VIRUDHUNAGAR S.VELLAICHAMY NADAR POLYTECHNIC COLLEGE
(Affiliated to Directorate of Technical Education, Chennai 600 025)
Virudhunagar - 626 001

MISSION

"Our Mission is to Produce Disciplined and Quality Technocrats through Academic Programme of Noted Excellence to Serve the Society"

VISION

"To be an Institute of Excellence in Technical Education and Training of individuals , Focusing on the needs of the Nation and Society in tune with Technological Developments"

COURSE MATERIAL	
SCHEME	**N1**
PROGRAMME	**Basic Engineering**
TERM	**I**
COURSE	**Engineering Physics-I**
PREPARED BY	**T. Jeyagopal V. Muthuvel**
VERIFIED BY	

DEPARTMENT OF BASIC ENGINEERING

N1BE103 ENGINEERING PHYSICS – I
DETAILED SYLLABUS

UNIT I - S I UNITS AND STATICS

1.1 UNITS AND MEASUREMENTS - *Unit-Definition-Fundamental Quantities-Definition-Seven fundamental quantities; their SI units and symbol for the units- Supplementary quantities-plane angle and solid angle; their SI units and symbol for the units Derived physical quantities.*

Dimensional formula for length, mass and time-derivation of dimensional formula for area, volume, density, velocity, momentum, acceleration, force, impulse, work or energy and power. Uses of Dimensional formula. Conventions followed in SI –Units Multiples & sub-multiples and prefixes of units.

1.2 STATICS-*Scalar and vector quantities–Definitions and examples–Concurrent forces and coplanar forces–Definition-Resolution of a vector into two perpendicular components-Resultant and equilibrant–Definitions-Parallelogram law of forces-statement-Expressions for magnitude and direction of the resultant of two forces acting at a point with an acute angle between them-Lami's theorem-Statement and explanation-Experimental verification of parallelogram law of forces and Lami's theorem. Simple problems based on expressions for magnitude and direction of resultant.*

Moment of a force-Clockwise and anti-clockwise moments-Principle of moments-Couple–Torque acting due to a Couple–Experimental determination of mass of the given body using principle of moments.

UNIT II - PROPERTIES OF MATTER

2.1 ELASTICITY - *Elastic and plastic bodies–Definition-stress, strain-Definitions–Hooke's law –statement-three types of strain–Elastic and plastic limit–Young's modulus, Bulk modulus, Rigidity modulus–Definitions-Uniform and non-uniform bending of beams-Experimental determination of the Young's modulus of the material of a beam by uniform bending method. Simple problems based on stress, strain and Young's modulus.*

2.2 VISCOSITY - *Viscosity–Definition-Coefficient of viscosity-Definition, SI unit and dimensional formula-Stream line flow, turbulent flow-Explanation-Critical velocity–Definition-Experimental comparison of coefficient of viscosity of two low viscous liquids–Terminal velocity–Definition-Experimental determination of coefficient of viscosity of a highly viscous liquid by Stokes method–Practical applications of viscosity.*

2.3 SURFACE TENSION:- *Surface tension & angle of contact-Definitions-Expression for surface tension of a liquid by capillary rise method-Experimental determination of surface tension of water by capillary rise method–Practical applications of capillarity. Simple problems based on expression for surface tension.*

UNIT III - DYNAMICS–I

3.1.STRAIGHTLINE MOTION - *Introduction-Newton's Laws of motion-Fundamental Equations of motion for objects- horizontal motion-falling freely-thrown vertically upwards.*

3.2 PROJECTILE MOTION - *Projectile motion, angle of projection, trajectory, maximum height, time of flight, and horizontal range–Definitions-Expressions for maximum height, time of flight and horizontal range–Condition for getting the maximum range of the projectile. Simple problems based on expressions for maximum height, time of flight and horizontal range.*

3.3 CIRCULAR MOTION - *Circular motion, angular velocity, period and frequency of revolutions–Definitions–Relation between linear velocity and angular velocity–Relation between angular velocity, period and frequency–Normal acceleration, centripetal force and centrifugal force–Definitions–Expressions for normal acceleration and centripetal force. Banking of curved paths–Angle of banking–Definition–Expression for the angle of banking of a curved path. { $\tan\theta = v^2/(r\,g)$ } Simple problems based on the expressions for centripetal force and angle of banking.*

UNIT IV - DYNAMICS–II

4.1 ROTATIONAL MOTION OF RIGID BODIES -*Rigid body–Definition-Moment of inertia of a rigid body about an axis–expressions–Radius of gyration–Definition– Expression for the kinetic energy of a rotating rigid body about an axis–Angular momentum–Definition–Expression for the angular momentum of a rotating rigid body about an axis–Law of conservation of angular momentum–Examples.*

4.2 GRAVITATION - *Newton's laws of gravitation–Acceleration due to gravity on the surface of earth–Expression for variation of acceleration due to gravity with altitude*

4.3 SATELLITES - *Satellites–Natural and artificial–Escape velocity and orbital velocity–Definitions–Expression for escape velocity–Polar and Geostationary satellites –Uses of artificial satellites. Simple problems based on the expressions for escape velocity.*

UNIT V - SOUND AND MAGNETISM

5.1 SOUND - *Wave motion–Introduction and definition–Audible range-Infrasonic-Ultrasonics-Progressive waves, longitudinal and transverse waves–Examples- Amplitude,*

Wave length, period and frequency of a wave – Definitions - Stationary or standing waves. Vibrations-Free & forced vibrations and resonance–definitions and examples–Sonometer–Experimental determination of frequency of a tuning fork. Acoustics of buildings–Echo-Reverberation, reverberation time, Sabine's formula for reverberation time (no derivation) –Coefficient of absorption of sound energy–Noise pollution. Simple problems based on expression for frequency of vibration.

5.2 MAGNETISM - *Pole strength –Definitions–Magnetic moment, intensity of magnetisation, magnetising field intensity, magnetic induction, hysteresis, saturation, retentivity and coercivity – Definitions - Method of drawing hysteresis loop of a specimen using a solenoid–Uses of Hysteresis loop. Simple problems based on intensity of magnetization.*

UNIT – I

SI UNITS AND STATICS

1.1 UNITS AND MEASUREMENT

Introduction:

The word physics comes from the Greek word meaning “nature”. Today physics is treated as the most fundamental branch of science and finds numerous applications in all walks of life. Physics deals with matter in relation to energy and the accurate measurement of the same. Thus physics is inherently a science of measurement. The fundamentals of physics form the basis for the study and the development of engineering and technology.

Measurement consists of the comparison of an unknown quantity with a known fixed quantity. The quantity used as the standard of measurement is called ‘unit’. For example, a vegetable vendor weighs the vegetables in terms of units like kilogram.

Fundamental physical quantities

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

(e.g.) length, mass and time.

Derived quantities

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

(e.g.) area, volume, density.

Unit

Unit of a physical quantity is defined as the accepted standard used for comparison of given physical quantity.

The unit in which the fundamental quantities are measured are called fundamental unit and the units used to measure derived quantities are called derived units.

SI Units

SI unit is the abbreviation for **System International d’ units** and is the modern form of metric system finally agreed upon at the eleventh International conference of weights and measures, 1960. This system of units is now being adopted throughout the world and will remain the primary system of units of measurement. SI system possesses features that make it logically superior to any other system.

There are seven fundamental units (base units) and two supplementary units.

SI system of units

Physical quantity	Unit	Symbol
Fundamental quantities		
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
Supplementary quantities		
1. Plane angle	radian	Rad
2. Solid angle	steradian	Sr

Derived quantities and their units

Sl. No	Physical quantity	Formula	Unit	Symbol
1	Area of the square	side × side	$metre^2$ or square metre	m^2
2	Volume of the cube	side × side × side	$metre^3$ or cubic metre	m^3
3	Density	Mass / Volume	kilogram $metre^{-3}$	kgm^{-3}
4	Velocity	Displacement / time	metre $second^{-1}$	ms^{-1}
5	Acceleration	Velocity / time	metre $second^{-2}$	ms^{-2}
6	Momentum	mass × velocity	kilogram metre $second^{-1}$	$kgms^{-1}$
7	Force	mass × acceleration	Newton	N
8	Impulse	force × time	newton second	Ns
9	Work (or) Energy	force × displacement	newton metre or joule	J
10	Power	work / time	joule $second^{-1}$ or watt	W

Dimensions

The fundamental physical quantities namely length, mass and time are symbolically represented by the capital letters L, M and T respectively.

Dimensional formula is the formula in which the given physical quantity is expressed in terms of the fundamental quantities raised to suitable powers.

Dimensional formula

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 × L = L^2 (or) $L^2 M^0 T^0$
2. Volume = Length × breadth × height
   = L × L × L = L^3 (or) $L^3 M^0 T^0$
3. Density $= \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3} = M L^{-3}$ (or) $M L^{-3} T^0$
4. Velocity $= \frac{\text{Displacement}}{\text{Time}} = \frac{L}{T} = L T^{-1}$
5. Acceleration $= \frac{\text{Change in velocity}}{\text{Time}} = \frac{L T^{-1}}{T} = L T^{-2}$
6. Momentum $= \text{Mass} \times \text{Velocity} = M L T^{-1}$
7. Force $= \text{Mass} \times \text{acceleration} = M L T^{-2}$
8. Impulse $= \text{Force} \times \text{time} = M L T^{-2} \times T = M L T^{-1}$
9. Work $= \text{Force} \times \text{displacement} = MLT^{-2} \times L = ML^2T^{-2}$
10. Power $= \frac{\text{Work}}{\text{Time}} = \frac{M L^2T^{-2}}{T} = M L^2T^{-3}$
11. Energy $= \text{Force} \times \text{displacement} = MLT^{-2} \times L = ML^2T^{-2}$

Note: The dimensions are used to

(i) Check the correctness of an equation
(ii) Used to derive an equation between different physical quantities

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) The units named after scientists are not written with capital initial letter.
   (e.g.) newton and not Newton.
2) Symbol for units named after scientists should be written by capital letter.
   (e.g) N for newton and not n; J for joule and not j
3) Small letters are used as symbols for units not derived from proper name.
   (e.g) m for metre; kg for kilogram
4) Only the singular form of the unit is to be used.
   (e.g) kg and not kgs; sec and not seconds.

5) Don't use full stop at the end of the symbol.

   (e.g) kg and not kg.

6) The degree notation(°) is omitted for temperature.

   (e.g) 273K and not 273°K

7) Use only accepted symbols.

   (e.g) for ampere A and not amp; for second s and not sec.

8) Express the numerical value in scientific notation.

   (e.g) density of mercury is 1.36×10^{4} kgm^{-3} and not 13600 kgm^{-3}

9) More than one solidus should be avoided.

10) One letter space is to be left between the number and symbol of the unit

Multiples and Submultiples of units

In SI, some units are not of convenient size to measure certain quantities. Hence multiples and submultiples of the base units are used in measurements.

Multiplication factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	Tera	T
1 000 000 000 = 10^{9}	Giga	G
1 000 000 = 10^{6}	Mega	M
1 000 = 10^{3}	Kilo	K
100 = 10^{2}	hector*	H
10 = 10^{1}	deca*	Da
0.1 = 10^{-1}	deci	D
0.01 = 10^{-2}	centi*	C
0.001=10^{-3}	milli	M
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	N
0.000 000 000 001 = 10^{-12}	pico	P
0.000 000 000 000 001 = 10^{-15}	femto	F
0.000 000 000 000 000 001 = 10^{-18}	atto	A

*These are not preferred ones. They are used where the other prefixes are inconvenient

1.2 STATICS

Statics is the part of mechanics which deals with forces acting on bodies at rest. The weight of the body, the tension of a string, the load and the reaction are the different names of forces that are used in statics.

Any force can be represented in magnitude and direction by a straight line with an arrow head. The beginning of the line represents the point of application of the force. The arrow head represents the direction of the force. The magnitude of the force is given by the length of the line drawn to scale.

Scalar and Vector quantities

Physical quantities which have magnitude only are called scalar quantities.

(e.g) Mass, Volume, Speed

Physical quantities which have both magnitude and direction are called vector quantities.

(e.g) Velocity, Momentum, Force

Concurrent forces

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

Coplanar forces

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

Resultant

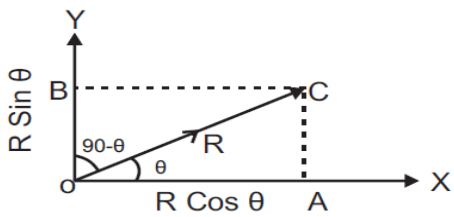
Resultant is that single force which produces the same effect as that produced by two or more forces acting on the body.

Equilibrant

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

Resolution of a vector into two perpendicular components

The process of splitting up a vector (force) into two perpendicular component parts is known as resolution of a vector. As the two component forces are mutually perpendicular, they are called rectangular components.



Let a force R act at a point O at an angle θ with x- axis. This force can be resolved into two rectangular components along x and y axis. Two lines CA and CB are drawn perpendicular to x and y axis as shown in the figure.

In the right angled triangle OAC,

$$\cos\theta = \frac{OA}{OC}$$

$$OA = OC\ COS\theta$$

$$= R\ COS\ \theta$$

Therefore the horizontal component of the force R is R cosθ. In the right angled triangle OBC,

$$\sin\theta = \frac{OB}{OC}$$

$$OB = OC\ \sin\theta$$

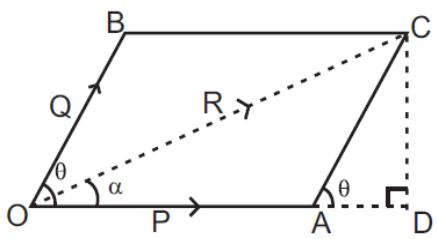
$$= R\ \sin\theta$$

The vertical component of the force R is R sinθ.

Parallelogram law of forces

If two forces acting at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from that point, their resultant is given in magnitude and direction by the diagonal of the parallelogram drawn through that point. **Parallelogram law of forces**

Expressions for the magnitude and direction of the resultant of two forces acting at a point, with an acute angle between them.



Consider two forces P and Q acting at a point O with an angle θ between them as shown in the figure. The forces P and Q are represented in magnitude and direction by the sides OA and OB of a parallelogram OACB. The diagonal OC gives the resultant of two forces P and Q in magnitude and direction. From C draw a perpendicular to meet OA extended at D.

Magnitude:

In the right angled triangle OCD

$OC^2 = OD^2 + CD$

$= (OA + AD)^2 + CD^2$

$$OC^2 = OA^2 + AD^2 + 2\ OA\ .\ AD + CD^2 \qquad ...(1)$$

In the right angled triangle ACD

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

$$AD = Q\ COS\ \theta$$

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

$$CD = Q\ \sin\theta$$

Substituting AD and CD values in eqn.(1)

$$R^2 = P^2 + Q^2 \cos^2\theta + 2\ P\ Q\ \cos\theta + Q^2\sin^2\theta$$

$$R^2 = P^2 + Q^2 (\cos^2\theta + \sin^2\theta) + 2\ P\ Q\ \cos\theta$$

$$R^2 = P^2 + Q^2 + 2\ P\ Q\ \cos\theta \qquad (\text{since } \cos^2\theta + \sin^2\theta = 1)$$

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

This is the expression for the magnitude of the resultant

Direction

In the right angled triangle COD

Let α be the angle between the resultant R and the force P.

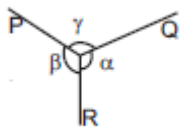
$$\tan\alpha = \frac{CD}{OD} = \frac{CD}{OA+AD} = \frac{Q\sin\theta}{P+Q\cos\theta}$$

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

This is the expression for the direction of the resultant.

Lami's theorem

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

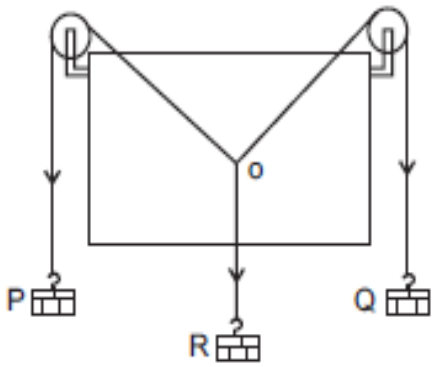


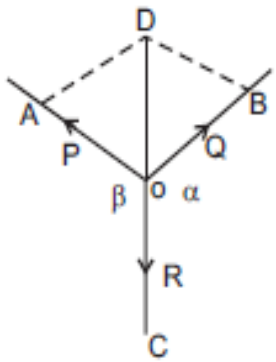
Let P, Q and R be three forces acting at a point O. Under the action of three forces, the point is at rest. Let α, β and γ be the angles opposite to the forces P, Q and R respectively.

By Lami's theorem

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

Experimental verification of parallelogram law of forces





A wooden drawing board is fixed vertically by two rigid supports. Two smooth pulleys are fixed at the top two corners of the drawing board. Three light and inextensible strings are tied together to form a common knot at a point O. Two strings are passed over the two pulleys and the third string is allowed to hang freely downwards. The free ends of the string are tied with weights. P, Q and R. Due to the action of three forces the point O is in equilibrium.

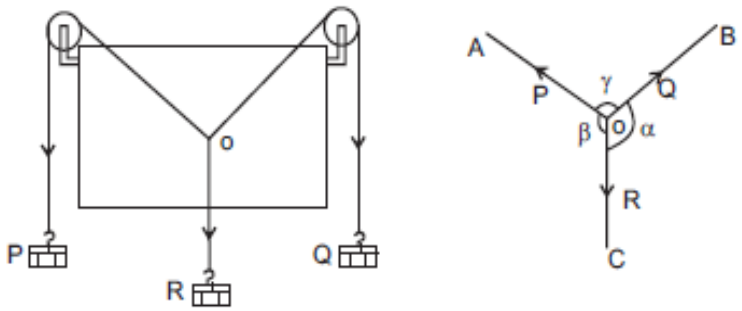
A white sheet is placed just behind the string. The point O and the directions of the forces are marked on the paper. Then the paper is taken from the board and the points are joined.

Using suitable scale the line OA, OB and OC are drawn to represent the forces P,Q and R respectively. The parallelogram OADB and the diagonal OD are drawn. The length OD and ∠COD are measured. The experiment is repeated for different values of P, Q and R and the readings are tabulated.

In all cases, it is found that OC = OD, ∠COD = 180°. Thus the diagonal OD is the equilibrant which is equal and directly opposite to the resultant R of the forces P and Q. Hence the parallelogram law is verified.

Sl. No	P	Q	R	OA	OB	OC	OD	∠COD

Experimental verification of Lami's theorem



A wooden drawing board is fixed vertically by two rigid supports. Two smooth pulleys are fixed at the top two corners of the drawing board. Three light and inextensible strings are tied together to form a common knot at a point O. Two strings are passed over the two pulleys and the third string is allowed to hang freely downwards. The free ends of the string are tied with weights P, Q and R. Due to the action of three forces, the point O is in equilibrium.

A white sheet is placed just behind the string. The point O and the directions of the forces are marked on the paper. Then the paper is taken from the board and the points are joined.

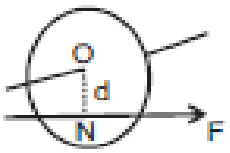
The angles α, β and γ are measured. The experiment is repeated for different values of P, Q and R and the readings are tabulated.

In all cases it is found that $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$. Hence Lami's theorem is verified.

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

Moment of a force

Consider a body which is fixed at a point, about which it can rotate freely. Let a force F is acting on the body. The effect of the force is to rotate the body about the fixed point, unless the line of action of the force passes through that fixed point O. This rotating tendency or the turning effect of the force about that point is called moment of force i.e. the turning effect of the force acting on a body about an axis or point is called moment of force.



It is common experience that in opening or closing a door, the force we apply rotates the door about its hinges. This rotating effect is known as the moment of force.

Moment of force is also equal to the product of the magnitude of the force and the perpendicular distance of the line of action of the force from the axis of rotation.

Moment of force about the point O = Force × perpendicular distance of the force from the point O

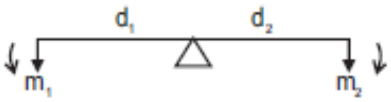
$$= F \times ON$$

The unit of moment of force is N m and the dimensional formula is ML^2T^{-2}.

Clockwise and anti-clockwise moments

If the moment of a force turns or rotates the body in clockwise direction, then it is called as clockwise moment.

If the moment of a force turns or rotates the body in anti-clockwise direction, then it is called anti-clockwise moment.

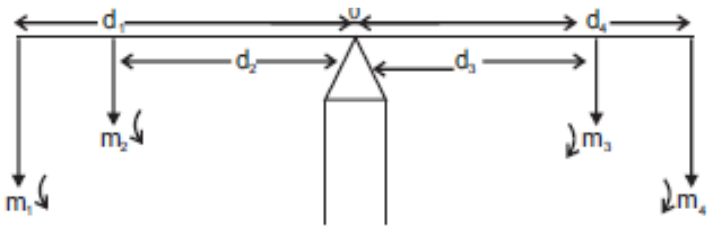


Clockwise moment = $m_2 \times d_2$

Anti-clockwise moment = $m_1 \times' d_1$

Principle of moments

The principle of moment states that if a body is in equilibrium under the action of a number of parallel forces, the sum of the clockwise moments about any point must be equal to the sum of anti-clockwise moments about the same point.



According to the principle of moments,

Sum of anti-clockwise moments = sum of clockwise moments

From figure,

$$m_1d_1 + m_2d_2 = m_3d_3 + m_4d_4.$$

Couple:

Two equal and opposite parallel forces constitute a couple.

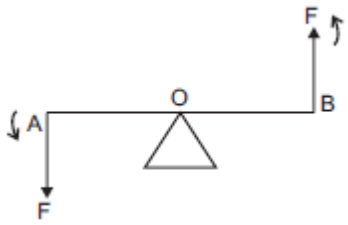
A body acted upon by the couple will rotate the body in clockwise direction or anti-clockwise direction.

Steering wheel and pedals of bicycles are the examples for couple, where the two forces are equal but acting in opposite direction.

Torque acting due to couple (or) Moment of couple

Torque is calculated by the product of either of forces forming the couple and the arm of the couple.

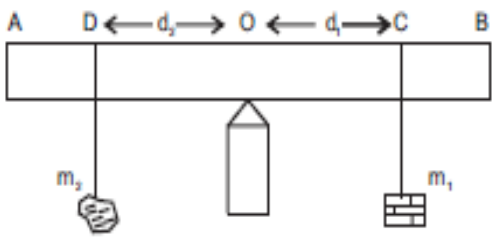
i.e.) Torque = one of the force ´× perpendicular distance between the forces.



Consider two equal forces F and F acting on the arm AB. Let O be the mid- point of the arm .The forces F and Fare acting in opposite direction as shown in the figure, they constitute a couple. Then, Moment of couple or torque = F × AB.

If the forces acting on the body have the same line of action then the moment becomes zero. The torque is maximum when the forces are at right angles to the arm i.e.) θ = 90º.

Determination of mass of the given body using principle of moments.



A meter scale AB is supported on a knife edge at its centre such that it remains in equilibrium state. Let O be the centre of the scale. On the right side suspend the weight hanger of mass m_1 and on the left side suspend the given body m_2 whose mass is to be calculated. Adjust the positions of m_1 and m_2 until the scale comes to the exact equilibrium position. Let d_1 (OC) and d_2 (OD) be the distances of m_1 and m_2.

According to the principle of moments

$m_2 \times' d_2 = m_1 \times d_1$

The mass of the given body $m_2 = (m_1 \times' d_1) / d_2$

By changing the values of m_1, the experiment is repeated and the readings are tabulated.

Sl.No	m_1 kg	d_1 m	d_2 m	$m_2 = (m_1 \times' d_1) / d_2$

Mean =

The average value of the last column gives the mass of the body.

WORKED EXAMPLES

1. Find the magnitude and direction of the two forces 20N and 25N acting at an angle 60º to each other.

Given

P = 20N; Q = 25N; θ = 60º

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

$= \sqrt{20^2 + 25^2 + 2 \times 20 \times 25 \times \cos\theta} = \sqrt{1525}$

R = 39.05 N

Direction,

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

$$= \tan^{-1}\left(\frac{25\sin 60°}{20+25\cos 60°}\right) = \tan^{-1}(0.6661)$$

$$\alpha = 33°40'$$

2. Find the magnitude and direction of the resultant of two forces 30N and 40N acting at right angles to each other.

Given

P = 30N

Q = 40N

θ = 90°

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

$= \sqrt{30^2 + 40^2 + 2 \times 30 \times 40 \times \cos 90°}$

$= \sqrt{2500}$

R = 50N

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

$= \tan^{-1}\left(\frac{40\sin 90°}{30+40\cos 90°}\right)$

$\alpha = \tan^{-1}(1.333)$

$\alpha = 53°7'$

3. If the resultant of two equal force is $\sqrt{3}$ times a single force, find the angle between the forces.

Given,

Two forces are equal

$P = Q = P$

$R = \sqrt{3}P$

$R^2 = P^2 + Q^2 + 2\,P\,Q\cos\theta$

$3P^2 = P^2 + P^2 + 2\,P\,P\cos\theta$

$3P^2 - 2\,P^2 = 2P^2\cos\theta$

$P^2 = 2P^2\cos\theta$

$\cos\theta = \frac{P^2}{2P^2} = \frac{1}{2}$

$\cos\theta = \frac{1}{2}$

$\theta = 60°$

4. If the resultant of two equal forces inclined to each other at 60° is $8\sqrt{3}$N, find the component forces.

Given: Two forces are equal.

$P = Q = P$

$R = 8\sqrt{3}N$

$\theta = 60°$

$R^2 = P^2 + Q^2 + 2\,P\,Q\cos\theta$

$(8\sqrt{3})^2 = P^2 + P^2 + 2\,P\,P\cos 60°$

$192 = 2P^2 + \left(2P^2 \times \frac{1}{2}\right)$

$192 = 3P^2$

$P^2 = 64$

$P = 8N$

Component force is 8N

QUESTIONS

Part A

1. What are the fundamental quantities? Give examples.
2. What are the derived quantities? Give examples.
3. What are the supplementary quantities and their SI units?
4. What are the units for momentum and force?
5. What are the units for impulse and work?
6. What are the units for energy and power?
7. Derive the dimensional formula for impulse, power and force.
8. Derive the dimensional formula for work or energy.
9. Give two examples for scalar and vector quantities.
10. Write any two conventions followed in SI.
11. Define moment of a force.
12. Write the principle of moments.
13. Define couple.
14. Define moment of a couple.

Part- B

1. Define scaler and vector quantity.
2. What is resultant and equilibrant?
3. State parallelogram law of forces.
4. State Lami's theorem.
5. What are concurrent and coplanar forces?
6. Explain how a vector can be resolved into two rectangular components.
7. Describe an experiment to determine the mass of the given body using principle of moments.

Part- C

1. What are the rules and conventions to be followed while writing SI units.
2. Derive expressions for magnitude and direction of two forces acting at a point with an acute angle between them.
3. Describe an experiment to verify the parallelogram law of forces.
4. Describe an experiment to verify Lami's theorem.
5. Describe an experiment to determine the mass of the given body using principle of moments

Exercise Problems

1. Find the magnitude and direction of the resultant of two forces of 5N and 3N at an angle of 60º. (Ans: R =7N, α = 21º47')

2. Two forces of magnitude 4N and 2.5N acting at a point inclined at an angle of 40º to each other. Find their resultant. (Ans: R= 6.149N, α =15º8')

3. Find the resultant of two forces 3N and 4N acting on a particle in direction inclined at 30º.

   (Ans: R= 6.767N, α =17º19')

4. Two forces of magnitude 4N and 3N respectively, act on a particle at right angles to each other. Find the magnitude and direction of the resultant of two forces.

   (Ans: R= 5N, α =36º52')

5. If the resultant of two equal forces is 2 times the single force, find the angle between them.

   (Ans: θ=0º)

6. If the resultant of two equal forces inclined to each other at 60º is 8.660 N, find the component force. (Ans:5N)

7. If the resultant of two forces 6N and 8N is 12N, find the angle between them.

   (Ans: 62º43')

UNIT - II

PROPERTIES OF MATTER

2.1 ELASTICITY

Introduction:

When an external force is applied on a body, which is not free to move, the shape and size of the body change. The force applied is called deforming force. When the deforming forces are removed, the body tends to regain its original shape and size due to a force developed within the body. The force developed within the body, which is equal and opposite to deforming force is called restoring force.

Bodies, which completely regain their original size and shape after the removal of the deforming force, are called elastic bodies. Bodies which change the shape and size on the application of force and which do not regain their original condition on removal of the deforming forces are said to be plastic bodies. Bodies which do not change their shape and size on application of force are called rigid bodies.

The property by virtue of which a body tends to regain its original shape and size after removal of the deforming force is known as elasticity.

Stress :

When an external force is acting on an elastic body, it causes deformation (change in shape or in size or both). At the same time, due to elastic property, a force is developed within the material, which is equal and opposite to the applied force, to bring the body to its original shape and size. This force is ‘restoring force’.

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

The stress is defined as the restoring force acting on unit area.

Since the applied force and the restoring force are equal in magnitude, the ‘stress’ is measured as the applied force acting per unit area.

The unit for stress is newton metre^{-2} with symbol N m^{-2} or 'pascal' with symbol 'Pa'.

Strain:

When there is change in the dimension of a body because of the stress applied, ***the ratio of change in dimension to original dimension is called strain.***

$$\text{Linear Strain} = \frac{\text{Change in Length}}{\text{Original Length}} = \frac{l}{\text{L}}$$

$$\text{Bulk Strain} = \frac{\text{Change in Volume}}{\text{Original Volume}}$$

Shearing strain is the angle through which a line originally normal to the tangential force is turned.

As strain is ratio between same quantities, it has no unit or dimension.

Hooke's Law:

Within the elastic limit, the stress is directly proportional to the strain. i.e. The ratio between the stress and the strain is a constant is called modulus of elasticity.

$$\text{Modulus of elasticity} = \frac{\text{Stress}}{\text{Strain}}$$

Three modulii of elasticity

There are three types of modulii depending upon the three kinds of strain.

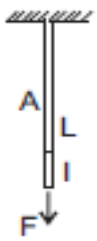
Young's modulus (E):

It is defined as the ratio of linear stress to linear strain.

Let a wire of initial length L and cross-sectional area ' A', undergo an extension *l*, when a stretching force 'F', is applied in the direction of its length.

The modulus of elasticity, in this case, is called Young's modulus and is given by

$$\text{i.e., Young's modulus(E)} = \frac{\text{Linear Stress}}{\text{Linear Strain}}$$



Then, longitudinal or linear stress = $\frac{\text{F}}{\text{A}}$

And longitudinal strain = $\frac{l}{\text{L}}$

$$E = \frac{Linear\ stress}{Linear\ Strain} = \frac{\text{F/A}}{l/\text{L}} = \frac{\text{F.L}}{\text{A}.l}$$

The unit for Young's modulus is newton metre^{-2} with symbol N m^{-2}. The single term unit which is widely used for Young's modulus is 'pascal' with symbol 'Pa'.

Bulk (or) Volume modulus (k):

It is defined as the ratio of bulk stress to bulk strain.

When a body is subjected to a uniform compressive force, its volume decreases and the strain produced is a bulk or volume strain.

If 'v' is the change in volume and V is the original volume, then

If F is the total compressive force acting on a total area A, then bulk stress = F/A = P

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

If P is the stress applied i.e. (force/unit area) then,

$$\text{bulk strain} = \frac{v}{V}$$

$$\text{bulk modulus k} = \frac{p}{v/V} = \frac{p.v}{v}$$

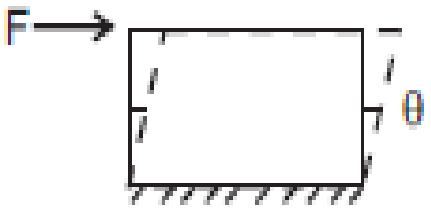
The unit for bulk modulus is 'newton metre^{-2}' with symbol N m^{-2}. The single term unit which is widely used for bulk modulus is 'pascal' with symbol 'Pa'.

Shearing (or) Rigidity modulus 'n':

The ratio of the shearing stress to shearing strain is called the rigidity modulus and denoted by the letter 'n'.

The T is the tangential force/unit area and if θ is the angle of shear measured in radian, then

$$\text{Rigidity modulus } n = \frac{F/A}{\theta} = \frac{F}{A\theta}$$



The unit for rigidity modulus is 'newton metre^{-2} radian^{-1}' with symbol N m^{-2} rad^{-1}. The other unit which is widely used for rigidity modulus is 'pascal radian $^{-1}$' with symbol 'Pa rad^{-1}'.

Bending of beams:

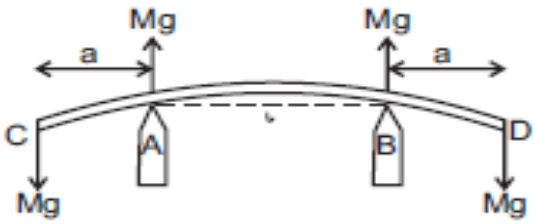
A beam is a body having uniform cross section, the length of which is very large compared to its thickness. When such a beam is fixed at one end and loaded at the other end, it is called a cantilever.

A beam is supported symmetrically on two knife edges A and B at the same level. It is loaded symmetrically with two equal weights W, W, beyond the knife edges, at C and D, so that AC=BD=a. Now the beam is elevated at the centre. This type of bending is called uniform bending of beam

A beam is supported symmetrically on two knife edges A and B near its ends in a horizontal level. A weight hanger W is suspended by means of a loop of thread from a point which is exactly midway between the two knife edges. Now the beam is depressed at the centre. This type of bending is called non-uniform bending of beam.

Experiment to determine the Young's modulus of the material of a beam by uniform bending method:

The given bar is supported symmetrically on two knife edges in a horizontal level, so that a quarter of the bar projects beyond each knife edge. Two weight hangers are suspended from two loops of string tightly attached at distances about 5 cm from each end so that their distances from the knife edges are equal. A pin is fixed vertically at the midpoint of the bar. A traveling microscope is focused on the pin such that the horizontal crosswire coincides with the tip of the pin. The reading in the vertical scale of the microscope is noted. Weights are added in steps of M kg and the corresponding readings of the image of the pin in the microscope are noted. Similarly readings are taken while unloading and tabulated.



The mean elevation y is found for a load of M kg. The distance 'I' between the knife edges is measured. The distance 'a' between the point of suspension of the weight and the nearest knife edge is also measured. The breadth 'b' of the bar found accurately with the vernier calipers and its thickness d is found with a screw gauge. Young's modulus is calculated using the formula.

$$E = \frac{3Mgal^2}{2bd^3y} \quad Nm^{-2}$$

Load in Kg	Microscope reading			Elevation y for M kg
	Load Increasing	Load Decreasing	Mean	
W W+50 W+100 W+150				

2.2 VISCOSITY

Let us consider a liquid flowing over a horizontal surface. The layer in contact with the surface is at rest. The top most layer have the maximum velocity. The intermediate layers have intermediate velocity. To maintain this relative motion of the layers, an external force must be acting on the liquid. Otherwise the liquid will come to rest due to internal frictional forces acting between the layers of the liquid. ***The tangential force between two liquid layers is known as viscous force and this property is known as viscosity.***

The property by virtue of which the relative motion between the layers of a liquid is maintained is called viscosity. We can also say viscosity is the resistance to flow.

Coefficient of viscosity of a liquid

Let F be the viscous force acting between two layers of a liquid separated by a distance dx. Let dv be the difference in velocity between the two layers. Let A be the area of the layers. The velocity gradient dv/dx acts perpendicular to direction of flow of the liquid.

The viscous force F is found to be directly proportional to

i. the area of the layers 'A'

ii. the velocity gradient $\frac{dv}{dx}$

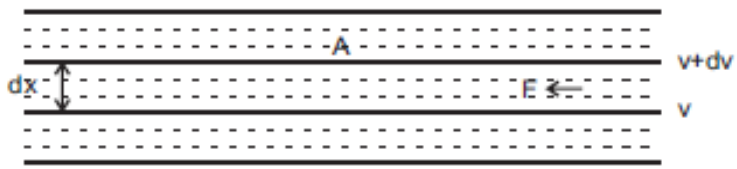
$$F \propto \frac{Adv}{dx}$$

$$F = \frac{\eta Adv}{dx}$$

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

Where η is constant, called Coefficient of viscosity of the liquid

Coefficient of viscosity of a liquid is defined as the viscous force acting between two layers of a liquid having unit area of layers and unit velocity gradient normal to the direction of flow of the liquid.



The unit of coefficient of viscosity $\eta = Nsm^{-2}$

Dimensional formula of η

The dimensional formula of coefficient of viscosity $\eta = \frac{MLT^{-2}}{L^2LT^{-1}/L} = ML^{-1}T^{-1}$

Stream line flow (laminar flow) and turbulent flow:

(i) Stream line motion

Consider a liquid flows through a narrow horizontal tube under low pressure. The flow of liquid at every point is parallel to the axis of the tube are equal. Such motion is called stream line motion.

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

(ii) Turbulent motion

Consider a liquid flows through a narrow horizontal tube under high pressure. The flow of the liquid at every point is not parallel to the axis of the tube. The velocity of all particle along a line to the axis of the tube are not equal. Such motion is called turbulent motion.

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

Critical velocity (V_c):

Upto certain limit of velocity of the liquid, the motion is stream line motion above which the motion is turbulent.

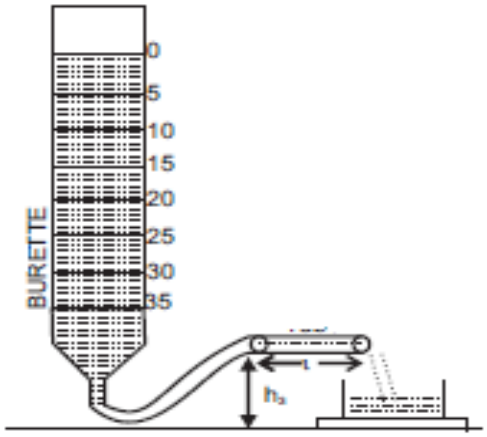
The velocity at which stream line motion stops and turbulent motion begins is called critical velocity

Distinction between streamline motion and turbulent motion

SL.No.	Stream line motion	Turbulent motion
1	Flow of liquid is orderly	Flow of liquid is zig zag and random
2	At any point along a straight line parallel to the axis of the tube, velocity is constant	Velocity varies along the straight line parallel to the axis of the tube
3	Velocity is proportional to the pressure	Velocity is proportional to the square root of pressure
4	Velocity will always be less than critical velocity	Velocity will always be greater than critical velociy

Comparison of coefficient of viscosities of two liquids

A graduated burette is fixed vertically and the capillary tube is fixed horizontally. They are connected by means of a rubber tube.



The given first liquid of co-efficient of viscosity η_1 is filled in the burette till the level is above the zero mark. Adjust the burette such that the liquid comes out of the tube drop by drop. When the burette level of the liquid reaches zero mark start a stop clock. The time is noted when the liquid reaches 5,10,15,….,15 c.c. gradually. The experiment is repeated for the second liquid of co-efficient of viscosity η_2. The readings are tabulated.

The time taken by the two liquids for the same range of flow t_1 and t_2 are calculated. From this find the mean value t_1/t_2. If ρ_1 and ρ_2 are the densities of two liquids, the ratio of co-efficient of viscosities of two liquids is calculated using the formula.

$$\frac{\eta_1}{\eta_2} = \frac{p_1}{p_2} \times \frac{t_1}{t_2}$$

Range cc	**Time of flow**		$\frac{t_1}{t_2}$
	Liquid – I	**Liquid – II**	
0-5 5-10 10-15 : : 30-35			

Mean $\frac{t_1}{t_2} =$

Terminal velocity

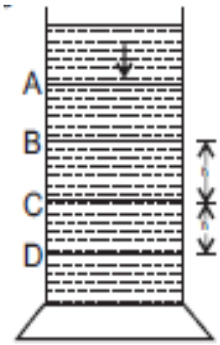
When a small metallic sphere is gently placed on the surface of a highly viscous liquid it descends down with an acceleration. As its velocity increases, the viscous force opposing the motion of the sphere also increases.

At some stage the apparent weight of the sphere becomes equal to the force due to viscous drag. So the resultant force on the sphere is zero. Therefore the sphere moves down with a constant velocity known as terminal velocity.

Definition: A small metallic sphere is dropped on the surface of a highly viscous liquid. At particular depth, the apparent weight of the sphere is equal to the upward viscous force. Then the sphere moves down with a constant velocity is known as terminal velocity.

Experimental determination of the coefficient of viscosity of a high viscous liquid by Stokes' method:

Stokes method is used to determine the co-efficient of viscosity of high viscous liquid. The given liquid is taken in a tall wide jar. Two marks C and D are marked to a height 'h'.



A small metal sphere of radius 'r' is determined using a screw gauge and it is dropped on the surface. When the ball crosses the mark C, start a stop clock and stop the clock when it crosses 'D'. The time 't' to travel the height 'h' is noted. The experiment is repeated for the balls of different radii and the readings are tabulated.

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

Mean =

From the tabular column the average value r^2t, the values of the density of the sphere ρ the density of castor oil σ and the value of h are substituted in the Stokes' formula we can find the co-efficient of viscosity of castor oil

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

2.3 SURFACE TENSION

Introduction:

The free surface of a liquid at rest behaves like a stretched elastic membrane with a tendency to contract in area. The following simple experiments will illustrate this property.

When a camel hairbrush is dipped into water, the hairs remain spread out. When the brush is taken out, the hairs cling together on account of the films of water between them contracting.

A film of the soap solution is formed in a wire ring. If a wetted loop of thread is gently placed on the film, the film is unaffected and the thread remains in any form in which it is placed on the film. But if the film is pricked inside the loop, the film outside contracts on all sides and hence the circular loop is formed. The area of the film is reduced to a minimum.

The above examples show that a force acts on the surface of liquid to reduce the surface area to a minimum. This force is known as surface tension.

A water drop takes the spherical shape because for a given volume, sphere has the minimum surface area. This is due to surface tension.

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.

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 liquids like water and kerosene which spread on glass, the angle of contact $\theta = 0°$. In the case of mercury and clean glass, the angle of contact $\theta = 138°$. For ordinary water and glass, the angle of contact $\theta = 8°$.

When a glass rod is dipped vertically in water, which wets the glass, the water is drawn up around the glass rod at all points of contact. Here, the angle of contact is acute. When a glass rod is dipped vertically in mercury, which does not wet the glass, the liquid is depressed around the glass rod at all points of contact. Here, the angle of contact is obtuse.

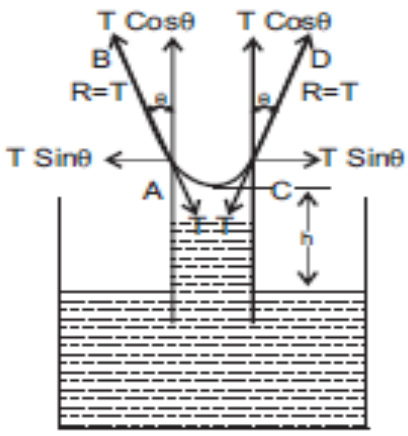
Explanation for capillary rise and capillary dip

When a capillary tube is dipped vertically into a liquid, it is found that the liquid rises or falls in the tube. This phenomenon is known as capillarity and it is due to the surface tension of the liquid.

When a capillary tube is dipped vertically in mercury, taken in a beaker, the level of mercury inside is found to be lower than the level of mercury outside the capillary tube, in the beaker. This is called 'capillary dip'.

Expression for the surface tension by capillary rise:

When a uniform capillary tube of radius 'r' is dipped vertically in a liquid of density ρ. Because of capillarity the liquid rises to a height, 'h'. Let θ is the angle of contact and T, the surface tension of the liquid.



The surface tension T acting tangential to the liquid surface and the reaction R = T acts at an angle 'θ' to the vertical. The reaction T can be resolved vertically as Tcosθ and horizontally as Tsinθ. The horizontal component along the circumference are equal and opposite in direction, so they cancells each other.

The total upward force is due to the vertical component only.

∴The total upward force along the circumference $(2\pi r) = 2\pi r.\ T\cos\theta$

This force balances the weight of the cylindrical liquid column of height 'h' and radius 'r'.

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

Total upward force = Weight of liquid column

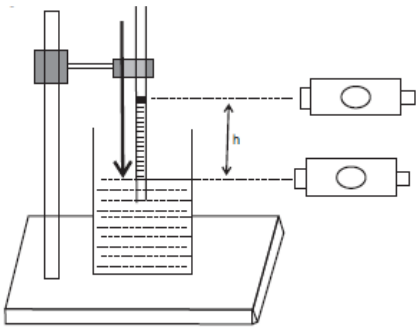
$$2\pi r T\cos\theta = \pi r^2 h \rho g$$

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

For water, angle of contact $\theta = 0°$, $\cos 0° = 1$

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

Experimental determination of the surface tension of water by capillary rise method.



A capillary tube of uniform radius is cleaned well and dipped vertically in water. Due to capillarity the water rises to a certain height. A pointer is mounted vertically such that its tip just touches the surface of water.

The horizontal cross-wire of the eye piece is focused with the lower meniscus image of the water in the tube. The vertical scale reading is taken as h_1. The beaker is removed and the microscope is lowered. The tip of the pointer is focused and the reading is taken as h_2. The difference between h_1 and h_2 gives the height 'h'.

Repeat the experiment for three times and tabulate the readings. Hence calculate the average capillary rise h.

Sl.No	Water level (Capillary tube) h_1	Water level (beaker) h_2	Capillary rise h

The diameter and hence the radius r of the capillary tube is determined with the microscope. Know the value of density of water ρ, then the surface tension of water is calculated using the formula.

$$\boxed{T = \frac{hr\rho g}{2} Nm^{-1}}$$

Practical application 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) Water rises to the other parts of the plant.
6) The continuous flow of ink from the pen through the nib.

1. A load of 5 kg is attached to the free end of a wire of length 2 m and diameter 0.6 mm. If the extension of the wire is 0.2 mm, calculate the Young's modulus of the material of the wire. ($g = 9.8\ ms^{-2}$)

Length of the wire L = 2 m

Extension of the wire I = 0.2 mm = 0.2×10^{-3} m

Force acting of the wire F = 5kgf = 5 x 9.8 N

Diameter of the wire d = 0. 6 mm = 0.6×10^{-3} m

Radius of the wire = 0.3×10^{-3} m

Area of cross section of the wire a = $\pi r^2 = \pi (3 \times 10^{-4})^2$ m^2

Young's modulus = Linear stress / Linear strain

$$\text{Linear stress } \frac{F}{A} = \frac{5 \times 9.8}{(3 \times 10^{-4})^2} = 1.734 \times 10^8 \quad Nm^{-2}$$

$$\text{Linear strain } = \frac{2\times10^{-4}}{2}$$

$$= 1 \times 10^{-4}$$

$$\text{Young's modulus } = \frac{1.734\times10^8}{1\times10^{-4}}$$

$$= 1.734 \times 10^{12}$$

2. A copper wire of 3 m length and 1 mm diameter is subjected to a tension of 5 kg wt. Calculate the elongation produced in the wire, if Young's modulus of elasticity of copper is 120 G Pa.

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

$$= \frac{FL}{Al}$$

$$\text{Elongation produced } l = \frac{FL}{AE}$$

$$= \frac{MgL}{\pi r^2 E} = \frac{5\times9.8\times3}{3.14(0.5\times10^{-3})^2\times120\times10^9}$$

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

3.A capillary tube of diameter 0.5 mm is dipped into a liquid vertically and the liquid rises to a height of 6 cm. If the density of the liquid is 1000 kgm^{-3}, calculate the value of surface tension of the liquid. (g =9.81ms^{-2})

Diameter of the capillary tube2r = 0.5 mm

Radius of the capillary tube r = 0.25 x 10^{-3}m

Rise of liquid in the tube h = 6 cm = 6 x 10^{-2}m

Density of the liquid ρ = 1000kg m^{-3}

Liquid being water, angle of contact $\theta = 0°$

$$\text{Surface tension of the liquid } T = \frac{h\,\rho\,g\,r}{2\cos\theta}$$

$$= \frac{6\times10^{-2}\times1000\cup\times9.81\times0.25\times10^{-3}}{2\cos 0°}$$

$$= 72.5 \times 10^{-3}\ Nm^{-1}$$

4.Calculate the diameter of a capillary tube in which a liquid rises 2.34×10^{-2} m. Surface tension of the liquid is 25×10^{-3} Nm^{-1}. Relative density of the liquid is 0.79. Angle of contact = 11°12'. ($g = 9.81ms^{-2}$)

Relative density of the liquid = 0.79

Density of the liquid $\rho = 0.79 \times 10^{3}$ kgm^{-3}

Diameter of the tube = 2r = 5.41×10^{-4}m

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

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

$$= \frac{2\times25\times10^{-3}\cos 11°12'}{2.34\times10^{-2}\times0.79\times10^{3}\times9.81}$$

$$= 2.705 \times 10^{-4}\ m$$

5.A liquid of density 1000 kgm^{-3} is taken in a beaker. A capillary tube of diameter 1.0 mm is dipped vertically in it. Calculate the rise of liquid in the tube. Surface tension of the liquid is $72\times10^{-3}Nm^{-1}$

For water, angle of contact $\theta = 0°$

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

Diameter of the capillary tube 2r = 1 mm

Radius of the capillary tube $r = 0.5 \times 10^{-3}$ m

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

Rise of liquid in the tube $h = \frac{2\,T\cos\theta}{r\rho g}$

$$h = \frac{2\times72\times10^{-3}\cos 0°}{0.5\times10^{-3}\times1000\times9.8}$$

$$= 2.705 \times 10^{-4}\text{m}$$

6.A capillary tube of internal diameter 0.5 mm is dipped into a liquid of density 1140 kgm^{-3}. The liquid rises to a height of 2.6 cm in the capillary tube. If the angle of contact of liquid with glass is 55°, calculate the surface tension of the liquid.

Diameter of the capillary tube = 0.6 mm

Radius of the capillary tube r = 0.3×10^{-3} m

Density of the liquid, ρ = 1140 kg m^{-3}

Height through which liquid rises h = 2.6×10^{-2} m

Angle of contact, θ = 55°

Surface tension of the liquid $T = \frac{h\,\rho\,g\,r}{2\cos\theta}$

$$T = \frac{2.6\times10^{-2}\times0.3\times10^{-3}\times1140\times\times9.8}{2\cos 55°}$$

$T = 75.96 \times 10^{-3}$ Nm^{-1}

Questions

Part – A

1. Define stress and strain.
2. State Hooke's law.
3. Define elastic limit.
4. Define coefficient of viscosity
5. What is stream line motion?
6. What is turbulent motion?
7. What is critical velocity?
8. Write the application of viscosity.
9. Define surface tension of a liquid.
10. Define angle of contact.
11. Define capillarity.

Part - B

1. Define Young's modulus, Bulk modulus and Rigidity modulus
2. Distinguish between stream line and turbulent motion.
3. What is terminal velocity?
4. List the various applications of capillarity.

Part – C

1. Describe an experiment to determine the Young's modulus of a beam by Uniform bending method.
2. Describe an experiment to compare the coefficient of viscosity of two low viscous liquids by flow method.
3. Describe Stokes' method of determining the coefficient of viscosity of a transparent, high viscous liquid.
4. Derive an expression for the surface tension of a liquid in the case of the capillary rise.
5. Describe an experiment to determine the surface tension of water by capillary rise method.

Exercise Problems

1. Calculate the surface tension of water if it rises to a height of 4.2cm in a capillary tube dipped vertically in it. Radius of the capillary tube is 3.5×10^{-4}m. (72.03×10^{-3}Nm^{-1})
2. A capillary tube of diameter 0.5 m is dipped into a liquid vertically and the liquid rises to a height of 4.4 cm. If the density of the liquid is 1000 kg m^{-3}, calculate the value of the surface tension of the liquid.
3. A capillary tube of bore 0.84 mm in dipped into a liquid of density 840 kgm^{-3} and surface tension 0.049 Nm^{-1}. Find the rise of the liquid in the tube.

UNIT-III

DYNAMICS - I

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.

1) Newton's laws of motion :

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

I Law :

Everybody 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.

III Law :

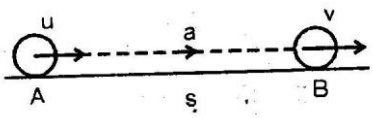
For every action, there is an equal and opposite reaction.

2. Equations of motion :

(i) For horizontal motion of a body

Let the initial velocity of the object be u and final velocity v after time 't'. Let a be the uniform acceleration and s the displacement of the object.

Acceleration $a = \frac{v-u}{t}$



$at = v - u$

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

Average velocity in time t = $\frac{\text{Distance travelled}}{\text{time}}$

$$\frac{u+v}{2} = \frac{s}{t}$$

using equation (1) $s = (u + u + at)\frac{1}{2}$

$$s = (2u + at)\frac{1}{2}$$

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

From equation (1), $v = u + at$

$$v - u = at$$

$$t = \frac{v-u}{a}$$

But average velocity $\frac{u+v}{2} = \frac{s}{t}$

$$s = \frac{(u+v)t}{2}$$

Substituting for t

$$s = \frac{(u+v)}{2} \times \frac{(v+u)}{a}$$

$$= \frac{v^2-u^2}{2a}$$

$$2as = v^2 - u^2$$

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

1) $v = u + at$

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

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

Hence the above three equations are known as equations of horizontal motion of bodies with uniform acceleration.

ii) For 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) $v^2 = u^2 - 2gs$

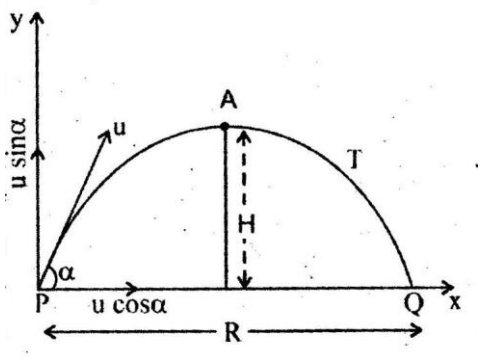
3.2. PROJECTILE MOTION

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. 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. 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.

2. Angle of projection (∝)

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

3. Trajectory

The path described by the projectile is called trajectory.

4. Maximum Height (H)

Maximum height is the maximum vertical displacement of the projectile from the horizontal plane through the point of projection.

5. Time of flight (T)

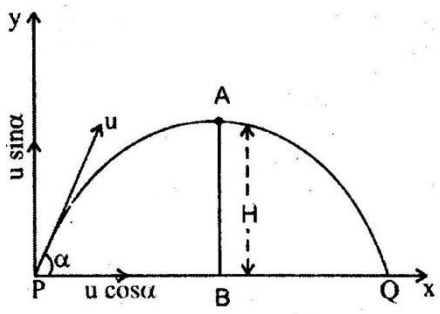
The time taken by the projectile from the instant of projection to the instant when it again reaches the horizontal plane through the point of projection is called the time of flight.

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 called range.

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

Let a body be projected with a velocity u and an angle of projection∝. The velocity of projection u is resolved into ucos∝ in the horizontal direction and usin ∝ in the vertical direction. The body describes a parabolic path.



At the highest point usin∝ becomes zero. The distance from the ground to the highest point is the maximum height H (ie.) AB = H.

Equation of motion is $v^2 = u^2 + 2as$

$u = u \sin \propto$; $v = 0$; $a = -g$; $s = H$

Substitute the values in the equation

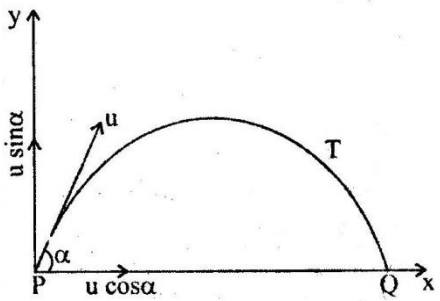
$0 = u^2 \sin^2 \propto - 2gH$

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

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

8. Expression for Time of flight (T)

Let a body be projected with a velocity u and an angle of projection ∝. The velocity of projection u is resolved into ucos∝ in the horizontal direction and usin ∝ in the vertical direction.



Let T be the time taken by the practice from P to Q. During the time interval the vertical displacement is zero.

Equation of motion is $s = ut + \frac{1}{2} at^2$

Substituting s = 0; $u = u \sin \propto$; a = - g and t = T

We get $0 = u \sin \propto \; T - ½ gT^2$

$\frac{1}{2} gT2 = u \sin \propto T$

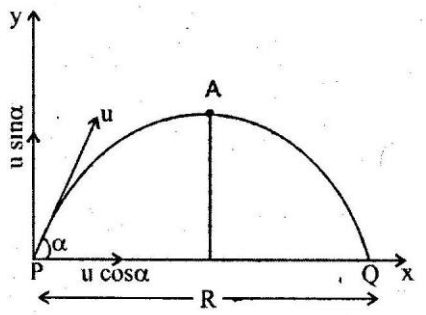
Time of flight $\boxed{T = \frac{2u \sin \propto}{g}}$

Time of flight of a projectile is double the time to reach the maximum height. (i.e.,)

$$\frac{2u \sin \propto}{g}$$

9. Expression for Range (R)

Let a body be projected with a velocity u and an angle of projection $\propto$. The velocity of projection u is resolved into u cos $\propto$ in the horizontal direction and usin $\propto$ in the vertical direction.



Range is the horizontal displacement made by the projectile in the time of flight T. (ie) PQ = R.

Range = horizontal component of velocity x time of flight

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

$$R = \frac{u^2}{g} 2 \sin \propto \cos \propto \qquad (\therefore \sin 2 \propto = 2 \sin \propto \cos \propto)$$

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

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

Let a body be projected with a velocity u and an angle of projection $\propto$

Then, range of the projectile $R = \frac{u^2}{g} \sin 2 \propto$

For a given velocity of projection, the range is maximum only if the value of $2\propto$ is maximum. (ie) sin 2 $\propto$ = 1

Since sin 90° = 1, $2\propto = 90o$ (or) $\propto = 45^o$

$\therefore$ The range is maximum when the angle of projection is 45°

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

This is the expression for maximum range.

3.3 CIRCULAR MOTION

Introduction:

The motion of the body in a circular path is called circular motion. The motion of the body in the circular path with uniform velocity is called uniform circular motion. When it is in uniform velocity, the direction of motion at any point is along the tangent to the circle at that point. If the body is set free, it would move in the direction of the tangent at that point.

Angular Velocity

Consider a body (or particle) moving along a circular path. If q is the angle turned by the radius vector in t second, then

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

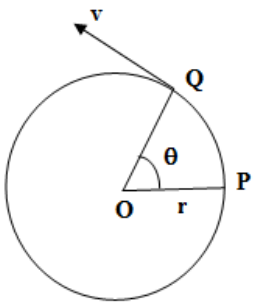
The angle turned by the radius vector in one second is known as angular velocity.

SI Unit of angular velocity is radian / second (rad s^{-1})

Radian is the angle made at the centre of the circle by an arc whose length is equal to the radius of the circle.

Relation between linear velocity and angular velocity

Consider a particle moving along the circumference of a circle of radius r with linear velocity v and angular velocity ω. Let t be the time taken to move from the point P to Q. Let θ be the angle described in t seconds.



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

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

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

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

Period and frequency of revolution

Period (T): Period of revolution of a particle is the time taken by the particle to complete one revolution.

Frequency (n): Frequency of revolution of a particle is the number of revolutions made in one second.

Relation between period T and angular velocity ω:

For one complete revolution (in T second)

Angle turned by the radius vector in T second = 2π

Angle turned by the radius vector in one second $= \frac{2\pi}{T}$

i.e., Angular velocity $\omega = \frac{2\pi}{T}$ (or) $T = \frac{2\pi}{\omega}$

Relation between period T and frequency n:

Let the particle completes n notations in one second

This is called frequency. So, the time taken complete one rotation which gives period = $\frac{1}{n}$ Therefore, $T = \frac{1}{n}$

Relation between frequency n and angular velocity ω:

No. of revolutions in 1 second = n

Angle turned by the radius vector for one revolution = 2π

Angle covered by the radius vector for n revolutions in 1 second = $2\pi n$

i.e., Angular velocity , $\omega = 2\pi n$

Normal Acceleration

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

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.

Examples for centripetal force:

The centripetal force is responsible for circular motion. Without this force the body cannot move along a circular path. This forcer can be produced in different ways.

A body tied to one end of a string is being rotated in a circle; the centripetal force is supplied by the tension of the string.

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

A person riding a cycle along a circular path, the necessary centripetal force is supplied by a sidewise pressure exerted by the road on the tyres.

Definition of Centrifugal Force

The force which is equal to and opposite to centripetal force is known as centrifugal force.

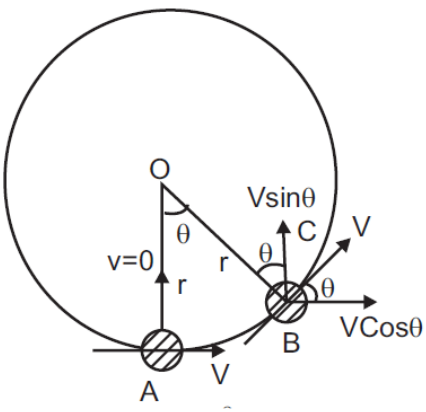
Examples for centrifugal force:

A stone tied to one end 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.

A centrifugal pump is used to pump well water on the basis of centrifugal force.

Expressions for Normal acceleration

Consider a particle moving along a circular path of radius r with uniform velocity v and angular velocity ω. Let t be the time taken to move from the point P to Q.



Let θ be the angle described by the radius vector.

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

Initially,

The velocity component at P in PO direction = 0

After t seconds

The velocity component at Q in PO direction = v sinθ

Change in velocity = v sinθ - 0

= v sinθ

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

If θ is very small, sinθ = θ

Normal acceleration $a = \frac{v.\theta}{t}$

Since $\omega = \frac{\theta}{t}$ $a = v\omega$

Since $v = r\omega$ $a = r\omega^2$

Since $\omega = \frac{v}{r}$ $a = \frac{v^2}{r}$

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

Expressions 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 $a = r\omega$ (or) $\frac{v^2}{r}$ (or) $r\omega^2$

Centripetal force $F = mv\omega$ (or) $mr\omega^2$ (or) $\frac{mv^2}{r}$

Worked Examples

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

   Given:

   m = 1 kg, v = 10 ms^{-1}, r = 2m

   $$F = \frac{mv^2}{r} = \frac{1\times10\times10}{2} = 50 \text{ N}$$

2) **A rope of length 1 m can withstand a maximum weight of 10kg. 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.**

   Given:

   m = 200g = 0.2 kg;

   F = mg = 10 × 9.8 N

   $$F = \frac{mv^2}{r}$$

   $$\therefore v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{10\times9.8\times1}{0.2}}$$

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

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 120 revolutions per minute.**

   Given:

   m = 500 gm = 0.5 kg;

   r = 1.5 m

   No. of revolutions = 120 per minute

   $$n = \frac{120}{60} = 2 \text{ per second}$$

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

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

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

   $$= 118.4\text{N}$$

Banking of curved paths:

Curved track is to be considered as a part of the circular path. Consider a motor car moving along a curved road. Now two forces are acting on the car, one is the weight of the car acting downward and second is the normal reaction acting upward. In addition to these two forces, a horizontal centripetal force should act on the car for safe negotiation of curved motion. This force is supplied by the pressure exerted by the road on the tyres of the car towards inner side.

According to Newton's third law of motion, the tyres exert an equal and opposite pressure on the road towards the outer side. Hence there must be a frictional force between the road and the tyres. This frictional force tries to balance the centrifugal force. If the road is in horizontal level, the friction may not be sufficient to balance the centrifugal force. Then the car may skid. To avoid this the outer edge of the road is raised a little above the level of the inner edge. This formation is called as banking of curved paths.

In the case of train moving along a curved track, the necessary centrifugal force is supplied by the pressure exerted by the rails on the flanges of the wheels. Also the flanges of the wheels exert an equal and opposite pressure on the rails. Hence there must be a large amount of friction and it leads to damage the rails also to derailment of the train.

To avoid this damage and derailment, the outer rail is suitably raised over the inner rail to eliminate the flange pressure on the rails. This formation is called as banking of curved railway tracks.

The raising of outer edge of a curved path than the inner edge for providing the necessary centripetal force is known as banking of curved path.

Angle of Banking:

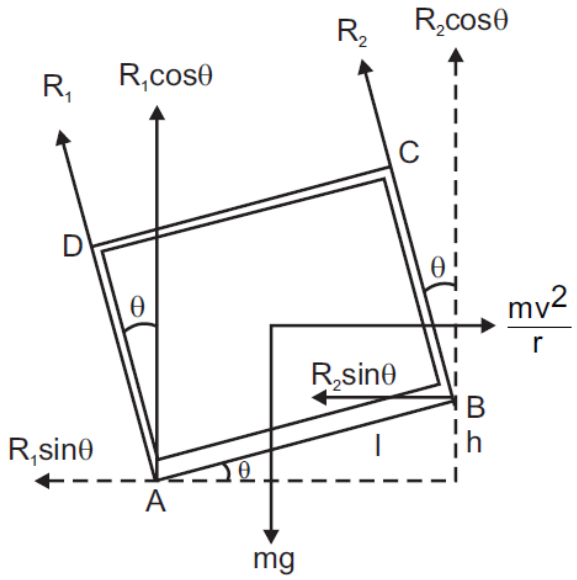
It is the angle between the normal horizontal path and the curved banked path.

The angle of banking of a curved path is defined as the angle through which the outer edge of the road is raised over the inner edge.

The angle of banking of curved railway tracks is defined as the angle through which the outer rail is raised over the inner rail.

Expression for Angle of banking of Railway tracks

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, the floor of the carriage is also inclined to the horizontal by an angle θ. This angle θ is known as angle of banking.



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

The total vertical component of R_1 and R_2

$$= R_1 \cos\theta + R_2 \cos\theta = (R_1 + R_2)\cos\theta$$

This balances the weight of the carriage

$$(R_1 + R_2)\cos\theta = W = mg \quad \text{----- (1)}$$

The total horizontal component of

$$R_1 \text{and } R_2 = R_1 \sin\theta + R_2 \sin\theta = (R_1 + R_2)\sin\theta$$

This gives the necessary centripetal force and it balances the centrifugal force

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

Equ $\frac{(2)}{(1)}$ $\quad \tan\theta = \frac{v^2}{r\,g}$

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

The height of the outer rail over the inner rail.

$$BB' = AB \sin\theta$$

Worked Examples:

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

   Given:

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

   $$\tan\theta = \frac{v^2}{rg} = \frac{20\times20}{100\times9.8} = 0.4082$$

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

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

   Given:

   r = 300 m ; θ = 10°

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

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

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

   $$v^2 = 518.4$$

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

PART – A

1. Write the equation of motion for a body in horizontal motion.
2. Write the equation of motion for a feely falling body.
3. Write the equation of motion when a body is thrown vertically upwards.
4. What is a projectile?
5. Define angle of projection.
6. Define range of a projectile.
7. Define time of flight of a projectile
8. Define angular velocity
9. Define normal acceleration
10. Define centripetal force
11. What is centrifugal force?
12. Define angle of banking

PART – B

1. State Newton's laws of motion.
2. Derive the relation between angular velocity and linear velocity.
3. Derive the relations between angular velocity, period and frequency.
4. Define normal acceleration
5. Obtain the condition for maximum range of a projectile.
6. Why does the outer rail is raised over the inner rail along a curved railway track?

PART-C

1. Derive an expression for Maximum height attained by the projectile.
2. Derive expressions for Time of flight and Range of a projectile.
3. Obtain expressions for the normal acceleration and centripetal force of a body executing uniform circular motion.
4. Derive an expression for the angle of banking of a curved railway track.

Exercise Problem

1. A body of mass 2kg tied to a string of length 2 m revolves in a horizontal circle. If the angular velocity of the body is 5 rad s^{-1}. Calculate the centripetal force acting on the body.

   [A**ns:** F = 100 N]

2. In a circus, a man is riding a motor cycle in the form of vertical circle inside the hollow spherical cave of diameter 6m. Find the minimum speed of the rider with which he can be riding without falling at the highest point.

   [A**ns:** v = 7.668 ms^{-1} or 27.6 kmph]

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

   [A**ns:** RPM = 38.6]

4. A scooter rider negotiates a curve of 100 m radius on a level road with a speed of 72 kmph. Calculate the angle of inclination to the vertical he should make to avoid falling.

[A**ns:** $\theta = 22°12`$]

5. An electric train has to travel a curved railway line of radius 50m with maximum speed of 36 kmph. Calculate the angle through which the outer rail should be raised so that there is no lateral thrust on the rails.

[A**ns:=**11°31`]

6. An aeroplane with a speed of 120 ms^{-1} negotiates a curve of radius 1200 m. calculate its angle of banking.

[A**ns:=**50°45`]

7. The expected average speed of the traffic on a high way around the curve is 20 kmph. Calculate the angle of banking of the high way if its radius of curvature be 12m.

[A**ns:=**14°42`]

8. A cyclist is riding at a speed of 22 ms^{-1} takes a turn on a curved circular road of radius 44m. What is his inclination to the vertical?

9. An electric train has to travel on a railway track with a curve of radius 120m with a speed of 36 kmph. Calculate the angle of banking of the rails.

UNIT – IV

DYNAMICS -II

4.1 ROTATIONAL MOTION OF RIGID BODIES

Introduction

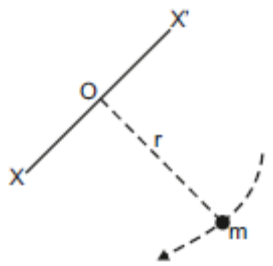
A rigid body is one in which the distance between two particles remains unchanged when an external force acting on it.

A rigid body may be defined as that body which does not undergo any change in its shape or size due to the application of force.

Actually, no body is a perfect rigid body. When the changes in the body are negligible, it can be considered as a rigid body.

Moment of Inertia of a particle

The moment of inertia of a particle about an axis is equal to the product of the mass of the particle and square of its distance from the axis.

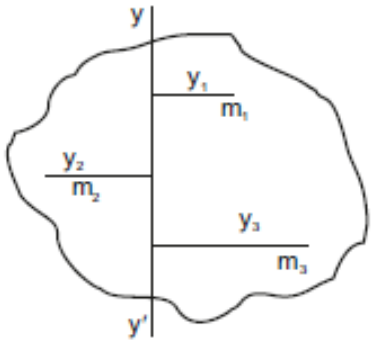


Consider a particle of mass 'm' is placed at a distance 'r' from the fixed axis. Then, **the moment of inertia of the particle = mr^2**. The S.I. unit for moment of inertia is kg m^2.

Moment of Inertia of a rigid body

Inertia of a body is its inability to change by itself its state of rest or of uniform motion in a straight line.

Similarly Moment of inertia of a body is its inability to change by itself its state of rest or of uniform rotatory motion about an axis.



An external torque (rotating effect of force) is necessary to change its state.

Let us consider the rotation of a rigid body about an axis. It consists of a large number of particles of masses m_1, m_2, m_3 etc., situated at distances r_1, r_2, r_3 etc., from the axis yy'. Then m_1r_1 is known as the moment of inertia of the particle of mass m_1 about that fixed axis.

Then, the moment of inertia of the rigid body = Sum of moments of inertia of all the particles present in the body.

$$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots\ldots\ldots\ldots$$

$$I = \sum_{i=1}^{n} m_i r_i^2$$

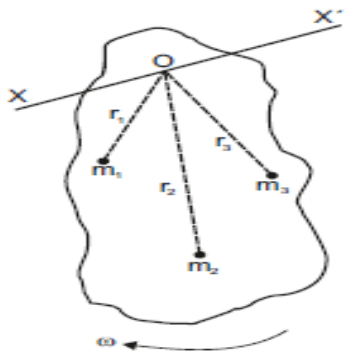
Hence the moment of inertia of a rigid body about a fixed axis is the sum of the moment of inertia of all the particles of the rigid body.

Radius of gyration

Radius of gyration(K) : Radius of gyration is the perpendicular distance between the axis of rotation and the point where the whole mass of the body is supposed to be concentrated.

Expression for Kinetic Energy of a Rigid body rotating about an axis:

Consider a rigid body rotating about a fixed axis XOX'. The rigid body is made up of larger number of particles of masses m_1, m_2, m_3 etc., and r_1, r_2, r_3 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 energy of all particles.

∴ Kinetic energy of the rigid body

$$= \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \cdots + \frac{1}{2} m_n r_n^2 \omega^2$$

$$= \frac{1}{2} \omega^2 (m_1 r_1^2 + \frac{1}{2} m_2 r_2^2 + \cdots + \frac{1}{2} m_n r_n^2)$$

$$= \frac{1}{2} \omega^2 \sum_{i=1}^{n} m_i r_i^2$$

$$\left\{\because \sum_{i=1}^{n} m_i r_i^2 = I\right\}$$

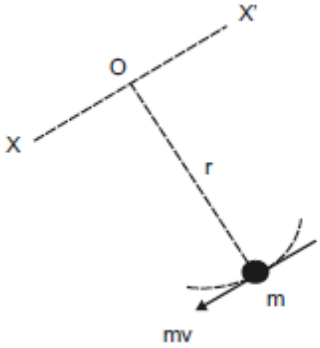
Kinetic energy of the rigid body = $\frac{1}{2} I\omega^2$

(i.e) K.E. = $\frac{1}{2} I\omega^2$

Angular momentum

The moment of linear momentum is known as angular momentum. Consider a particle of mass m is at a distance r from the axis of rotation. When a particle is in rotational motion about an axis, it has both linear velocity 'v' and angular velocity 'w'.

Then, Angular momentum of the particle = linear momentum x perpendicular distance between the particle and the axis of rotation



m v × r

m r ω × r

Angular momentum = $mr^2\omega$

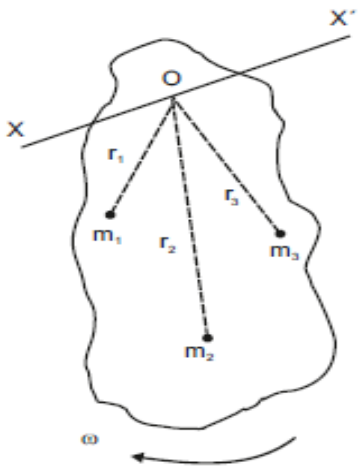
Where ω is the angular velocity of the particle.

The SI unit for angular momentum is kg m^2s^{-1}

Expression for Angular momentum of a Rigid body rotating about an axis:

Consider a rigid body rotating about a fixed axis XOX'. The rigid body is made up of larger number of particles of masses m_1, m_2, m_3 etc., and r_1, r_2, r_3 etc are the distances 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 $= m_1v_1 \times r_1 = m_1r_1^2\omega$ $\{\because v_1 = r_1\omega\}$

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

The angular momentum of the rigid body.

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

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

$$= \omega \sum_{i=1}^{n} m_i r_i^2$$

$$= \omega I \qquad \{\because \sum_{i=1}^{n} m_i r_i^2 = I\}$$

$$L = I\omega$$

4.2 GRAVITATION

1. Newton's law of gravitation

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.

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

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r^2}$$

$$F \propto \frac{m_1 m_2}{r^2}$$

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

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

Then, force of attraction, $F = \frac{G\, M\, m}{R^2}$

The value of G is 6.673×10^{-11} Nm^2kg^{-2}. F is also called as gravitational force.

2. Acceleration due to gravity on the surface of earth.

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

By Newton's law of gravitation.

Force of attraction $F = \frac{G\,M\,m}{R^2}$ --- (1)

By Newton's II law of motion,

Force F = mg --- (2)

Equating the two forces,

$mg = \frac{G\,Mm}{R^2}$ (or) $gR^2 = GM$

∴Acceleration due to gravity on the surface of earth

$$\boxed{g = \frac{G\ M}{R^2}}$$

Here g is independent of mass m. But g varies inversely as square of the radius R. The radius of the radius R. The radius of the earth R is greater at the equator, so the value of g is least. (g = 9.78 ms^{-2}). The radius of the earth R is least at the poles, so the value of g is maximum at the poles. (g = 9.83 ms^{-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. Consider the earth as a spherical shaped body.

Force of attraction $F = \frac{G\,Mm}{R^2}$

By Newton's II law of motion **F = mg**

Acceleration due to gravity at P,

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

Acceleration due to gravity at Q,

$g_h = \frac{G\ M}{(R+h)^2}$ --- (2)

(2) ÷ (1) (i.e.) $\frac{g_h}{g} = \frac{R^2}{(R+h)^2}$

By simplifying and expanding using binomial theorem.

$$g_h = g\left(1 - \frac{2h}{R}\right)$$

The value of g decreases with increase in height.

4.3 SATELLITES

A body moving in an orbit around another bigger body is called a satellite. A body that moves around a planet is called a satellite.

The objects that are moving in orbit by nature itself around a planet are called natural satellites. For example, moon is the **natural satellite** for the earth.

The earth is a satellite for the sun. Man also has placed artificially some satellites to move in orbit around the desired planets. These satellites are called **artificial satellite**.

The artificial satellites are carried by rockets to the predetermined height, a few hundred kilometers above the surface of the earth. At this height the air is in a rarefied state and hence air friction is negligible.

After reaching the predetermined height, the satellite is given very high horizontal velocity so that it remains moving in a nearly circular orbit.

The artificial satellites are broadly classified as earth resources satellites, meteorological satellites and satellites carrying microwave sensors.

Escape velocity and Orbital velocity

Escape Velocity (V_c)

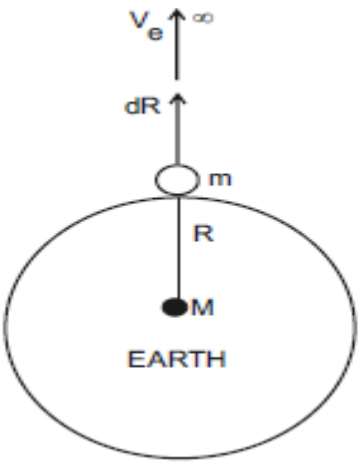
The minimum velocity required to project upwards a body from the surface of the planet so that it just escapes from the gravitational pull of the planet is called escape velocity.

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.

Expression for Escape Velocity (Ve) :

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, the force of attraction on m, $F = \frac{G\ M\ m}{R^2}$

where G is gravitational constant

Work done is carrying the body from the surface of earth to infinity is

$$W = \int_R^{\infty} \frac{GMm}{R^2}\, dR$$

$$W = \frac{GMm}{R} \qquad \text{--- (1)}$$

If the body is thrown with this amount of work done it will escape from the earth's gravitational force.

If Ve is the escape velocity, then its Kinetic energy $= \frac{1}{2} m V_e^2$ --- (2)

This kinetic energy is converted into work done to escape the body from gravitational force.

Equating the equations (2) and (1)

$$\frac{1}{2} m V_e^2 = \frac{GMm}{R}$$

$$V_e = \sqrt{\frac{GMm}{R}} \qquad \text{--- (3)}$$

On the surface of the earth the gravitational force is equal to the weight of the body.

$$\frac{GMm}{R^2} = mg$$

$$GM = gR^2 \qquad \text{--- (4)}$$

Substituting (4) in (3) the escape velocity $\boxed{V_e = \sqrt{2gR}}$

The escape velocity is independent of the mass of the planet.

Uses of Artificial satellites

1. It is used to send radio, television and telephone signals over long distances.
2. It is used in weather monitoring
3. It is used in remote sensing
4. To navigate ships and aeroplanes during all kinds of weather

Worked Problems

1. If the radius of the earth is 6400km and the acceleration due to gravity is $9.8ms^{-2}$. Calculate the escape velocity

   Given R = 6400 km and g = $9.8\ ms^{-2}$

   Escape velocity $V_e = \sqrt{2gR} = \sqrt{2 \times 9.8 \times 6400 \times 10^3}$

$$V_e = 11.2 \text{ km per second}$$

QUESTIONS

Part – A

1) Define rigid body
2) Define moment of inertia of a particle
3) Define moment of inertia of a rigid body
4) Define radius of gyration
5) Define angular momentum
6) What is a satellite?
7) Define escape velocity
8) Define orbital velocity

Part – B

1) Derive an expression for the moment of inertia of a rigid body about an axis
2) Derive an expression for acceleration due to gravity on the surface of earth.
3) State Newton's law of gravitation.
4) State the law of conservation of angular momentum.
5) Write the uses of artificial satellite.

Part - C

1) Derive an expression for the kinetic energy of a rigid body rotating about an axis.
2) Derive an expression for the angular momentum of a rigid body rotating about an axis.
3) Derive an expression for the variation of acceleration due to gravity with altitude
4) Derive an expression for the escape velocity of a satellite.

Exercise Problems

1) Calculate the escape velocity on the surface of the moon taking the radius of moon to be 2×10^6 m and acceleration due to gravity on the surface of moon is 1.69 ms^{-2}.

   (2.6 km/s)

2) Calculate the escape velocity for a particle 1000km above the surface of the earth. Radius of the earth is 6.4×10^6 m (12.04 km/s)

3) The escape velocity on the surface of the earth is 11.2 kms^{-1} Find the radius of the earth ($g = 9.8ms^{-2}$) (6400 km)

4) The acceleration due to gravity at the moon's surface is 1.67 ms^{-2}, if the radius of the moon is 1.74×10^6m. Calculate the mass of the moon ($G = 6.67 \times 10^{-11}$ Nm^2kg^{-2})

   (7.58×10^{22} kg)

UNIT – V

SOUND AND MAGNETISM

5.1 SOUND

Introduction

Sound is produced due to the vibrations of the body. These vibrations are transferred to the air medium and propagated in all directions in the form of waves. When the vibrations sound waves reach out ear, the diaphragm of the ear vibrates with equal vibrations produced by the body. Hence we are able to hear the sound by the sensation perceived by the nerves of the ear.

The number of vibrations made in one second is known as frequency of the sound. It is expressed in hertz (Hz). The range of the frequency between 20 Hz and 20,000 Hz is the audible range, Human ears cannot respond to the sound below and above this range. In this sense, all vibrating bodies cannot produce audible sound. The vibrations of frequency below 20Hz are called infrasonic and above 20,000 Hz are called ultrasonic.

Sound is a mechanical wave and hence it requires a medium to propagate. So we can't hear the sound in vacuum. It travels with the velocity of 330 ms^{-1} in air. Sound waves are reflected and refracted like light waves.

Wave motion:

When a stone is thrown on a pond of water, ripples spread out in all directions on the surface of water. The stone disturbs the water medium at one place but the disturbance is transferred in all directions continuously. This continuous movement of the disturbance is called a wave.

If a wave passes in a medium, the particles of the medium vibrate about their mean position. The particles do not move along with the wave, only the vibrations are transferred from one particle to adjacent particle of the medium in the form of energy.

There are two types of wave motion. They are

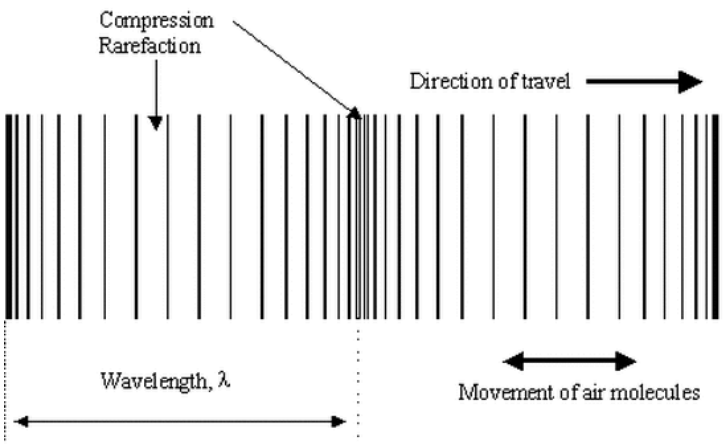
1) Longitudinal wave motion and 2) Transverse wave motion

(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 and the places where the particles spread out are called rarefactions.

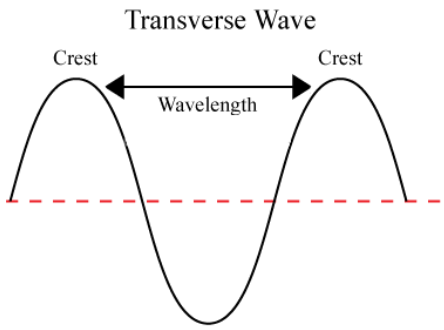
(ii)Transverse wave motion:

If the particles of the medium vibrate perpendicular to the direction of propagation the wave, the wave is known as transverse.

(Ex.) (i) Waves produced on the surface of water.

(ii) Waves travelling along a rope.

(iii) Other waves like light waves, thermal radiations, radio waves etc.



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.

(iii) Difference between Longitudinal and Transverse waves.

S.No	Longitudinal Wave	Transverse Wave
1	Particles of the medium vibrate parallel to the propagation 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 polarized	Can be reflected, refracted diffracted and also polarized
5	Distance between two successive compressions or rarefactions is called wave length	Distance between two successive crests or troughs is called wave length.

Progressive Waves:

If a wave travels continuously in a medium without any disturbance, then the wave is said to be progressive wave. Longitudinal waves and Transverse waves are two types of progressive waves and they can travel continuously in any medium if there is no obstruction.

Amplitude:

When sound wave propagates in a medium, the maximum displacement of the vibrating particles of the medium from their mean position is called amplitude.

Wavelength *(l)*:

The wavelength is the distance between two consecutive particles of the medium which are in the same state of vibration.

Ii is also defined as the distance travelled by the wave during the time the vibrating particle completes one vibration.

In longitudinal waves, the wavelength is the distance between two successive compressions or rarefactions. In transverse waves, the wavelength is the distance between two successive crests or troughs.

Period (T):

The time taken by the vibrating particle to make one vibration is called period.

Frequency (n):

The frequency is the number of vibrations made by the vibrating particle in one second.

Velocity (v):

The distance travelled by the second wave in one second is known as velocity of sound.

Relation between Wavelength, Frequency and Velocity of a Wave:

Let n be the number of vibrations made by the vibrating particle in one second. It is also known as its frequency.

Time taken for one vibration = period (T) = 1/n

Let T be the wavelength of the wave produced.

Velocity of the wave is the distance through which the wave advances in the medium in one second.

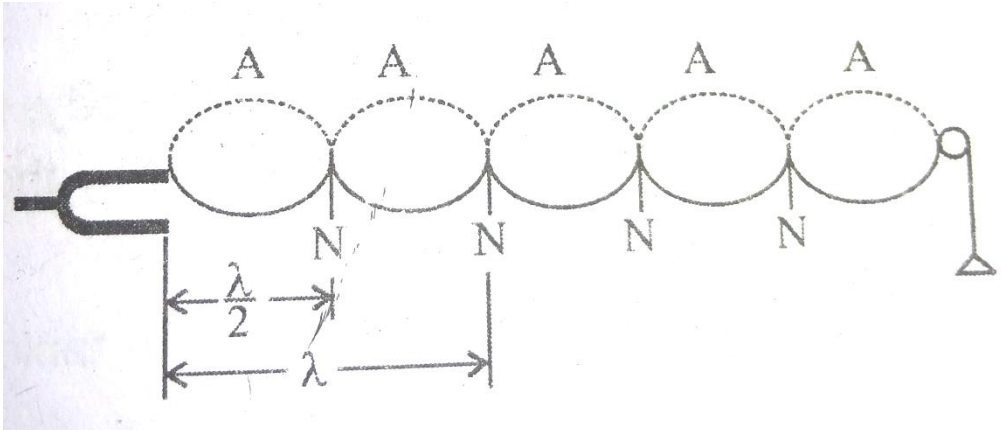
$$\text{Velocity of wave motion}, \mathrm{V} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{\lambda}{\mathrm{T}} \qquad (n = \frac{1}{\mathrm{T}})$$

$$\mathrm{V} = \mathrm{n}\,\lambda$$

Stationary or Standing Waves:

When a progressive waves strikes against a hard surface, it gets reflected. The reflected wave superimposition the incident wave to form stationary wave.

When two identical waves having equal wave length 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.

The points N,N,N are called nodes and A,A,A are called antinodes.

The distance between a node and the adjacent antinode = $\frac{\lambda}{4}$.

VIBRATIONS

Free Vibrations:

The vibrations of anybody with its natural frequency are called free vibrations.

When a body is set in vibration and left free, it executes vibrations. The frequency depends upon the dimensions and elastic constants of the body. Such vibrations are called free vibrations and the frequency of vibration is known as the natural frequency.

If a tuning fork is set in vibration, it vibrates with its own frequency. Such vibrations are called free vibrations or natural frequency.

Forced Vibrations:

The vibrations of a body with a frequency induces vibrations on another vibrating agent are called forced vibrations.

Suppose a vibrating tuning fork is placed with its stem on a table, the vibrations of the fork are impressed on the table and the table is forced to vibrate. The vibrations set up on the table are called forced vibrations.

Resonance:

When the forced vibrations given on the body is equal to its natural frequency of vibrations, the body vibrates with maximum amplitude. This phenomenon is called resonance.

When a vibrating tuning fork is kept on a table, the table is forced to vibrate with the frequency of the tuning fork. If the natural frequency of the table is equal to the frequency of the tuning fork, the table vibrates with its natural frequency and hence resonance occurs.

Laws of vibration is stretched strings:

I law: The frequency of vibrating string is inversely proportional to its length, when the tension and linear density of the string are kept constant.

$$\boldsymbol{n \propto \frac{1}{l}}$$

II law: The frequency of vibration is directly proportional to the square root of the tension, when the length and linear density of the string are kept constant.

$$\mathbf{n \propto \sqrt{T}}$$

III law: The frequency of vibration is inversely proportional to the square root of the linear density of the string, when the tension and length of the string are kept constant.

$$\boldsymbol{n \propto \frac{1}{\sqrt{m}}}$$

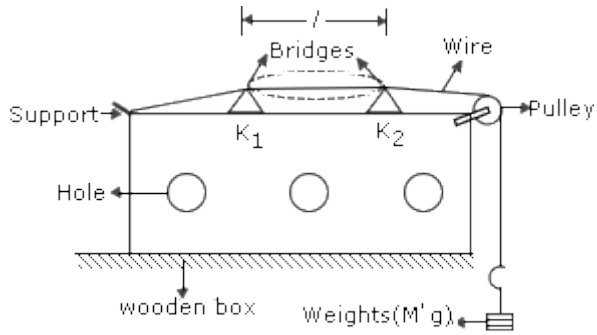
According to above laws, $\boldsymbol{n \propto \frac{1}{l}\sqrt{\frac{T}{m}}}$ **(or)** $\boldsymbol{n = k\frac{1}{l}\sqrt{\frac{T}{m}}}$

Where k – is a constant and its value is equal to ½.

The frequency $\boxed{\boldsymbol{n = \frac{1}{2\,l}\sqrt{\frac{T}{m}}}}$

Determination of frequency of a tuning fork using Sonometer

Sonometer is using to find the frequency of a tuning fork, it consists of a hollow wooden box with a thin wire. One end of the wire is tied to the nail and other end passes over a smooth pulley and carries a weight hanger. The string is supported by three knife edges P, Q and R. A movable knife edge R is placed between two fixed knife edges P and Q.



Sonometer

A suitable load (T=Mg) is applied to the hanger. A small paper rider is placed on the wire. A tuning fork of unknown frequency is excited and its stem is placed on the wooden box. The length of the wire is adjusted until the paper rider violently falls down. The paper rider falls because of resonance. Now the vibrating length of the string l is measured. The experiment is repeated for different loads and the average value of $\frac{M}{l^2}$ is calculated.

Let r be the radius of the string measured by using screw gauge and ρ is the density of the material of the wire, then the linear density m is calculated using the formula $m = \pi r^2 \rho$.

S.No	Load M	Vibrating length l	l^2	$\frac{M}{l^2}$

The frequency of the tuning fork is calculated using the formula.

$$\boxed{n = \frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}} \text{ Hz}$$

ACOUSTICS OF BUILDINGS

1. **Loudness (or) intensity of sound**

   The loudness of a sound depends on intensity of sound. The intensity of sound is defined as the amount of sound energy crossing per unit area per sec perpendicular to the direction of propagation of wave.

2. **Echo**

   The first reflection of sound is known as echo

   The sound produced by a source is propagated continuously in a medium if there is no disturbance. But it meets the surface of an obstacle it is reflected. The clear echo depends upon the following factors.

   1. Good reflector of sound
   2. Maximum surface area of the reflector
   3. The fixed distance of the reflector from the source of sound.

3. **Reverberation**

   The reverberation is the multiple reflection of sound from the walls, floor and ceiling of the hall. The reverberation is also called multiple echo.

4. **Reverberation time**

   The time require for the intensity of sound produced by the reverberation to die out is known as reverberation time.

5. **Sabine's formula for reverberation time**

According to Sabine the reverberation time is defined as the time taken by the sound to fall in intensity to one- millionth of its original value is called reverberation time.

The **Sabine's formula** for reverberation time

$$T = \frac{0.16V}{\alpha A} \text{ seconds}$$

Where V - Volume of the hall

α - Co-efficient of absorption of sound energy

A - total sound absorbing area.

6. **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.

Let α be the co-efficient of absorption of sound energy of a surface, then

$$\propto = \frac{\text{The sound energy absorbed by the surface}}{\text{The total sound energy incident on the surface}}$$

7. **Noise Pollution**

Definition

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.

Noise reaches the hall through open windows, doors are called air borne noise. Echos and reverberation are produced by the wrong structure of building are called structure borne noise. The noise produced inside the hall is known as 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.

8. **Acoustics of buildings (Architectural acoustics)**

The term 'Acoustics of building' describe the production and transmission of sound inside the building. The following points should be taken into consideration for the acoustic design of the buildings like auditorium, chema theatre etc.

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 completely eliminated.
5) There should not be any vibrations due to resonance.

For achieving the above conditions the following factors should also 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.

The echo and reverberation must be avoided. To rectify these defects the walls and other surfaces must be covered with sound absorbing materials like curtains, carpets and porous tiles. It can also be avoided by providing number of doors and windows.

(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 to loudness an optium reverberation time must be maintained.

To minimize this effect, Sabine derived a formula for the reverberation time.

$$\mathbf{T} = \frac{\mathbf{0.16V}}{\boldsymbol{\alpha}\mathbf{A}} \text{ seconds}$$

Where V - Volume of the hall

α - Co-efficient of absorption of sound energy

A - total sound absorbing area.

T will minimized by increasing the value of α. It is done by using absorption materials like curtains, carpets and porous tiles.

5.2 MAGNETISM

MAGNETIC FIELD

1. Magnetic field

The space around the magnet in which the magnetic lines of force act is called magnetic field. The direction of magnetic field at a point is given by the direction of the force acting on the north pole of a magnetic needle placed at that point. If the magnetic lines of force are parallel, the field is called uniform field and have equal strength at all the points.

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.

Unity is ampere-metre (Am)

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 x 2*l* wher P is the pole strength and 2*l*, the length of the magnet.

Unit is ampere-metre^2 (Am^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-m^{-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})

6. Magnetic permeability (μ)

Magnetic permeability is the ratio of the magnetic induction to the intensity of magnetic field at a point.

(i.e) $\mu = \frac{B}{H}$

Where B is the magnetic induction and

H is the intensity of magnetic field.

Unit is henry/metre (Hm^{-1})

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

$$= \frac{Magnetic\ moment\ (m)}{Volume\ of\ the\ magnet\ (V)}$$

Unit is ampre/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 = $l$bh.

Intensity of magnetisation $$M = \frac{m}{V} = \frac{m}{l\,bh}$$

HYSTERESIS

1. 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 in the solenoid is increased the magnetism induced in the rod also increases upto a certain level. Beyond this the induced magnetism is not increased whatever be the magnetising field. Now the rod is said to be saturated.

If the magnetising field is gradually decreased, the induced magnetism in the specimen also decreases. However, when the magnetising field is reduced to zero, the induced magnetism in the specimen is 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.

A graphical curve which represents the variation of the intensity of magnetisation (M) with magnetic field intensity (H) is known as hysteresis loop.

2. Retentivity, coercivity and magnetic saturation

i) Retentivity (or) residual magnetism :

Retentivity is the strength of the intensity of magnetisation retained in the specimen when the magnetising field is reduced to zero.

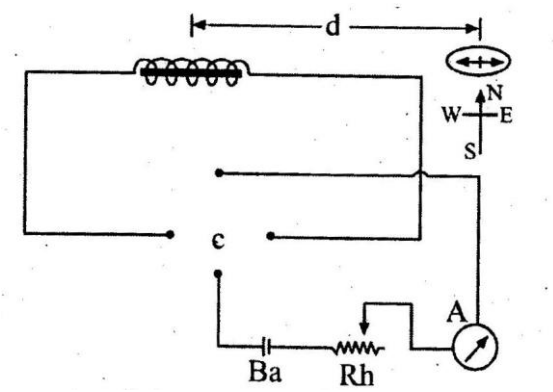
ii) Coercivity (or)coercive force :

Coercivity is the reverse magnetisingfield that is necessary to completly demagnetise the residual magnetism in the specimen.

iii) Magnetic saturation :

During hysteresis, the magnetic material is magnetised upto a particular value. After that this value remains constant eventhough increasing the intensity of magnetic field. Now the material attains magnetic saturation.

3. 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. The deflection magnetometer in tan A position is placed at a distance.

i) The magnetising field can be calculated as $H = \frac{N I}{l}$

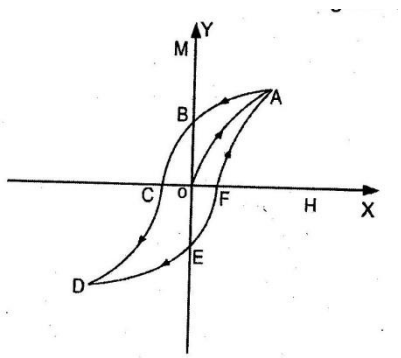
where N is the number of turns in the solenoid,

l is the length of the solenoid, and

I is the strength of the current.

ii) The intensity of magnetisation can be calculated as $M = k \tan \theta$

where k is a constant and θ is the angle of deflection.



The circuit is closed. With the help of reheostat and commutator, the current is increased in steps of 0.2A both in forward and reverse directions. The corresponding values of M and H are calculated. A graph is drawn taking H along X-axis and M along Y-axis.

The value of H increases correspondingly M also increases upto the point A. Then it is not increased. This point is known as ***saturation point.***

The value of M decreases, H also decreases. When the value of H is zero M is OB. This is ***retentivity*** of the specimen.

Then change the direction of current using the commutator. The value of H increases correspondingly M decreases. When the value of M is zero H is OC. This is ***coercivity*** of the specimen.

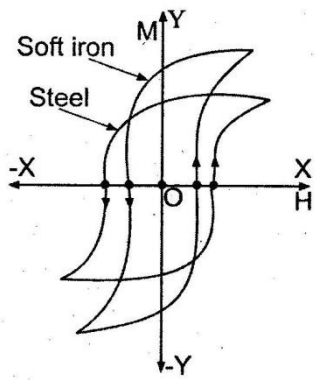
Further repeating the process the remaining portion CDEFA is obtained.

The specimen is taken through a cycle of magnetisation. A closed loop ABCDEFA is obtained. This is known as hysteresis loop. During the cycle of magnetisation there is a loss of energy in the form of heat. The loss of energy is directly proportional to the area of hysteresis loop.

4. Selection of magnetic materials for permanent and temporary magnets :

The hysteresis loops are very useful in the selection of magnetic materials for permanent and temporary magnets and other industrial purposes. In the figure the hysteresis loops are drawn for soft iron and steel.

5.21



During the cycle of magnetisation there is loss of energy in the form of heat. This heat is directly proportional to the area of hysteresis loop. Here the area of the hysteresis loop for steel is more than that of soft iron. So the energy loss in steel is more than soft iron. For this reason, soft iron is selected as a core material for transformers, chockes, dynamo, AC motors etc.

For temporary magnets the materials should possess (i) large retentivity (ii) small coercitvity (iii) large M for small H and (iv) minimum hysteresis loss. From the figure, soft iron possess the above properties. So soft iron is selected for temporary magnets.

For permanent magnets the materials should possess (i) large rententivity (ii) large coercivity. Here the hysteresis loss need not be considered. From the figure, steel possess the above properties. So steel is selected for permanent magnets.

WORKED EXAMPLES

1) **The moment of a bar magnet is 0.6 Am^2 and its volume is 3 x 10^{-5} m^3. Calculate the intensity of magnetisation of the magnet. (Ap. 94)**

   Given : Moment of the magnet, m = 0.6 Am^2

   Volume of the magnet, V = 3 x 10^{-5} m^3

   Intensity of magnetisation, $M = \frac{m}{V} = \frac{0.6}{3 \times 10^{-5}}$

   M = 0.2 x 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 x 10^{-6} Am^2. (Ap. 96)**

   Given : l = 150mm = 150 x 10^{-3}m

   b = 20mm = 20 x 10^{-3}m

   h = 10mm = 10 x 10^{-3}m and m = 9 x 10^{-6} Am^2

   $$M = \frac{m}{V} = \frac{m}{lbh} = \frac{9 \times 10^{-6}}{150 \times 10^{-3} \times 20 \times 10^{-3}}$$

   = 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 x 10^{-6} Am^2.** **(Oct. 04)**

Given :l = 30cm = 30 x 10^{-2}m.

b = 2cm = 2 x 10^{-2}m

h = 1mm = 1 x 10^{-2} m and m = 6 x 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. Define transverse wave motion
2. Define longitudinal wave motion
3. Define progressive wave
4. Define amplitude of a wave
5. Define wavelength of a wave
6. Define period of wave motion
7. Define frequency of a wave
8. Define velocity of sound wave
9. Define stationary wave
10. Define free vibrations
11. Define forced vibrations
12. Define Resonance
13. What is reverberation?
14. Define reverberation time.
15. Define co-efficient of absorption of sound energy.
16. Define magnetic moment.
17. Define magnetic permeability.

PART – B

1. What are Infrasonics and Ultrasonics?
2. Distinguish between transverse and longitudinal wave motion

3. Write short notes on stationary waves.
4. Define intensity of magnetization.
5. Define Hysteresis.
6. Define retentivity and coercivity

PART – C

1. What are stationary waves? How are they formed?
2. Describe how the frequency of a tuning fork is determined using a sonometer
3. Write a note on acoustics of buildings.
4. Explain noise pollution and the methods of controlling industrial noise
5. Describe an experiment to draw the Hysteresis loop for a given specimen.
6. Explain how the Hysteresis loop is helpful for the selection of magnetic materials for temporary and permanent magnet.

Exercise Problems

1. A sonometer wire of 0.5m long gives vibrations of 256 Hz when stretched with a load of 5 kg. find the linear density of the material of the wire.
2. Find the frequency of sound produced by a string 25 cm long stretched by load of 5 kg. The linear density of the wire is 4.9×10^{-3} kg m^{-1}
3. A wire of 50 cm long and of mass 6×10^{-3} kg is stretched so that it makes 60 vibrations per second. Find the tension in the wire.

   (Ans:43. 20N)
4. A vibrating length of 0.75 m of a sonometer wire is unison with a tuning fork when stretched by weight of 5 kg. the linear density of the wire is 0.5×10^{-3} kg m^{-1}. Calculate the frequency of the tuning fork.

   (Ans: 209 HZ)
5. A wire 50 cm long and of mass 0.6×10^{-3} kg is stretched by a tension of 5 kg.wt. When sounded, it is found to vibrate in 2 loops. Calculate the frequency of the note emitted by the wire.

   (Ans:361 HZ)
6. A wire 0.5 m long vibrates 100 times a second. If the length of the wire is shortened to 0.4 m and the stretching force is increased to 4 times its original value, what will be the new frequency?

Model question - I

Time – Three hours

(Maximum Marks: 75)

[N.B: 1) Answer any FIVE questions in each of PART-A & PART-B and any two divisions of each question in PART-C.

2) Each question carries two marks in PART-A, three marks in PART-B and five marks for each division in PART-C.]

PART –A

1. What are the fundamental quantities?
2. Define couple.
3. Define stress.
4. Define Hooke's law.
5. Define angular velocity.
6. Define angle of banking.
7. What is a rigid body?
8. Define frequency of a wave.

PART-B

9. State parallelogram law of forces.
10. Define concurrent forces and coplanar forces
11. What is the difference between stream line motion and turbulent motion?
12. Define Young's modulus, Bulk modulus and Rigidity modulus.
13. Define period and frequency.
14. State Newton's law of gravitation .
15. Define radius of gyration
16. Define Hysteresis.

PART-C

17. (a) Describe an experiment to determine the mass of the given body using principle of moments. .

    (b) State the conventions to be followed in writing S.I units.

    (c) Find the magnitude and direction of two forces 10N and 20N acting at an angle 60° to each other.

18 (a) Describe an experiment to find the Young's modulus of a meter scale by uniform bending method.

(b) Describe an experiment to determine coefficient of viscosity of a high viscous liquid by Stoke's method.

(c) Calculate the surface tension of water if water rises to a height of 4.2 cm in a Capillary tube dipped vertically in it. Radius of capillary tube is 3.5×10^{-4}m.

19.(a) Derive the expression for the normal acceleration and centripetal force of a body executing uniform circular motion.

(b) Derive an expression for the angle of banking of a curved railway track.

(c) Find the centripetal force on a body of mass 500gm when it revolves in a circle of radius1.5m. The body makes 120 revolutions per minute.

20.(a) Derive an expression for the kinetic energy of a rigid body and angular momentum of a rigid body rotating about an axis.

(b) Derive an expression for escape velocity.

(c) What is satellite? Mention the uses of artificial satellite.

21.(a) Describe an experiment to determine the frequency of a tuning fork using sonometer.

(b) Write a note on Acoustics of building.

(c) 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}.

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Model question - II

Time – Three hours

(Maximum Marks: 75)

[N.B: 1) Answer any FIVE questions in each of PART-A & PART-B and any two divisions of each question in PART-C.

2) Each question carries two marks in PART-A, three marks in PART-B and five marks for each division in PART-C.]

PART –A

1. Write any two conventions in writing S.I. unit.
2. What are scalar and vector quantities?
3. State Hooke's law.
4. Define bulk modulus.
5. Define trajectory of a projectile.
6. Define centrifugal force.
7. State law of conversation of angular momentum.
8. Define reverberation.

PART – B

9. State Lami's Theorem.
10. Define terminal velocity.
11. Define normal acceleration.
12. Derive the condition for maximum range of projectile.
13. Define radius of gyration.
14. State Newton's law of gravitation.
15. Define stationary waves.
16. Define retentivity and coercivity.

PART – C

17. a) Describe an experiment to verify Lami's theorem.

    b) Describe an experiment to determine the mass of the given body using principle of moments.

    c) If the resultant of two forces 6N and 8N is 12N. Find the angle between two forces.

18. a) Describe an experiment to compare the viscosity of two low viscous liquid.

b) Derive an expression for surface tension of a liquid by capillary rise method.

c) A body of mass 5 kg suspended by means of a steel wire of length 1m and diameter 1mm. The Young's modulus of steel is $21 \times 10^{10} Nm^{-2}$. Calculate the elongation of the wire.

19. a) Derive an expression for maximum height and time of flight of a projectile.

b) Derive expressions for normal acceleration and centripetal force of a body in circular motion.

c) An aeroplane with a speed of 120 ms^{-1} negotiates a curve of radius 1200m. Calculate the angle of banking.

20. a) Derive an expression for kinetic energy of a rigid body rotating about an axis.

b) Obtain an expression for the variation of acceleration due to gravity with altitude.

c) The escape velocity on the surface of earth is 11.2kms^{-1}. Find the radius of the earth. ($g = 9.8\ ms^{-2}$)

21. a) Write a note on acoustics of buildings

b) Explain the usefulness of the hysteresis loop in selection of magnetic materials.

c) The moment of a bar magnet is 0.6 Am^2 and its volume is $3 \times 10^{-5}\ m^3$. Calculate the intensity of magnetization of the magnet.