Ap.17)

Coercivity is the reverse magnetising field given to remove the residual magnetism completly from the specimen.

24. What is magnetic saturation ?

The stage when there is no further increase in the induced magnetism on increasing the magnetising field is known as saturation.

25. Define diamagnetic substances. Give example

When the material is placed in a magnetic field which repells the magnetic field lines are known as dia magnetic substances.

(Eg.) Copper, Zinc, Bismuth

26. Define para magnetic substances. Give example.

When the material is placed in a magnetic field which attracts the magnetic field lines are known as para magnetic substances.

(Eg.) Aluminium, titanium

27. Define ferro magnetic substances. Give example

When the material is placed in a magnetic field which strongly attracts the magnetic field lines are known as ferro magnetic substances.

(Eg.) Iron, Nickel, Cobalt

PART - C

1) Explain longitudinal and transverse wave motion. (Oct.16,19) (Ans : Sec.5.1.2)

2) Distinguish betwen longitudinal and transwerse wave motion. (Ans : Sec. 5.1.3)

3) Describe an experiment to determine the frequency of a tuning fork using sonometer (Oct.15,16,17,18, Ap.18,19) (Ans : Sec. 5.1.10)

4) Write a note on acoustics of buildings. (Ap.16,17, Oct.17) (Ans : Sec. 5.1.11)

5) Write about noise pollution. (Ans : 5.1.13)

6) What is doppler effect? Write its applications. (Ans : Sec. 5.1.14)

7) Write the applications of ultrasonic waves and sonar. (Ans : Sec. 5.1.15 & 5.1.16)

8) Describe an experiment to draw the hysteresis loop (M-H curve) for a given specimen. (Oct. 15,Ap.16,18) (Ans :Sec. 5.2.10)

9) Explain the usefulness of the hysteresis loop in the selection of magnetic materials for temporary and permanent magnets (or) Explain the usefulness of hysteresis loop (Oct. 16,18Ap.17) (Ans : Sec. 5.2.11)

10) Write the types of magnetic materials and their applications. (Ans : 5.2.12)

PROBLEMS

1) In a sonometer 400kg of tension acts in a string of length 1m and mass 2gm. Calculate the frequency of vibration of the string. (Ans : 700 Hz)

2) A wire of length 1m and mass 12x10–3 kg is stretched by a tension of 200N. Calculate the frequency of vibration. (Ap.16) (Ans: 64.54Hz)

3) The vibrating length of 0.32m of a sonometer wire is unison with a tuning fork when stretched by a weight of 5.5kg. The liner density of the wire is 0.75x10–3 kg m–1. (Ap.19) (Ans. 419Hz)

4) The vibrating length 0.24m of a sonometer wire is unison with a tuning fork when strectched by a weight of 4.5kg. The linear density of the wire is 0.65×10^{-3} kgm^{-1}. Calculate the frequency of the tuning fork. (Ap.17) (Ans : 542.6 Hz)

5) Find the frequency of sound produced by a string 25cm long stretched by a load of 5kg and the linear density of the wire is 4.9×10^{-3} kgm^{-1} (Ans :200 Hz)

6) A string of length 75cm is having a mass of 3.1gram. Calculate the tension on the string if its frequency is 256Hz when vibrating in one segment. (Ans:609.4N)

7) The moment of a bar magnet is $0.8Am^2$ and its volume is 2×10^{-5} m^3. Calculate the intensity of magnetisation. (Oct. 17) (Ans :$4x10^{-4}$ Am^{-1})

8) The length, breadth and thickness of a bar magnet are 4cm, 2cm and 1cm respectively. Calculate the intensity of magnetisation if its magnetic moment is 8×10^{-6} Am^2 (Ap.05) (Ans : 1 Am^{-1})

9) The length, breadth and thickness of a bar magnet are 3cm, 2cm and 1cm respectively. Calculate the intensity of magnetisation if its magnetic moment is $6{\times}10^{-6}Am^2$ (Ap.03) (Ans : 1 Am^{-1})

10) The length, breadth and thickness of a bar magnet are 100mm, 20mm and 10mm respectively. Calculate the intensity of magnetisation, if its magnetic moment is $6{\times}10^{-6}$ Am^2 (Ans : 0.3 Am^{-1})

MODEL QUESTION PAPER

Time : 3hrs | Marks : 100

Part - A   5 x 1 = 5

Note : Answer ALL questions. All questions carry equal marks.

1. Mention any two fundamental physical quantities.
2. Why rain drops fall slowly?
3. What is the condition for maximum range of a projectile?
4. Define moment of inertia of a rigid body.
5. Define magnetic moment.

Part - B   10 x 2 = 20

Note : Answer any TEN questions. All questions carry equal marks.

6. What are the uses of dimensional formula?
7. What is meant by coplanar force?
8. State Lami's theorem.
9. What are three modull of elasticity?
10. Explain turbulent flow.
11. Define angle of contact.
12. State Newton's laws of motion.
13. Define normal acceleration.
14. Define angle of banking.
15. State law of conservation of angular momentum.
16. State Newton's law of gravitation
17. Write any two uses of artificial satellites.
18. Define resonance.
19. Define Doppler effect.
20. Explain hysteresis.

Part - C   5 x 15 = 75

Note : Answer ALL questions by choosing either A (or) B

21.A i) State the conventions to be followed in the S.I.units. (8)

ii) Explain how to resolve a vector quantity into two rectangular components. (7)

OR

B. i) Describe an experiment to verify the parallelogram law of forces. (8)

ii) If the resultant of two equal forces is $\sqrt{3}$ times each force. Find the angle between the forces. (7)

22.A i) Explain uniform and non uniform bending of beams. (8)

ii) Describe an experiment to determine the Young's modulus of the material of the beam by uniform bending method. (7)

(OR)

B. i) Describe an experiment to compare the coefficient of viscosities of two liquids. (8)

ii) Calculate the surface tension of water If it rises to a height of 4.2 cm in a capillary tube dipped vertically in it. Radius of the capillary tube is 3.5×10^{-4}m and density of water is 1000 kgm^{-3}. (7)

23.A i) Derive an expression for the maximum height and time of flight reached by the projectile. (8)

ii) Derive expression for normal acceleration and centipetal force acting on a body executing uniform circular motion. (7)

OR

B. i) Derive an expression for the angle of banking. (8)

ii) A ball weighing 0.5 kg tied to one end of a string of length 2m is rotated at a constant speed of $10ms^{-1}$ in a horizontal plane. Calculate the centripetal force on the ball. (7)

24.A i) Derive an expression for angular momentum of rotation of a rigid body rotating about an axis. (8)

ii) Derive an expression for variation of acceleration due to gravity with altitude. (7)

OR

B. i) Write short notes on polar and geostationary satellites. (8)

ii) If the radius of the earth is 6400 km, and acceleration due to gravity is $9.8ms^{2}$. Calculate the escape velocity on the surface of the earth. (7)

25.A i) Distinguish between longitudinal and transverse wave. (8)

ii) Write a note on acoustics of buildings. (7)

OR

B. i) Explain the method of drawing hysteresis loop of a given specimen. (8)

ii) The vibrating length of 0.24m of a sonometer wire is unison with a turning fork when stretched by a weight of 4.5kg. The linear density of the wire is 0.65×10^{-3} kgm^{-1}. Calculate the frequently of the fork. (7)